



Florida Department of Transportation

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MIKE DEW
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June 14, 2018

Khoa Nguyen
Director, Office of Technical Services
Federal Highway Administration
3500 Financial Plaza, Suite 400
Tallahassee, Florida 32312

Re: State Specifications Office
Section: **455**
Proposed Specification: **4550701 Structures Foundations.**

Dear Mr. Nguyen:

We are submitting, for your approval, two copies of the above referenced Supplemental Specification.

The changes are proposed by Juan Castellanos of the State Construction Office (SCO) to modify the language.

Please review and transmit your comments, if any, within two weeks. Comments should be sent via email to dan.hurtado@dot.state.fl.us.

If you have any questions relating to this specification change, please call me at 414-4130.

Sincerely,

Signature on file

Dan Hurtado, P.E.
State Specifications Engineer

DH/dt

Attachment

cc: Florida Transportation Builders' Assoc.
State Construction Engineer

STRUCTURES FOUNDATIONS.**(REV ~~4-27-18~~ 1-186-14-18)**

SUBARTICLE 455-7.1 is deleted and the following substituted:

455-7.1 Description: Provide prestressed concrete piles that are manufactured, cured, and driven in accordance with the Contract Documents. Provide piles full length without splices when transported by barge or the pile length is less than or equal to 120 feet. When piles are transported by truck and the pile length exceeds 120 feet ~~but is less than or~~ the maximum length for a ~~three~~3-point pick-up according to Standard Plans, Index 455-001, and splicing is desired, provide minimal splices. Include the cost of the splices in the cost of the pile.

SUBARTICLE 455-11.10 is deleted and the following substituted:

455-11.10 Pile Extraction: Piles authorized to be extracted by the Engineer and successfully extracted as provided in 455-11.2.73 will be paid for as described in 455-11.2.73. No payment for extraction will be made for piles shown in the Plans to be extracted or piling damaged or mislocated by the Contractor that are ordered to be extracted by the Engineer.

SUBARTICLE 455-15.1.1 is deleted and the following substituted:

455-15.1.1 Templates: ~~When drilling from a barge, P~~provide a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations, ~~when drilling from a barge~~. Do not use floating templates (attached to a barge). ~~The Engineer will require a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations~~When the Contractor fails to properly maintain shaft position and alignment without use of a template, for shafts ~~when drilled~~ing on land, ~~when the Contractor fails to demonstrate satisfactorily that he can properly maintain shaft position and alignment without use of a template~~Engineer will require a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations.

SUBARTICLE 455-15-1.2 is deleted and the following substituted:

455-15.1.2 Drilled Shaft Installation Plan (DSIP): At the preconstruction conference submit a DSIP for review by the Engineer. Final approval will be subject to satisfactory performance. Include in this plan the following details:

1. Name and experience record of drilled shaft superintendent or foreman in responsible charge of drilled shaft operations. Ensure the drilled shaft superintendent or foreman in responsible charge of the drilled shaft operations has a minimum of one year of experience of installing drilled shafts of the size and depth shown in the Plans and a minimum of three years experience in the construction of drilled shafts using the following methods:

- a. Wet Method (mineral and polymer slurry),
- b. Casings up to the length shown in the Plans,

c. Shaft drilling operations on water under conditions as shown in the Plans.

2. List and size of proposed equipment, including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies or concrete pumps, ~~and~~ casings, and equipment to install and remove casing.

3. Details of sequence of construction operations and sequence of shaft construction in bents or shaft groups.

4. Details of shaft excavation methods, including casing installation procedures.

5. Details of slurry, including proposed methods to mix, circulate, desand, test methods, and proposed CTQP certified technician that will perform and document the fluid tests.

6. Details of proposed methods to clean the shaft excavation.

7. Details of shaft reinforcement, including methods to ensure centering/required cover, cage integrity during placement, placement procedures, cage support, and tie downs.

8. Details of concrete placement, including elapsed concrete placement times and proposed operational procedures for concrete tremie or pump, including initial placement, raising during placement, and overfilling of the shaft concrete. Include provisions to ensure proper final shaft cutoff elevation.

9. Details of casing removal when removal is required, including minimum concrete head in casing during removal.

10. Required submittals, including shop drawing and concrete design mixes.

11. Details of any required load tests, including equipment and procedures, and recent calibrations for any jacks or load cells.

12. Proposed Cross-Hole Sonic Logging (CSL) and Thermal Integrity Testing for Drilled (TITDS) Specialty Engineer to supervise field testing and report the test results.

13. Methods and equipment proposed to prevent displacement of casing and/or shafts during placement and compaction of fill.

14. Provide the make and model of the shaft inspection device, if applicable.

15. Details of environmental control procedures used to prevent loss of slurry or concrete into waterways or other protected areas.

16. Proposed schedule for test shaft installation, load tests and production shaft installation.

17. Other information shown in the Plans or requested by the Engineer.

18. For drilled shafts constructed using polymer slurry, identify the polymer slurry meeting the requirements of 455-15.8.3, the pH and viscosity ranges recommended by the manufacturer for the materials to be excavated and a description of the mixing method to be used. Submit the Material Safety Data Sheets (SDS) for the product, and certifications that the polymer slurry and components meet the requirements of 455-15.8.3. Submit the contact information for the manufacturer's representative available for immediate contact during shaft construction and the representative's schedule of availability.

19. Procedure for grouting non-destructive testing access tubes.

The Engineer will evaluate the DSIP for conformance with the Contract Documents. Within 20 days after receipt of the plan, the Engineer will notify the Contractor of any additional information required and/or changes that may be necessary in the opinion of the Engineer to satisfy the Contract Documents. The Engineer will reject any part of the plan that is unacceptable. Submit changes agreed upon for reevaluation. The Engineer will notify the Contractor within seven days after receipt of proposed changes of their acceptance or rejection. All equipment and procedures are subject to trial and satisfactory performance in the field.

Acceptance by the Engineer does not relieve the Contractor of the responsibility to perform the work in accordance with the Contract Documents. The installation plan is for the Contractor to explain the approach to the work and allow the Engineer an opportunity to comment on the equipment and procedures chosen before field operations begin. The Engineer's acceptance is not a guarantee that the chosen methods and equipment are capable of obtaining the required results, this responsibility lies with the Contractor.

SUBARTICLE 455-15.8 is deleted and the following substituted:

455-15.8 Slurry and Fluid in Excavation ~~at Time of Concrete Placement:~~

455-15.8.1 General: Thoroughly premix the slurry with clean fresh water prior to introduction into the shaft excavation. Introduce slurry before the excavation advances below the bottom of the casing. Ensure that the percentage of polymer or mineral admixture used to make the suspension is such as to maintain the stability of the shaft excavation. The Engineer will require adequate water and/or slurry tanks when necessary to perform the work in accordance with this Section. The Engineer will not allow excavated pits on projects requiring slurry tanks without the written permission of the Engineer. Take the steps necessary to prevent the slurry from "setting up" in the shaft; including, but not limited, to agitation, circulation, and adjusting the composition and properties of the slurry. Provide suitable offsite disposal areas and dispose of all waste slurry in a manner meeting all requirements pertaining to pollution.

Provide a CTQP qualified drilled shaft inspector to perform control tests using suitable apparatus on the slurry mixture to determine the slurry and fluid properties as specified in 455-15.8.2 to 455-15.8.4.

Measure the viscosity of the freshly mixed slurry regularly as a check on the quality of the slurry being formed using an approved measuring device.

Perform tests from the fluid in the excavation to determine density, viscosity, and pH value to establish a consistent working pattern, taking into account the mixing process and blending of freshly mixed slurry and previously used slurry. ~~Perform a set of~~ Repeat tests to determine density, viscosity, and pH value at intervals not exceeding 2 hours during the first 8 hours slurry is in use and ~~one set~~ every 4 hours thereafter, including overnight, until concrete placement. Perform ~~one set of~~ density, viscosity and pH tests again when the excavation reaches the midpoint.

The Department may perform comparison tests as determined necessary during the mineral and polymer slurry operations.

If, at any time in the opinion of the Engineer, the wet construction method ~~of stabilizing excavations~~ fails to ~~produce the desired final result~~ stabilize the excavation, discontinue this method of construction, propose backfill the excavation and submit modifications in procedure or alternate means of construction for approval.

455-15.8.2 Mineral Slurry: When mineral slurry is used in an excavation, use only processed attapulgite or bentonite clays with up to 2% (by dry weight) of added polymer. Use mineral slurry having a mineral grain size such that it will remain in suspension and having sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. Use a percentage and specific gravity of the material to make the suspension sufficient to maintain the stability of the excavation and to allow proper placement of concrete. Ensure that the material used to make the slurry is not detrimental to concrete or surrounding ground strata. During construction, maintain the level of the slurry at a height sufficient to prevent caving of the hole. In the event of a sudden significant loss of slurry such that the slurry level cannot practically be maintained by adding slurry to the hole, backfill the excavation and delay the construction of that foundation until an alternate construction procedure has been approved.

Perform the following tests on the mineral slurry supplied to and in the shaft excavation and ensure that the results are within the ranges stated in the table below:

Item to be measured	Range of Results at 68°F	Test Method
Density	64 to 73 lb/ft ³ (in fresh water environment) 66 to 75 lb/ft ³ (in salt water environment)	Mud density balance: FM 8-RP13B-1
Viscosity	30 to 40 seconds	Marsh Cone Method: FM 8-RP13B-2
pH	8 to 11	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	4% or less	FM 8-RP13B-3

The Contractor may adjust the limits in the above table when field conditions warrant as successfully demonstrated in a test hole or with other methods approved by the Engineer. The Engineer must approve all changes in writing before the Contractor can continue to use them.

During construction, maintain the level of mineral slurry in the shaft excavation within the excavation and at a level not less than 4 feet above the highest expected piezometric water pressureelevation along the depth of a shaft.

455-15.8.3 Polymer Slurry: Materials manufactured expressly for use as polymer slurry for drilled shafts that meet the requirements of this Section may be used as slurry for drilled shaft excavations. A representative of the manufacturer must be on-site or available for immediate contact to assist and guide the construction of the first three drilled shafts at no additional cost to the Department. This representative must also be available for on-site assistance or immediate contact if problems are encountered during the construction of the remaining drilled shafts as determined by the Engineer. Use polymer slurry only if the soils below the casing are not classified as organic, and the pH of the fluid in the hole can be maintained in accordance with the manufacturer's published recommendations. Submit the SDS for the product, the manufacturer's published mixing procedures, and the manufacturer's published range of values for pH and viscosity of the mixed slurry. Submit a report in accordance with Section 2.4, Volume II of the Department's Material Manual, which may be

viewed at the following URL:

<http://www.fdot.gov/programmanagement/Implemented/URLinSpecs/Section24V2.shtm> .

The report must include test results, certification and documentation that demonstrate the polymer slurry and additives meet the following requirements:

1. The polymer slurries to be used on the project and their waste products are classified as non-hazardous as defined by Resource Conservation and Recovery Act (RCRA) Subpart C rules, Table 1 of 40 CFR 261.24 Toxicity Characteristic.

2. Pull out tests demonstrate the bond between the bar reinforcement and the concrete is not materially affected by exposure to the slurry under typical construction conditions, over the typical range of slurry viscosities to be used.

3. Load tests demonstrate the bond between the concrete and the soil is not materially affected by exposure to the polymer slurry under typical construction conditions, over the typical range of polymer slurry viscosities to be used.

