Florida Department of Transportation

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DENVER J. STUTLER, JR.
SECRETARY

August 8, 2005

Mr. Donald Davis
Program Operations Engineer
Federal Highway Administration
545 John Knox Road, Suite 200
Tallahassee, Florida 32303

Re: Office of Design, Specifications
Section 455
Proposed Specification: 4550000.D01

Dear Mr. Davis:

We are submitting, for your approval, two copies of a proposed Supplemental Specification for Structures Foundations.

This change was proposed by Larry Jones of the Structures Design Office to update this Section to reflect current requirements.

Please review and transmit your comments, if any, within two weeks. Comments should be sent via Email to SP965DB or duane.brautigam@dot.state.fl.us.

If you have any questions relating to this specification change, please call Duane F. Brautigam, State Specifications Engineer at 414-4110.

Sincerely,

Duane F. Brautigam, P.E.
State Specifications Engineer

DFB/jf
Attachment
cc: General Counsel
Florida Transportation Builders' Assoc.
State Construction Engineer

STRUCTURES FOUNDATIONS.
(REV 8-6-05)

SECTION 455 (Pages 462-533) is deleted and the following substituted:

SECTION 455
STRUCTURES FOUNDATIONS

Index

A. GENERAL

455-1 General Requirement.

The Contractor may examine available soil samples and/or rock cores obtained during the soil boring operations at the appropriate District Materials Office.

455-1.1 Protection of Existing Structures: When the plans require foundation construction operations in close proximity to existing structures, take all reasonable precautions to prevent damage to such structures. The requirements described herein apply to all types of structures (on or off the right-of-way) that may be adversely affected by foundation construction operations (including phase construction) due to vibrations, ground loss, ground heave, or dewatering. Protect utilities as described in-the applicable provisions of Section 7.

Monitor structures for settlement in a manner approved by the Engineer, recording elevations to 0.001 foot [0.5 mm]. Monitor the following structures:

(1) shown in the plans.

(2) within a distance, in feet, of pile driving operations equal to 0.5 times the square root of the *impact* hammer energy, in foot-pounds [in meters, of pile driving operations equal to 4.14 times the square root of the hammer energy, in kilojoules]. Take required measurements before the initiation of driving and then daily on days when driving occurs or as indicated in the plans and weekly for two weeks after driving has stopped.

(3) within a distance of ten shaft diameters or the estimated depth of excavation, whichever is greater.

(4) within a distance of three times the depth of excavation for the footing.

Obtain the Engineer's approval of the number and location of monitoring points. Take elevation;

(1) before beginning construction,

(2) daily during the driving of any casings, piling, or sheeting,
(3) weekly for two weeks after stopping driving,
(4) during excavation,
(5) during blasting,
(6) or as directed by the Engineer.

Notify the Engineer of any movements detected and immediately take any remedial measures required to prevent damage to the existing structures.

Employ a qualified Specialty Engineer to survey all structures, or portions thereof, within:

(1) a distance, in feet, of pile driving operations equal to 0.25 times the square root of the *impact* hammer energy, in foot-pounds [in meters, of pile driving operations equal to 2.07 times the square root of the hammer energy, in kilojoules]

(2) a distance of ten shaft diameters or the estimated depth of excavation, whichever is greater

(3) three times the excavation depth for footings and caps

(4) or as shown in the plans

The Department will make the necessary arrangements to provide right-of-way entry for the Contractor's engineer to survey. Adequately document the condition of the structures and all existing cracks with descriptions and pictures. Prepare two reports documenting the condition of the structures: one report before beginning foundation construction operations and a second report after completing foundation construction operations. The Department will take ownership of both reports. Do not perform pre-driving and post-driving surveys of the condition of bridges owned by the Department except when shown in the Contract Documents.

When shown in the Contract Documents, employ a qualified Specialty Engineer to monitor and record vibration levels during the driving of casings, piling, sheeting, or blasting operations. Provide vibration monitoring equipment capable of detecting velocities of 0.1 in/s [2.5 mm/s] or less.

Upon detecting settlement or heave of 0.005 foot [1.5 mm], vibration levels reaching 0.5 in/s [13 mm/s], levels otherwise shown in the Contract Documents, or damage to the structure, immediately stop the source of vibrations, backfill any open drilled shaft excavations, and contact the Engineer for instructions.

When the plans require excavations for construction of footings or caps, the Contractor is responsible for evaluating the need for, design of, and providing any necessary features to protect adjacent structures. When sheeting and shoring are not detailed in the plans, employ a Specialty Engineer to design the sheeting and shoring, and to sign and seal the plans and specification requirements. Send these designs to the Engineer for his record before beginning construction.

Also, when shown in the Contract Documents or when authorized by the Engineer, install the piling to the depth required to minimize the effects of vibrations or ground heave on adjacent structures by approved methods other than driving (preformed holes, predrilling, jetting, etc.). In the event the Department authorizes the use of preformed pile holes to meet this requirement, the Department will pay for this work as described in 455-5.9.3

Also if not otherwise provided in the plans, the Contractor is responsible for evaluating the need for, design of, and providing all reasonable precautionary features to prevent damage, including, but not limited to, selecting construction methods and procedures that will prevent damaging caving of the shaft excavation and monitoring and controlling the vibrations from construction activities, including driving of casings, driving of sheeting, and blasting.

When shown in the plans or directed by the Engineer, install a piezometer near the right-of-way line and near any structure that may be affected by lowering the ground water when dewatering is required. Monitor the piezometer and record the ground water elevation level daily. Notify the Engineer of any ground water lowering near the structure of 12 inches [300 mm] or more.

455-1.2 Excavation: Complete all excavation of the foundations prior to installing piles or shafts unless otherwise authorized by the Engineer. After completing pile/shaft installation, remove all loose and displaced materials from around the piles/shafts, leaving a clean, solid surface. Compact the soil surface on which concrete is to be placed or which will support the forming system for the concrete to a density not less than 90% of the maximum density as determined by AASHTO T 180, and which will support the load of the plastic concrete without settling or causing the concrete to crack, or as shown in the Contract Documents. The Engineer will not require the Contractor to compact for excavations made below water for seals or when the footing or cap or forming system (including supports) does not rest on the ground surface.

455-1.2.1 Abutment (End Bent) Fill: Place and compact the fill before installing end-bent piling/shafts, except when:

(1) driving specified test piling in end bents or,

(2) the plans show uncased piles through proprietary retaining wall fills.

When installing piles/shafts or casing prior to placing fill, take necessary precautions to prevent displacement of piles/shafts during placing and compacting fill materials within 15 feet [4.5] of the piles/shafts or casing. Reference and check the position of the piles/shafts or casing at three approximately equal intervals during construction of the embankment.

Place embankment material in 6 inch [150 mm] loose lifts in the 15 foot [4.5 m] area around the piles/shafts or casing. Compact embankment material within the 15 foot [4.5 m] area adjacent to the piles/shafts or casing to the required density with compaction equipment weighing less than 1,000 pounds [450 kg]. When installing piles/shafts prior to the completion of the surrounding fills, do not cap them until placing the fills as near to final grade as possible, leaving only the necessary working room for construction of the caps.

Provide permanent casings installed prior to placement of the fill, for all drilled shafts through mechanically stabilized fills (for example, behind proprietary retaining walls) for shafts installed after fill placement. Install temporary casings through the completed conventional fill when permanent casings are not required.

Provide permanent casings, if required, before the fill is placed extending a sufficient distance into the existing ground to provide stability to the casings during construction of the abutment fill.

455-1.3 Cofferdams: Construct cofferdams as detailed in the plans. When cofferdams are not detailed in the plans, employ a Specialty Engineer to design cofferdams, and to sign and seal the plans and specification requirements. Send the designs to the Engineer for his records before beginning construction.

Provide a qualified diver and a safety diver to inspect the conditions of the foundation enclosure or cofferdam when the Contract Documents require a seal for construction. Equip these divers with suitable voice communications, and have them inspect the foundation enclosure and cofferdam periphery including each sheeting indentation and around each piling or drilled shaft to ensure that no layers of mud or other undesirable materials were left above the bottom of seal elevation during the excavation process. Also have the divers check to make sure the surfaces of the piles or drilled shafts are sufficiently clean to allow bond of the concrete down to the minimum bottom of seal elevation. When required, ensure that there are no mounds of stone, shell, or other authorized backfill material left after placement and grading. Assist the Engineer as required to ensure that the seal is placed as specified and evaluate the adequacy of the foundation soils or rock. Correct any deficiencies found by the divers. Upon completion of inspection by the divers, the Department may also elect to inspect the work before authorizing the Contractor to proceed with subsequent construction operations. Furnish the Engineer a written report by the divers indicating the results of their underwater inspection before requesting authorization to place the seal concrete.

455-2 Static Compression Load Tests.

455-2.1 General: Employ a professional testing laboratory, or Specialty Engineer with prior load test experience *on at least ~~3~~three projects*, to conduct the load test in compliance with these Specifications, to record all data, and to furnish reports of the test results to the Engineer except when the Contract Documents show that the Department will supply a Geotechnical Engineer to provide these services.

Perform the load test by applying a load up to the load required in the Contract Documents or to the failure load, whichever occurs first.

Do not apply test loads to piles sooner than 48 hours (or the time interval shown in the plans) after driving of the test pile or reaction piles, whichever occurs last.

Allow up to four weeks after the last load test for the analysis of the load test data and to provide all the estimated production tip elevations. If the Contractor is willing to construct production foundation elements in areas designated by the Engineer, tip elevations will be determined in these areas beginning seven days after the receipt of the load test data which represents the designated area.

Do not begin static load testing of drilled shafts until the concrete has attained a compressive strength of 3,400 psi [23.5 MPa]. The Contractor may use high early strength concrete to obtain this strength at an earlier time to prevent testing delays.

Load test piles/shafts in the order directed by the Engineer. The Department will furnish certain load test equipment and/or personnel when shown in the plans. Inspect all equipment to be furnished by the Department at least 30 days prior to use, and notify the Engineer of any equipment that is not in satisfactory operating condition. The Department will consider any necessary repairs ordered by the Engineer to place the equipment in satisfactory operating condition as Unforeseeable Work. Provide the remainder of the equipment and personnel needed to conduct the load tests. Unless shown otherwise in the Contract Documents, provide all equipment, materials, labor, and technical personnel required to conduct the load tests, including determination of anchor reaction member depths. In this case, provide a loading apparatus designed to accommodate the maximum load plus an adequate safety factor.

While performing the load test, provide safety equipment, and employ safety procedures consistent with the latest approved practices for this work. Include with these safety procedures adequate support for the load test plates and jack to prevent them from falling in the event of a release of load due to hydraulic failure, test pile/shaft failure, or any other cause.

Include in the bid the cost of transporting load test equipment and instrumentation supplied by the Department from their storage location to the job site and back. Handle these items with care. The Contractor is responsible for the safe return of these items. After completion of the static load tests, return all Department furnished equipment in satisfactory operating condition. Repair all damage to the test equipment furnished by the Department to the satisfaction of the Engineer. Clean all areas of rust on structural steel items, and repaint those areas in accordance with Section 561. Return all load test equipment supplied by the Department within 30 days after completing the load tests.

The Contractor is responsible for the equipment from the time it leaves its storage area until the time it is returned. During this time, insure the equipment against loss or damage for the replacement cost thereof (the greater of $150,000 or the amount shown in the plans) or for the full insurable value if replacement cost insurance is not available.

Notify the Engineer at the preconstruction conference or no later than 30 days before beginning test pile installation of the proposed testing schedule so that items supplied by the Department may be reserved. Notify the Department at least ten working days before pick-up or return of the equipment. During pick-up, the Department will complete a checklist of all equipment placed in the Contractor’s possession. The Department will later use this checklist to verify that the Contractor has returned all equipment. Provide personnel and equipment to load or unload the equipment at the Department’s storage location. Provide lifting tongs or nylon slings to handle Department owned test girders. Do not perform cutting, welding, or drilling on Department owned girders, jacks, load cells, or other equipment.

455-2.2 Loading Apparatus: Provide an apparatus for applying the vertical loads as described in one of the following:

(1) As shown and described in the Contract Documents.

(2) As supplied by the Contractor, one of the following devices designed to accommodate a load at least 20% higher than that shown in the Contract Documents or described herein for test loads:

(a) Load Applied by Hydraulic Jack Acting Against Weighted Box or Platform: Construct a test box or test platform, resting on a suitable support, over the pile, and load it with earth, sand, concrete, pig iron, or other suitable material with a total weight greater than the anticipated maximum test load. Locate supports for the weighted box or platform at least 6 feet [2 m] or three pile/shaft diameters, whichever is greater, measured from the edge of the pile or shaft to the edge of the supports. Insert a hydraulic jack with pressure gauge between the test pile or shaft and the underside of the reaction beam, and apply the load to the pile or shaft by operating the jack between the reaction beam and the top of the pile or shaft.

(b) Load Applied to the Test Pile or Shaft by Hydraulic Jack Acting Against Anchored Reaction Member: Construct reaction member anchorages as far from the test piles/shafts as practical, but in no case closer than the greater of 3 pile/shaft diameters or 6 feet [2 m] from the edge of the test pile/shaft. Attach a girder(s) of sufficient strength to act as a reaction beam to the upper ends of the anchor piles or shafts. Insert a hydraulic jack with pressure gauges between the head of the test pile/shaft and the underside of the reaction beam, and apply the test load to the pile/shaft by operating the jack between the reaction beam and the pile/shaft head.

If using drilled shafts with bells as reaction member anchorages, locate the top of the bell of any reaction shaft anchorage at least three shaft diameters below the bottom of the test shaft.

(c) Combination Devices: The Contractor may use a combination of devices (a) and (b), as described above, to apply the test load to the pile or shaft.

(d) Other Systems Proposed by the Contractor and Approved by the Engineer: When necessary, provide horizontal supports for loading the pile/shaft, and space them so that the ratio of the unsupported length to the minimum radius of gyration of the pile does not exceed 120 for steel piles, and the unsupported length to the least cross-section dimension does not exceed 20 for concrete piles or drilled shafts. Ensure that horizontal supports provide full support without restraining the vertical movement of the pile in any way.

When required by the Contract Documents, apply a horizontal load to the shaft either separately or in conjunction with the vertical load. Apply the load to the test shaft by hydraulic jacks, jacking against Contractor provided reaction devices. After receiving the Engineer’s approval of the proposed method of load application, apply the horizontal load in increments, and relieve it in decrements as required by the Contract Documents.

455-2.2.1 Modified Quick Test:

(a) Loading Procedure: Apply vertical loads concentric with the longitudinal axis of the tested pile/shaft to accurately determine and control the load acting on the pile/shaft at any time. Place the load on the pile/shaft continuously, in increments equal to approximately 5% of the maximum test load specified until approaching the failure load, as indicated by the measuring apparatus and/or instruments. Then, apply increments of approximately 2.5% until the pile/shaft “plunges” or attains the limiting load. The Engineer may elect to stop the loading increments when he determines the Contractor has met the failure criteria or when a settlement equal to 10% of the pile/shaft width or diameter is reached. Apply each load increment immediately after taking and verifying the complete set of readings from all gauges and instruments. Apply each increment of load within the minimum length of time practical, and immediately take the readings. Complete the addition of a load increment and the completion of the readings within five to 15 minutes. The Engineer may elect to hold the maximum applied load up to one hour.

Remove the load in decrements of about 10% of the maximum test load. Remove each decrement of load within the minimum length of time practical, and immediately take the readings. Complete the removal of a load decrement and the taking of the readings within five to 15 minutes. The Engineer may also require up to two reloading cycles with five loading increments and three unloading decrements.

Record the final recovery of the pile/shaft until movement is essentially complete for a period up to one hour after the last unload interval.

(b) Failure Criteria and Safe-Load: Use the criteria described herein to establish the failure load. The failure load is defined as the load that causes a pile/shaft top deflection equal to the calculated elastic compression plus 0.15 inch [4 mm] plus 1/120 of the pile/shaft minimum width or the diameter in inches [millimeters] for piles/shafts 24 inches [610 mm] or less in width, and equal to the calculated elastic compression plus 1/30 of the pile/shaft minimum width or diameter for piles/shafts greater than 24 inches [610 mm] in width. Consider the safe allowable load of any pile/shaft so tested as either 50% of the maximum applied load or 50% of the failure load, whichever is smaller.

455-2.3 Measuring Apparatus: Provide an apparatus for measuring movement of the test piles/shafts that consists of all of the following devices:

(1) Wire Line and Scale: Stretch a wire as directed by the Engineer between two supports located at a distance at least:

(a) 10 feet [3 m] from the center of the test pile but not less than 3.5 times the pile diameter or width.

(b) 12 feet [3.7 m] from the centerline of the shaft to be tested but not less than three shaft diameters.

Locate the wire supports as far as practical from reaction beam anchorages. At over-water test sites, the Contractor may attach the wire line as directed by the Engineer to the sides of the service platform. Mount the wire with a pulley on one support and a weight at the end of the wire to provide constant tension on the wire. Ensure that the wire passes across the face of a scale mounted on a mirror attached to the test pile/shaft so that readings can be made directly from the scale. Use the scale readings as a check on an average of the dial readings. When measuring both horizontal and vertical movement, mount separate wires to indicate each movement, horizontal or vertical. Measure horizontal movements from two reference wires set normal to each other in a horizontal.

(2) Wooden Reference Beams And Dial Gauges: Attach wooden reference beams as detailed in the plans or approved by the Engineer to independent supports. For piles, install the greater of 3.5 times the pile diameter or width or 10 feet [3 m] from the centerline of the test pile. For drilled shafts install the greater of three shaft diameters or 12 feet [3.7 m] from the centerline of the shaft to be tested. Locate the reference beam supports as far as practical from reaction beam anchorages. For over-water test sites, the Contractor may attach the reference beams as directed by the Engineer between two diagonal platform supports. Attach dial gauges, with their stems resting either on the top of the pile/shaft or on lugs or similar reference points on the pile/shaft, to the fixed beams to record the movement of the pile/shaft head. Ensure that the area on the pile/shaft or lug on which the stem bears is a smooth surface which will not cause irregularities in the dial readings.

For piles, the minimum acceptable method for measuring vertical movement is two dial gauges, each with 0.001 inch [0.025 mm] divisions and with 2 inch [50 mm] minimum travel, placed at 180 degrees or at the diagonal corners of the pile.