4. The method of disposal meets the approval of all federal, state and local regulatory authorities.

Perform the following tests on the polymer slurry supplied to and in the shaft excavation and ensure that the results are maintained within the ranges stated in the table below:

Mixed Polymer Slurry Properties		
Item to be measured	Range of Results at 68°F	Test Method
Density	62 to 65 lb/ft ³ (fresh water) 64 to 67 lb/ft ³ (salt water)	Mud density balance: FM 8-RP13B-1
Viscosity	Range 50 seconds to upper limit published by the manufacturer, limited by 455-15.8.3 items 2 and 3 above (2) and 455-15.8.3 (3) above , for materials excavated	Marsh Cone Method: FM 8-RP13B-2
pH	Range published by the manufacturer for materials excavated	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	0.5% or less	FM 8-RP13B-3

Premix polymer slurry in accordance with the manufacturer's published procedures. ~~However, at no time shall slurry be~~ Do not mixed the slurry in the excavation as a means to initially prepare slurry; adjustments to slurry properties can be made in the excavation as needed.

During construction, maintain the level of the slurry at a height sufficient to prevent caving of the hole ~~and which should not be lower than 4 feet above the highest expected piezometric water elevation along the depth of the shaft.~~

455-15.8.4 Fluid In Excavation At Time Of Concrete Placement: When any fluid is present in any drilled shaft excavation, including shafts to support sign, signal, lighting and ITS structures, the applicable test methods and reporting requirements described in

455-15.8.1, 455-15.8.2 and 455-15.8.3 apply to tests of fluid in the shaft prior to placing the concrete.

Test samples of the fluid in the shaft from within 1 inch of the base of the shaft and from the middle of the shaft height for shafts up to 60 feet in depth. Test samples of the fluid in the shaft from within 1 inch of the base of the shaft and at intervals not exceeding 30 feet up the shaft for shafts deeper than 60 feet. Use a sampling tool, approved by the Engineer, designed to sample over a depth range of 12 inches or less. Take whatever action is necessary prior to placing the concrete to bring the fluid within the specification and reporting requirements, outlined in the tables in 455-15.8.2 and 455-15.8.3, except as follows:

The Engineer will not require tests for pH or viscosity, nor require the fluid to meet the minimum density specified in 455-15.8.2 and 455-15.8.3 when neither polymer nor mineral slurry has been introduced into the shaft excavation.

SUBARTICLE 455-15.11.1 is deleted and the following substituted:

455-15.11.1 Dimensions and Alignment: Provide equipment for checking the dimensions and alignment of each permanent shaft excavation. Determine the dimensions and alignment of the shaft excavation under the observation and direction of the Department. Generally check the alignment and dimensions by any of the following methods as necessary:

1. Check the dimensions and alignment of dry shaft excavations using reference stakes and a plumb bob.

2. Check the dimensions and alignment of casing when inserted in the excavation.

3. ~~Insert a casing in shaft excavations temporarily for alignment and dimension checks.~~

4. ~~Insert a rigid rod or pipe assembly with several 90-degree offsets equal to the shaft diameter into the shaft excavation for alignment and dimension checks.~~

Insert any casing, rod or pipe assembly, or other device used to check dimensions and alignment into the excavation to full depth.

SUBARTICLE 455-15.11.3 is deleted and the following substituted:

455-15.11.3 Shaft Inspection Device (SID): When shown in the Plans, furnish all power and equipment necessary for the Engineer to inspect the bottom conditions of a drilled shaft excavation and to measure the thickness of bottom sediment or any other debris using a SID. Provide a means to position and lower the SID into the shaft excavation to enable the bell housing to rest vertically on the bottom of the excavation. Include all cost related to the inspection device in the cost of drilled shaft items.

Furnish a SID meeting the following requirements:

1. A remotely operated, high resolution, color video camera sealed inside a watertight bell housing.

2. Provides a clear view of the bottom inspection on a video monitor at the surface in real time.

3. Provides a permanent record of the entire inspection with voice annotation on a quality DVD with a resolution of not less than 720 x 480.

4. Provides a minimum field of vision of 110 square inches, with at least two graduated measuring devices to record the depth of sediment on the bottom of the shaft excavation to a minimum accuracy of 1/2 inch and a length greater than 1-1/2 inches.

5. Provides sufficient lighting to illuminate the entire field of vision at the bottom of the shaft in order for the operator and inspector to clearly see the depth measurement scale on the video monitor and to produce a clear recording of the inspection.

6. Provides a regulated compressed air or gas system to displace precisely adjust the drilling fluids from level within the bell housing and a pressurized water system to assist in determination of bottom sedimentation depth.

Obtain the Engineer's approval of the device in advance of the first inspection contingent on satisfactory field performance. Notify the Engineer for approval before a different device is used for any subsequent inspection.

SUBARTICLE 455-16.4 is deleted and the following substituted:

455-16.4 Nondestructive Integrity Testing Access Tubes: Install access tubes full length in all drilled shafts from the tip of shaft to a point high enough above top of shaft to allow thermal integrity testing for drilled shafts (TITDS) and cross-hole sonic logging (CSL) testing, but not less than 30 inches above the top of the drilled shaft, ground surface or water surface, whichever is higher. Equally space tubes around circumference of drilled shaft. Securely tie access tubes to the inside of the reinforcing cage and align tubes to be parallel to the vertical axis of the center of the cage. Access tubes from the top of the reinforcing cage to the tip of the shaft shall be NPS 1-1/2 Schedule 40 black iron or black steel (not galvanized) pipe. Access tubes above the top of the reinforcing cage may be the same black iron or black steel pipe or Schedule 40 PVC pipe. Ensure that the access tubes are free from loose rust, scale, dirt, paint, oil and other foreign material. Couple tubes as required with threaded couplers, such that inside of tube remains flush. Seal the bottom and top of the tubes with threaded caps. The tubes, joints and bottom caps shall be watertight. Seal the top of the tubes with lubricated, threaded caps sufficient to prevent the intrusion of foreign materials. Stiffen the cage sufficiently to prevent damage or misalignment of access tubes during the lifting and installation of the cage. Exercise care in removing the caps from the top of the tubes after installation so as not to apply excess torque, hammering or other stress which could break the bond between the tubes and the concrete.

Provide the following number (rounded up to the next whole number of tubes) and configuration of cross-hole sonic logging access tubes in each drilled shaft based on the diameter of the shaft.

Shaft Diameter	Number of Tubes Required	Configuration around the inside of Circular Reinforcing Cage
36 to 48 inches	4	90 degrees apart
Greater than 48 inches	1 tube per foot of Shaft Diameter	360 degrees divided by the Number of Tubes

Insert simulated or mock probes in each access tube prior to concreting to ensure the serviceability of the tube. Fill access tubes with clean potable water and recap prior to

concreting. Repair or replace any leaking, misaligned or unserviceable tubes as in a manner acceptable to the Engineer prior to concreting.

For drilled shaft foundations requiring anchor bolts, verify access tubes will not interfere with anchor bolt installation before excavating the shaft. When access tube locations conflict with anchor bolt locations, move the access tube location plus or minus 2 inches along the inner circumference of the reinforcing cage. Notify the Engineer before excavating the shaft if the access tube locations cannot be moved out of conflict with anchor bolt locations.

For drilled shafts supporting sign, signal, lighting and ITS structures, if the shaft cleaning operations result in excavating below the required tip elevation, the access tubes do not need to be extended. If the reinforcing steel cage is suspended in place from the top rather than resting on the bottom of the excavation, clearly mark the top of shaft location on each tube.

When called for in the Contract Documents, provide embedded thermal wires and equipment to allow TITDS in accordance with ASTM- D7949 Method- B.

SUBARTICLE 455-17.6.1.2 is deleted and the following substituted:

455-17.6.1.2 Procedure: Perform TITDS testing between 24 and 72 hours the minimum and maximum times shown below after the batching time of the first truck load placed in the drilled shaft concrete placement, unless otherwise directed by the Engineer.

<u>Shaft Diameter (inches)</u>	<u>Minimum time (hours)</u>	<u>Maximum time (hours)</u>
<u>36-48</u>	<u>24</u>	<u>54</u>
<u>49-60</u>	<u>24</u>	<u>72</u>
<u>61-72</u>	<u>24</u>	<u>72</u>
<u>73-84</u>	<u>24</u>	<u>90</u>
<u>85-120</u>	<u>24</u>	<u>108</u>
<u>When retarders are used to slow the onset of hydration, add the retardation time to the testing times indicated.</u>		

The Contractor may propose modifications in the above table for site specific and special concrete mix conditions, as demonstrated from lab and field testing and instrumentation. The Engineer must approve all changes to the testing times prior to the Contractor use them.

Furnish information regarding the shaft, tube lengths and depths, construction dates, and other pertinent shaft installation observations and details to the Department at the time of testing. Verify access tube lengths and their condition in the presence of the Department, at least 24 hours prior to TITDS the end of concrete placement. If the access tubes do not provide access over the full length of the shaft, repair the existing tube(s) or core additional hole(s), as directed by the Engineer, at no additional cost to the Department.

Just prior to inserting the thermal probe, remove water from the access tubes. Store the removed water in an insulated container for later replacement. Allow the thermal probe to acclimate in accordance with the equipment manufacturer recommendations. Continuously record temperatures at depth intervals of 3.0 inches or less from the top to the bottom of each access tube. Repeat the test at each access tube until two sets of data from the

same access tube provide similar results. Return the warm water to the access tubes immediately after the testing has been completed.

Immediately report any potential defects indicated by low temperature anomalies to the Engineer.

SUBARTICLE 455-17.6.1.5 is deleted and the following substituted:

455-17.6.1.5 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the TITDS tests and other testing, or observes problems during drilled shaft construction, core the shaft to allow further evaluation and repair, or replace the shaft as directed by the Engineer. If coring to allow further evaluation of the shaft and repair is chosen, one or more core samples shall be taken from each unacceptable shaft for full depth of the shaft or to the depth directed by the Engineer. The Engineer will determine the number, location, and diameter of the cores based on the results of the TITDS. Keep an accurate log of cores. Properly mark and place the cores in a crate showing the shaft depth at each interval of core recovery. Submit the coring log and transport the cores, along with five copies of the coring log to the location designated by the Engineer. Perform strength testing by an AASHTO certified lab on portions of the cores -as required by the Engineer. If the TITDS and coring indicate the shaft is defective, propose remedial measures for approval by the Engineer. Such improvement may consist of, but is not limited to correcting defective portions of the shaft, providing straddle shafts to compensate for capacity loss, or providing a replacement shaft. Repair all detected defects and conduct post repair integrity testing using horizontal and offset CSL testing and 3-D tomographic imaging as described in 455-17.6.2. Engage a Specialty Engineer to perform gamma-gamma density logging calibrated to 1-1/2- inch black iron access tubes, prior to and after the repair is performed, to verify the integrity of the shaft outside the reinforcing cage in the same locations where the repair was required. When straddle shafts or replacement shafts are used to correct a deficient foundation perform TITDS in accordance with 455-17.6.1 through 455-17.6.3 to verify integrity of these shafts. Submit all results to the Engineer within five days of test completion for approval. Perform all work described in this subarticle at no additional cost to the Department, and with no increase in Contract Time.

SUBARTICLE 455-17.6.2 is deleted and the following substituted:

455-17.6.2 Cross Sonic Logging (CSL) and Tomography: When required by the Engineer, perform CSL testing in accordance with ASTM D6760. Engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer must be a Professional Engineer in the State of Florida and have a minimum six months experience of CSL testing, supervising the collection of CSL data and interpretation of CSL results. The individual performing the CLS testing in the field must work for the Specialty Engineer firm and have a minimum of six months experience of CSL testing. The Contractor shall provide all necessary access and assistance to the CSL Specialty Engineer to satisfactorily perform the testing.

When a shaft contains four tubes, test every possible tube combination. For shafts with five or more tubes, test all pairs of adjacent tubes around the perimeter, and one-half of the remaining number of tube combinations, as chosen by the Engineer. Pull the probes simultaneously, starting from the bottoms of the tubes, over an electronic depth measuring

device. Perform the CSL tests with the source and receiver probes in the same horizontal plane. Continuously record **temperature CSL signals** at depth intervals of 2-1/2 inches or less from the bottom of the tubes to the top of each shaft. Remove all slack from the cables prior to pulling to provide accurate depth measurements in the CSL records. When the measurements indicate a 30% or greater reduction in velocity between one or more pairs perform 3D tomography analysis as indicated below.

To perform 3D tomography analysis, conduct offset CSL measurements between the tube pair combinations in addition to the horizontal measurements. Record offset measurements with source and receiver vertically offset in the tubes. These measurements add four measurements per tube combination to the horizontal measurements described in this section. Offset measurements are described by the angle, in degrees, and direction the signal travels between the probes with respect to the horizontal plane: plus 45, plus 22.5 (source below receiver), and minus 45, minus 22.5 (source above receiver). Record offset measurements from the point where the higher probe is at least 5 feet below the velocity reduction to the point where the lower probe is at least 5 feet above the velocity reduction. When repairs are done, provide offset measurements from the point where the higher probe is at least 5 feet below the lower limit of the repaired zone to the point where the lower probe is at least 5 feet above the upper limit of the repaired zone. Perform offset measurements and provide CSL logs and 3D tomographic analysis at no additional cost to the Department.

After acceptance of production shafts by the Engineer, fill the tubes or core holes with a structural non-shrink grout in accordance with 455-17.6.1.

If the Contractor determines at any time during the non-destructive testing and evaluation of the drilled shaft that the drilled shaft should be replaced, no further testing or evaluation of that shaft is required.

455-17.6.2.1 Required CSL Reports: Present the CSL data and analysis results to the Engineer in a signed and sealed report. Include CSL logs with analyses of first pulse arrival time (FAT) versus depth and pulse energy/amplitude versus depth. Present a CSL log for each tube pair tested with any defect zones identified on the logs and discussed in the test report as appropriate. When offset measurements are required, perform 3D tomographic analysis using all offset data, and include color coded 3D tomographic images in the report.

455-17.6.2.2 Evaluation of Cross Hole Sonic logging Testing: The Engineer will evaluate the observations during drilled shaft construction and the CSL test results to determine whether or not the drilled shaft construction is acceptable. Drilled shafts with velocity reduction exceeding 30% are not acceptable without an engineering analysis.

455-17.6.2.3 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the CSL test and other testing, core the shaft to allow further evaluation and repair, or replace the shaft in accordance with 455-17.6.1.5.

If repairs are performed or additional shafts installed to correct a deficient foundation, conduct integrity testing and submit the results to the Engineer in accordance with 455-17.6.1.5.

SUBARTICLE 455-21 is deleted and the following substituted:

455-21 Drilled Shaft Excavations Constructed out of Tolerance.

Do not construct drilled shaft excavations in such a manner that the concrete shaft cannot be completed within the required tolerances. The Contractor may make corrections to an unacceptable drilled shaft excavation by any combination of the following methods:

1. Overdrilling the shaft excavation to a larger diameter to permit accurate placement of the reinforcing steel cage with the required minimum concrete cover.
2. Increasing the number and/or size of the steel reinforcement bars.

When the tolerances are not met, the Contractor may propose a redesign to incorporate shafts installed out of tolerance into caps or footings. Incorporate shafts installed out of tolerance at no expense to the Department. Ensure the Contractor's Engineer of Record performs any redesign and signs and seals the redesign drawings and computations. Do not begin any proposed construction until the redesign has been reviewed ~~for acceptability~~ and approved by the Engineer.

Backfill any out of tolerance shafts in an approved manner when directed by the Engineer until the redesign is complete and approved. Furnish additional materials and work necessary, including engineering analysis and redesign, to effect corrections of out of tolerance drilled shaft excavations at no expense to the Department.

SUBARTICLE 455-24.1 is deleted and the following substituted:

455-24.1 Drilled Shafts: Price and payment will be full compensation for all drilled shafts, including the cost of concrete, reinforcing steel, ~~and cross hole sonic logging~~ nondestructive integrity testing access tubes, embedded thermal wires when required by the Contract Documents, and including all labor, materials, equipment, and incidentals necessary to complete the drilled shaft. The cost of the reinforcing steel, including lap lengths, to accommodate shaft lengths longer than shown in the Plans is included in the cost of drilled shafts. Costs associated with repairing defects found in the drilled shaft shall be included in the cost of the drilled shaft.

SUBARTICLE 455-30 is deleted and the following substituted:

455-30 Fill or Backfill.

In all excavations, including over-excavations below the footing, use only fill or backfill materials considered Select in accordance with Standard Plans, Index 120-001. Ensure the material is free of rubble, debris, or rocks that would prevent uniform placement and compaction. Ensure the material below the top of the footing is free of Recycled Asphalt Pavement (RAP). Perform sampling and testing in accordance with 120-10.1.4, except replace AASHTO FM 1-T99, Method C with FM 1-T180, Method D.

SUBARTICLE 455-31 is deleted and the following substituted:

455-31 Compaction and Density Requirements.

Compact the bottom of the excavation with suitable equipment. Compact the soil beneath footing excavation (whether dug to the bottom of footing or over-excavated) to a density not less than 95% of the maximum density as determined by FM 1-T180, ~~Method D~~ for a minimum depth of 2 feet below the bottom of the excavation or to the depth shown in the Plans before backfilling begins. For every 500 feet of excavation or isolated compaction operation, perform two Quality Control (QC) density tests with a 12 inch depth of measurement: one QC density test with the gauge placed at an elevation of 1 foot below the bottom of the excavation and one QC density test with the gauge placed at the bottom of the excavation in accordance with FM 1-T238. Compact the backfill in footing excavations which have been over-excavated to a density not less than 95% of the maximum density as determined by FM 1-T180, ~~Method D~~. Ensure that the maximum lift thickness after compaction does not exceed 6 inches. For every 500 ft of backfill or isolated compaction operation, perform at least one QC density test. The Engineer will conduct one density verification test per every 4 QC test, with a minimum of one density test below the bottom of the excavation and one density test in the backfill. Verification comparison criteria and resolution procedures will be in accordance with 120-10.4 except replace ~~AASHTO FM 1-T99, Method C~~ with FM 1-T180, ~~Method D~~.

For compaction, use an approved heavy vibratory roller with a static drum weight of at least 4 tons. Compact each lift to the required density. Also, compact the final lift below the footing with a suitable sled vibratory compactor to remove any upper disturbance caused by the drum roller. When conditions require use of smaller compaction equipment, obtain the Engineer's approval for the equipment, and reduce the lift thickness to achieve the required density.

Perform backfilling to the original ground surface, finished grade, or subgrade as required by the Plans in the immediate vicinity by approved mechanical compactors weighing less than 1,000 pounds. The Contractor may compact backfill located more than 15 feet away from the exterior periphery of the footing with heavier compactors. Do not place backfill on the footing until the Engineer has given permission and until the concrete is at least seven days old.

When the plans indicate spread footing abutments on mechanically stabilized earth (MSE) walls, place and compact the backfill material underneath the footing in accordance with the requirements of 548-8.5. Meet the density requirements of 548-9.4.

SUBARTICLE 455-36.1 is deleted and the following substituted:

455-36.1 Dewatering: ~~The quantity to be paid for will be at the Contract unit price for each footing excavation, only at locations authorized by the Engineer and acceptably dewatered~~
No separate payment will be made for dewatering.

SUBARTICLE 455-37.1 is deleted and the following substituted:

455-37.1 Dewatering: ~~Price and payment will be full compensation for all work related to the successful~~
No separate payment will be made for dewatering of footing excavations, including installing, maintaining, and monitoring piezometer wells. Dewatering will be

considered Unforeseeable Work when the Engineer determines that dewatering deeper than the requirements described in 455-28 is required ~~and the Plans do not include a dewatering item.~~

SUBARTICLE 455-37.5 is deleted and the following substituted:

455-37.5 Payment Items: Payment will be made under:

Item No. 125-	1-	Excavation F for Structures - per cubic yard.
Item No. 400-	2-	Class II Concrete - per cubic yard.
Item No. 400-	3-	Class III Concrete - per cubic yard.
Item No. 400-	4-	Class IV Concrete - per cubic yard.
Item No. 400-	91-	Dewatering For Spread Footings—each.
Item No. 415-	1-	Reinforcing Steel - per pound.

ARTICLE 455-38 is deleted and the following substituted:

455-38 Description.

Furnish and install auger cast piles (ACP), ~~also known as or augered- cast-in-place (ACIP) piles~~, used for structural support, other than bridge foundations.

ACP piles are defined as a foundation made by rotating a hollow-stem auger into the ground to the required pile depth with sufficient crowd (downward thrust) to prevent mining of the soil. A fluid cement grout is injected through the auger shaft under continuous positive pressure as the auger is being withdrawn. A reinforcing steel cage, as specified, is inserted into the column of fluid grout following the completion of grout placement.

ARTICLES 455-40 through 455-50 are deleted and the following substituted:

455-40 Materials.

Meet the following material requirements:

Portland Cement and Blended Cement	Section 921
Pozzolans and Slag	Section 929
Fine Aggregate (Sand)*	Section 902
Admixtures.....	Section 924
Water.....	Section 923
Fluidifier	ASTM C 937
<u>Reinforcing Steel.....</u>	<u>Section 415</u>

* The Engineer will only permit Silica Sand except as provided in 902-5.2.3.

455-41 Grout Mix Proportions.

Use a cement grout ~~cement~~ mix consisting of a mixture of cementitious materials, admixtures, sand and water proportioned and mixed to produce a mortar grout capable of maintaining the solids in suspension without appreciable bleed water which may be pumped without difficulty and will fill open voids in the adjacent soils and rock. The grout mix may also

include a fluidifier if desired. Proportion these materials to produce a hardened grout of the required strength.

455-42 Mixing and Pumping Cement Grout.

Meet the following requirements:

1. Only use pumping equipment approved by the Engineer in the preparation and handling of the grout. Before using the mixers, remove all oil or other rust inhibitors from the mixing drums, stirring mechanisms, and other portions of the equipment in contact with the grout.

2. Use a quantity of water and mixing time that will produce a homogenous grout having an efflux of not less than 21 seconds, when tested with a flow cone in accordance with ASTM D6449. Reject loads with efflux of less than 21 seconds. Notify the production facility to adjust the mix design. Calibrate the flow cone in accordance with ASTM D 6449. Conduct the calibration initially before its first use and as directed by the Engineer, when there is a question of the flow cone's accuracy.

Technicians performing the efflux test must take the Auger Cast Pile course and pass the final examination to be qualified to test for any auger cast pile installations in the field. Assist the Engineer in verifying the technicians meet these requirements.

Conduct tests for efflux time at the beginning of each days grouting operation and as directed by the Engineer to ensure the specification requirements are met.

3. Mix the grout at least one minute. If agitated continuously, the grout may be held in the mixer or agitator for a period not exceeding 2.5 hours at grout temperatures below 70°F; two hours for temperatures from 70°F to 100°F. Do not place grout when its temperature exceeds 100°F. If there is a lapse in the operation of grout injection, recirculate the grout through the pump, or through the mixer drum or agitator.

4. Use mixers capable of combining components into a thoroughly mixed and uniform mass, free from balls or lumps and capable of discharging the concrete grout with a satisfactory degree of uniformity. The Engineer's approval of grout mixers and all other equipment will be contingent on proper performance during construction of the demonstration pile and subsequent production work.

5. Use a screen no larger than 3/4 inch mesh between the mixer and pump to remove large particles which might clog the injection system.