For shafts, ensure that three dial gauges, each with 0.001 inch [0.025 mm] divisions and with 2 inch [50 mm] minimum travel, placed at 120 degree intervals around the shaft, are the minimum acceptable method for measuring vertical movement. Ensure that four dial gauges, each with 0.001 inch [0.025 mm] divisions and with 2 inch [50 mm] minimum travel, placed at 90 degree intervals are the minimum required for measuring horizontal movement.

(3) Survey Level: As a check on the dial gauges, determine the elevation of a point near the top of the test pile/shaft (on plan datum) by survey level at each load and unload interval during the load test. Unless approved otherwise by the Engineer, level survey precision is 0.001 foot [0.3 mm]. Alternately, the surveyor may read an engineer's 50 scale attached near the pile/shaft head. Determine the first elevation before applying the first load increment; make intermediate readings immediately before a load increment or an unload decrement, and after the final unload decrement that completely removes the load. Make a final reading at the time of the last recovery reading or as directed by the Engineer.

For over-water test sites, when shown in the plans or directed by the Engineer, the Contractor shall drive an H pile through a 36 inch [914 mm] casing to provide a stable support for the level and to protect it against wave action interfering with level measurements. Provide a suitable movable jig for the surveyor to stand. Use a jig that has a minimum of three legs, has a work platform providing at least 4 feet [1.2 m] width of work area around the casing, and is approved by the Engineer before use. The described work platform may be supported by the protective casing when approved by the Engineer.

455-2.4 Load Test Instrumentation:

(1) General: The intent of the load test instrumentation is to measure the test load on top of the pile/shaft and, when provided in the Contract Documents, its distribution between side friction and end bearing to provide evaluation of the preliminary design calculations and settlement estimates and to provide information for final pile/shaft length design. Ensure that the instrumentation is as described in the Contract Documents.

When requested by the Engineer, provide assistance during installation of any instrumentation supplied by the Department. Supply 110 V, 60 Hz, 30 A of AC electric power in accordance with the National Electric Code to each test pile/shaft site during the installation of the instrumentation, during the load testing, and during any instrumented redrives ordered by the Engineer.

Place all of the internal instrumentation on the rebar cage before installation in the test shaft. Construct the rebar cage at least two days before it is required for construction of the test shaft. Provide assistance during installation of instrumentation supplied by the Department, including help to string, place, and tie the instrumentation and any assistance needed in moving or repositioning the cage to facilitate installation. Place the rebar cage in one segment complete with its instrumentation. The Engineer may require multiple lift points and/or a suitable "stiffleg" (length of H pile or other suitable section) to get the cage in a vertical position without causing damage to the instrumentation. Successfully demonstrate the lifting and handling procedures before the installing instrumentation.

(2) Hydraulic Jack and Load Cell: Provide hydraulic jack(s) of adequate size to deliver the required test load to the pile/shaft unless shown otherwise in the plans. Before load testing begins, furnish a certificate from a reputable testing laboratory

showing a calibration of gauge readings for all stages of jack loading and unloading for jacks provided. Ensure that the jack has been calibrated within the preceding six months unless approved otherwise. Recalibrate the jack after completing load testing if so directed by the Engineer. Ensure that the accuracy of the gauge is within 5% of the true load.

Provide an adequate load cell approved by the Engineer that has been calibrated within the preceding six months. Provide an approved electrical readout device for the load cell. Before beginning load testing, furnish a certificate from a reputable testing laboratory showing a calibration of readings for all stages of loading and unloading for load cells furnished by the Contractor. Ensure that the accuracy of the load cell is within 1% of the true load.

If the Department supplies the Contractor with the jack and/or load cell, have the equipment calibrated and include the cost in the cost for static load test.

(3) Telltales: When shown in the Contract Documents, provide telltales that consist of an unstressed steel rod placed, with appropriate clearance and greased for reducing friction and corrosion, inside a constant-diameter pipe that rests on a flat plate attached to the end of the pipe at a point of interest shown in the plans. Construct telltales in accordance with details shown in the Contract Documents. Install dial gauges reading to 0.001 inch [0.025 mm] with 1 inch [25 mm] minimum travel as directed by the Engineer to measure the movement of the telltale with respect to the top of the pile/shaft.

(4) Embedded Strain Gauges: When shown in the Contract Documents, provide strain gauges which shall be placed in the test shaft to measure the distribution of the load. Ensure that the type, number, and location of the strain gauges are as shown in the plans or as directed by the Engineer. Use strain gauges that are waterproof and have suitable shielded cable that is unspliced within the shaft.

455-2.5 Support Facilities: Furnish adequate facilities for making load and settlement readings 24 hours per day. Provide such facilities for the instrumented area, and include lighting and shelter from rain, wind, and direct sunlight.

455-2.6 Load Test Personnel Furnished by the Contractor: Provide a certified welder, together with necessary cutting and welding equipment, to assist with the load test setup and to make any necessary adjustments during the load test. Provide personnel to operate the jack, generators, and lighting equipment, and also provide one person with transportation to assist as required during load test setup and conducting of the load tests. Provide qualified personnel, as determined by Specialty Engineer or testing lab, required to read the dial gauges, take level measurements, and conduct the load test, except when the Contract Documents show that the Department will provide these personnel.

455-2.7 Cooperation by the Contractor: Cooperate with the Department, and ensure that the Department has access to all facilities necessary for observation of the conduct and the results of the test.

455-2.8 Required Reports: Submit a preliminary static load test report to the Engineer within five days after completing the load test. When the Contract Documents do not require internal instrumentation, submit the final report within ten days after completing the load test. Furnish the final report of test results for internally instrumented shafts within 30 days after completing the load test. Include in the report of the load test the following information:

(1) A tabulation of the time of, and the amount of, the load and settlement readings, and the load and recovery readings taken during the loading and unloading of the pile/shaft.

(2) A graphic representation of the test results, during loading and unloading of pile/shaft top movement as measured by the average of the dial gauge readings, from wireline readings and from level readings.

(3) A graphic representation of the test results, when using telltales, showing pile/shaft compression and pile/shaft tip movement.

(4) The estimated failure and safe loads according to the criteria described herein.

(5) Remarks concerning any unusual occurrences during the loading of the pile/shaft.

(6) The names of those making the required observations of the results of the load test, the weather conditions prevailing during the load test, and the effect of weather conditions on the load test.

(7) All supporting data including jack and load cell calibrations and certificates and other equipment requiring calibration.

(8) When the Contract Document requires internal instrumentation of the pile/shaft, furnish all of the data taken during the load test together with instrument calibration certifications. In addition, provide a report showing an analysis of the results of axial load and lateral load tests in which soil resistance along and against the pile/shaft is reported as a function of deflection.

Provide the necessary report(s) prepared ~~by a~~ *by the* qualified Geotechnical Engineer registered in Florida as a Specialty Engineer *responsible for collection and interpretation of the data,* except when the Contract Documents show that the Department will provide a Geotechnical Engineer.

455-2.9 Disposition of Loading Material: After completing all load tests, clean, remove all ~~rustand~~*rust and* debris from Department equipment, repaint all areas having damage to the paint in accordance with Section 561, and return all load test equipment supplied by the Department to its designated storage area. Repair any structural damage to Department owned equipment to the satisfaction of the Engineer. Notify the Department at least ten working days in advance so that arrangements can be made to unload the equipment. Remove all equipment and materials, which remains the Contractor’s property, from the site. Clean up and restore the site to the satisfaction of the Engineer.

455-2.10 Disposition of Tested Piles/Shafts: After completing testing, cut off the tested piles/shafts, which are not to be incorporated into the final structure, and any reaction piles/shafts at an elevation 24 inches [600 mm] below the finished ground surface. Take ownership of the cut-offs and provide areas for their disposal.

B. PILING

455-3 Description.

Furnish and install concrete, steel, or wood piling including driving, jetting, preformed pile holes, cutting off, splicing, dynamic load testing, and static load testing of piling.

455-4 Classification.

The Department classifies piling as follows:

(1) Treated timber piling.
(2) Prestressed concrete piling.
(3) Steel piling.
(4) Test piling.
(5) Sheet piling.
(a) Concrete sheet piling.
(b) Steel sheet piling.

455-5 General Requirements.

455-5.1 Site Preparation:

455-5.1.1 Predrilling of Pile Holes: Predrilled pile holes are either 4 foot [1.2 m] maximum depth starter holes or holes drilled through embankment/fill material down to the natural ground surface. When using low displacement steel piling such as structural shapes, drive them through the compacted fill without the necessity of drilling holes through the fill except when the requirements for predrilling are shown in the plans. When using concrete or other high displacement piles, drill pile holes through fill, new or existing, to at least the elevation of the natural ground surface. Use the drill diameters listed below for square concrete piles.

12 inch [305mm] square piles.............. 15 inches [380 mm]
14 inch [355 mm] square piles............. 18 inches [460 mm]
18 inch [455 mm] square piles............. 22 inches [560 mm]
20 inch [510 mm] square piles............. 24 inches [610 mm]
24 inch [610 mm] square piles............. 30 inches [760 mm]
30 inch [760 mm] square piles............. 36 inches [910 mm]

For other pile sizes, use the diameter of the drills shown in the plans or approved by the Engineer. Accurately drill the pile holes with the hole centered over the plan location of the piling. Maintain the location and vertical alignment within the tolerances allowed for the piling.

For predrilled holes ~~that are~~ required through rock *or other hard (i.e. debris, obstructions, etc.)* material*s* that may damage the pile during installation, predrill hole diameters approximately 2 inches [50 mm] larger than the largest dimension across the pile cross-section. For predrilled holes which are required through material that caves during driving to the extent that the predrilled hole does not serve its intended purpose, case the hole from the embankment surface to the approximate elevation of the natural ground surface. After driving the piles and obtaining the Engineer’s acceptance, remove the casings unless shown otherwise in the plans and fill the annular space around the piles with concrete sand or other approved clean sand in a manner approved by the Engineer after driving the pile.

In the setting of permanent and test piling, the Contractor may initially predrill holes to a depth up to 4 feet [1.2 m], except that, where installing piles in compacted fill, predrill the holes to the elevation of the natural ground surface. With prior written authorization from the Engineer, the Contractor may predrill holes to depths greater than 4 feet [1.2 m], to minimize the effects of vibrations on existing structures adjacent to the work and/or for other reasons the Contractor proposes. Perform such work the Engineer allows but does not require at no expense to the Department. When the Engineer requires such work, the Department will pay for the additional cost of such work beyond the initial 4 feet [1.2 m] as Preformed Pile Holes as described in 455-5.9.

Fill any voids between the pile and soil remaining after driving through predrilled holes with concrete sand or other approved clean sand.

455-5.1.2 Underwater Driving: Underwater driving is defined as any driving through water which is above the pile head at the time of driving.

When conducting underwater driving, provide a diver equipped with voice communications to aid in placing the hammer back on the pile for required cushion changes or for subsequent redriving, to attach or recover instrumentation the Engineer is using, to inspect the condition of the pile, or for other assistance as required.

Select one of the following methods for underwater driving:

(a) Accomplish underwater driving using conventional driving equipment and piling longer than authorized so that the piling will extend above the water surface during final driving. When choosing this option, furnish a pile hammer that satisfies the requirements of this Section for use with the longer pile.

(b) Accomplish underwater driving using an underwater hammer that meets the requirements of this Section and is approved by the Engineer. When choosing this option, provide at least one pile longer than authorized at each pile group, extending above the water surface at final driving. At each group location, drive the longer pile first. The Engineer will evaluate the adequacy of the underwater driving system. The Engineer may use the pile tip elevation of the longer pile that the Contractor has driven and the Engineer has accepted, to evaluate the acceptability of the piles driven with the underwater hammer.

(c) Accomplish underwater driving using conventional driving equipment with a suitable approved pile follower. When choosing this option, provide at least one pile longer than required at each pile group, extending above the water surface at final driving. At each group location, drive the full length pile first without using the follower. The Engineer will evaluate the adequacy of the follower used for underwater driving. The Engineer may choose to perform a dynamic load test on the first pile the Contractor drives with the follower in each group. The Engineer may use the pile tip elevation of the longer pile, that the Contractor has driven and the Engineer has accepted, to evaluate the acceptability of the piles driven with the follower.

Prior to use, submit details of the follower for the Engineer's evaluation and approval along with the information required in 455-10. Include the weight, cross-section details, stiffness, type of materials, and dimensions of the follower.

455-5.2 Pile Hammers: Furnish to the Engineer all technical specifications and operating instructions related to hammer equipment. All equipment is subject to satisfactory field performance. Use a variable energy hammer to drive concrete piles. Hammers will be rated based on the theoretical energy of the ram at impact. *Supply driving equipment which provides the required resistance at a blow count ranging from 3 blows per inch [3 blows per 25 mm] (36 blows per foot [36 blows per 300 mm]) to 10 blows per inch [10 blows per 25 mm] (120 blows per foot [120 blows per 300 mm]) at the end of initial drive, unless approved otherwise by the Engineer after satisfactory field* *trial. When the Engineer determines the stroke height or bounce chamber pressure readings do not adequately determine the energy of the hammer, provide and maintain a device to measure the velocity of the ram at impact. Determine the actual hammer energy in the field so that it is consistent with the hammer energy used for each bearing capacity determination.*

455-5.2.1 Air/steam: Variable energy air/steam hammers shall be capable of providing at least two ram stroke lengths. The short ram stroke length shall be approximately half of the full stroke for hammers with strokes up to 4 feet [1.2 m] and no more than 2 feet [0.6 m] for hammers with maximum strokes lengths over 4 feet [1.2 m]. Operate and maintain air/steam hammers within the manufacturer's specified ranges. Use a plant and equipment for steam and air hammers with sufficient capacity to maintain, under working conditions, the hammer, volume and pressure specified by the manufacturer. Equip the plant and equipment with accurate pressure gauges which are easily accessible to the Engineer. The Engineer will not accept final bearing on piles the Contractor drives with air/steam hammers unless the Contractor operates the hammers within 10% of the manufacturer's rated speed in blows per minute, unless otherwise authorized by the Engineer.

455-5.2.2 Diesel: Variable energy diesel hammers shall have at least three fuel settings that will produce reduced strokes. Operate and maintain diesel hammers within the manufacturer's specified ranges. Determine the rated energy of diesel hammers using measured ram stroke length multiplied by the weight of the ram for open end hammers and by methods recommended by the manufacturer for closed end hammers. ~~Determine the actual hammer energy in the field so that it is consistent with the hammer energy used for each bearing capacity determination.~~

Equip open-end (single acting) diesel hammers with a scale (jump stick) extending above the ram cylinder to permit the Engineer to visually determine the hammer stroke at all times during pile driving operations. Provide the Engineer with a chart from the hammer manufacturer equating stroke and blows per minute for the open-end diesel hammer to be used. Also provide and maintain in working order for the Engineer's use an approved device to automatically determine and display ram stroke for open-end diesel hammers.

Equip closed-end (double acting) diesel hammers with a bounce chamber pressure gauge, in good working order, mounted near ground level so the Engineer can easily read. Also, provide the Engineer with a chart, calibrated to actual hammer performance within 30 days prior to initial use, equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used.

455-5.2.3 Hydraulic: Variable energy hydraulic hammers shall have at least three hydraulic control settings that provide for predictable stroke control. The shortest stroke shall be a maximum of 2 feet [0.6 m] for the driving of concrete piles. The remaining strokes shall be full stroke and approximately halfway between minimum and maximum stroke.

Determine the hammer energy according to the manufacturer's recommendations. When pressure measuring equipment is required to determine hammer energy, calibrate the pressure gauges before use.

455-5.2.4 Vibratory: Vibratory hammers of sufficient capacity (force and amplitude) may be used to drive steel sheet piles and, with approval of the Engineer, to drive steel bearing piles a sufficient distance to get the impact hammer on the pile (to stick the pile). The Engineer will determine the allowable depth of driving using the vibratory hammer based on site conditions. However, in all cases, use a power impact hammer for the last 15 feet [4.5 m] or more of the final driving of steel bearing piles for bearing determinations *after all piles in the bent/pier have been driven with a vibratory hammer*. Do not use vibrating hammers to install concrete piles*, or to install support or reaction piles for a load test*.

455-5.3 Cushions and Pile Helmet:

455-5.3.1 Capblock: Provide a capblock cushion (also called the hammer cushion) as recommended by the hammer manufacturer. Use capblocks constructed of durable manmade materials with uniform known properties. Do not use wood chips, wood blocks, rope, cable, or other material which permit excessive loss of hammer energy. Do not use capblocks constructed of asbestos materials. Obtain the Engineer's approval for all proposed capblock materials and proposed thickness for use. Maintain capblocks in good condition, and change them when charred, melted, or otherwise significantly deteriorated. The Engineer will inspect the capblock before driving begins and weekly or at appropriate intervals determined by the Engineer based on field trial. Replace or repair any hammer cushion which loses more than 25% of its original thickness, in accordance with the manufacturer's instructions, before permitting further driving.

455-5.3.2 Pile Cushion: Provide a pile cushion that is adequate to protect the pile from being overstressed in compression and tension during driving. Use a pile cushion sized so that it will fully fill the lateral dimensions of the pile helmet. Determine the thickness based upon the hammer-pile-soil system. For driving concrete piles, use a pile cushion made from pine plywood. Alternative materials may be used with the approval of the Engineer. Obtain the Engineer's approval for all pile cushions. Maintain pile cushions in good condition and change when charred, splintered, excessively compressed, or otherwise deteriorated to the point it will not protect the pile against overstressing in tension and/or compression. Protect cushions from the weather, and keep them dry. Do not soak the cushions in any liquid unless approved by the Engineer. Replace the pile cushion if, during the driving of any pile, the cushion is either compressed more than one-half the original thickness or begins to burn. Provide a new cushion for each pile unless approved otherwise by the Engineer after satisfactory field trial.

Reuse pile cushions in good condition to perform all set-checks and redrives. Use the same cushion to perform the set-check or redrive as was used during the initial driving, unless this cushion is unacceptable due to deterioration, in which case use a similar cushion.