6. Use a positive displacement piston type grout pump equipped with a pressure gauge, capable of developing displacing pressures at the pump ~~up to~~ not less than 350 psi. The pump shall must be appropriately sized to the pile diameter. Provide a grout pressure gauge in clear view of the equipment operator. Provide a second pressure gauge near the drill rig where it can be observed by the Engineer.

7. Accurately monitor the volume and pressure of the grout flow. Test and calibrate the equipment during construction of the demonstration pile to demonstrate flow volume measurement accuracy of plus or minus 3% over the range of grouting pressures anticipated during this work. Provide a pump stroke counter in good working condition on the grout pump. Perform a calibration test of the pumping equipment, prior to construction of the demonstration piles, to determine the average volume of grout for every pump stroke, in accordance with FM 5-612. Also calibrate the equipment any time the Engineer determines the grout pump performance may have changed.

455-43 Testing Cement Grout.

Prepare three 4 inches x 8 inches cylinders in accordance with ASTM C31, except pour grout in a single lift into cylinders molds without rodding, for each LOT. Plastic properties in accordance with ASTM C31 are not required. A LOT is defined as the lesser of 50 cubic yards of cement grout placed or one day of pile placement. Prepare one additional “hold” cylinder on the lot that is selected by the Engineer for Verification. Provide curing facilities for all QC and Verification test cylinders in accordance with ASTM C31. Test the cylinders at 28 days, in accordance with ASTM C39.

When one of the three QC cylinders from a LOT is lost, missing, damaged or destroyed, determination of compressive strength will be made by averaging the remaining two cylinders. If more than one QC cylinder from a LOT is lost, missing, damaged or destroyed, core the structure at no additional expense to the Department to determine the compressive strength. Acceptance of LOT may be based on verification data at the discretion of the Engineer. Obtain the approval of the Engineer to core, and of the core location prior to coring. Repair core holes after samples are taken with a product meeting the approval of the Engineer, at no additional cost to the Department.

For each QC cylinder that is lost, missing, damaged or destroyed, payment for that LOT will be reduced by \$750.00 per 1,000 psi of the specified design strength [Example: For $f'_c=5,500$ psi, the loss of two auger cast pile grout QC cylinders that have no verification data will require the element to be cored and a pay reduction will be assessed ($5,500 \text{ psi} / 1,000 \text{ psi}$) x $\$750 \times 2 = \$8,250$]. This reduction will be in addition to any pay adjustment for low strength.

The Engineer will also cast three verification cylinders and one “hold” cylinder from one of every four consecutive lots, randomly selected. The Engineer will compare QC and Verification results in accordance with Section 346. If the results do not compare, the Engineer will initiate a Resolution Investigation in accordance with Section 346

Personnel making/curing concrete grout cylinders shall be certified as ACI Concrete Field Testing Technician Grade I. Personnel performing tests on hardened properties of concrete grout, such as strength determination of cylinders or beams, they shall be certified as ACI Concrete Strength Testing Technician.

All low strength cement grout accepted by the Engineer will be subject to reduced payment as follows: \$0.80 per cubic yard for each 10 psi of strength test value below the specified minimum strength. The Engineer will use the average compressive strength of the LOT tests for the computation of this pay reduction.

The Engineer will compute the volume of grout for which the reduction will be applied as 115% of the theoretical volume of the auger cast pile diameter required in the Contract Documents. Reduction in pay will be applied to the entire length of all piles containing low strength cement grout, in any quantity. The quantity of cement grout affected by the price reduction may exceed the quantity of cement grout contained in the LOT.

When separate payment for auger grouted piles is provided, the dollar reduction will be equated to an equivalent length of pile not to exceed the total pile length constructed utilizing the subject LOT based on the following formula:

$$PLR = RC/UC$$

Where: PLR = Equivalent Pile Length Reduction in feet

RC = Total Reduction in payment, dollars

UC = Unit Cost of pile, dollars /foot

When a cement grout acceptance strength test falls more than 500 psi below the specified minimum strength perform one of the following:

1. Remove and replace the ~~cement grout represented~~ piles affected fully or partially by the low strength LOT ~~in question~~ at no additional cost to the Department; or,
2. Submit a structural analysis performed by the Contractor's Engineer of Record. If the results of the analysis, approved by the Department, indicate adequate strength to serve the intended purpose with adequate durability, the ~~concrete~~ grout may remain in place.

Otherwise, abandon and install additional piles to the foundation, or remove and replace the piles affected fully or partially by the low strength LOT of ~~concrete~~ grout ~~in question~~ at no additional cost to the Department. When installing additional piles to resolve the strength deficiency, submit a foundation redesign to add piles into pile caps or footings, at no expense to the Department in accordance with 455-46.

455-44 Pile Installation.

Meet the following requirements:

1. Locate the piles as shown on the drawings.
2. Should soft, compressible muck, organics, clay or other unsuitable materials (non A-1, A-3, A-2-4 or limestone materials) be encountered, remove the unsuitable material to a maximum depth of 5 feet and a ~~maximum diameter about~~ radial distance around the pile centerline ~~not to exceed 1/2 of the distance to the adjacent~~ of 2two piles diameters unless otherwise indicated in the Plans. Backfill with clean granular backfill materials (A-1, A-3, A-2-4), placed and compacted in maximum 12 inch lifts to at least 95% of maximum dry density as determined by ~~AASHTO~~ FM 1-T180. Complete this work to the Engineer's satisfaction prior to ~~auger cast pile~~ ACP construction. Should more than 5 feet depth or excessive quantities of unsuitable material be encountered, immediately advise the Engineer and proceed with the work as directed by the Engineer.
3. Provide continuous auger flighting from the auger head to the top of auger with no gaps or other breaks. Ensure the auger flights are uniform in diameter throughout its length, and of the diameter specified for the piles less a maximum of 3%. Provide augers with a distance between flights of approximately half the diameter of the auger.
4. Use augers with the grout injection hole located at the bottom of the auger head below the bar containing the cutting teeth, and with pile auger leads containing a bottom guide.
5. Construct piles of the length and diameter shown on the ~~drawing~~ Plans.
6. Clearly mark the auger leads to facilitate monitoring of the incremental drilling and grout placement. Provide individual foot marks with 5 foot increments highlighted and clearly visible. Provide a clear reference mark on the moving auger assembly to facilitate accurately monitoring the vertical movement of the auger.
7. Place piles by rotating a continuous flight hollow shaft auger into the ground at a continuous rate that prevents removal of excess soil. Stop advancement after reaching the predetermined depth.
8. Should auger penetration to the required depth prove difficult due to hard materials/refusal, the pile location may be predrilled, upon approval of the Engineer, through the obstruction using appropriate drilling equipment, to a diameter no larger than 1/2 the prescribed finish diameter of the ~~auger cast pile~~ ACP. Commence ~~auger cast pile~~ ACP construction immediately upon completion of predrilling to minimize ground loss and soil relaxation. Should non-drillable material be encountered preventing placement to the depth required, immediately

advise the Engineer and proceed with the work as directed by the Engineer. Refusal is defined as the depth where the penetration of the standard auger equipment is less than 12 inches per minute.

9. Plug the hole in the bottom of the auger ~~while being~~ prior to ~~advancing~~ into the ground. ~~Remove the plug by the grout or with the reinforcing bar.~~

10. Pump the grout with sufficient pressure as the auger is withdrawn to completely fill the auger hole, preventing hole collapse and to cause the lateral penetration of the grout into soft or porous zones of the surrounding soil or rock. Prior to commencing withdrawal of the auger, establish a head of at least 5 feet of grout by pumping a volume of grout equivalent to 5 feet of pile volume. Maintain this head of at least 5 feet of grout above the injection point around the perimeter of the auger to displace and remove any loose material from the hole. Maintain positive rotation of the auger at least until placement of the grout.

11. Once the grout head has been established, greatly reduce the speed of rotation of the auger and commence extraction at a rate consistent with the pump discharge. Maintain extraction at a steady rate to prevent a locked-in auger, necking of the pile, or a substantially reduced pile section. Ensure grout starts flowing out from the hole when the cutting head is at least 5 feet below the ground surface. Place a minimum volume of grout in the hole of at least 115% of the column of the auger hole from a depth of 5 feet to the tip. Place a minimum volume of grout in the hole of at least 105% of the column of the auger hole from the ground surface to a depth of 5 feet. Do not include any grout needed to create surplus grout head in the volume of grout placed into the hole. If the grout does not flow out from the hole when the cutting head is at least 5 feet below the ground surface, redrill the pile under the direction of the Engineer. If grouting is interrupted for any reason, reinsert the auger by drilling at least 5 feet below the tip of the auger when the interruption occurred, and then regrout.

Use this method of placement at all times. Do not depend on the stability of the hole without the earth filled auger. Place the required steel reinforcement while the grout is still fluid, but no later than 1/2 hour after pulling of the auger.

12. Assume responsibility for the grout volume placed. If less than 115% of the theoretical volume of grout is placed in any 5 foot increment (105% in the top 5 foot increment), reinstall the pile by advancing the auger 10 feet or to the bottom of the pile if that is less, followed by controlled removal and grout injection.

13. Furnish and install the reinforcing steel and anchoring bolts as shown in the Contract ~~drawings~~ Documents. Use wheels or other approved noncorrosive spacing devices within 3 feet of the bottom, within 3 feet of the top, and intervals not exceeding 10 feet along the pile to ensure concentric spacing for the entire length of the cage. Do not use block or wire type spacers. Use a minimum of one spacer per 30 inches of circumference or perimeter of cage with a minimum of three (3) at each level.

14. Use reinforcement that is without kinks or nonspecified bends, free of mud, oil or other coatings that could adversely affect the bond. Make splices in reinforcement as shown on the Contract ~~drawings~~ Documents, unless otherwise approved by the Engineer. Place the required steel reinforcement while the grout is still fluid, and immediately after finishing grouting and clearing it from any contaminating material. Install ~~the~~ steel cage ~~shall be installed~~ into the grout by its own weight or manually. Do not use a mechanical equipment or tool to impact the steel cage or to force it into the grout.

15. Leave any temporary supports of/for items placed into a grouted pile (reinforcement template, anchor bolt template, precast column supports, etc.) in place for a minimum of 12 hours after completion of the pile. Do not place wall panels or other significant

loads, before piles are accepted and the grout has set a minimum of seven days or reached the 28 day strength.

455-45 Construction Tolerances.

Locate piles as shown in the drawings Plans, or as otherwise directed by the Engineer. Locate pile centers to an accuracy of plus or minus 3 inches. Ensure that the top of pile elevation is within an accuracy of plus or minus 3 inches of the plan elevation. Ensure the tolerances of in 534-5.1 can be met.

455-46 Unacceptable Piles.

Repair or replace unacceptable piles, as directed by the Engineer, at no cost to the Department. Unacceptable piles are defined as piles that fail for any reason, including but not limited to the following: piles placed out of position or to improper elevation; piles with reduced cross section, contaminated grout, lack of grout consolidation (honeycombed), or deficient grout strength; and piles with reinforcement, anchor devices or other components cast or placed into the fluid grout out of position. When the Engineer determines that a pile is unacceptable, the Contractor may propose a foundation redesign to add piles into pile caps or footings, at no expense to the Department. The Contractor's Engineer of Record must perform any redesign, and sign and seal the redesign drawings and calculations. Do not begin any proposed construction until the redesign has been reviewed and approved by the Engineer.

455-47 Auger Cast Pile Installation Plan (ACPIP).

At the preconstruction conference, but no later than 30 days before auger cast pile ACP construction begins, submit an auger cast pile installation plan ACP for approval by the Engineer. Provide the following detailed information on the plan:

1. Name and experience record of auger cast pile ACP superintendent or foreman in responsible charge of auger cast pile ACP operations. Place a person in responsible charge of day to day auger cast pile ACP operations who possesses satisfactory prior experience constructing auger cast piles similar to those described in the Contract Documents. The Engineer will give final approval subject to satisfactory performance in the field.
2. List and size of the proposed equipment, including cranes, augers, concrete pumps, mixing equipment etc., including details of proposed pump calibration procedures.
3. Details of pile installation methods.
4. Details of reinforcement placement and method of centering in pile, including details of all temporary supports for reinforcement, anchor bolts, precast columns, etc.
5. Details of how and by whom the grout volumes will be determined, monitored and documented.
6. Required submittals, including shop drawings and concrete ement grout design mixes.
7. Other information shown in the Plans or requested by the Engineer.

455-48 Inspection and Records.

The Engineer will monitor pile installation.

455-49 Method of Measurement.

455-49.1 Auger Cast Pile: The quantity to be paid for will be at the Contract unit price per foot between tip and required pile top elevations for all piles completed and accepted.

455-50 Basis of Payment.

455-50.1 Auger Cast Piles: Price and payment will be full compensation for all labor, materials, and incidentals for construction of ~~auger cast piles~~ ACP of the sizes and depths indicated on the Contract drawing Documents or as otherwise ~~required under this Contract~~ directed by the Engineer. Price and payment will also include the removal and proper disposal off site of all spoil from the auger operation and all excess grout displaced from the auger hole, unless otherwise approved by the Engineer. Work to remove and replace unsuitable material when necessary as specified in 455-44 will be considered Unforeseeable Work.

455-50.2 Payment Items: Payment will be made under:

Item No. 455-112- Auger Grouted Piles - per foot.

STRUCTURES FOUNDATIONS.**(REV 6-14-18)**

SUBARTICLE 455-7.1 is deleted and the following substituted:

455-7.1 Description: Provide prestressed concrete piles that are manufactured, cured, and driven in accordance with the Contract Documents. Provide piles full length without splices when transported by barge or the pile length is less than or equal to 120 feet. When piles are transported by truck and the pile length exceeds 120 feet or the maximum length for a 3-point pick-up according to Standard Plans, Index 455-001, and splicing is desired, provide minimal splices. Include the cost of the splices in the cost of the pile.

SUBARTICLE 455-11.10 is deleted and the following substituted:

455-11.10 Pile Extraction: Piles authorized to be extracted by the Engineer and successfully extracted as provided in 455-11.2.3 will be paid for as described in 455-11.2.3. No payment for extraction will be made for piles shown in the Plans to be extracted or piling damaged or mislocated by the Contractor that are ordered to be extracted by the Engineer.

SUBARTICLE 455-15.1.1 is deleted and the following substituted:

455-15.1.1 Templates: When drilling from a barge, provide a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations. Do not use floating templates (attached to a barge). When the Contractor fails to properly maintain shaft position and alignment without use of a template when drilling on land, the Engineer will require a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations.

SUBARTICLE 455-15-1.2 is deleted and the following substituted:

455-15.1.2 Drilled Shaft Installation Plan (DSIP): At the preconstruction conference submit a DSIP for review by the Engineer. Final approval will be subject to satisfactory performance. Include in this plan the following details:

1. Name and experience record of drilled shaft superintendent or foreman in responsible charge of drilled shaft operations. Ensure the drilled shaft superintendent or foreman in responsible charge of the drilled shaft operations has a minimum of one year of experience of installing drilled shafts of the size and depth shown in the Plans and a minimum of three years experience in the construction of drilled shafts using the following methods:

- a. Wet Method (mineral and polymer slurry),
- b. Casings up to the length shown in the Plans,
- c. Shaft drilling operations on water under conditions as shown in

the Plans.

2. List and size of proposed equipment, including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies or concrete pumps, casings, and equipment to install and remove casing.

3. Details of sequence of construction operations and sequence of shaft construction in bents or shaft groups.

4. Details of shaft excavation methods, including casing installation procedures.

5. Details of slurry, including proposed methods to mix, circulate, desand, test methods, and proposed CTQP certified technician that will perform and document the fluid tests.

6. Details of proposed methods to clean the shaft excavation.

7. Details of shaft reinforcement, including methods to ensure centering/required cover, cage integrity during placement, placement procedures, cage support, and tie downs.

8. Details of concrete placement, including elapsed concrete placement times and proposed operational procedures for concrete tremie or pump, including initial placement, raising during placement, and overfilling of the shaft concrete. Include provisions to ensure proper final shaft cutoff elevation.

9. Details of casing removal when removal is required, including minimum concrete head in casing during removal.

10. Required submittals, including shop drawing and concrete design mixes.

11. Details of any required load tests, including equipment and procedures, and recent calibrations for any jacks or load cells.

12. Proposed Cross-Hole Sonic Logging (CSL) and Thermal Integrity Testing for Drilled (TITDS) Specialty Engineer to supervise field testing and report the test results.

13. Methods and equipment proposed to prevent displacement of casing and/or shafts during placement and compaction of fill.

14. Provide the make and model of the shaft inspection device, if applicable.

15. Details of environmental control procedures used to prevent loss of slurry or concrete into waterways or other protected areas.

16. Proposed schedule for test shaft installation, load tests and production shaft installation.

17. Other information shown in the Plans or requested by the Engineer.

18. For drilled shafts constructed using polymer slurry, identify the polymer slurry meeting the requirements of 455-15.8.3, the pH and viscosity ranges recommended by the manufacturer for the materials to be excavated and a description of the mixing method to be used. Submit the Material Safety Data Sheets (SDS) for the product, and certifications that the polymer slurry and components meet the requirements of 455-15.8.3. Submit the contact information for the manufacturer's representative available for immediate contact during shaft construction and the representative's schedule of availability.

19. Procedure for grouting non-destructive testing access tubes.

The Engineer will evaluate the DSIP for conformance with the Contract Documents. Within 20 days after receipt of the plan, the Engineer will notify the Contractor of

any additional information required and/or changes that may be necessary in the opinion of the Engineer to satisfy the Contract Documents. The Engineer will reject any part of the plan that is unacceptable. Submit changes agreed upon for reevaluation. The Engineer will notify the Contractor within seven days after receipt of proposed changes of their acceptance or rejection. All equipment and procedures are subject to trial and satisfactory performance in the field.

Acceptance by the Engineer does not relieve the Contractor of the responsibility to perform the work in accordance with the Contract Documents. The installation plan is for the Contractor to explain the approach to the work and allow the Engineer an opportunity to comment on the equipment and procedures chosen before field operations begin. The Engineer's acceptance is not a guarantee that the chosen methods and equipment are capable of obtaining the required results, this responsibility lies with the Contractor.

SUBARTICLE 455-15.8 is deleted and the following substituted:

455-15.8 Slurry and Fluid in Excavation:

455-15.8.1 General: Thoroughly premix the slurry with clean fresh water prior to introduction into the shaft excavation. Introduce slurry before the excavation advances below the bottom of the casing. Ensure that the percentage of polymer or mineral admixture used to make the suspension is such as to maintain the stability of the shaft excavation. The Engineer will require adequate water and/or slurry tanks when necessary to perform the work in accordance with this Section. The Engineer will not allow excavated pits on projects requiring slurry tanks without the written permission of the Engineer. Take the steps necessary to prevent the slurry from "setting up" in the shaft; including, but not limited, to agitation, circulation, and adjusting the composition and properties of the slurry. Provide suitable offsite disposal areas and dispose of all waste slurry in a manner meeting all requirements pertaining to pollution.

Provide a CTQP qualified drilled shaft inspector to perform control tests using suitable apparatus on the slurry mixture to determine the slurry and fluid properties as specified in 455-15.8.2 to 455-15.8.4.

Measure the viscosity of the freshly mixed slurry regularly as a check on the quality of the slurry being formed using an approved measuring device.

Perform tests from the fluid in the excavation to determine density, viscosity, and pH value to establish a consistent working pattern, taking into account the mixing process and blending of freshly mixed slurry and previously used slurry. Repeat tests to determine density, viscosity, and pH value at intervals not exceeding 2 hours during the first 8 hours slurry is in use and every 4 hours thereafter, including overnight, until concrete placement. Perform density, viscosity and pH tests again when the excavation reaches the midpoint.

The Department may perform comparison tests as determined necessary during the mineral and polymer slurry operations.

If, at any time in the opinion of the Engineer, the wet construction method fails to stabilize the excavation, discontinue this method of construction, backfill the excavation and submit modifications in procedure or alternate means of construction for approval.

455-15.8.2 Mineral Slurry: When mineral slurry is used in an excavation, use only processed attapulgite or bentonite clays with up to 2% (by dry weight) of added polymer. Use mineral slurry having a mineral grain size such that it will remain in suspension and having sufficient viscosity and gel characteristics to transport excavated material to a suitable screening

system. Use a percentage and specific gravity of the material to make the suspension sufficient to maintain the stability of the excavation and to allow proper placement of concrete. Ensure that the material used to make the slurry is not detrimental to concrete or surrounding ground strata. During construction, maintain the level of the slurry at a height sufficient to prevent caving of the hole. In the event of a sudden significant loss of slurry such that the slurry level cannot practically be maintained by adding slurry to the hole, backfill the excavation and delay the construction of that foundation until an alternate construction procedure has been approved.

Perform the following tests on the mineral slurry supplied to and in the shaft excavation and ensure that the results are within the ranges stated in the table below:

Item to be measured	Range of Results at 68°F	Test Method
Density	64 to 73 lb/ft ³ (in fresh water environment) 66 to 75 lb/ft ³ (in salt water environment)	Mud density balance: FM 8-RP13B-1
Viscosity	30 to 40 seconds	Marsh Cone Method: FM 8-RP13B-2
pH	8 to 11	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	4% or less	FM 8-RP13B-3

The Contractor may adjust the limits in the above table when field conditions warrant as successfully demonstrated in a test hole or with other methods approved by the Engineer. The Engineer must approve all changes in writing before the Contractor can continue to use them.

During construction, maintain the level of mineral slurry in the shaft excavation within the excavation and at a level not less than 4 feet above the highest expected piezometric water elevation along the depth of a shaft.

455-15.8.3 Polymer Slurry: Materials manufactured expressly for use as polymer slurry for drilled shafts that meet the requirements of this Section may be used as slurry for drilled shaft excavations. A representative of the manufacturer must be on-site or available for immediate contact to assist and guide the construction of the first three drilled shafts at no additional cost to the Department. This representative must also be available for on-site assistance or immediate contact if problems are encountered during the construction of the remaining drilled shafts as determined by the Engineer. Use polymer slurry only if the soils below the casing are not classified as organic, and the pH of the fluid in the hole can be maintained in accordance with the manufacturer's published recommendations. Submit the SDS for the product, the manufacturer's published mixing procedures, and the manufacturer's published range of values for pH and viscosity of the mixed slurry. Submit a report in accordance with Section 2.4, Volume II of the Department's Material Manual, which may be viewed at the following URL:

<http://www.fdot.gov/programmanagement/Implemented/URLinSpecs/Section24V2.shtm> .

The report must include test results, certification and documentation that demonstrate the polymer slurry and additives meet the following requirements:

1. The polymer slurries to be used on the project and their waste products are classified as non-hazardous as defined by Resource Conservation and Recovery Act (RCRA) Subpart C rules, Table 1 of 40 CFR 261.24 Toxicity Characteristic.

2. Pull out tests demonstrate the bond between the bar reinforcement and the concrete is not materially affected by exposure to the slurry under typical construction conditions, over the typical range of slurry viscosities to be used.

3. Load tests demonstrate the bond between the concrete and the soil is not materially affected by exposure to the polymer slurry under typical construction conditions, over the typical range of polymer slurry viscosities to be used.