455-5.3.3 Pile Helmet: Provide a pile helmet suitable for the type and size of piling being driven. Use a pile helmet deep enough to adequately contain the required thickness of pile cushion and to assist in maintaining pile-hammer alignment. Use a pile helmet that fits loosely over the pile head and is at least 1 inch [25 mm] larger than the pile dimensions. Use a pile helmet designed so that it will not restrain the pile from rotating.

455-5.4 Leads: Provide pile leads constructed in a manner which offers freedom of movement to the hammer and that have the strength and rigidity to hold the hammer and pile in the correct position and alignment during driving. When using followers, use leads that are long enough and suitable to maintain position and alignment of the hammer, follower, and pile throughout driving.

455-5.5 Followers: Use followers only for underwater driving. Obtain the Engineer's approval for the type of follower, when used, and the method of connection to the leads and pile. Use followers constructed of steel with an adequate cross-section to withstand driving stresses. When driving concrete piles, ensure that the cross-sectional area of the follower is at least 18% of the cross-sectional area of the pile. When driving steel piles, ensure that the cross-sectional area of the follower is greater than or equal to the cross-sectional area of the pile. Provide a pile helmet at the lower end of the follower sized according to the requirements of 455-5.3.3. Use followers constructed that maintain the alignment of the pile, follower, and hammer and still allow the pile to be driven within the allowable tolerances. Use followers designed with guides adapted to the leads that maintain the hammer, follower, and the piles in alignment.

Use information from driving full length piles described in 455-5.1.2 compared to driving piles with the follower and/or dynamic load tests described in 455-5.13 to evaluate the adequacy of the follower and to establish the blow count criteria when using the follower.

455-5.6 Templates: Provide a fixed template, adequate to maintain the pile in proper position and alignment during driving with swinging leads or with semi-fixed leads. For piles on land, locate the template within 5 feet [1.5 m] of cutoff or within 5 feet [1.5 m] of ground line, whichever is less. For piles in water, locate the template within 5 feet [1.5 m] of cutoff or within 5 feet [1.5 m] of the waterline, whichever is less. Do not use floating templates (attached to a barge). Where practical, place the template so that the pile can be driven to cut-off elevation before removing the template. When proposing to use a free hammer, provide a rigid double template that will independently support the pile. Provide free hammers with approved guide extensions that hold the hammer in alignment with the pile to ensure that the hammer blow is applied axially to the pile at all times. When driving piles with a follower using floating equipment, provide a double template or other approved equipment to maintain alignment of the hammer, follower, and pile. Use a double template consisting of a pile template within 5 feet [1.5 m] of cut-off elevation and a second upper support above the water surface for the leads. Where practical, place the template so that the pile can be driven to cut-off elevation before removing the template. Ensure that the individual pile positions of the second upper template are adjustable in size to serve as a guide for both the pile and follower. Ensure that templates do not restrict the vertical movement of the pile.

455-5.7 Water Jets: Use jet pumps, supply lines, and jet pipes that provide adequate pressure and volume of water to freely erode the soil. Do not perform jetting without prior approval by the Engineer or unless allowed by the plans.

Do not perform jetting in the embankment. Where conditions warrant, with approval by the Engineer, perform jetting on the holes first, place the pile therein, then drive the pile to secure the last few feet [meters] of penetration. Only use one jet for prejetting or jetting through piles constructed with a center jet-hole. Use two jets when using external jets. When jetting and driving, position the jets slightly behind the advancing pile tip (approximately 3 feet [0.9 m] or as approved by the Engineer). When using water jets in the driving, determine the pile bearing only from the results of driving after withdrawing the jets, except where using jets to continuously eliminate soil resistance through the scour zone, ensure that they remain in place as directed by the Engineer and operating during pile bearing determination. Where practical, perform jetting on all piles in a pile group before driving begins. When large pile groups or pile spacing and batter make this impractical, or when the plans specify a jet-drive sequence, set check a sufficient number of previously driven piles in a pile group to confirm their capacity after completing all jetting.

455-5.8 Penetration Requirements: Measure the penetration of piles from the elevation of natural ground, scour elevation shown in the plans, or the bottom of excavation, whichever is lower. When the Contract Documents show a minimum pile tip elevation or a minimum depth of penetration, drive the tip of the pile to this minimum elevation or this minimum penetration depth. In all such cases, the Engineer will accept the bearing ~~capacity~~ of a pile only if the Contractor achieves the required bearing ~~value~~ when the tip of the pile is at or below the specified minimum tip elevation or depth of penetration *and below the bottom of the preformed or predrilled pile hole*.

When the plans do not show a minimum depth of penetration, scour elevation, or minimum tip elevation, ensure that the required penetration is at least 10 feet [3 m] into firm bearing material or at least 20 feet [6 m] into soft material unless otherwise permitted by the Engineer. If a scour elevation is shown in the plans, achieve these penetrations below the scour elevation. The Engineer may accept a penetration between 15 and 20 feet [4.5 and 6 m] when there is an accumulation of five consecutive feet [1.5 consecutive meters] or more of firm bearing material. Firm bearing material is any material offering a driving resistance greater than or equal to 30 tons/ft^2 [3 MPa] of gross pile area as determined by the Wave Equation (45-5.11.2). Soft material is any material offering less than these resistances. The gross pile area is the actual pile tip cross-sectional area for solid concrete piles, the product of the width and depth for H piles, and the area within the outside perimeter for pipe piles and voided concrete piles.

Do not drive piles beyond practical refusal (20 blows per inch [25 mm]). To meet the requirements in this Subarticle, provide penetration aids, such as jetting or preformed pile holes, when piles cannot be driven to the required penetration without reaching practical refusal.

If the Contractor encounters unforeseeable, isolated obstructions that the Contractor cannot practically penetrate by driving, jetting, or preformed pile holes, and the Contractor must remove the pile to obtain the required pile penetration, the Department will pay the costs for such removal as Unforeseeable Work.

455-5.9 Preformed Pile Holes:

455-5.9.1 Description: Preformed Pile Holes are holes necessary due to the presence of rock or strong strata of soils which will not permit the installation of piles to the desired penetration by driving or a combination of jetting and driving, or holes determined necessary by the Engineer or when authorized by the Engineer to minimize the effects of vibrations on adjacent existing structures. The Engineer may require preformed holes for any type of pile. Preformed Pile Holes serve as a penetration aid when all other pile installation methods fail to produce the desired penetration and when authorized by the Engineer to minimize the effects of vibrations on adjacent structures.

Drive all piles installed in Preformed Pile Holes to determine that the bearing requirements have been met.

Fill all voids between the pile and soil remaining after driving through preformed holes with concrete sand or clean sand.

455-5.9.2 Provisions for Use of Preformed Pile Holes: The Department generally anticipates the necessity for Preformed Pile Holes and includes directions in the Contract Documents. The Department will pay for Preformed Piles Holes when the Contractor establishes that the required results cannot be obtained when driving the load bearing piles with specified driving equipment, while jetting the piles and then driving, or while jetting the piles during driving.

455-5.9.3 Conditions Under Which Payment Will Be Made: The Department will make payment for Preformed Pile Holes where the Contractor demonstrates that such work is necessary to achieve the required penetration of the pile. The Department considers, but does not limit to, the following conditions as reasons for Preformed Pile Holes:

(a) Inability to drive piles to the required penetration with driving and jetting equipment.

(b) To penetrate a hard layer or layers of rock or strong stratum that the Engineer considers not sufficiently thick to support the structure.

(c) To obtain greater penetration into dense (strong) material and into dense material containing holes, cavities or unstable soft layers.

(d) To obtain penetration into a stratum in which it is desired to found the structure.

(e) To minimize the effects of vibrations or heave on adjacent existing structures.

(f) To obtain a penetration up to 20 feet [6 m] except where the Contract Documents show a required pile penetration in excess of 20 feet [6 m].

(g) To minimize the effects of ground heave on adjacent piles.

455-5.9.4 Construction Methods: Construct Preformed Pile Holes by drilling, or driving and withdrawing a suitable punch or chisel at the locations of the piles. Construct a hole that is equal to or slightly greater than the pile and of sufficient depth to obtain the required penetration. Carefully form the preformed hole by using a drill or punch guided by a template or other suitable device, and do not exceed the minimum dimensions necessary to achieve the required penetration of the pile. When Preformed Pile Holes are oversized to the extent that the sides of the pile are not in contact with the soil and the pile has inadequate lateral stability, restore lateral stability by filling the space between the pile and the sides of the hole with concrete sand or other approved clean sand. When the plans call for grouting the Preformed Pile Holes, provide the minimum dimension of the pile hole that is 2 inches [50 mm] larger than the largest pile dimension. Construct the holes at the plan position of the pile and the tolerances in location, and ensure that the batter is the same as allowed for the pile.

455-5.9.5 Grouting of Pile Holes: Grout Preformed Pile Holes for bearing piles, when the plans require grouting after driving. Clean the Preformed Pile Holes, and fill them with cement grout as shown in the plans. Use grout that has a minimum compressive strength of 3,000 psi [20 MPa] at 28 days or as specified. Pump the grout through three or more grout pipes initially placed at the bottom of the preformed hole. The Contractor may raise the grout pipes when necessary to prevent clogging and to complete the grouting operations. Maintain the grout pipes below the surface of the previously placed grout. Continue grouting until the grout reaches the ground surface all around the pile. Provide divers to monitor grouting operations when the water depth is such that it is impractical to monitor from the ground surface. When grouting is shown in the plans, include the cost in the price for Piles. In the event that the Engineer determines the Contractor must grout and the required grouting is not shown in the plans, the Department will pay for the grouting work as Unforeseeable Work.

455-5.10 Bearing Requirements:

455-5.10.1 General: Drive piles to provide the bearing capacities required for carrying the loads shown in the plans. For all types of bearing piles, consider the driving resistance as determined by the methods described herein sufficient for carrying the specified loads as the minimum bearing which is accepted for any type of piles. Determine pile bearing using the method described herein or as shown in the plans.

The Engineer may accept a driven pile when the pile has achieved minimum penetration, the blow count is generally increasing and the minimum required bearing capacity obtained for 24 inches [600 mm] of consecutive driving. At his discretion, the Engineer may also accept a driven pile when the minimum penetration is achieved and driving has reached practical refusal in firm material.

455-5.10.2 Blow Count Criteria: The Engineer will determine the number of blows required to provide the required bearing according to the methods described herein. Determine the pile bearing by computing the penetration per blow with less than 1/4 inch [6 mm] rebound averaged through 12 inches [300 mm] each of penetration. When it is considered necessary by the Engineer, the Contractor may determine the average penetration per blow by averaging the penetration per blow through the last 10 to 20 blows of the hammer. ~~Supply driving equipment which provides the required resistance at a blow count ranging from 3 blows per inch [3 blows per 25 mm] (36 blows per foot [36 blows per 300 mm]) to 10 blows per inch [10 blows per 25 mm] (120 blows per foot [120 blows per 300 mm]) unless approved otherwise by the Engineer after satisfactory field trial.~~

455-5.10.3 Practical Refusal: Practical refusal is defined as 20 blows per inch [20 blows per 25 mm] with the hammer operating at the highest ~~full~~ setting or ~~at~~ setting determined by the Engineer and less than 1/4 inch [6 mm] rebound per blow. Stop driving as soon as the Engineer determines that the pile has reached practical refusal. The Engineer will generally make this determination within 2 inches [50 mm] of driving. However, the Engineer will in no case approve the continuation of driving at practical refusal for more than 12 inches [300 mm]. When the required pile penetration cannot be achieved by driving without exceeding practical refusal, use other penetration aids such as jetting or Preformed Pile Holes.

455-5.10.4 Set-checks and Pile Redrive:

(a) Set-checks: In the event that the Contractor has driven the pile to approximately 12 inches [300 mm] above cut-off without reaching the required resistance, the Engineer may require the Contractor to interrupt driving at least 15 minutes prior to performing a set-check. A set-check consists of ten hammer blows or 10 inches [250 mm] or more of driving. Provide an engineer’s level or other suitable equipment for elevation determinations to determine accurate pile penetration during the set-checks. There will be no separate payment for an initial set-check. In the event the result of an initial set-check is not satisfactory, the Engineer may direct additional set-checks. For each additional set-check ordered by the Engineer within 72 hours from the end of original driving, the Contractor will be paid an additional quantity of 10 feet [3 m] of Piling. The Engineer may accept the pile as driven when a set-check shows that the Contractor has achieved the minimum required pile bearing and has met all other requirements of this Section.

(b) Pile Redrive: Pile Redrive consists of redriving the pile after 72 hours from original driving to determine time effects, to reestablish pile capacity due to pile heave, or for other reasons determined by the Engineer. Redrive piles as directed by the Engineer. Redrives may range from ten hammer blows to 12 inches [300 mm] or more of driving.

455-5.10.5 Pile Heave: Pile heave is the upward movement of a pile from its originally driven elevation. Drive the piles in an approved sequence to minimize the effects of heave and lateral displacement of the ground. Monitor piles previously driven in a pile group for possible heave during the driving of the remaining piles. When required by the Engineer, take elevation measurements to determine the magnitude of the movement of piles and the ground surface resulting from the driving process. Redrive all piles that have heaved 1/4 inch [6 mm] or more unless the Engineer determines that the heave is not detrimental to pile capacity. The Department will pay for all work in conjunction with redriving piles due to pile heave under the Pile Redrive item.

455-5.10.6 Piles with Insufficient Bearing: In the case that the Engineer determines that the safe bearing capacity of any pile is less than the required bearing capacity, the Contractor may splice the pile and continue driving or may extract the pile and drive a pile of greater length, or, if so ordered by the Engineer, drive additional piles until reducing the ~~adjusted~~ required bearing per pile to the determined bearing capacity of the piles already driven.

455-5.11 Methods to Determine Pile Capacity:

455-5.11.1 General: Dynamic load test will be used to determine pile capacity for all structures or projects unless shown otherwise in the Contract Documents. When necessary, the Engineer may require static load tests to confirm pile capacities. When the Contract Documents do not include items for static load tests, the Engineer will consider all required testing Unforeseeable Work. When considered necessary by the Engineer, adjust the blow count criteria to match the resistance determined from static load tests.

455-5.11.2 Wave Equation:

General: ~~The Engineer may u~~*U*se ~~the~~ Wave Equation Analysis for Piles (WEAP) programs~~.~~

~~The Engineer will use the Wave Equation~~ to evaluate the suitability of the ~~Contractor's~~ proposed driving system (including the hammer, follower, capblock and pile cushions) as well as to estimate the driving resistance, in blows per 12 inches [300 mm] or blows per inch [25 mm], to achieve the pile bearing requirements and to evaluate pile driving stresses. ~~The required driving resistance is equal to the design load multiplied by the appropriate factor of safety plus the scour and down drag resistance shown in the plans (no safety factor is required) or the ultimate bearing capacity shown in the plans, whichever is higher.~~

~~The factor of safety applied to the design load is:~~
~~2.0 when static load tests are required.~~
~~2.5 when the Pile Driving Analyzer~~
~~and Wave Equation Analysis are required.~~
~~3.0 when only the Wave Equation Analysis is required.~~

The Engineer may modify the scour resistance shown in the plans if the dynamic load test is used to determine the actual soil resistance through the scour zone. Also, the Engineer may make modifications in scour resistance when the Contractor proposes drilling and/or jetting to reduce the soil resistance in the scour zone.

~~The Engineer will not approve any hammer for driving unless~~ *Use* Wave Equation ~~a~~*A*nalyses *to* show ~~it~~ *the hammer is* capable of driving to a resistance equal to at least ~~3.0~~*2.0* times the *factored* design ~~*service*~~ load plus the scour and down drag resistance (if applicable) shown in the Contract Documents ~~or 1.25 times the ultimate *(nominal bearing)* resistance shown in the Contract Documents, whichever is higher~~, without overstressing the piling in compression or tension and without reaching practical refusal (20 blows per inch [20 blows per 25 mm]). Ensure that the hammer provided also meets the requirements described in 455-5.~~10.~~2.

(b) Required Equipment For Driving: Hammer approval is solely based on *satisfactory field trial including* ~~the~~ *PDA, CAPWAP and* Wave Equation Analysis~~, PDA and CAPWAP analysis~~. Supply a hammer system that meets the requirements described in the specifications based on the above analysis. Obtain ~~preliminary~~ approval from the Engineer for *the pile driving system based on* ~~all proposed driving equipment. All equipment is subject to~~ satisfactory field performance.

In the event ~~that~~ piles require different hammer sizes, the Contractor may elect to drive with more than one size hammer or with a variable energy hammer, provided the hammer is properly sized~~,~~ *and* cushioned, ~~and the Wave Equation analyses show that it~~ will not damage the pile*,* and will develop the required resistance.

(c) ~~Allowable~~ *Maximum Allowed* Pile Stresses:

(1) General: The ~~allowable~~ *maximum allowed driving* stresses for concrete, steel, and timber piles are given below. In the event Wave Equation analyses show that the hammer will overstress the pile, ~~the Engineer will reject the proposed driving system. Upon such rejection,~~ modify the driving system or method of operation as required to prevent overstressing the pile. In such cases~~, meet the Engineer's reevaluation requirements by providing~~ *provide* additional cushioning or mak~~eing~~ other appropriate agreed upon changes. For penetration of weak soils by concrete piles, use thick cushions and/or reduced stroke to control tension stresses during driving.

(2) Concrete Piles: ~~The Engineer will u~~*U*se the wave equation to evaluate the *proposed* pile cushioning~~. the Contractor proposes to use.~~ Use the following equations to determine the maximum ~~allowable~~ *allowed pile* stresses as predicted by the wave equation*, and/or measured during driving* when driving prestressed concrete piling:

Non SI Units

$$s_{apc} = 0.7\ f_c' - 0.75\ f_{pe} \quad (1)$$

$$s_{apt} = 6.5\,(f_c')^{0.5} + 1.05\ f_{pe} \quad (2a)$$

for piles less than 50 feet long

$$s_{apt} = 3.25\,(f_c')^{0.5} + 1.05\ f_{pe} \quad (2b)$$

for piles 50 feet long and greater

$s_{apt} = 800$ *(2b) within 10 feet of a mechanical splice*

where:

s_{apc}= maximum allow*ed*~~able~~ pile compressive stress, psi
s_{apt}= maximum allow*ed*~~able~~ pile tensile stress, psi
f'_c= specified minimum compressive strength of concrete, psi
f_{pe}= effective prestress (after all losses) at the time of driving, psi, taken as 0.8 times the initial prestress force (f_{pe}= 0 for *dowel* spliced piles).

SI Units

$$s_{apc} = 0.7\,f_c' - 0.75\,f_{pe} \quad (1)$$

$$s_{apt} = 0.54\,(f_c')^{0.5} + 1.05\ f_{pe}$$ (2a) for piles less than 15 m long

$$s_{apt} = 0.27\,(f_c')^{0.5} + 1.05\ f_{pe} \quad (2b)$$

for pile over 15 m long and greater

$s_{apt} = 5.52$ *(2c) within 3 m of a mechanical splice*

where:

s_{apc}= maximum allow*ed*~~able~~ pile compressive stress, MPa
s_{apt}= maximum allow*ed*~~able~~ pile tensile stress, MPa
f'_c= specified minimum compressive strength of concrete, MPa
f_{pe}= effective prestress (after all losses) at the time of driving, MPa, taken as 0.8 times the initial prestress force (f_{pe}= 0 for *dowel* spliced piles).

(3) Steel Piles: Ensure ~~that~~ the maximum ~~allowable~~ *allowed* pile compression and tensile stresses as predicted by the Wave Equation*, and/or measured during driving* are *no greater than* ~~equal to~~ 0.9 times the yield strength (0.9 f_y) of the steel.

(4) Timber Piles: Ensure ~~that~~ the maximum ~~allowable~~ *allowed* pile compression and tensile stresses as predicted by the wave equation*, and/or measured during driving are no greater than* ~~are~~ 3.6 ksi [25 MPa] for Southern Pine and Pacific Coast Douglas Fir and 0.9 of the ultimate parallel to the grain strength for piles of other wood.

455-5.11.3 Temporary Piles: Submit for the Engineers approval, a Wave Equation analysis signed and sealed by a Specialty Engineer which establishes the driving criteria for temporary piles. *The required driving resistance is equal to the design (service) load multiplied by the appropriate factor of safety plus the scour and down drag resistance shown in the plans (no safety factor is required) or the ultimate bearing capacity shown in the plans, whichever is higher.*

The factor of safety applied to the design (service) load is:

2.0...................... when static load tests are required.
2.5........................... when the Pile Driving Analyzer .... and Wave Equation Analysis are required.
3.0 when only the Wave Equation Analysis is required.

455-5.11.4 Dynamic Load Tests: Dynamic load testing consists of predicting pile capacity from blows of the hammers during drive and/or redrive of an instrumented pile.

455-5.11.5 Static Load Tests: Static load testing consists of applying a static load to the pile to determine its capacity. Use The Modified Quick Test Procedure in accordance with 455-2.2.1.

455-5.11.6 Fender Pile Installation: For piles used in fender systems, regardless of type or size of pile, either drive them full length or jet the piles to within 2 feet [600 mm] of cutoff and drive to cutoff elevation to seat the pile. The Engineer will not require a specific driving resistance unless noted in the plans. Use methods and equipment for installation that do not damage the piles. If the method or equipment used causes damage to the pile, modify the methods or equipment at no expense to the Department.

455-5.12 Test Piles:

455-5.12.1 Description: Drive piles of the same cross-section and type as the permanent piles shown in the plans, in order to determine any or all of the following:

(a) the ~~safe bearing value of~~ *installation criteria for* the piles.
(b) the nature of the soil.
(c) the lengths of permanent piles required for the work.
(d) the driving resistance characteristics of the various soil strata.
(e) the amount of work necessary to obtain minimum required pile penetration.
(f) the ability of the driving system to do the work.
(g) the need for point protection.

Because test piles are exploratory in nature, drive them harder (within the limits of practical refusal), deeper, and to a greater bearing ~~value~~ *resistance* than required for the permanent piling. ~~Where practical~~*Except for test piles which are to be statically (or Statnamically) load tested*, drive test piles their full length *or to practical* *refusal*. Build up test piles which have been driven their full length and have developed only minimal required bearing, and proceed with further driving.

As a minimum, unless otherwise directed by the Engineer, do not cease driving of test piles until obtaining the required bearing capacity continuously, where the blow count is increasing, for 10 feet [3 m] unless reaching practical refusal first. For test piles which are to be statically *(or Statnamically)* load tested, ignore this minimum and drive these piles as anticipated for the production piles.

When test piles attain practical refusal prior to attaining minimum penetration, perform all work necessary to attain minimum penetration and the required bearing. Where practical, use water jets to break the pile loose for further driving. Where jetting is impractical, extract the pile and install a Preformed Pile Hole through which driving will continue. The Department will consider the work of extracting the pile to be Unforeseeable Work.

When driving test piles other than low displacement steel test piles, have water jets as specified in 455-5.7 and preforming equipment available at the site, ready for use, before the test pile driving begins.

The Engineer may elect to interrupt pile driving up to four times on each test pile, two times for 15 minutes and two additional times within 72 hours of initial driving to determine time effects during the driving of test piles at no additional cost to the Department. If set-checks are determined necessary by the Engineer after 72 hours from the end of initial driving, each set-check will be paid for as Pile Redrive.

Install instruments on test piles when dynamic load tests are included in the plans or when directed by the Engineer.

455-5.12.2 Location of Test Piles: Drive all test piles in the position of permanent piles at the designated locations. ~~Unless all piles at the designated location are battered, drive plumb test piles.~~ Ensure that all test piles designated to be statically load tested are plumb. In the event that all the piles are battered at a static load test site, the Engineer will designate an out-of-position location for driving a plumb pile for the *static* load test.

455-5.12.3 Equipment for Driving: Use the same ~~type, size, and weight~~ hammer and equipment for driving test piles as ~~is intended~~ for driving the permanent piles. Also use the same equipment to redrive ~~any test~~ piles.

455-5.12.4 Ground Elevations: At the time of driving test piles, furnish the Engineer with elevations of the original ground *and template* at each pile or pile group location. Note the highest and lowest elevation at each required location and the ground elevation at all the test piles. Present the elevations in plotted and tabular form and submit with the test pile data.

455-5.13 Dynamic Load Tests: The Engineer will take dynamic measurements during the driving of piles designated in the plans or authorized by the Engineer as Dynamic Load Test Piles. Install instruments on test piles and selected permanent piles for dynamic load testing. When the Contract Documents include Dynamic Load Tests, all test piles will have dynamic load tests. The Engineer will perform Dynamic Load Tests to evaluate any or all of the following:

1. Evaluate suitability of Contractor’s driving equipment, including hammer, capblock, pile cushion, and any proposed follower.

2. Determine pile capacity.

3. Determine pile stresses.
4. Determine energy transfer to pile.
5. Determine distribution of soil resistance.
6. Evaluate soil variables including quake and damping.
7. Evaluate hammer-pile-soil system for Wave Equation analyses.
8. Evaluate pile installation problems.
9. Other.

Attach instruments (strain transducers to measure force and accelerometers to measure acceleration) with screws to the pile for dynamic load testing. To allow the Engineer to perform dynamic load testing, supply 110 V, 60 Hz, 30 A of AC electric power to operate an electric drill and to operate the pile driving analyzer equipment. When required in the plans, also provide a suitable shelter within 50 feet [15 m] and within view of the test location to protect the equipment from the elements. Ensure that this shelter is 7 feet [2 m] high and 8 by 8 feet [2.5 by 2.5 m] in plan. Provide a suitable man basket, having a working area of at least 4 by 4 feet [1.2 by 1.2 m] with 4 foot [1.2 m] high safety rails all around, to be lifted by the crane, for use as required, to provide access to the top of the pile. Supply a stable platform which is satisfactory, in the opinion of the Engineer, for reference of the pile penetration.

Make each pile to be dynamically tested available to drill holes for attaching instrumentation and for wave speed measurements. Support the pile with timber blocks placed at appropriate intervals. Ensure that the pile is in a horizontal position and does not contact adjacent piles. Provide a sufficient clear distance at the sides of the pile for drilling the holes. The Engineer will furnish the equipment, materials, and labor necessary for drilling holes and taking the wave speed measurements. If the Engineer directs dynamic load testing of piles already driven, provide the Engineer safe access to the top of the piles for drilling the attachment holes. After placing the leads provide the Engineer reasonable means of access to the piles to attach the instruments and for removal of the instruments after completing the pile driving.

The Engineer will monitor the stresses in the piles with the dynamic test equipment during driving to ensure the Contractor does not exceed the *maximum* ~~allowable~~ *allowed* stresses. If necessary, add additional cushioning, replace the cushions, or reduce the hammer stroke to maintain stresses below the maximum allowable. If dynamic test equipment measurements indicate non-axial driving, immediately realign the driving system. If the cushion is compressed to the point that a change in alignment of the hammer will not correct the problem, add cushioning or change the cushion as directed by the Engineer.

Drive the pile to the required penetration and resistance or as directed by the Engineer. The Engineer may elect to interrupt driving for up to two waiting periods, ~~15~~ *60* minutes each (set-checks) during the initial driving of the pile. Dynamic load testing of a pile may average up to two hours longer than for driving an uninstrumented pile.

When directed by the Engineer, perform instrumented redrives. Do not use a cold diesel hammer for a redrive unless in the opinion of the Engineer it is impractical to do otherwise. Generally, warm up the hammer by *driving another pile or* applying at least 20 blows to a previously driven pile or to timber mats placed on the ground.

455-5.14 Pile Lengths:

455-5.14.1 Test Pile Length: Provide the length of test piles shown in the plans or as directed by the Engineer.

455-5.14.2 Production Pile Length: When shown in the plans, the lengths are based on information available during design and are approximate only. The Engineer will determine final pile lengths in the field which may vary significantly from the lengths or quantities shown in the plans.

455-5.14.3 Authorized Pile Lengths: The authorized pile lengths are the lengths determined by the Engineer based on all information available before the driving of the permanent piles, including, but not limited to, information gained from the driving of test piles, dynamic load testing, static load testing, ~~set-checks, pile redrives,~~ supplemental soil testing, etc. *When authorized by the Department, soil freeze information obtained during set checks and pile redrives may be used to determine authorized pile lengths for sites with extreme soil conditions.* These lengths represent the lengths ~~that~~ the Department has assumed ~~to~~ *will* remain in the completed structure. The Contractor may elect to provide piling with lengths longer than authorized to suit his method of installation *or schedule*. When the Contractor elects to provide longer than authorized pile lengths, the Department will pay for the furnished length as either the originally authorized length or the length between cut-off elevation and the final accepted pile tip elevation, whichever is the longer length.

Within 30 days after driving all the test piles, completing all load tests, completing all redrives, and receiving all test reports, the Engineer will furnish the Contractor an itemized list of authorized pile lengths and driving criteria. Use these lengths for furnishing the permanent piling for the structure. If the Contractor is willing to start his pile driving operations in phases designated by the Engineer, and if the Contractor so requests in writing at the beginning of the test pile program, the Department will furnish pile lengths and driving criteria for these designated phases within seven days after driving all the test piles, completing all load tests, completing all redrives, and receiving all test reports for those designated phases.

On multiple phase projects, the Engineer will not furnish pile lengths on subsequent phases until completing the piling on initial phases.

455-5.15 Allowable Driving Tolerances:

455-5.15.1 General: Meet the tolerances described in this Subarticle to the piles that are free standing without lateral restraint (after the template is removed). After the piles are driven, do not move the piles laterally to force them to be within the specified tolerances. The Contractor may move battered piles laterally to overcome the dead load deflections caused by the pile's weight. When this is necessary, submit calculations signed and sealed by a Specialty Engineer to the Engineer that verify the amount of dead load deflection prior to moving any piles.

455-5.15.2 Position: Ensure that the final position of the pile head at cut-off elevation is no more than 3 inches [75 mm] from the plan position indicated in the plans.

455-5.15.3 Axial Alignment: Ensure that the axial alignment of the driven piles does not deviate by more than 1/4 in/ft [20 mm/m] from the vertical or batter line indicated in the plans.

455-5.15.4 Elevation: Ensure that the final elevation of the pile head is no more than 1 1/2 inches [38 mm] above, or more than 4 inches [100 mm] below, the elevation shown in the plans. Do not embed the pile less than 6 inches [150 mm] below the elevation shown in the plans unless a minimum penetration requirement is shown.

455-5.15.5 Deviation From Above Tolerances: When the Contractor has failed to meet the above tolerances, the Contractor may request design changes in the pile caps or footings to incorporate piles driven out of tolerance. Bear the expense of redesign and Unforeseeable Work resulting from approved design changes to incorporate piles driven out of tolerance. Employ a Specialty Engineer to perform any redesign and who shall sign and seal the redesign drawings and computations. Do not begin any proposed redesign until it has been reviewed for acceptability and approved by the Engineer.

455-5.16 Disposition of Pile Cut-offs, Test Piles, and Load Test Materials:

455-5.16.1 Pile Cut-offs:

(a) Steel Piling: Unless shown otherwise in the plans, the Department will retain ownership of cut-off sections, or portions of cut-off sections, and unused piling 20 feet [6 m] long or longer that are not damaged. Deliver them to the Department's nearest maintenance yard. Ensure that sections of piles delivered to the maintenance yard are straight and undamaged. Cut off the damaged portions prior to delivery. Take ownership of cut-off sections less than 20 feet [6 m] long. Remove them from the job, and dispose of them.

(b) Other Pile Types: Upon completion of all work under the Contract in connection with piling, unless shown otherwise in the plan, take ownership of any unused cut-off lengths remaining, and remove them from the right-of-way. Provide areas for their disposal.

455-5.16.2 Test Piles: Where so directed by the plans or the Engineer, cut off, or build-up as necessary, test piles, and leave them in place as permanent piles. Extract and replace test piles driven in permanent position and found not suitable for use at no expense to the Department. Pull, or cut off at an elevation 2 feet [0.6 m] below the ground surface or bottom of proposed excavation, test piles driven out of permanent position, and dispose of the removed portion of the test pile.

When test piles are required to be driven in permanent pile positions, the Contractor may elect to drive the test pile out of position, with the approval of the Engineer, provided that a replacement pile is furnished and driven by the Contractor at no expense to the Department in the position that was to be occupied by the test pile. Under this option, the Department will pay for the test pile in the same manner as if it were in permanent position.

Unless otherwise directed in the plans or by the Engineer, retain ownership of test piles that are pulled or cut off and provide areas for their disposal.

455-6 Timber Piling.

455-6.1 Description: Drive timber piles constructed of round timber of the kind and dimensions specified in the plans at the locations and to the elevations shown in the plans, or as directed by the Engineer.

455-6.2 Materials: Meet the timber piling requirements of Section 953. Treat the piles according to the applicable provisions of Section 955. Treat all cuts and drilled holes in accordance with 470-3.

455-6.3 Preparation for Driving:

455-6.3.1 Caps: Protect the heads of timber piles during driving, using a cap of approved type, that will distribute the hammer blow over the entire cross-section of the pile. When necessary, cut the head of the pile square before beginning pile driving.

455-6.3.2 Collars: Provide collars or bands to protect piles against splitting and brooming at no expense to the Department.

455-6.3.3 Shoes: Provide piles shod with metal shoes, of a design satisfactory to the Engineer, at no expense to the Department. Shape pile tips to receive the shoe and install according to the manufacturer's directions.

455-6.4 Storage and Handling: Store and handle piles in the manner necessary to avoid damage to the piling. Take special care to avoid breaking the surface of treated piles. Do not use cant dogs, hooks, or pike holes when handling and storing the piling.

455-6.5 Cutting Off: Saw off the tops of all timber piles at the elevation indicated in the plans. Saw off piles which support timber caps to the exact plane of the superimposed structure so that they exactly fit it. Withdraw and replace broken, split, or misplaced piles.

455-6.6 Build-ups: The Engineer will not permit splices or build-ups for timber piles. Extract piles driven below plan elevation and drive a longer pile.

455-6.7 Pile Heads:

455-6.7.1 Piles with Timber Caps: On piles wider than the timber caps, dress off to a slope of 45 degrees the part of the pile head projecting beyond the sides of the cap. Coat the cut surface with the required preservative over which place a sheet of copper, of a weight of 10 oz/ft^2 [3 kg/m^2] or greater, meeting the requirements of ASTM B 370. Provide a cover that measures at least 4 inches [100 mm] more in each dimension greater than the diameter of the pile. Bend the cover down over the pile and fasten the edges with large head copper nails or three wraps of No. 12 [2 mm] copper wire.

455-6.7.2 Fender and Bulkhead Piles: First paint the heads of fender piles and of bulkhead piles with preservative and then cover with copper as provided above for piles supporting timber caps.

455-7 Prestressed Concrete Piling.

455-7.1 Description: Provide prestressed concrete piles that are manufactured, cured, and driven in accordance with the requirements of the Contract Documents. Provide piles full length without splices when transported by barge or transported by truck without the need of a special over length permit. When piles are of a length which requires a special over length permit to transport and splicing is desired, provide minimal splices. Include the cost of the splices in the cost of the pile.

455-7.2 Manufacture: Fabricate piles in accordance with Section 450.

455-7.3 Storage and Handling:

455-7.3.1 Time of Driving Piles: Drive prestressed concrete piles at any time after the concrete has aged at least seven days and the concrete compressive strength is equal to or greater than the specified 28 day compressive strength.

455-7.3.2 Storage: Support piles on adequate dunnage both in the prestress yard and at the job site in accordance with the locations shown in the plans to minimize undue bending stresses or creating a sweep or camber in the pile.

455-7.3.3 Handling: Handle and store piles in the manner necessary to eliminate the danger of fracture by impact or of undue bending stresses in handling or transporting the piles from the forms and into the leads. In general, lift concrete piles by means of a suitable bridge or slings attached to the pile at the locations shown in the plans. Construct slings used to handle piles of a fabric material or braided wire rope constructed of six or more wire ropes which will not mar the corners or the surface finish of the piles. Do not use chains to handle piles. During transport, support concrete piles at the lifting locations shown in the plans or fully support them throughout 80% or more of their length. In handling piles for use in salty or brackish water, exercise special care to avoid damaging the surface and corners of the pile. If an alternate transportation support arrangement is desired, submit calculations, signed and sealed by the Specialty Engineer, for approval by the Engineer prior to transporting the pile. Calculations must show that the pile can be transported without exceeding the bending moments calculated using the support locations shown in the plans.