4. The method of disposal meets the approval of all federal, state and local regulatory authorities.

Perform the following tests on the polymer slurry supplied to and in the shaft excavation and ensure that the results are maintained within the ranges stated in the table below:

Mixed Polymer Slurry Properties		
Item to be measured	Range of Results at 68°F	Test Method
Density	62 to 65 lb/ft ³ (fresh water) 64 to 67 lb/ft ³ (salt water)	Mud density balance: FM 8-RP13B-1
Viscosity	50 seconds to upper limit published by the manufacturer, limited by 455-15.8.3(2) and (3) above, for materials excavated	Marsh Cone Method: FM 8-RP13B-2
pH	Range published by the manufacturer for materials excavated	Electric pH meter or pH indicator paper strips: FM 8-RP13B-4
Sand Content	0.5% or less	FM 8-RP13B-3

Premix polymer slurry in accordance with the manufacturer's published procedures. Do not mix the slurry in the excavation as a means to initially prepare slurry, adjustments to slurry properties can be made in the excavation as needed.

During construction, maintain the level of the slurry at a height sufficient to prevent caving of the hole and which should not be lower than 4 feet above the highest expected piezometric water elevation along the depth of the shaft.

455-15.8.4 Fluid In Excavation At Time Of Concrete Placement: When any fluid is present in any drilled shaft excavation, including shafts to support sign, signal, lighting and ITS structures, the applicable test methods and reporting requirements described in 455-15.8.1, 455-15.8.2 and 455-15.8.3 apply to tests of fluid in the shaft prior to placing the concrete.

Test samples of the fluid in the shaft from within 1 inch of the base of the shaft and from the middle of the shaft height for shafts up to 60 feet in depth. Test samples of the fluid in the shaft from within 1 inch of the base of the shaft and at intervals not exceeding 30 feet up the shaft for shafts deeper than 60 feet. Use a sampling tool, approved by the Engineer, designed to sample over a depth range of 12 inches or less. Take whatever action is necessary

prior to placing the concrete to bring the fluid within the specification and reporting requirements, outlined in the tables in 455-15.8.2 and 455-15.8.3, except as follows:

The Engineer will not require tests for pH or viscosity, nor require the fluid to meet the minimum density specified in 455-15.8.2 and 455-15.8.3 when neither polymer nor mineral slurry has been introduced into the shaft excavation.

SUBARTICLE 455-15.11.1 is deleted and the following substituted:

455-15.11.1 Dimensions and Alignment: Provide equipment for checking the dimensions and alignment of each permanent shaft excavation. Determine the dimensions and alignment of the shaft excavation under the observation and direction of the Department. Generally check the alignment and dimensions by any of the following methods as necessary:

1. Check the dimensions and alignment of dry shaft excavations using reference stakes and a plumb bob.
2. Check the dimensions and alignment of casing when inserted in the excavation.
3. Insert any casing, rod or pipe assembly, or other device used to check dimensions and alignment into the excavation to full depth.

SUBARTICLE 455-15.11.3 is deleted and the following substituted:

455-15.11.3 Shaft Inspection Device (SID): When shown in the Plans, furnish all power and equipment necessary for the Engineer to inspect the bottom conditions of a drilled shaft excavation and to measure the thickness of bottom sediment or any other debris using a SID. Provide a means to position and lower the SID into the shaft excavation to enable the bell housing to rest vertically on the bottom of the excavation. Include all cost related to the inspection device in the cost of drilled shaft items.

Furnish a SID meeting the following requirements:

1. A remotely operated, high resolution, color video camera sealed inside a watertight bell housing.
2. Provides a clear view of the bottom inspection on a video monitor at the surface in real time.
3. Provides a permanent record of the entire inspection with voice annotation on a quality DVD with a resolution of not less than 720 x 480.
4. Provides a minimum field of vision of 110 square inches, with at least two graduated measuring devices to record the depth of sediment on the bottom of the shaft excavation to a minimum accuracy of 1/2 inch and a length greater than 1-1/2 inches.
5. Provides sufficient lighting to illuminate the entire field of vision at the bottom of the shaft in order for the operator and inspector to clearly see the depth measurement scale on the video monitor and to produce a clear recording of the inspection.
6. Provides a regulated compressed air or gas system to precisely adjust the drilling fluid level within the bell housing and a pressurized water system to assist in determination of bottom sedimentation depth.

Obtain the Engineer's approval of the device in advance of the first inspection contingent on satisfactory field performance. Notify the Engineer for approval before a different device is used for any subsequent inspection.

SUBARTICLE 455-16.4 is deleted and the following substituted:

455-16.4 Nondestructive Integrity Testing Access Tubes: Install access tubes full length in all drilled shafts from the tip of shaft to a point high enough above top of shaft to allow thermal integrity testing for drilled shafts (TITDS) and cross-hole sonic logging (CSL) testing, but not less than 30 inches above the top of the drilled shaft, ground surface or water surface, whichever is higher. Equally space tubes around circumference of drilled shaft. Securely tie access tubes to the inside of the reinforcing cage and align tubes to be parallel to the vertical axis of the center of the cage. Access tubes from the top of the reinforcing cage to the tip of the shaft shall be NPS 1-1/2 Schedule 40 black iron or black steel (not galvanized) pipe. Access tubes above the top of the reinforcing cage may be the same black iron or black steel pipe or Schedule 40 PVC pipe. Ensure that the access tubes are free from loose rust, scale, dirt, paint, oil and other foreign material. Couple tubes as required with threaded couplers, such that inside of tube remains flush. Seal the bottom and top of the tubes with threaded caps. The tubes, joints and bottom caps shall be watertight. Seal the top of the tubes with lubricated, threaded caps sufficient to prevent the intrusion of foreign materials. Stiffen the cage sufficiently to prevent damage or misalignment of access tubes during the lifting and installation of the cage. Exercise care in removing the caps from the top of the tubes after installation so as not to apply excess torque, hammering or other stress which could break the bond between the tubes and the concrete.

Provide the following number (rounded up to the next whole number of tubes) and configuration of cross-hole sonic logging access tubes in each drilled shaft based on the diameter of the shaft.

Shaft Diameter	Number of Tubes Required	Configuration around the inside of Circular Reinforcing Cage
36 to 48 inches	4	90 degrees apart
Greater than 48 inches	1 tube per foot of Shaft Diameter	360 degrees divided by the Number of Tubes

Insert simulated or mock probes in each access tube prior to concreting to ensure the serviceability of the tube. Fill access tubes with clean potable water and recap prior to concreting. Repair or replace any leaking, misaligned or unserviceable tubes as in a manner acceptable to the Engineer prior to concreting.

For drilled shaft foundations requiring anchor bolts, verify access tubes will not interfere with anchor bolt installation before excavating the shaft. When access tube locations conflict with anchor bolt locations, move the access tube location plus or minus 2 inches along the inner circumference of the reinforcing cage. Notify the Engineer before excavating the shaft if the access tube locations cannot be moved out of conflict with anchor bolt locations.

For drilled shafts supporting sign, signal, lighting and ITS structures, if the shaft cleaning operations result in excavating below the required tip elevation, the access tubes do not

need to be extended. If the reinforcing steel cage is suspended in place from the top rather than resting on the bottom of the excavation, clearly mark the top of shaft location on each tube.

When called for in the Contract Documents, provide embedded thermal wires and equipment to allow TITDS in accordance with ASTM D7949 Method B.

SUBARTICLE 455-17.6.1.2 is deleted and the following substituted:

455-17.6.1.2 Procedure: Perform TITDS testing between the minimum and maximum times shown below after the batching time of the first truck load placed in the drilled shaft, unless otherwise directed by the Engineer.

Shaft Diameter (inches)	Minimum time (hours)	Maximum time (hours)
36-48	24	54
49-60	24	72
61-72	24	72
73-84	24	90
85-120	24	108

The Contractor may propose modifications in the above table for site specific and special concrete mix conditions, as demonstrated from lab and field testing and instrumentation. The Engineer must approve all changes to the testing times prior to the Contractor use them.

Furnish information regarding the shaft, tube lengths and depths, construction dates, and other pertinent shaft installation observations and details to the Department at the time of testing. Verify access tube lengths and their condition in the presence of the Department, at the end of concrete placement. If the access tubes do not provide access over the full length of the shaft, repair the existing tube(s) or core additional hole(s), as directed by the Engineer, at no additional cost to the Department.

Just prior to inserting the thermal probe, remove water from the access tubes. Store the removed water in an insulated container for later replacement. Allow the thermal probe to acclimate in accordance with the equipment manufacturer recommendations. Continuously record temperatures at depth intervals of 3.0 inches or less from the top to the bottom of each access tube. Repeat the test at each access tube until two sets of data from the same access tube provide similar results. Return the warm water to the access tubes immediately after the testing has been completed.

Immediately report any potential defects indicated by low temperature anomalies to the Engineer.

SUBARTICLE 455-17.6.1.5 is deleted and the following substituted:

455-17.6.1.5 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the TITDS tests and other testing, or observes problems during drilled shaft construction, core the shaft to allow further evaluation and repair,

or replace the shaft as directed by the Engineer. If coring to allow further evaluation of the shaft and repair is chosen, one or more core samples shall be taken from each unacceptable shaft for full depth of the shaft or to the depth directed by the Engineer. The Engineer will determine the number, location, and diameter of the cores based on the results of the TITDS. Keep an accurate log of cores. Properly mark and place the cores in a crate showing the shaft depth at each interval of core recovery. Submit the coring log and transport the cores to the location designated by the Engineer. Perform strength testing by an AASHTO certified lab on portions of the cores as required by the Engineer. If the TITDS and coring indicate the shaft is defective, propose remedial measures for approval by the Engineer. Such improvement may consist of, but is not limited to correcting defective portions of the shaft, providing straddle shafts to compensate for capacity loss, or providing a replacement shaft. Repair all detected defects and conduct post repair integrity testing using horizontal and offset CSL testing and 3-D tomographic imaging as described in 455-17.6.2. Engage a Specialty Engineer to perform gamma-gamma density logging calibrated to 1-1/2 inch black iron access tubes, prior to and after the repair is performed, to verify the integrity of the shaft outside the reinforcing cage in the same locations where the repair was required. When straddle shafts or replacement shafts are used to correct a deficient foundation perform TITDS in accordance with 455-17.6.1 through 455-17.6.3 to verify integrity of these shafts. Submit all results to the Engineer within five days of test completion for approval. Perform all work described in this subarticle at no additional cost to the Department, and with no increase in Contract Time.

SUBARTICLE 455-17.6.2 is deleted and the following substituted:

455-17.6.2 Cross Sonic Logging (CSL) and Tomography: When required by the Engineer, perform CSL testing in accordance with ASTM D6760. Engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer must be a Professional Engineer in the State of Florida and have a minimum six months experience of CSL testing, supervising the collection of CSL data and interpretation of CSL results. The individual performing the CSL testing in the field must work for the Specialty Engineer firm and have a minimum of six months experience of CSL testing. The Contractor shall provide all necessary access and assistance to the CSL Specialty Engineer to satisfactorily perform the testing.

When a shaft contains four tubes, test every possible tube combination. For shafts with five or more tubes, test all pairs of adjacent tubes around the perimeter, and one-half of the remaining number of tube combinations, as chosen by the Engineer. Pull the probes simultaneously, starting from the bottoms of the tubes, over an electronic depth measuring device. Perform the CSL tests with the source and receiver probes in the same horizontal plane. Continuously record CSL signals at depth intervals of 2-1/2 inches or less from the bottom of the tubes to the top of each shaft. Remove all slack from the cables prior to pulling to provide accurate depth measurements in the CSL records. When the measurements indicate a 30% or greater reduction in velocity between one or more pairs perform 3D tomography analysis as indicated below.