455-7.4 Cracked Piles: The Engineer will reject any pile that becomes cracked in handling to the point that a transverse or longitudinal crack extends through the pile, shows failure of the concrete as indicated by spalling of concrete on the main body of the pile adjacent to the crack, or which in the opinion of the Engineer will not withstand driving stresses. The Engineer will not reject any pile for the occasional minor surface hairline cracking caused by shrinkage or tensile stress in the concrete from handling.

Do not drive piling with irreparable damage, which is defined as any cracks that extend through the pile cross-sectional area that are, or will be, below ground or water level at the end of driving. Such cracks are normally evidenced by emitting concrete dust during their opening and closing with each hammer blow. Remove and replace broken piles or piles cracked to the extent described above at no expense to the Department. The Engineer will accept cracks less than 0.005 inch [0.15 mm] which do not extend through the pile. Using approved methods, cut off and splice or build-up to cut-off elevation piles with cracks greater than 0.005 inch [0.15 mm] at the pile head or above ground or water level, and piles with cracks above ground or water level which extend through the cross-sectional area of the pile. The Engineer, at his discretion, may require correction of pile damage or pile cracks by cutting down the concrete to the plane of sound concrete below the crack and rebuilding it to cut-off elevation, or the Engineer may reject the pile. Extract and replace rejected piles that cannot be repaired, at no expense to the Department.

Take appropriate steps to prevent the occurrence of cracking, whether due to handling or driving. When cracking occurs during driving take immediate steps to prevent additional cracking by using thicker cushions or reducing the ram stroke length. Revise handling and transporting equipment and procedures as necessary to prevent cracking during handling and transportation.

455-7.5 Preparation for Transportation: Cut any strands protruding beyond the ends of the pile flush with the surface of the concrete using an abrasive cutting blade before transporting the piles from the casting yard.

Cut the metal handling devices cast into the concrete back to a minimum depth of 1 inch [25 mm] and patch with an approved epoxy mortar, mixed, applied and cured in accordance with the manufacturer’s recommendations before transporting the piles from the casting yard.

455-7.6 Method of Driving: Unless otherwise directed, drive piles by a hammer or by means of a combination of water jets and hammer. When using jets in combination with a hammer, withdraw the jets and drive the pile by the hammer alone, to secure final penetration and to rigidly fix the tip end of the pile. Keep jets in place if they are being used to continuously eliminate the soil resistance in the scour zone.

455-7.7 Extensions and Build-ups Used to Increase Production Lengths:

455-7.7.1 General: Where splices and build-ups for concrete piles are necessary, such splices and build-ups to be driven, or those21 feet [6.4 m] or longer, are to be prestressed precast sections. Ensure that build-ups less than21 feet [6.4 m] in length and not to be driven consist of a non-prestressed reinforced section meeting the requirements of 455-7.7.3. The Contractor may construct build-ups less than 2 feet [0.6 m] in length in accordance with 455-11.8. When splicing a prestressed precast section onto the original pile and, after driving, the length of spliced section below cut-off elevation is4 feet [1.2 m] or less, remove the pile concrete to the cut-off elevation and leave the dowels in place to be incorporated into the cap as directed by the Engineer. The Contractor may cut the length of dowels which becomes exposed to a length of 48 inches [1,220 mm] from the plane of pile-splice.

These requirements are not applicable to specially designed piling. Make splices for special pile designs as shown in the plans.

455-7.7.2 Extensions to be Driven or Those 21 feet [6.4 m] or Longer: Construct extensions to be driven or extensions 21 feet [6.4 m] or longer in length in accordance with the details shown in the plans and in a manner including the requirements, sequences, and procedures outlined below:

(a) Cast a splice section in accordance with Section 450 with the dowel steel in the correct position and alignment.

(b) Drill dowel holes using an approved steel template that will position and align the drill bit during drilling. Drill holes a minimum of 2 inches [50 mm] deeper than the length of the dowel to be inserted.

(c) Clean the drilled dowel holes by inserting a high pressure air hose to the bottom of the hole and blowing the hole clean from the bottom upward. Eliminate any oil, dust, water, and other deleterious materials from the holes and the concrete surfaces to be joined.

(d) Mix the adhesive components in accordance with the manufacturer’s directions. Do not mix sand or any other filler material with the epoxy components unless it is prepackaged by the manufacturer for this specific purpose. Use adhesives meeting the requirements of Section ~~416~~ *926 for Type B Epoxy Compounds*.

(e) After ensuring that all concrete surfaces are dry, fill the dowel holes with the adhesive material.

(f) Place forms around joints between the pile sections.

(g) Insert the dowels of the spliced section into the adhesive filled holes of the bottom section and position the spliced section so that the axes of the two sections are in concentric alignment and the ends of the abutting sections are spaced 1/2 inch [15 mm] apart. The Contractor may use small steel spacers of the required thickness provided they have 3 inches [75 mm] or more of cover after completing the splice. Fill the space between the abutting sections completely with the adhesive.

(h) Secure the spliced sections in alignment until the adhesive is cured in accordance with the manufacturer’s directions for the time appropriate with the prevailing ambient temperatures. Do not utilize the crane to secure the pile extension during the adhesive cure time. Utilize alignment braces to maintain the proper pile alignment during the epoxy cure time.

(i) After curing is completed, remove alignment braces and forms and clean and dress the spliced area to match the pile dimensions.

455-7.7.3 Precast Reinforced Build-ups: Construct Precast Reinforced Build-ups in accordance with the requirements of this Subarticle, Section 346, and Section 400. Provide the same material for the form surfaces for precast build-ups as was used to form the prestressed piles. Use concrete of the same mix as used in the prestressed pile and dimension the cross-section the same as piling being built up. Install build-ups as specified in 455-7.7.2(b) through 455-7.7.2(i). Apply to the build-ups the same surface treatment or sealant applied to the prestressed piles. The Department will make payment for authorized build-ups at the respective Contract unit prices per foot [meter] for Prestressed Concrete Piling.

455-7.8 Pre-Planned Splices: When the contractor elects to use piles which are spliced together to obtain the authorized production length, splices shall be made by the doweled splice method contained in the plans or may be made using proprietary splices which are listed on the Department’s QPL. Splice test piles in the same manner as the production piles. Include in the pile installation plan, the chosen method of splicing and the approximate locations of the splice. Generally, place the splice at approximately the midpoint between the estimated pile tip and the ground surface, considering scour if applicable. Stagger the splice location between adjacent piles by a minimum of 10 feet [3 meters]. Obtain the Engineer’s approval prior to constructing any pile sections. Construct piles which are to be spliced using the doweled splice with preformed dowel holes in the bottom section and embedded dowels in the upper section. Provide splices constructed using doweled splice shown in the plans or a mechanical pile splice, listed on the Department’s QPL. Mechanical pile splices shall be capable of developing the following capacities in the pile section unless shown otherwise in the plans and capable of being installed without damage to the pile or splice:

a) Compressive strength = (Pile Cross sectional area) x (28 day concrete strength)

b) Tensile Strength = (Pile Cross sectional area) x 900 psi [6.21 MPa]

Non SI Units	
Pile Size (inches)	Bending Strength (kip-feet)
18	245
20	325
24	600
30	950

SI Units	
Pile Size (mm)	Bending Strength (KN-m)
455	330
510	440
610	815
760	1,290

455-7.9 Pile Cut-offs: After the completion of driving, cut piles off which extend above the cut-off elevation with an abrasive saw. Make the cut the depth necessary to cleanly cut through the prestressed strands. Take ownership and dispose of cut-off sections not used elsewhere as allowed by this Section.

455-8 Steel Piling.

455-8.1 Description: Furnish, splice, drive, and cut off structural steel shapes to form bearing piles. Include in this work the installation of bracing members of structural steel by bolting or welding, construction of splices and the filling of pipe piles with the specified materials.

455-8.2 Material: For the material in rolled steel piles, pile bracing, scabs, wedges, and splices, meet the requirements for structural steel as specified in 962-2, Miscellaneous Steel.

455-8.3 Pile Splices: Order and use the full authorized pile length where practicable. Do not splice to obtain authorized lengths less than 40 feet [12 m] except when shown in the plans. When approved by the Engineer, perform splicing to obtain authorized lengths between 40 and 60 feet [12 and 18 m]. The Engineer will permit splicing to obtain authorized lengths in excess of 60 feet [18 m].

Where the pile length authorized is not sufficient to obtain the required bearing value or penetration, order an additional length of pile and splice it to the original length.

Make all splices in accordance with the plan details. Payment for pile splicing will be limited as specified in 455-11.8.

455-8.4 Welding: Make all welded connections to steel piles by electric arc welding, in accordance with details shown in the plans and in compliance with the requirements of 460-6, except 460-6 (1) and 460-6 (2). Only visual inspection methods will be used to inspect pile welds.

455-8.5 Pile Heads and Tips: Cut off all piles at the elevation shown in the plans. If using a cutting torch, make the surface as smooth as practical.

Where foundation material is so dense that the Contractor cannot drive the pile to the required penetration and firmly seat it without danger of crumpling the tip, reinforce the tips with approved cast steel point protectors as shown in the plans or required by the Engineer. Construct point protectors in one piece of cast steel meeting the requirements of ASTM A 27, Grade 65-35 [ASTM A 27M, Grade 450-240] heat treated to provide full bearing for the piles. Attach points by welding according to the recommendations of the manufacturer.

455-8.6 Pile Bent Bracing Members: Place structural steel sway and cross bracing, and all other steel tie bracing, on steel pile bents and bolt or weld in place as indicated in the plans. Where piles are not driven into position in exact alignment as shown in the plans, the Engineer may require the use of fills and shims between the bracing and the flanges of the pile. Furnish and place all fills and shims required to square and line up faces of flanges for cross bracing at no additional expense to the Department.

455-8.7 Painting: Paint exposed parts of steel piling, wedging, bracing, and splices in accordance with the provisions for painting structural steel as specified in Section 561, except as might be otherwise specified in the plans.

455-8.8 Storage and Handling: While handling or transporting the piles from the point of origin and into the leads, store and handle in the manner necessary to avoid damage due to bending stresses. In general, lift steel piles by means of a suitable bridge or a sling attached to the pile at appropriate points to prevent damage. Lift the pile from the horizontal position in a manner that will prevent damage due to bending of the flanges and/or web.

455-8.9 Filling Pipe Piles: When required by the plans, fill pipe piles with the specified materials. Use clean concrete sands and concrete meeting the requirements of Section 346. Place concrete in pipes containing water using methods in accordance with 455-15.9 with modified tremie and pump line sizes. Concrete may be placed directly into pipes which are dry. Construct and place reinforcement cages in accordance with 455-16. Reinforcement cages may be installed before concrete placement or after concrete placement is completed if proper alignment and position is obtainable.

455-9 Sheet Piling.

455-9.1 Description: Leave permanent piling in place as part of the finished work and generally remove temporary piling after each construction phase.

455-9.2 Materials: Meet the following requirements:

Concrete with Air Entrainment......................................Section 346
Bar Reinforcement...Section 931
Prestressing Reinforcement ....Section 933
Steel Sheet Piles..Section 962*

*For temporary steel sheet piles meet the requirements specified in the plans.

455-9.3 Steel Sheet Piling: Drive steel sheet piling and cut off true to line and grade. Install steel sheet piling with a suitable hammer. Remove and replace any section damaged during handling and installation at no additional expense to the Department.

455-9.3.1 Method of Installation: Where rock or strong material is encountered such that the sheet piles cannot be set to grade by driving, remove the strong material by other acceptable means, such as excavation and backfilling or by punching. When the plans do not indicate the existence of rock or strong material, work of removing or punching the strong material or rock will be paid for as Unforeseeable Work.

455-9.4 Concrete Sheet Piling:

455-9.4.1 Description: Ensure that Concrete Sheet Piling is of prestressed concrete construction and manufactured, cured, and driven in accordance with the requirements of the Contract Documents. Use these piles in bulkheads and abutments and at other locations as shown in the plans.

455-9.4.2 Manufacture of Piles: Ensure that the piles are fabricated in accordance with Section 450.

455-9.4.3 Method of Installation: Jet concrete sheet piling to grade where practical. The Engineer will require a minimum of two jets. Provide water at the nozzles of sufficient volume and pressure to freely erode material adjacent to the piles. Where encountering rock or strong material, such that the sheet piles cannot be set to grade by jetting, remove the strong materials by other acceptable means, such as excavation and backfilling or by punching with a suitable punch. When the plans do not indicate the existence of rock or strong material and the piles cannot be set by jetting, the Department will pay for the work of removing or punching the strong material or rock as Unforeseeable Work.

455-9.4.4 Grouting and Caulking: Concrete sheet piles are generally detailed to have tongues and grooves on their lower ends, and double grooves on their upper ends. Where so detailed, after installation, clean the grooves of all sand, mud, or debris, and fully grout the grooves. Use approved plastic bags (sheaths) which will meet the shape and length of the groove to be grouted to contain the plastic grout within the double grooves. Provide grout composed of one part cement and two parts sand. The Contractor may use clean local sand or beach sand in this grout. In lieu of sand-cement grout, the Contractor may use Class I concrete, using small gravel or crushed stone coarse aggregate. Deposit the grout through a grout pipe placed within a watertight plastic sheath (bag) extending the full depth of the double grooves and which, when filled, completely fills the slot formed by the double grooves.

455-9.5 Storage and Handling: Handle and store all sheet piles in a manner to prevent damage. Handle long sheet piles with fabric slings or braided wire rope constructed of six or more wire ropes placed at appropriate lift points to prevent damage due to excessive bending.

455-10 Pile Installation Plan.

455-10.1 General: Complete the Pile Driving Installation Plan form provided by the Engineer. Return the Pile Driving Installation Plan information to the Engineer at the preconstruction conference or no later than 30 days before driving the first pile. Ensure the Pile Driving Installation Plan information includes the following:

1. List and size of proposed equipment including cranes, barges, driving equipment, jetting equipment, compressors, and preformed pile hole equipment. Include manufacturer’s data sheets on hammers.
2. Methods to determine hammer energy in the field for determination of pile capacity. Include in the submittal necessary charts and recent calibrations for any pressure measuring equipment.
3. Detailed drawings of any proposed followers.
4. Detailed drawings of templates.
5. Details of proposed load test equipment and procedures, including recent calibrations of jacks and required load cells.
6. Sequence of driving of piles for each different configuration of pile layout.
7. Proposed schedule for test pile program and production pile driving.
8. Details of proposed features and procedures for protection of existing structures.
9. Required shop drawings for piles, cofferdams, etc.

10. Methods and equipment proposed to prevent displacement of piles during placement and compaction of fill within 15 feet [4.5 m] of the piles.

11. Methods to prevent deflection of battered piles due to their own weight and to maintain their as-driven position until casting of the pile cap is complete.

12. Proposed pile splice locations and details of any proprietary splices anticipated to be used.

455-10.2 Acceptance of Equipment and Procedures: All equipment and procedures are subject to satisfactory field performance. Make any required changes that may result from unsatisfactory field performance. The Engineer will give final acceptance after the Contractor makes necessary modifications. Do not make any changes in the driving system after acceptance without authorization of the Engineer. A hammer repaired on site or removed from the site and returned is considered to have its performance altered (efficiency increased or decreased), which is considered a change in the driving system and is subject to a Dynamic Load Test in accordance with 455-5.13 at no additional cost to the Department.

455-11 Method of Measurement (All Piling).

455-11.1 Treated Timber Piling: The quantity to be paid for will be the length, in feet [meters], furnished, placed, and accepted according to the authorized lengths list, including any additions and excluding any deletions thereto, as approved by the Engineer.

455-11.2 Prestressed Concrete Piling:

455-11.2.1 General: The quantity to be paid for will be the length, in feet [meters], of Prestressed Concrete Piling furnished, driven and accepted according to the authorized lengths list, including any additions and excluding any deletions thereto, as approved by the Engineer.

455-11.2.2 Furnished Length: The furnished length of precast concrete piles will be considered as the overall length from head to tip. Final pay length will be based on the casting length as authorized in accordance with 455-5.14.3 subject to provisions of 455-11.2.3 through 455-11.2.12, 455-11.8 and 455-11.9.

455-11.2.3 Build-ups: The lengths of pile build-ups authorized by the Engineer, measured from the plane of cutback or the joint between the sections, to head of build-up, will be included in the quantities of Piling.

455-11.2.4 Piles Requiring Cut-offs: No deduction from the length, in feet [meters], of Piling will be made if cut-offs are required after the pile has been driven to satisfactory bearing.

455-11.2.5 Piles Driven Below Cut-off Elevation: Where a pile is driven below cut-off elevation and satisfactory bearing is obtained so that no further driving is required, the length of pile driven will be measured from cut-off elevation to tip of the pile.

455-11.2.6 Driving of Splice: If a pile is driven below cut-off and satisfactory bearing is not obtained, and additional driving is required after construction of a satisfactory splice, an additional 10 feet [3.0 m] of piling will be paid for the additional driving. This compensation for driving of splice, however, will not be allowed for test piles that are spliced and redriven.

455-11.2.7 Replacing Piles: In the event a pile is broken or otherwise damaged to the extent that the damage is irreparable, in the opinion of the Engineer, the Contractor shall extract and replace the pile at no additional expense to the Department.

In the event that a pile is mislocated by the Contractor, the Contractor shall extract and replace the pile at no expense to the Department except when a design change proposed by the Contractor is approved by the Department as provided in 455-5.15.5.

In the event that a pile is driven below cut-off without obtaining the required bearing, and the Engineer elects to have the pile pulled and a longer pile substituted, it will be paid for as Unforeseeable Work. In the event a pile is damaged or mislocated, and the damage or mislocation is determined to be the Department's responsibility, the Engineer may elect to have the pile extracted, and it will be paid for as Unforeseeable Work. If the extracted pile is undamaged and driven elsewhere the pile will be paid for at 30% of the Contract unit price for Piling. When the Department determines that it is responsible for damaged or mislocated pile, and a replacement pile is required, compensation will be made under the item for Piling, for both the original pile and replacement pile.

The Contractor may substitute a longer pile in lieu of splicing and building-up a pile. In this event, the Contractor will be paid for the original authorized length of the pile, plus any additional length furnished by the Contractor up to the authorized length of the build-up, as Piling. No payment will be made for extracting the original pile furnished or will any payment be made for a pile splice.

455-11.2.8 Underwater Driving: When the Contractor selects one of the optional underwater driving methods, payment will be made by selecting the applicable method from the following:

(a) Using a pile longer than the authorized length: Payment for piling will be made only for the authorized length at that location unless the length of pile from cut-off elevation to the final tip elevation is greater than the authorized length, in which case payment for piling will be made from cut-off elevation to final tip elevation. No payment will be made for pile splice, when this option is selected, unless the pile is physically spliced and the splice is driven below cut-off elevation to achieve bearing. When making and driving a pile splice below cut-off elevation to achieve bearing, the length to be paid for piling will be the length between cut-off elevation and final pile tip elevation.

(b) Using an underwater hammer: Payment for piling and pile splices will be in accordance with 455-11.2.1 through 455-11.2.7 and 455-11.2.10. The Contractor shall furnish additional lengths required to provide the full length confirmation pile at no expense to the Department. Payment for piling for the full length confirmation pile will be the authorized length of the pile, unless the length driven below cut-off elevation is greater than the authorized length, in which case the length to be paid for will be the length between cut-off elevation and the final tip elevation. Splices in confirmation piles will be paid for only when the splice is driven below cut-off elevation.

(c) Using a pile follower: When a pile follower is used with a conventional pile driving system, the method of payment will be the same as shown above in 455-11.2.10(b).

455-11.2.9 Set-Checks/Test Piles: As described in 455-5.12.1, there will be no separate payment for the initial four set-checks performed within 72 hours of initial driving. For each additional set-check performed within 72 hours of initial driving, an additional quantity of 10 feet [3.0 m] piling will be paid.

455-11.2.10 Set-Check/Production Piles: As described in 455-5.10.4(a), there will be no separate payment for one initial set-check. For each additional set-check performed within 72 hours from the end of initial driving, an additional quantity of 10 feet [3.0 m] of piling will be paid.

455-11.3 Steel Piling:

455-11.3.1 General: The quantity to be paid for will be the length, in feet [meters], of Steel Piling furnished, spliced, driven and accepted, up to the authorized length, including any additions and excluding any deletions thereto as approved by the Engineer.

455-11.3.2 Point Protectors: The quantity to be paid for will be each for the total of point protectors authorized, furnished, and properly installed.

455-11.4 Test Piles: The quantity to be paid for of test piles of various types, will be the length, in feet [meters], of Test Piling furnished, driven and accepted, according to the authorized length list, and any additions or deletions thereof as approved by the Engineer.

Where a test pile is left in place as a permanent pile, it will be paid for only as Test Piles. Any extensions necessary to continue driving the pile for test purposes, as authorized by the Engineer, will be paid for as Test Piles. Other build-ups made only to incorporate the pile into the structure as a permanent pile will be included in the quantities of regular Piling and will not be paid for as Test Piling.

455-11.5 Dynamic Load Tests: The quantity to be paid for will be the number of dynamic load tests as shown in the plans or authorized by the Engineer, actually applied to piles, completed and accepted in accordance with the Contract Documents. Dynamic load tests may be applied to test piles and/or production piles.

No separate payment will be made for dynamic load tests used to evaluate the Contractor's driving equipment. This will generally be done on the first test pile or production pile driven on a project with each combination of proposed hammer and pile size and/or a separate pile to evaluate any proposed followers, or piles driven to evaluate proposed changes in the driving system.

The price for Dynamic Load Tests will include all costs related to dynamic testing as described in 455-5.13 including the initial instrumented drive, up to two set-checks, and two additional instrumented set-checks within 72 hours after the initial driving of a dynamic load test pile. In the event the Engineer requires an instrumented redrive of a pile previously instrumented more than 72 hours after initial driving, it will be paid for at 1/2 the bid price for a Dynamic Load Test.

455-11.6 Steel Sheet Piling: The quantity to be paid for will be the plan quantity area, in square feet [square meters], measured from top of pile elevation to the bottom of pile elevation and longitudinally along the top of the sheet piles as shown in the plans. Sheet piling used in cofferdams and to incorporate the Contractor's specific means and methods, and not ordered by the Engineer, will be paid for as required in Section 125.

455-11.7 Concrete Sheet Piling: The quantity to be paid for will be the product of the number of such piles satisfactorily completed, in place, times their lengths in feet [meters] as shown in the plans or authorized by the Engineer. This quantity will be based upon piles 2 1/2 feet [0.75 m] wide.

When the Engineer approves, the Contractor may furnish the concrete sheet piling in widths wider than shown in the plans; then the number of piles shall be the actual number of units completed times the width used divided by the width in the plans.

455-11.8 Pile Splices: Authorized splices in concrete piling, steel piling and test piling, which are made for the purpose of obtaining greater lengths than originally authorized by the Engineer, or to incorporate test piling in the finished structure, or for further driving of test piling, will be paid for as described in 455-12.12. No separate payment will be made for splices required to obtain the authorized length.

For concrete piles, where the head of the pile to be spliced is not more than 2 feet [0.6 m] below the elevation of cut-off, the Contractor, if he so elects, may cast the pile build-up with the cap, under the following conditions:

(a) Reinforcing steel and pile dimensions will conform in every respect to a standard splice.

(b) Reinforcing steel used for the build-up will be paid for as an overrun in the Contract quantity for substructure reinforcing steel.

(c) Concrete used for the build-up will be paid for as an overrun in the Contract quantity for substructure concrete.

(d) 9 feet [2.7 m] of piling, will be paid for as compensation for drilling and grouting the dowels and all other costs for which provision has not otherwise been made.

(e) No payment for the build-up will be made under the item for Piling.

455-11.9 Pile Redrive: The quantity to be paid for will be the number of redrives, each, authorized by the Engineer. Pile Redrive is defined in 455-5.10.4(b). Payment for any pile redrive ordered by the Engineer will consist of 20 feet [6.0 m] of additional piling. The size of the pile redriven will be the same size as the furnished item for payment.

Pile Redrive will be paid under any of the following conditions:

(a) When the Engineer directs the Contractor to redrive a pile to determine its capacity as described in 455-5.10.4.

(b) When the Engineer orders the Contractor to redrive piles to reestablish their capacity as the result of pile heave as described in 455-5.10.5.

455-11.10 Pile Extraction: Piles authorized to be extracted by the Engineer and successfully extracted as provided in 455-11.2.9 will be paid for as Unforeseeable Work. 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.

455-11.11 Protection of Existing Structures: The quantity to be paid for will be at the Contract lump sum price. When the Contract Documents do not include an item for protection of existing structures, the cost of settlement monitoring as required by these Specifications will be included in the cost of the piling items; however, work in addition to settlement monitoring will be paid for as Unforeseeable Work when such additional work is ordered by the Engineer.

455-11.12 Static Load Tests: The quantity to be paid for will be the number of static load tests of the designated tonnages, each, as shown in the plans or authorized by the Engineer, actually applied to piles, completed and accepted in accordance with the plans and these Specifications.

455-11.13 Preformed Pile Holes: The quantity to be paid for will be the length in feet (meters) of completed Preformed Pile Holes acceptably provided, complete for the installation of the bearing piles, regardless of the type of pile installed therein. Only those holes authorized to be paid for, as provided in 455-5.9.3, will be included in the measurement for payment. The Engineer will authorize payment for Preformed Pile Holes only when the pile has been placed in proper position and has achieved the required penetration.

455-12 Basis of Payment (All Piling).

455-12.1 Treated Timber Piling: Price and payment will be full compensation for furnishing all materials, including collars, metal shoes, copper cover sheets, preservatives and tar, and for wrapping pile clusters with wire cable, where so shown in the plans.

455-12.2 Prestressed Concrete Piling: Price and payment will be full compensation for the cost of furnishing and placing all reinforcing steel, predrilled holes, furnishing the material for and wrapping pile clusters with wire cable where so shown in the plans and grouting of preformed pile holes when shown in the plans. Payment will be made in two increments: 70% of the unit price for Prestressed Concrete Piling for each foot (meter) fabricated and accepted as stockpiled materials, and 30% of the unit price for Prestressed Concrete Piling for the entire authorized length upon completion of driving.

455-12.3 Steel Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing Steel Piling, including welding and painting as specified and the cost of predrilling pile holes described in 455-5.1.1. The cost of any sand or concrete fill and reinforcing steel in pipe piles will be included in the price for Steel Piling. Payment will be made in two increments: 70% of the unit price for Steel Piling for each foot (meter) fabricated and accepted as stockpiled materials, and 30% of the unit price for Steel Piling for the entire authorized length upon completion of driving.

Bracing and other metal parts attached to or forming a part of piling or bracing and not otherwise classified, will be measured and paid for as provided in Section 460.

455-12.4 Test Piles: Price and payment will be full compensation for all incidentals necessary to complete all the work of this item except splices, build-ups, pile extractions and preformed pile holes authorized by the Engineer and paid for under other pay items or payment methods. The cost of all additional work not listed above necessary to ensure required penetration and attain required bearing of the test piles will be included in the price bid per foot [meter] of Test Pile, including driving and all other related costs. Payment will be made in two increments: 70% of the unit price for Test Piles for each foot (meter) fabricated and accepted as stockpiled materials, and 30% of the unit price for Test Piles for the entire authorized length upon completion of driving.

455-12.5 Dynamic Load Tests: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.6 Steel Sheet Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing steel sheet piling including preformed holes, but will not include furnishing and placing anchors when an anchored wall system, temporary or permanent, is designed and detailed in the plans. In such cases, furnishing and installing anchors will be paid for separately. For installations designed by the Contractor, the cost of furnishing and installing anchors will be incidental to the cost of steel sheet piling. For temporary installations, removal of the sheet piling, anchors, and incidentals will be included in the cost per square foot [square meter] for Steel Sheet Piling (Temporary).

455-12.7 Concrete Sheet Piling: Price and payment will be full compensation for furnishing all materials, including reinforcing steel, grouting, preformed holes and installation.

455-12.8 Preformed Pile Holes: There will be no separate pay item for Preformed Pile Holes. Payment will be made as ~~30% of~~ the unit price for Piling of the applicable pile type *(excluding sheet pile)* for *30% of* each linear foot (meter) of hole which is preformed when authorized by the Engineer. Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.9 Protection of Existing Structures: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.10 Point Protectors: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.11 Static Load Tests: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.12 Pile Splices: The quantity of this item will be determined as provided in 455-11.8. Payment for each Steel Pile Splice authorized by the Engineer will be made as 20 feet [6 m] of additional steel piling. Payment for each Concrete Pile Splice authorized by the Engineer will be made as 30 feet [9 m] of additional prestressed concrete piling.

455-12.13 Prestressed Concrete Pile Cut-Off: There will be no separate pay item for pile cut-off. Payment for each cut-off will be made as 5 feet [1.5 m] of additional piling furnished.

455-12.14 Payment Items: Payment will be made under:

Item No .	455- 2-	Treated Timber Piling - per foot.
Item No .	2455- 2-	Treated Timber Piling - per meter.
Item No.	455- 14-	Concrete Sheet Piling - per foot.
Item No.	2455- 14-	Concrete Sheet Piling - per meter.
Item No.	455- 18-	Protection of Existing Structures - lump sum.
Item No.	2455- 18-	Protection of Existing Structures - lump sum.
Item No .	455- 34-	Prestressed Concrete Piling – per foot.
Item No.	2455- 34-	Prestressed Concrete Piling – per meter.
Item No.	455- 35-	Steel Piling – per foot.
Item No.	2455- 35-	Steel Piling – per meter.
Item No.	455-119-	Test Loads- each.
Item No.	2455-119-	Test Loads- each.
Item No.	455-120-	Point Protection - each.
Item No.	2455-120-	Point Protection - each.
Item No.	455-133-	Steel Sheet Piling - per square foot.
Item No.	2455-133-	Steel Sheet Piling - per square meter.
Item No.	455-137-	Dynamic Load Tests - each.

Item No. 2455-137- Dynamic Load Tests - each.
Item No. 455-143- Test Piles (Prestressed Concrete) – per foot.
Item No. 2455-143- Test Piles (Prestressed Concrete) – per meter.
Item No. 455-144- Test Piles (Steel) – per foot.
Item No. 2455-144- Test Piles (Steel) – per meter.
Item No. 455-145- Test Piles (Concrete Cylinder) – per foot.
Item No. 2455-145- Test Piles (Concrete Cylinder) – per meter.

C. DRILLED SHAFTS

455-13 Description.

Construct drilled shaft foundations consisting of reinforced, or unreinforced when indicated in the plans, concrete drilled shafts with or without bell footings.

455-14 Materials.

455-14.1 Concrete: For all concrete materials, meet the requirements of Section 346. Use concrete that is specified in the plans.

455-14.2 Reinforcing Steel: Meet the reinforcing steel requirements of Section 415. Ensure that reinforcing steel is in accordance with the sizes, spacing, dimensions, and the details shown in the plans.

455-15 Construction Methods and Equipment.

455-15.1 General Requirements:

455-15.1.1 Templates: 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 not require a template for shafts drilled on land provided the Contractor demonstrates satisfactorily to the Engineer that shaft position and alignment can be properly maintained. The Engineer will require a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations, for shafts drilled on land when the Contractor fails to demonstrate satisfactorily that he can properly maintain shaft position and alignment without use of a template.

455-15.1.2 Drilled Shaft Installation Plan: At the preconstruction conference submit a drilled shaft installation plan 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. Mineral 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, etc.

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

4. Details of shaft excavation methods and drilling log procedures.

5. Details of slurry, including proposed methods to mix, circulate, desand, test methods, and proposed testing laboratory to document test results.

6. Details of proposed methods to clean shaft after initial 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. Provide 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. Details of any required cross-hole-sonic logging (CSL) tubes, test equipment, procedures and proposed CSL Specialty Engineer to perform, log, analyze, and report the test results.

~~12~~*13*. Methods and equipment proposed to prevent displacement of casing and/or shafts during placement and compaction of fill.

~~13~~*14*. Details of environmental control procedures used to prevent loss of slurry or concrete into waterways or other protected areas.

~~14~~*15*. Proposed schedule for test shaft installation, load tests and production shaft installation.

~~15~~*16*. Other information shown in the plans or requested by the Engineer.

The Engineer will evaluate the drilled shaft installation plan 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 of the equipment and procedures chosen before field operations begin. The Engineers acceptance is not a guarantee that the chosen methods and equipment are capable of obtaining the required results, this responsibility lies with the Contractor.

455-15.1.3 General Methods & Equipment: Perform the excavations required for the shafts and bell footings, through whatever materials encountered, to the dimensions and elevations shown in the Contract Documents, using methods and equipment suitable for the intended purpose and the materials encountered. Provide equipment capable of constructing shafts supporting bridges to a depth equal to the deepest shaft shown in the plans plus 15 foot [4.5 m] or plus three times the shaft diameter, whichever is greater, except when the plans require equipment capable of constructing shafts to a deeper depth. Provide equipment capable of constructing shafts supporting non-bridge structures, including mast arms, signals, signs and light supports to a depth equal to the deepest shaft shown in the plans plus 5 feet [1.5 m].

Construct drilled shafts according to the Contract Documents using generally either the dry method, wet method, casing method, or permanent casing method as necessary to produce sound, durable concrete foundation shafts free of defects. Use the permanent casing method only when required by the plans or authorized by the Engineer. When the plans describe a particular method of construction, use this method except when permitted otherwise by the Engineer after field trial. When the plans do not describe a particular method, propose a method on the basis of its suitability to the site conditions and submit it for approval by the Engineer.

Set a suitable temporary removable surface casing. The minimum surface casing length is the length required to prevent caving of the surface soils and to aid in maintaining shaft position and alignment. The Engineer may require predrilling with slurry and/or overreaming to the outside diameter of the casing to install the surface casing at some sites.

455-15.2 Dry Construction Method: Use the dry construction method only at sites where the ground water table and soil conditions, generally stiff to hard clays or rock above the water table, make it feasible to construct the shaft in a relatively dry excavation and where the sides and bottom of the shaft are stable and may be visually inspected by the Engineer prior to placing the concrete.

In applying the dry construction method, drill the shaft excavation, remove accumulated seepage water and loose material from the excavation and place the shaft concrete in a relatively dry excavation.

Use the dry construction method only when shaft excavations, as demonstrated in a test hole, have 12 inches [300 mm] or less of seepage water accumulated over a four hour period, the sides and bottom remain stable without detrimental caving, sloughing, or swelling for a four hour period, and the loose material and water can be satisfactorily removed prior to inspection and prior to placing concrete. Use the wet construction method or the casing construction method for shafts that do not meet the requirements for the dry construction method.

Provide temporary surface casings to aid shaft alignment and position and to prevent sloughing unless the Engineer determines by demonstration that the surface casing is not required.

455-15.3 Wet Construction Method: Use the wet construction method at all sites where it is impractical to provide a dry excavation for placement of the shaft concrete.

The wet construction method consists of drilling the shaft excavation below the water table, keeping the shaft filled with fluid (mineral slurry, natural slurry or water), desanding and cleaning the mineral slurry and final cleaning of the excavation by means of a bailing bucket, air lift, submersible pump or other approved devices and placing the shaft concrete (with a tremie or concrete pump extending to the shaft bottom) which displaces the water or slurry during concreting of the shaft excavation. Provide temporary surface casings to aid shaft alignment and position and to prevent sloughing of the top of the shaft except when the Engineer declares that the surface casing is not required.

Where drilled shafts are located in open water areas, construct the shafts by the wet method using exterior casings extending from above the water elevation into the ground to protect the shaft concrete from water action during placement and curing of the concrete. Install the exterior casing in a manner that will produce a positive seal at the bottom of the casing so that there is no intrusion or extrusion of water or other materials into or from the shaft excavation.

Expandable or split casings that are removable are not permitted for use below the water surface.

455-15.4 *Temporary* Casing Construction Method: Use the *temporary* casing method at all sites where it is inappropriate to use the dry or wet construction methods without the use of temporary casings other than surface casings. In this method, the hole is advanced through caving material by the wet method as described above. When a formation is reached that is nearly impervious, place a casing in the hole and seal in the nearly impervious formation. Proceed with drilling as with the ~~dry~~ *wet* method to the projected depth. Proceed with the placement of the concrete as with the dry method except withdraw the casing after placing the concrete. In the event seepage conditions prevent use of the dry method, complete the excavation and concrete placement using wet methods.