To perform 3D tomography analysis, conduct offset CSL measurements between the tube pair combinations in addition to the horizontal measurements. Record offset measurements with source and receiver vertically offset in the tubes. These measurements add four measurements per tube combination to the horizontal measurements described in this section. Offset measurements are described by the angle, in degrees, and direction the signal

travels between the probes with respect to the horizontal plane: plus 45, plus 22.5 (source below receiver), and minus 45, minus 22.5 (source above receiver). Record offset measurements from the point where the higher probe is at least 5 feet below the velocity reduction to the point where the lower probe is at least 5 feet above the velocity reduction. When repairs are done, provide offset measurements from the point where the higher probe is at least 5 feet below the lower limit of the repaired zone to the point where the lower probe is at least 5 feet above the upper limit of the repaired zone. Perform offset measurements and provide CSL logs and 3D tomographic analysis at no additional cost to the Department.

After acceptance of production shafts by the Engineer, fill the tubes or core holes with a structural non-shrink grout in accordance with 455-17.6.1.

If the Contractor determines at any time during the non-destructive testing and evaluation of the drilled shaft that the drilled shaft should be replaced, no further testing or evaluation of that shaft is required.

455-17.6.2.1 Required CSL Reports: Present the CSL data and analysis results to the Engineer in a signed and sealed report. Include CSL logs with analyses of first pulse arrival time (FAT) versus depth and pulse energy/amplitude versus depth. Present a CSL log for each tube pair tested with any defect zones identified on the logs and discussed in the test report as appropriate. When offset measurements are required, perform 3D tomographic analysis using all offset data, and include color coded 3D tomographic images in the report.

455-17.6.2.2 Evaluation of Cross Hole Sonic logging Testing: The Engineer will evaluate the observations during drilled shaft construction and the CSL test results to determine whether or not the drilled shaft construction is acceptable. Drilled shafts with velocity reduction exceeding 30% are not acceptable without an engineering analysis.

455-17.6.2.3 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the CSL test and other testing, core the shaft to allow further evaluation and repair, or replace the shaft in accordance with 455-17.6.1.5.

If repairs are performed or additional shafts installed to correct a deficient foundation, conduct integrity testing and submit the results to the Engineer in accordance with 455-17.6.1.5.

SUBARTICLE 455-21 is deleted and the following substituted:

455-21 Drilled Shaft Excavations Constructed out of Tolerance.

Do not construct drilled shaft excavations in such a manner that the concrete shaft cannot be completed within the required tolerances. The Contractor may make corrections to an unacceptable drilled shaft excavation by any combination of the following methods:

1. Overdrilling the shaft excavation to a larger diameter to permit accurate placement of the reinforcing steel cage with the required minimum concrete cover.
2. Increasing the number and/or size of the steel reinforcement bars.

When the tolerances are not met, the Contractor may propose a redesign to incorporate shafts installed out of tolerance into caps or footings. Incorporate shafts installed out of tolerance at no expense to the Department. Ensure the Contractor's Engineer of Record performs any redesign and signs and seals the redesign drawings and computations. Do not begin any proposed construction until the redesign has been reviewed and approved by the Engineer.

Backfill any out of tolerance shafts in an approved manner when directed by the Engineer until the redesign is complete and approved. Furnish additional materials and work necessary,

including engineering analysis and redesign, to effect corrections of out of tolerance drilled shaft excavations at no expense to the Department.

SUBARTICLE 455-24.1 is deleted and the following substituted:

455-24.1 Drilled Shafts: Price and payment will be full compensation for all drilled shafts, including the cost of concrete, reinforcing steel, nondestructive integrity testing access tubes, embedded thermal wires when required by the Contract Documents, and including all labor, materials, equipment, and incidentals necessary to complete the drilled shaft. The cost of the reinforcing steel, including lap lengths, to accommodate shaft lengths longer than shown in the Plans is included in the cost of drilled shafts. Costs associated with repairing defects found in the drilled shaft shall be included in the cost of the drilled shaft.

SUBARTICLE 455-30 is deleted and the following substituted:

455-30 Fill or Backfill.

In all excavations, including over-excavations below the footing, use only fill or backfill materials considered Select in accordance with Standard Plans, Index 120-001. Ensure the material is free of rubble, debris, or rocks that would prevent uniform placement and compaction. Ensure the material below the top of the footing is free of Recycled Asphalt Pavement (RAP). Perform sampling and testing in accordance with 120-10.1.4, except replace FM 1-T99 with FM 1-T180.

SUBARTICLE 455-31 is deleted and the following substituted:

455-31 Compaction and Density Requirements.

Compact the bottom of the excavation with suitable equipment. Compact the soil beneath footing excavation (whether dug to the bottom of footing or over-excavated) to a density not less than 95% of the maximum density as determined by FM 1-T180, for a minimum depth of 2 feet below the bottom of the excavation or to the depth shown in the Plans before backfilling begins. For every 500 feet of excavation or isolated compaction operation, perform two Quality Control (QC) density tests with a 12 inch depth of measurement: one QC density test with the gauge placed at an elevation of 1 foot below the bottom of the excavation and one QC density test with the gauge placed at the bottom of the excavation in accordance with FM 1T238. Compact the backfill in footing excavations which have been over-excavated to a density not less than 95% of the maximum density as determined by FM 1-T180. Ensure that the maximum lift thickness after compaction does not exceed 6 inches. For every 500 ft of backfill or isolated compaction operation, perform at least one QC density test. The Engineer will conduct one density verification test per every 4 QC test, with a minimum of one density test below the bottom of the excavation and one density test in the backfill. Verification comparison criteria and resolution procedures will be in accordance with 120-10.4 except replace FM 1-T99 with FM 1-T180.

For compaction, use an approved heavy vibratory roller with a static drum weight of at least 4 tons. Compact each lift to the required density. Also, compact the final lift below the footing with a suitable sled vibratory compactor to remove any upper disturbance caused by the

drum roller. When conditions require use of smaller compaction equipment, obtain the Engineer's approval for the equipment, and reduce the lift thickness to achieve the required density.

Perform backfilling to the original ground surface, finished grade, or subgrade as required by the Plans in the immediate vicinity by approved mechanical compactors weighing less than 1,000 pounds. The Contractor may compact backfill located more than 15 feet away from the exterior periphery of the footing with heavier compactors. Do not place backfill on the footing until the Engineer has given permission and until the concrete is at least seven days old.

When the plans indicate spread footing abutments on mechanically stabilized earth (MSE) walls, place and compact the backfill material underneath the footing in accordance with the requirements of 548-8.5. Meet the density requirements of 548-9.4.

SUBARTICLE 455-36.1 is deleted and the following substituted:

455-36.1 Dewatering: No separate payment will be made for dewatering.

SUBARTICLE 455-37.1 is deleted and the following substituted:

455-37.1 Dewatering: No separate payment will be made for dewatering of footing excavations, including installing, maintaining, and monitoring piezometer wells. Dewatering will be considered Unforeseeable Work when the Engineer determines that dewatering deeper than the requirements described in 455-28 is required.

SUBARTICLE 455-37.5 is deleted and the following substituted:

455-37.5 Payment Items: Payment will be made under:

- | | | |
|---------------|----|---|
| Item No. 125- | 1- | Excavation for Structures - per cubic yard. |
| Item No. 400- | 2- | Class II Concrete - per cubic yard. |
| Item No. 400- | 3- | Class III Concrete - per cubic yard. |
| Item No. 400- | 4- | Class IV Concrete - per cubic yard. |
| Item No. 415- | 1- | Reinforcing Steel - per pound. |

ARTICLE 455-38 is deleted and the following substituted:

455-38 Description.

Furnish and install auger cast piles (ACP), or augered cast-in-place (ACIP) piles, used for structural support, other than bridge foundations.

ACP piles are defined as a foundation made by rotating a hollow-stem auger into the ground to the required pile depth with sufficient crowd (downward thrust) to prevent mining of the soil. A fluid cement grout is injected through the auger shaft under continuous positive pressure as the auger is being withdrawn. A reinforcing steel cage, as specified, is inserted into the column of fluid grout following the completion of grout placement.

ARTICLES 455-40 through 455-50 are deleted and the following substituted:

455-40 Materials.

Meet the following material requirements:

Portland Cement and Blended Cement	Section 921
Pozzolans and Slag	Section 929
Fine Aggregate (Sand)*	Section 902
Admixtures.....	Section 924
Water.....	Section 923
Fluidifier	ASTM C 937
Reinforcing Steel.....	Section 415

* The Engineer will only permit Silica Sand except as provided in 902-5.2.3.

455-41 Grout Mix Proportions.

Use a cement grout mix consisting of a mixture of cementitious materials, admixtures, sand and water proportioned and mixed to produce a grout capable of maintaining the solids in suspension without appreciable bleed water which may be pumped without difficulty and will fill open voids in the adjacent soils and rock. The grout mix may also include a fluidifier if desired. Proportion these materials to produce a hardened grout of the required strength.

455-42 Mixing and Pumping Cement Grout.

Meet the following requirements:

1. Only use pumping equipment approved by the Engineer in the preparation and handling of the grout. Before using the mixers, remove all oil or other rust inhibitors from the mixing drums, stirring mechanisms, and other portions of the equipment in contact with the grout.

2. Use a quantity of water and mixing time that will produce a homogenous grout having an efflux of not less than 21 seconds, when tested with a flow cone in accordance with ASTM D6449. Reject loads with efflux of less than 21 seconds. Notify the production facility to adjust the mix design. Calibrate the flow cone in accordance with ASTM D 6449. Conduct the calibration initially before its first use and as directed by the Engineer, when there is a question of the flow cone's accuracy.

Technicians performing the efflux test must take the Auger Cast Pile course and pass the final examination to be qualified to test for any auger cast pile installations in the field. Assist the Engineer in verifying the technicians meet these requirements.

Conduct tests for efflux time at the beginning of each days grouting operation and as directed by the Engineer to ensure the specification requirements are met.

3. Mix the grout at least one minute. If agitated continuously, the grout may be held in the mixer or agitator for a period not exceeding 2.5 hours at grout temperatures below 70°F; two hours for temperatures from 70°F to 100°F. Do not place grout when its temperature exceeds 100°F. If there is a lapse in the operation of grout injection, recirculate the grout through the pump, or through the mixer drum or agitator.

4. Use mixers capable of combining components into a thoroughly mixed and uniform mass, free from balls or lumps and capable of discharging the grout with a satisfactory degree of uniformity. The Engineer's approval of grout mixers and all other equipment will be

contingent on proper performance during construction of the demonstration pile and subsequent production work.

5. Use a screen no larger than 3/4 inch mesh between the mixer and pump to remove large particles which might clog the injection system.

6. Use a positive displacement piston type grout pump equipped with a pressure gauge, capable of developing displacing pressures at the pump not less than 350 psi. The pump must be appropriately sized to the pile diameter. Provide a grout pressure gauge in clear view of the equipment operator. Provide a second pressure gauge near the drill rig where it can be observed by the Engineer.

7. Accurately monitor the volume and pressure of the grout flow. Test and calibrate the equipment during construction of the demonstration pile to demonstrate flow volume measurement accuracy of plus or minus 3% over the range of grouting pressures anticipated during this work. Provide a pump stroke counter in good working condition on the grout pump. Perform a calibration test of the pumping equipment, prior to construction of the demonstration piles, to determine the average volume of grout for every pump stroke, in accordance with FM 5-612. Also calibrate the equipment any time the Engineer determines the grout pump performance may have changed.

455-43 Testing Cement Grout.