Where drilling through materials having a tendency to cave, advance the excavation by drilling in a mineral slurry. In the event that a caving layer or layers are encountered that cannot be controlled by slurry, install temporary removable casing through such caving layer or layers. The Engineer may require overreaming to the outside diameter of the casing. Take whatever steps are required to prevent caving during shaft excavation including installation of deeper casings. If electing to remove a casing and replace it with a longer casing through caving soils, adequately stabilize the excavation with slurry or backfill the excavation. The Contractor may use soil previously excavated or soil from the site if backfilling the excavation. The Contractor may use other approved methods which will control the size of the excavation and protect the integrity of the foundation soils to excavate through caving layers.

Before withdrawing the casing, ensure that the level of fresh concrete is at such a level that the fluid trapped behind the casing is displaced upward. As the casing is withdrawn, maintain the level of concrete within the casing so that fluid trapped behind the casing is displaced upward out of the shaft excavation without mixing with or displacing the shaft concrete.

The Contractor may use the casing method, when approved by the Engineer, to construct shafts through weak caving soils that do not contribute significant shaft shear resistance. In this case, place a temporary casing through the weak caving soils before beginning excavation. Conduct excavation using the dry construction method where appropriate for site conditions and the wet construction method where the dry construction method is not appropriate. Withdraw the temporary casing during the concreting operations unless the Engineer approves otherwise.

455-15.5 Permanent Casing *Construction* Method: Use the permanent casing method when required by the plans. In this method, place a casing to the prescribed depth before beginning excavation. If the Contractor cannot attain full penetration, the Engineer may direct the Contractor to excavate through the casing and advance the casing until reaching the desired penetration. In some cases the Engineer may require the Contractor to overream the outside diameter of the casing before placing the casing.

Cut the casing off at the prescribed elevation upon reaching the proper construction sequence and leave the remainder of the casing in place.

455-15.6 Excavations: *When pilot holes and/or load tests are performed, the Engineer will use the pilot hole and/or load test results to determine the authorized tip elevations and/or the authorized installation criteria of the drilled shafts. The resulting shaft tip elevations may vary from the Tip Elevations presented in the plans.* ~~The Contractor may e~~*E*xtend drilled shaft excavations deeper by extra depth excavation when the Engineer determines ~~that~~ the material encountered while drilling the shaft excavation is unsuitable and/or is not the same as anticipated in the design of the drilled shaft.

455-15.6.1 Pilot Hole: *When pilot holes are shown in the plans core a pilot hole, prior to shaft excavation, in accordance with ASTM D 2113 Standard Practice for Diamond Core Drilling for Site Excavation using a double or triple wall core barrel through part or all of the shaft, to a depth of 3 ~~to 5~~ times the diameter of the drilled shaft below the tip elevation shown in the plans, as directed by the ~~e~~Engineer. The Engineer may require the Contractor to cut any core to a total depth below the bottom of the drilled shaft excavation of up to 5 times the diameter of the drilled shaft. Maintain a drilling log during ~~during~~ pilot hole operations that contains information such as the description of and top and bottom elevation of each stratum encountered, depth of penetration, drilling time in each of the various strata, material description, and remarks. Classify, measure, and describe core samples in the drilling log. Furnish two copies of the drilling log, signed by a designated representative of the Contractor to the Department.*

455-15.6.2 Cores: Take cores when shown in the plans or directed by the Engineer to determine the character of the material directly below the shaft excavation. Cut the cores with an approved core barrel to a minimum depth of ~~5 feet [1.5 m]~~*3 ~~to 5~~ times the diameter of the drilled shaft* below the bottom of the drilled shaft excavation ~~when~~ *after* completing the shaft excavation*, as directed by the ~~e~~Engineer*. The Engineer may require the Contractor to cut any core ~~below the 5 foot [1.5 m] minimum depth and up~~ to a total depth ~~of 20 feet [6 m]~~ below the bottom of the drilled shaft excavation *of up to 5 times the diameter of the drilled shaft*. ~~The Engineer will inspect the cores and determine the depth of required excavation. When considered necessary by the Engineer, take additional cores.~~ *Maintain a drilling log during ~~during~~ coring operations that contains information such as the description of and top and bottom elevation of each* *stratum encountered, depth of penetration, drilling time in each of the various strata; classify, measure, and describe core samples in the drilling log. Furnish two copies of the drilling log, signed by a designated representative of the Contractor to the Department.*

For cores or pilot holes, ~~Use~~ *use* only a double or triple wall core barrel designed:

(a) to cut a core sample from 4 to 6 inches [100 to 150 mm] in diameter,

(b) so that the sample of material cored can be removed from the shaft excavation and the core barrel in an undisturbed state, and

(c) ~~in~~ *with* sufficient length to provide core samples *from a depth of* ~~*3 to*~~ *5 times the diameter of the drilled shaft below the bottom of the drilled shaft excavation*, as directed by the Engineer. ~~up to a depth of 20 feet [6 m] below the bottom of the drilled shaft excavation.~~

The Engineer will inspect the cores and determine the depth of required excavation. When considered necessary by the Engineer, take additional cores. Place the core samples in suitable containers, identified by shaft location, elevation from and to, and job number, and deliver to the Department within 48 hours after cutting. When called for in the plans, substitute Standard Penetration Tests (SPT) for coring. In such cases, supply these tests at no additional cost per foot [meter] to the Department above that bid for core (shaft excavation).

~~Maintain a drilling log during shaft excavation and during coring operations that contains information such as the description of and approximate top and bottom elevation of each stratum encountered, depth of penetration, drilling time in each of the various strata, material description, and remarks. Classify, measure, and describe core samples in the drilling log. Place the core samples in suitable containers, identified by shaft location, elevation from and to, and job number, and deliver to the Department within 48 hours after cutting. Furnish two copies of the drilling log, signed by a designated representative of the Contractor and co-signed by a designated representative of the Department, to the Department at the time the shaft excavation is completed and accepted.~~

Provide areas for the disposal of unsuitable materials and excess materials as defined in 120-5 that are removed from shaft excavations, and dispose of them in a manner meeting all requirements pertaining to pollution.

When shown in the plans, excavate bells to form a bearing area of the size and shape shown. Bell outlines varying from those shown in the plans are permissible provided the bottom bearing area equals or exceeds that specified. If the diameter of the bell exceeds three times the shaft diameter, drill the excavation deeper as directed and form a new bell footing. Excavate bells by mechanical methods.

Furnish the additional drilled shaft concrete over the theoretical amount required to complete filling any excavations for bells and shafts which are larger than required by the plans or authorized by the Engineer, at no expense to the Department.

455-15.7 Casings: Ensure that casings are metal, or concrete when indicated in the plans, of ample strength to withstand handling and driving stresses and the pressure of concrete and of the surrounding earth materials, and that they are smooth and water tight. Ensure that the inside diameter of casing is not less than the specified size of shaft except as provided below. The Department will not allow extra compensation for concrete required to fill an oversize casing or oversize excavation.

The Engineer will allow the Contractor to supply casing with an outside diameter equal to the specified shaft diameter (O.D. casing) provided he supplies additional shaft length at the shaft tip. Determine the additional length of shaft required by the following relationship:

$$Additional\ length = \frac{(D_1 - D_2)L}{D_2}$$

where:

D_1= casing inside diameter specified = shaft diameter specified
D_2= casing inside diameter provided ($D_2 = D_1$ minus twice the wall thickness).
L= authorized shaft length below ground for temporary casing methods or below casing for permanent casing methods.

Bear all costs relating to this additional length including but not limited to the cost of extra excavation, extra concrete, and extra reinforcing steel.

Remove all casings from shaft excavations except those used for the Permanent Casing Method. Ensure that the portion of casings installed under the Permanent Casing Method of construction below the shaft cut-off elevation remains in position as a permanent part of the Drilled Shaft. The Contractor may leave casings if in the opinion of the Engineer the casings will not adversely affect the shaft capacity in place. When casings that are to be removed become bound in the shaft excavation and cannot be practically removed, drill the shaft excavation deeper as directed by the Engineer to compensate for loss of capacity due to the presence of the casing. The Department will not compensate for the casing remaining. The Department will pay for the additional length of shaft under Item No. 455-88 [Item No. 2455-88] and the additional excavation under Item No. 455-125 [Item No. 2455-125].

When the shaft extends above ground or through a body of water, the Contractor may form the portion exposed above ground or through a body of water, with removable casing except when the Permanent Casing Method is specified (see 455-23.10). When approved, the Contractor may form drilled shafts extending through a body of water with permanent or removable casings. However, for permanent casings, remove the portion of metal casings between an elevation 2 feet [0.6 m] below the lowest water elevation or 2 feet [0.6 m] below ground whichever is higher and the top of shaft elevation after the concrete is cured. Dismantle casings removed to expose the concrete as required above in a manner which will not damage the drilled shaft concrete. Dismantle removable casings in accordance with the provisions of 455-17.5.

Generally when removal of the temporary casing is required, do not start the removal until completing all concrete placement in the shaft. The Engineer will permit movement of the casing by rotating, exerting downward pressure, and tapping it to facilitate extraction, or extraction with a vibratory hammer. Extract casing at a slow, uniform rate with the pull in line with the axis of the shaft. Withdraw temporary casings while the concrete remains fluid.

When conditions warrant, the Contractor may pull the casing in partial stages. Maintain a sufficient head of concrete above the bottom of the casing to overcome the hydrostatic pressure of water outside the casing. At all times maintain the elevation of the concrete in the casing high enough to displace the drilling slurry between the outside of the casing and the edge of the hole while removing the casing.

The Contractor may use special casing systems in open water areas, when approved, which are designed to permit removal after the concrete has hardened. Design special casings so that no damage occurs to the drilled shaft concrete during their removal.

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

455-15.8.1 Slurry: When *mineral* slurry is used in an excavation, use only ~~mineral slurry of~~ processed attapulgite or bentonite clays. The Engineer will not allow polymer slurries. Use 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, delay the construction of that foundation until an alternate construction procedure has been approved.

Thoroughly premix the mineral slurry with clean fresh water prior to introduction into the shaft excavation. Ensure that the percentage of 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 these Specifications. The Engineer will not allow excavated pits on projects requiring slurry tanks without the written permission of the Engineer. ~~The Engineer will require adequate desanding equipment when shown in the Contract Documents. However, the Engineer will not require desanding equipment for drilled shafts installed under mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures unless shown in the Contract Documents.~~ Take the steps necessary to prevent the slurry from "setting up" in the shaft, including but not limited to agitation, circulation, and/or 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 qualified professional soil testing laboratory approved by the Engineer to perform control tests using suitable apparatus on the mineral slurry mixture to determine the following parameters:

(a) Freshly mixed mineral slurry: Measure the density of the freshly mixed mineral slurry regularly as a check on the quality of the suspension being formed using a measuring device calibrated to read within ±0.5 lb/ft^3 [±8 kg/m^3].

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

Non SI Units		
Item to be measured	Range of Results at 68ºF	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	28 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

SI Units		
Item to be measured	Range of Results at 20ºC	Test Method
Density	1030 to 1170 kg/m^3 (in fresh water *environment*) 1060 to 1200 kg/m^3 (in salt water *environment*)	Mud density balance: FM 8-RP13B-1
Viscosity	28 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(s) 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.

Perform tests to determine density, viscosity, and pH value to establish a consistent working pattern, taking into account the mixing process and blending of freshly mixed mineral slurry and previously used mineral slurry. Perform a minimum of four sets of tests to determine density, viscosity, and pH value during the first 8 hours mineral slurry is in use.

When the results show consistent behavior, discontinue the tests for pH value, and only carry out tests to determine density and viscosity during each four hours mineral slurry is in use. If the consistent working pattern changes, reintroduce the additional tests for pH value for the time required to establish consistency of the test values within the required parameters.

(c) Furnish reports of all mineral slurry tests required above, signed and sealed by a Specialty Engineer, representing the soil testing laboratory to the Department on completion of each drilled shaft.

(d) The Department may perform comparison tests as determined necessary during the mineral slurry operations.

During construction, maintain the level of mineral slurry in the shaft excavation within the excavation and at a level not less than 4 feet [1.2 m] above the highest expected piezometric water pressure along the depth of a shaft.

At any time the wet construction method of stabilizing excavations fails, in the opinion of the Engineer, to produce the desired final result, discontinue this method of construction, and propose modifications in procedure or alternate means of construction for approval.

455-15.8.1.1 Exceptions for Shafts for Miscellaneous Structures**:** *Testing of the* ~~S~~slurry ~~testing before placement~~ *prior to introduction* in*to* the shaft *excavation* is not required for drilled shafts *up to 60 inches [1.5 m] in diameter installed to support* ~~installed under~~ mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures. ~~Fluid testing is required for these drilled shafts as outlined in 455-15.8.2.~~

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

~~Prior to placing concrete in any shaft excavation, including shafts under miscellaneous structures, ensure that heavily contaminated suspensions, which could impair the free flow of concrete from the tremie pipe, have not accumulated in the bottom of the shaft.~~ Take samples of the fluid in the shaft from the base of the shaft and at intervals not exceeding 10 feet [3 m] up the shaft, using an approved sampling tool. ~~Ensure that the density of the fluid in the shaft excavation, prior to concreting is less than 75 lb/ft^3 [1,200 kg/m^3]. The Engineer will not require tests for pH and viscosity when mineral slurry is not used in the excavationWhen a natural slurry (a slurry formed by water mixed with soil from the shaft) is utilized, do not test for PH or viscosity. Ensure that projects that require desanding equipment have a sand content not greater than 4% as determined by FM 8-RP13B-3.~~ Take whatever action is necessary ~~to modify the fluid in the shaft excavation~~ prior to placing the concrete to bring the fluid within the specification *and reporting* requirements*, outlined in the tables in 455-15.8.1. except as follows:*

The Engineer will not require tests for pH or viscosity when mineral slurry has not been introduced into the shaft excavation.

~~When fluid is present in the hole, the applicable density test method and reporting requirements described in 455-15.8.1 apply to tests of fluid in the shaft prior to placing the concrete.~~ When using mineral slurry*,* ~~such tests shall be performed by~~ *engage* an approved soil testing laboratory *to provide a CTQP qualified drilled shaft inspector,* ~~engaged by the Contractor~~ or ~~by~~ *provide* an experienced person ~~furnished by the Contractor and~~ approved by the Engineer *to perform slurry testing*. The Department may also perform comparison tests. Provide equipment for such comparison tests when requested by the Engineer ~~Furnish an experienced person, approved by the Engineer, to test the fluid in the shaft. When using mineral slurry, engage an approved soil-testing laboratory to test the fluid in the shaft. In either case the Engineer may perform the comparison test. When requested by the Engineer, provide the equipment required for the comparison test~~.

455-15.9 Tremies and Pumps:

455-15.9.1 General: The requirements of the applicable provisions of Section 400- will apply when using a tremie or a pump to place drilled shaft concrete.

455-15.9.2 Dry Excavations: Ensure that the tremie for depositing concrete in a dry drilled shaft excavation consists of a tube of solid construction, a tube constructed of sections which can be added and removed, or a tube of other approved design. The Contractor may pass concrete through a hopper at the top of the tube or through side openings as the tremie is retrieved during concrete placement. Support the tremie so that the free fall of the concrete is less than 5 feet [1.5 m] at all times. If the free falling concrete causes the shaft excavation to cave or slough, control the movement of concrete by reducing the height of free fall of the concrete and/or reducing the rate of flow of concrete into the excavation.

455-15.9.3 Wet Excavations: Construct the tremie or pump line used to deposit concrete beneath the surface of water so that it is water-tight and will readily discharge concrete. Construct the discharge end of the tremie or pump line to prevent water intrusion and permit the free flow of concrete during placement operations. Ensure that the tremie or pump line has sufficient length and weight to rest on the shaft bottom before starting concrete placement. Ensure that the discharge end of the tremie or pump line is entirely immersed in concrete at all times during placement operations. Ensure that the free fall of concrete into the hopper is less than 5 feet [1.5 m] at all times. Support the tremie so that it can be raised to increase the discharge of concrete and lowered to reduce the discharge of concrete. The Engineer will not allow rapid raising or lowering of the tremie to increase the discharge of the concrete. Maintain a continuous flow of concrete and a positive pressure differential of the concrete in the tremie or pump line at all times to prevent water or slurry intrusion into the shaft concrete.

455-15.10 Excavation and Drilling Equipment:

455-15.10.1 General: All shaft excavation is Unclassified Shaft Excavation. The Engineer will require Drilled Shaft Sidewall Overreaming when inspections show it to be necessary. These terms are defined in 455-15.10.2, 455-15.10.3, and 455-15.10.4, respectively.

Use excavation and drilling equipment having adequate capacity, including power, torque, and *crowd (*downthrust*)*, and excavation and overreaming tools of adequate design, size, and strength to perform the work shown in the plans or described herein. When the material encountered cannot be drilled using conventional earth augers and/or underreaming tools, provide special drilling equipment, including but not limited to rock augers, core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to continue the shaft excavation to the size and depth required. In the event blasting is necessary, obtain all necessary permits. The Contractor is responsible for the effects of blasting on already completed work and adjacent structures. The Engineer must approve all blasting.

455-15.10.2 Unclassified Shaft Excavation: Unclassified Shaft Excavation is defined as all processes required to excavate a drilled shaft of the dimensions shown in the Contract Documents to the depth indicated in the plans plus 15 feet [4.5 meters] or plus 3 shaft diameters, whichever is deeper, completed and accepted. Include in the work all shaft excavation, whether the material encountered is soil, rock, weathered rock, stone, natural or man-made obstructions, or materials of other descriptions.

455-15.10.3 Unclassified Extra Depth Excavation: Unclassified Extra Depth Excavation is defined as all processes required to excavate a drilled shaft of plan dimensions which is deeper than the limits defined as Unclassified Shaft Excavation.

455-15.10.4 Drilled Shaft Sidewall Overreaming: Drilled Shaft Sidewall Overreaming is defined as the unclassified excavation required to roughen its surface or to enlarge the drilled shaft diameter due to softening of the sidewalls or to remove excessive buildup of slurry cake when slurry is used. Increase the shaft radius a minimum of 1/2 inch [15 mm] and a maximum of 3 inches [75 mm] by overreaming. The Contractor may accomplish overreaming with a grooving tool, overreaming bucket, or other approved equipment.