Prepare three 4 inches x 8 inches cylinders in accordance with ASTM C31, except pour grout in a single lift into cylinders molds without rodding, for each LOT. Plastic properties in accordance with ASTM C31 are not required. A LOT is defined as the lesser of 50 cubic yards of cement grout placed or one day of pile placement. Prepare one additional "hold" cylinder on the lot that is selected by the Engineer for Verification. Provide curing facilities for all QC and Verification test cylinders in accordance with ASTM C31. Test the cylinders at 28 days, in accordance with ASTM C39.

When one of the three QC cylinders from a LOT is lost, missing, damaged or destroyed, determination of compressive strength will be made by averaging the remaining two cylinders. If more than one QC cylinder from a LOT is lost, missing, damaged or destroyed, core the structure at no additional expense to the Department to determine the compressive strength. Acceptance of LOT may be based on verification data at the discretion of the Engineer. Obtain the approval of the Engineer to core, and of the core location prior to coring. Repair core holes after samples are taken with a product meeting the approval of the Engineer, at no additional cost to the Department.

For each QC cylinder that is lost, missing, damaged or destroyed, payment for that LOT will be reduced by \$750.00 per 1,000 psi of the specified design strength [Example: For $f'_c=5,500$ psi, the loss of two auger cast pile grout QC cylinders that have no verification data will require the element to be cored and a pay reduction will be assessed $(5,500 \text{ psi} / 1,000 \text{ psi}) \times \$750 \times 2 = \$8,250$]. This reduction will be in addition to any pay adjustment for low strength.

The Engineer will also cast three verification cylinders and one "hold" cylinder from one of every four consecutive lots, randomly selected. The Engineer will compare QC and Verification results in accordance with Section 346. If the results do not compare, the Engineer will initiate a Resolution Investigation in accordance with Section 346

Personnel making/curing grout cylinders shall be certified as ACI Concrete Field Testing Technician Grade I. Personnel performing tests on hardened properties of grout, such as strength determination of cylinders or beams, shall be certified as ACI Concrete Strength Testing Technician.

All low strength cement grout accepted by the Engineer will be subject to reduced payment as follows: \$0.80 per cubic yard for each 10 psi of strength test value below the specified minimum strength. The Engineer will use the average compressive strength of the LOT tests for the computation of this pay reduction.

The Engineer will compute the volume of grout for which the reduction will be applied as 115% of the theoretical volume of the auger cast pile diameter required in the Contract Documents. Reduction in pay will be applied to the entire length of all piles containing low strength cement grout, in any quantity. The quantity of cement grout affected by the price reduction may exceed the quantity of cement grout contained in the LOT.

When separate payment for auger grouted piles is provided, the dollar reduction will be equated to an equivalent length of pile not to exceed the total pile length constructed utilizing the subject LOT based on the following formula:

$$PLR = RC/UC$$

Where: PLR = Equivalent Pile Length Reduction in feet

RC = Total Reduction in payment, dollars

UC = Unit Cost of pile, dollars /foot

When a cement grout acceptance strength test falls more than 500 psi below the specified minimum strength perform one of the following:

1. Remove and replace the piles affected fully or partially by the low strength LOT at no additional cost to the Department; or,
2. Submit a structural analysis performed by the Contractor's Engineer of Record. If the results of the analysis, approved by the Department, indicate adequate strength to serve the intended purpose with adequate durability, the grout may remain in place.

Otherwise, abandon and install additional piles to the foundation, or remove and replace the piles affected fully or partially by the low strength LOT of grout at no additional cost to the Department. When installing additional piles to resolve the strength deficiency, submit a foundation redesign to add piles into pile caps or footings, at no expense to the Department in accordance with 455-46.

455-44 Pile Installation.

Meet the following requirements:

1. Locate the piles as shown on the drawings.
2. Should soft, compressible muck, organics, clay or other unsuitable materials (non A-1, A-3, A-2-4 or limestone materials) be encountered, remove the unsuitable material to a maximum depth of 5 feet and a radial distance around the pile centerline of two pile diameters unless otherwise indicated in the Plans. Backfill with clean granular backfill materials (A-1, A-3, A-2-4), placed and compacted in maximum 12 inch lifts to at least 95% of maximum dry density as determined by FM 1-T180. Complete this work to the Engineer's satisfaction prior to ACP construction. Should more than 5 feet depth or excessive quantities of unsuitable material be encountered, immediately advise the Engineer and proceed with the work as directed by the Engineer.
3. Provide continuous auger flighting from the auger head to the top of auger with no gaps or other breaks. Ensure the auger flights are uniform in diameter throughout its length, and of the diameter specified for the piles less a maximum of 3%. Provide augers with a distance between flights of approximately half the diameter of the auger.

4. Use augers with the grout injection hole located at the bottom of the auger head below the bar containing the cutting teeth, and with pile auger leads containing a bottom guide.

5. Construct piles of the length and diameter shown on the Plans.

6. Clearly mark the auger leads to facilitate monitoring of the incremental drilling and grout placement. Provide individual foot marks with 5 foot increments highlighted and clearly visible. Provide a clear reference mark on the moving auger assembly to facilitate accurately monitoring the vertical movement of the auger.

7. Place piles by rotating a continuous flight hollow shaft auger into the ground at a continuous rate that prevents removal of excess soil. Stop advancement after reaching the predetermined depth.

8. Should auger penetration to the required depth prove difficult due to hard materials/refusal, the pile location may be predrilled, upon approval of the Engineer, through the obstruction using appropriate drilling equipment, to a diameter no larger than 1/2 the prescribed finish diameter of the ACP. Commence ACP construction immediately upon completion of predrilling to minimize ground loss and soil relaxation. Should non-drillable material be encountered preventing placement to the depth required, immediately advise the Engineer and proceed with the work as directed by the Engineer. Refusal is defined as the depth where the penetration of the standard auger equipment is less than 12 inches per minute.

9. Plug the hole in the bottom of the auger prior to advancing into the ground.

10. Pump the grout with sufficient pressure as the auger is withdrawn to completely fill the auger hole, preventing hole collapse and to cause the lateral penetration of the grout into soft or porous zones of the surrounding soil or rock. Prior to commencing withdrawal of the auger, establish a head of at least 5 feet of grout by pumping a volume of grout equivalent to 5 feet of pile volume. Maintain this head of at least 5 feet of grout above the injection point around the perimeter of the auger to displace and remove any loose material from the hole. Maintain positive rotation of the auger at least until placement of the grout.

11. Once the grout head has been established, greatly reduce the speed of rotation of the auger and commence extraction at a rate consistent with the pump discharge. Maintain extraction at a steady rate to prevent a locked-in auger, necking of the pile, or a substantially reduced pile section. Ensure grout starts flowing out from the hole when the cutting head is at least 5 feet below the ground surface. Place a minimum volume of grout in the hole of at least 115% of the column of the auger hole from a depth of 5 feet to the tip. Place a minimum volume of grout in the hole of at least 105% of the column of the auger hole from the ground surface to a depth of 5 feet. Do not include any grout needed to create surplus grout head in the volume of grout placed into the hole. If the grout does not flow out from the hole when the cutting head is at least 5 feet below the ground surface, redrill the pile under the direction of the Engineer. If grouting is interrupted for any reason, reinsert the auger by drilling at least 5 feet below the tip of the auger when the interruption occurred, and then regrout.

Use this method of placement at all times. Do not depend on the stability of the hole without the earth filled auger. Place the required steel reinforcement while the grout is still fluid, but no later than 1/2 hour after pulling of the auger.

12. Assume responsibility for the grout volume placed. If less than 115% of the theoretical volume of grout is placed in any 5 foot increment (105% in the top 5 foot increment), reinstall the pile by advancing the auger 10 feet or to the bottom of the pile if that is less, followed by controlled removal and grout injection.

13. Furnish and install the reinforcing steel and anchoring bolts as shown in the Contract Documents. Use wheels or other approved noncorrosive spacing devices within 3 feet of the bottom, within 3 feet of the top, and intervals not exceeding 10 feet along the pile to ensure concentric spacing for the entire length of the cage. Do not use block or wire type spacers. Use a minimum of one spacer per 30 inches of circumference or perimeter of cage with a minimum of three at each level.

14. Use reinforcement that is without kinks or nonspecified bends, free of mud, oil or other coatings that could adversely affect the bond. Make splices in reinforcement as shown on the Contract Documents, unless otherwise approved by the Engineer. Place the required steel reinforcement while the grout is still fluid, and immediately after finishing grouting and clearing it from any contaminating material. Install the steel cage into the grout by its own weight or manually. Do not use a mechanical equipment or tool to impact the steel cage or to force it into the grout.

15. Leave any temporary supports of/for items placed into a grouted pile (reinforcement template, anchor bolt template, precast column supports, etc.) in place for a minimum of 12 hours after completion of the pile. Do not place wall panels or other loads, before piles are accepted and the grout has set a minimum of seven days or reached the 28 day strength.

455-45 Construction Tolerances.

Locate piles as shown in the Plans, or as otherwise directed by the Engineer. Locate pile centers to an accuracy of plus or minus 3 inches. Ensure that the top of pile elevation is within an accuracy of plus or minus 3 inches of the plan elevation. Ensure the tolerances in 534-5.1 can be met.

455-46 Unacceptable Piles.

Repair or replace unacceptable piles, as directed by the Engineer, at no cost to the Department. Unacceptable piles are defined as piles that fail for any reason, including but not limited to the following: piles placed out of position or to improper elevation; piles with reduced cross section, contaminated grout, lack of grout consolidation (honeycombed), or deficient grout strength; and piles with reinforcement, anchor devices or other components cast or placed into the fluid grout out of position. When the Engineer determines that a pile is unacceptable, the Contractor may propose a foundation redesign to add piles into pile caps or footings, at no expense to the Department. The Contractor's Engineer of Record must perform any redesign, and sign and seal the redesign drawings and calculations. Do not begin any proposed construction until the redesign has been reviewed and approved by the Engineer.

455-47 Auger Cast Pile Installation Plan (ACPIP).

At the preconstruction conference, but no later than 30 days before ACP construction begins, submit an ACP/IP for approval by the Engineer. Provide the following detailed information on the plan:

1. Name and experience record of ACP superintendent or foreman in responsible charge of ACP operations. Place a person in responsible charge of day to day ACP operations who possesses satisfactory prior experience constructing auger cast piles similar to those described in the Contract Documents. The Engineer will give final approval subject to satisfactory performance in the field.

2. List and size of the proposed equipment, including cranes, augers, concrete pumps, mixing equipment etc., including details of proposed pump calibration procedures.
3. Details of pile installation methods.
4. Details of reinforcement placement and method of centering in pile, including details of all temporary supports for reinforcement, anchor bolts, precast columns, etc.
5. Details of how and by whom the grout volumes will be determined, monitored and documented.
6. Required submittals, including shop drawings and cement grout design mixes.
7. Other information shown in the Plans or requested by the Engineer.

455-48 Inspection and Records.

The Engineer will monitor pile installation.

455-49 Method of Measurement.

455-49.1 Auger Cast Pile: The quantity to be paid for will be at the Contract unit price per foot between tip and required pile top elevations for all piles completed and accepted.

455-50 Basis of Payment.

455-50.1 Auger Cast Piles: Price and payment will be full compensation for all labor, materials, and incidentals for construction of ACP of the sizes and depths indicated on the Contract Documents or as otherwise directed by the Engineer. Price and payment will also include the removal and proper disposal off site of all spoil from the auger operation and all excess grout displaced from the auger hole, unless otherwise approved by the Engineer. Work to remove and replace unsuitable material when necessary as specified in 455-44 will be considered Unforeseeable Work.

455-50.2 Payment Items: Payment will be made under:

Item No. 455-112- Auger Grouted Piles - per foot.