Meet the limit for depth of sidewall overreaming into the shaft sidewall material and the elevation limits between which sidewall overreaming is required.

455-15.11 Inspection of Excavations:

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:

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

(b) Check the dimensions and alignment of casing when inserted in the excavation.

(c) Insert a casing in shaft excavations temporarily for alignment and dimension checks.

(d) 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.

455-15.11.2 Depth: Generally reference the depth of the shaft during drilling to appropriate marks on the Kelly bar or other suitable methods. Measure final shaft depths with a suitable weighted tape or other approved methods after final cleaning.

455-15.11.3 Shaft Inspection Device: The Engineer, when shown in the plans, will furnish and use an inspection device comprised of a television camera sealed inside a water-tight jacket to inspect the bottoms of the shafts. The Engineer may also use a sidewall sampler attached to the inspection device to sample the sides of the shafts. Cooperate with the Engineer in using this inspection device, including placing the inspection device in position for inspection and removing it after the inspection. Furnish 110 V single phase current (minimum 30 A service), 220 V single phase current (minimum 15A service), and a 150 psi [1.0 MPa] compressor (8 cfm [0.0038 m^3/s] minimum) to operate the device. Include all cost related to the inspection device in the cost of drilled shaft items.

Provide the projected drilled shaft construction schedule to the Engineer at the preconstruction conference so that the inspection device may be scheduled. Include in the bid the cost of transporting the inspection device from its storage location to the job site and back.

Assume responsibility for the device from the time it leaves its storage area until the time it is returned. During this time, insure the device against loss or damage for the replacement cost thereof (the greater of $400,000 or the amount shown in the plans) or for the full insurable value if replacement cost insurance is not available.

Return the device in good working condition to its proper location within 30 days after completing the drilled shafts. Notify the Department at least ten working days before returning the inspection device.

455-15.11.4 Shaft Cleanliness Requirements: Adjust cleaning operations so ~~that~~ a minimum of 50% of the bottom of each shaft will have less than 1/2 inch [13 mm] of sediment at the time of placement of the concrete. Ensure ~~that~~ the maximum depth of sedimentary deposits or any other debris at any place on the bottom of the shaft excavation does not exceed 1 1/2 inches [40 mm]. The Engineer will determine shaft cleanliness by visual inspection for dry shafts, using divers or an inspection device or other methods the Engineer deems appropriate for wet shafts.

When using slurry, meet the requirements of 455-15.8 at the time of concrete placement.

455-15.11.4.1 Exceptions for Shafts for Miscellaneous Structures: Ensure ~~that~~ the depth of sedimentary deposits or other debris does not exceed 1 inch [25 mm] over the bottom of the shaft when installing drilled shafts *up to 60 inches [1.5 m] in diameter installed to support* ~~under~~ mast arms, *cantilever signs,* overhead truss signs, high mast light poles or other miscellaneous structures.

455-15.11.5 Time of Excavation: Any unclassified excavation work lasting more than 36 hours (measured from the beginning of excavation for all methods except the Permanent Casing Method, which begins at the time excavation begins below the casing) before placement of the concrete may require overreaming the sidewalls to the depth of softening or removing excessive slurry cake buildup as indicated by samples taken by the sidewall sampler or other test methods employed by the Engineer. Ensure that the minimum depth of overreaming the shaft ~~diameter~~ *sidewall* is 1/2 inch [13 mm] and the maximum depth is 3 inches [75 mm]. Provide any overreaming required at no expense to the Department when exceeding the 36-hour limit unless the time limit is exceeded solely to accomplish excavating deeper than the elevation shown in the plans as ordered by the Engineer. The Department will pay the Contractor for authorized overreaming resulting from softening or excessive filtercake buildup which is indicated by sidewall samples or other test methods employed by the Engineer during the initial 36-hour time period. The Department will pay the Contractor for authorized overreaming when sidewall samples indicate softening or excessive filter cake buildup in shaft excavations which exceed the 36-hour time limit in order to accomplish excavating deeper than the elevation shown in the plans as ordered by the Engineer.

When using *mineral* slurry, adjust excavation operations so that the maximum time that slurry is in contact with the bottom 5 feet [1.5 m] of the shaft (from time of drilling to concreting) does not exceed 12 hours. If exceeding the 12-hour time limit, overream the bottom 5 feet [1.5 m] of shaft at no additional expense to the Department prior to performing other operations in the shaft.

***455-15.11.5.1 Excavation Time for Shafts for Miscellaneous Structures*:** For drilled shafts *up to 60 inches [1.5 m] in diameter installed to support* ~~installed under~~ mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures, all references to a 36-hour time limit is changed to a 12-hour time limit.

455-16 Reinforcing Steel Construction and Placement.

455-16.1 Cage Construction and Placement: Completely assemble and place as a unit the cage of reinforcing steel, consisting of longitudinal bars, ties, and cage stiffener bars, immediately after the Engineer inspects and accepts the shaft excavation and immediately prior to placing concrete. Tie all intersections of drilled shaft reinforcing steel with cross ties or "figure 8" ties. Use double strand ties or ties with larger tie wire when necessary. The Engineer will give final approval of the cage construction and placement subject to satisfactory performance in the field.

455-16.2 Splicing Cage: If the bottom of the constructed shaft elevation is lower than the bottom of the shaft elevation in the plans, extend a minimum of one half of the longitudinal bars required in the upper portion of the shaft the additional length. Continue the tie bars for the extra depth, spaced on 2 foot [0.6 m] centers, and extend the stiffener bars to the final depth. The Contractor may lap splice these bars or use unspliced bars of the proper length. Do not weld bars to the planned reinforcing steel unless shown in the Contract Documents.

455-16.3 Support, Alignment, and Tolerance: Tie and support the reinforcing steel in the shaft so that the reinforcing steel will remain within allowable tolerances as specified in 455-8 and Section 415.

Use concrete wheels or other approved noncorrosive spacing devices near the ~~bottom~~*bottom, within 3 feet [1 m] of the top,* and intervals not exceeding 15 feet [4.5 m] ~~up~~ *along* the shaft 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 [750 mm] of circumference of cage with a minimum of three at each level. Provide concrete spacers, constructed as shown in the Contract Documents, at the bottom of the drilled shaft reinforcing cage to maintain the specified distance between the bottom of the cage and the bottom of the shaft is maintained. Use the number of bottom spacers as shown in the Contract Documents. Use spacers constructed of approved material equal in quality and durability to the concrete specified for the shaft. The Engineer will approve spacers subject to satisfactory performance in the field.

Check the elevation of the top of the steel cage before and after placing the concrete. If the rebar cage is not maintained within the specified tolerances, correct it as directed by the Engineer. Do not construct additional shafts until modifying the rebar cage support in a manner satisfactory to the Engineer.

455-16.4 Cross-Hole Sonic Logging (CSL) Tubes: *Install CSL access tubes full length in all drilled shafts from the tip of shaft to a point high enough above top of shaft to allow cross-hole-sonic-logging testing, but not less than 30 inches [750 mm] 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* ~~*shall*~~*must be Schedule 40 steel with a minimum inside diameter of 1.5 inches [38 mm]. 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. Repair or replace any unserviceable tube prior to concreting. 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 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 [915 mm to 1.220 m]	*4*	*90 degrees apart*
Greater than 48 inches [1.220 m]	*1 tube per 12 inches [305 mm] of Shaft Diameter*	*30 degrees divided by the Number of Tubes*

Insert simulated or mock probes in each cross-hole-sonic 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 damaged tubes as in a manner acceptable to the Engineer prior to concreting.

455-17 Concrete Placement.

455-17.1 General: Place concrete in accordance with the applicable portions of Sections 346 and 400, Standard Operating Procedures for Quality Control of Concrete, Subarticles 455-15.2, 455-15.3, 455-15.4, 455-15.5, 455-15.8, 455-15.9, and the requirements herein.

Place concrete as soon as possible after completing all excavation, cleaning the shaft excavation, inspecting and finding it satisfactory, and immediately after placing reinforcing steel. Continuously place concrete in the shaft to the top elevation of the shaft. Continue placing concrete after the shaft is full until good quality concrete is evident at the top of the shaft. Place concrete through a tremie or concrete pump using approved methods.

If the pressure head is lost during concrete placement for any reason, the Engineer may direct the Contractor to perform integrity testing at no expense to the Department.

Immediately after concreting, check the water levels in the CSL access tubes and refill as necessary. If tubes become unserviceable, core new holes in the drilled shaft as directed by the Engineer.

455-17.2 Placement Time Requirements: The elapsed time for placing drilled shaft concrete includes the concrete mixing and transit time, the concrete placement time, and the time required to remove any temporary casing that causes or could cause the concrete to flow into the space previously occupied by the casing. Maintain a minimum slump of 4 inches [100 mm] throughout the elapsed time. Use materials to produce and maintain the required slump through the elapsed time that meets the class of concrete specified. Provide slump loss tests that demonstrate to the Engineer that the concrete will maintain a 4 inch [100 mm] or greater slump for the anticipated elapsed time before beginning drilled shaft construction.

455-17.3 Forms: When the top of shaft elevation is above ground, form the portion of the shaft above ground with a removable form or another approved method to the dimensions shown in the plans.

When the shaft extends above the ground through a body of water, the Contractor may form the portion through the water with removable forms except when the Permanent Casing Method is specified.

When approved, the Contractor may form the portion through the water with permanent forms, provided the forms are removed from 2 feet [0.6 m] below the lowest water elevation to the top of shaft elevation.

455-17.4 Riser Blocks: The Contractor may cast a riser block of equal diameter as the column and of a maximum height of 6 inches [150 mm] at the top of the completed shaft. When this option is chosen, extend any dowel steel above the top of shaft an additional 6 inches [150 mm].

455-17.5 Curing: Cure the top surface in accordance with the applicable provisions of Section 400, and construct any construction joint area as shown in the plans. Protect portions of drilled shafts exposed to a body of water from the action of water by leaving the forms in place for a minimum of seven days after casting the concrete. The Contractor may remove forms prior to seven days provided the concrete strength has reached 2,500 psi [17 MPa] or greater as evidenced by cylinder breaks.

455-17.6 Non-Destructive Testing of Drilled Shaft Integrity*:*

455-17.6.1 Cross-Hole Sonic Logging (CSL) Tests: *Perform all CSL testing in accordance with ASTM 6760. In bridge bents or piers containing one column with one or two drilled shafts, or two columns with one or more of the columns supported by only one drilled shaft, test all drilled shafts in the bent or pier using CSL. For all other drilled shafts, perform CSL testing only on drilled shafts selected by the Engineer. The minimum number of shafts tested is the number of shafts indicated in the plans. At his/her discretion, the Engineer may increase the number shafts tested as deemed necessary.*

Engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer must have a minimum three (3) years experience of CSL testing and have a Florida Licensed Professional Engineer supervising the collection and interpretation of data. The Contractor shall provide all necessary assistance to the CSL Specialty Engineer to satisfactorily perform the testing.

When a shaft contains ~~4~~four tubes, test every possible tube combination. For shafts with ~~5~~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.

After acceptance of production shafts by the Engineer, remove all water from the access tubes or core holes and fill the tubes or core holes with a structural non-shrink grout approved by the Engineer.

455-17.6.1.1 Equipment: *Furnish Cross-Hole-Sonic logging test equipment as follows:*

(1) Include ultrasonic transmitter and receiver probes for 1.5 inch or 2.0 inch I.D. pipe, as appropriate, which produce measurements with consistent signal strength and arrival time in uniform, good quality concrete with all tube spacings on the project.

(2) Include a microprocessor based data acquisition system for display, storage, and transfer of data. Graphically display First pulse Arrival Time (FAT) during data acquisition.

(3) Electronically measure and record the relative position (depth) of the probes in the tubes with each CSL signal.

(4) Print the CSL logs for report presentation.

(5) Provide report quality plots of CSL measurements that identify each individual test.

(6) Electronically store each CSL log in digital format, with shaft identification, date, time and test details, including the transmitter and receiver gain.

455-17.6.1.2 Procedure: *Perform Cross-hole sonic logging between 72 hours and 25 calendar days of shaft concrete placement and after the concrete compressive strength exceeds 3,000 psi. 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 CSL testing. 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.*

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 2.5 inches [64 mm] 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.

Report any anomalies indicated by longer pulse arrival times and significantly lower amplitude/energy signals to the E~~NGINEER~~ngineer and conduct further tests as required to evaluate the extent of possible defects. Conduct offset CSL measurements between all tube pair combinations in any drilled shafts with 20% or greater in velocity reduction. 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: +45, +22.5 (source below receiver), and -45, -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. Provide offset CSL logs and 3-D tomographic analysis of all CSL data at no additional cost to the Department in the event 20% or greater in velocity reductions are detected.

455-17.6.1.3 Required Reports: *Present the CSL testing and ~~alnalysis~~analysis results to the Engineer in a 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 3-D tomographic analysis using all offset data, and include color coded 3-D tomographic images in the report.

455-17.6.1.4 Evaluation of CSL Test Results: *The Engineer will evaluate the CSL test results and determine whether or not the drilled shaft construction is acceptable. Drilled shafts with velocity reduction exceeding 20% are not acceptable.*

455-17.6.1.5 Coring and/or Repair of Drilled Shafts: *If the Engineer determines ~~that the~~ a drilled shaft is unacceptable based on the CSL tests and tomographic analyses, ~~replaced or~~ core the shaft to allow further evaluation and repair, or replace the shaft. 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 ~~shall~~will determine the number, location, and diameter of the cores based on the results of 3-D tomographic analysis of offset and horizontal CSL data. 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. Transport the cores, along with five (5) copies of the coring log to the Engineer. Perform strength testing by an AASHTO certified lab on portions of the cores that exhibit questionable concrete as determined by the Engineer. If the drilled shaft offset CSL testing, 3-D tomographic analyses and coring indicate ~~that~~ 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 3D tomographic imaging as described in this ~~s~~Section. Engage a Specialty Engineer to perform gamma-gamma density logging to verify the integrity of the shaft outside the reinforcing cage in the same locations offset CSL data was/is required. Submit all results to the Engineer within 5 days of test completion for approval. Perform all work described in this ~~s~~Section at no additional cost to the Department, and with no increase in contract time.*

455-18 Test Holes.

The Engineer will use the construction of test holes to determine if the methods and equipment used by the Contractor are sufficient to produce a shaft excavation meeting the requirements of the Contract Documents. During test hole excavations, the Engineer will evaluate the ability to control dimensions and alignment of excavations within tolerances; to seal the casing into impervious materials; to control the size of the excavation under caving conditions by the use of mineral slurry or by other means; to properly clean the completed shaft excavation; to construct excavations in open water areas; to establish elevations for belling; to determine the elevation of ground water; to place reinforcing steel and concrete meeting the requirements of these Specifications within the prescribed time frame; and to execute any other necessary construction operation. Revise the methods and equipment as necessary at any time during the construction of the test hole when unable to satisfactorily carry out any of the necessary operations described above or when unable to control the dimensions and alignment of the shaft excavation within tolerances.

Drill test holes out of permanent position at the location shown in the plans or as directed by the Engineer. Ensure ~~that~~ the diameter and depth of the test hole or holes are the same diameter and maximum depth as the production drilled shafts. Reinforce the test hole unless otherwise directed in the Contract Documents. Fill the test hole with concrete in the same manner ~~that~~ production ~~reinforced~~ *drilled* shafts will be constructed. Backfill test holes which are not filled with concrete with suitable soil in a manner satisfactory to the Engineer. Leave concreted test holes in place, except remove the top of the shaft to a depth of 2 feet [0.6 m] below the ground line. Use the same procedure for shafts constructed in water. Restore the disturbed areas at the sites of test holes drilled out of position as nearly as practical to their original condition. When the Contractor fails to demonstrate to the Engineer the adequacy of his methods or equipment, and alterations are required, make appropriate modifications and provide additional test holes at no expense to the Department. Include the cost of all test holes in the cost of the Drilled Shafts. Make no changes in methods or equipment after initial approval without the consent of the Engineer.

A separate test hole is not required for drilled shafts installed under mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures. The first production shaft will serve as a test hole for determining acceptability of the installation method.

455-19 Test Bells.

Ream the bells at specified test holes to establish the feasibility of belling in a specific soil strata. Use the diameter and shape of the test bell shown in the plans or as approved in writing.

455-20 Construction Tolerances.

Meet the following construction tolerances for drilled shafts:

(a) Ensure that the top of the drilled shaft is no more than 3 inches [75 mm] laterally from the position indicated in the plans.

(b) Ensure that the vertical alignment of the shaft excavation does not vary from the alignment shown in the plans by more than 1/4 in/ft [20 mm/m] of depth.

(c) After placing all the concrete, ensure that the top of the reinforcing steel cage is no more than 6 inches [150 mm] above and no more than 3 inches [75 mm] below plan position.

(d) Ensure that the reinforcing cage is concentric with the shaft within a tolerance of 1 1/2 inches [40 mm]. Ensure that concrete cover is 6 inches ± 1 1/2 inches [150 ± 40 mm] unless shown otherwise in the plans.

(e) All casing diameters shown in the plans refer to I.D. (inside diameter) dimensions. However, the Contractor may use casing with an outside diameter equal to the specified shaft diameter if the extra length described in 455-15.7 is provided. In this case, ensure that the I.D. of the casing is not less than the specified shaft diameter less 1 inch [25 mm]. When approved, the Contractor may elect to provide a casing larger in diameter than shown in the plans to facilitate meeting this requirement. When casing is not used, ensure that the minimum diameter of the drilled shaft is 1 inch [25 mm] less than the specified shaft diameter. When conditions are such that a series of telescoping casings are used, provide the casing sized to maintain the minimum shaft diameters listed above.

(f) Excavate the bearing area of bells to the plan bearing area as a minimum. Ensure that the diameter of the bells does not exceed three times the specified shaft diameter. The Contractor may vary all other plan dimensions shown for the bells, when approved, to accommodate his equipment.

(g) Ensure that the top elevation of the drilled shaft concrete has a tolerance of +1 and - 3 inches [+25 and -75 mm] from the top of shaft elevation shown in the plans.

(h) The dimensions of casings are subject to American Petroleum Institute tolerances applicable to regular steel pipe.

(i) Use excavation equipment and methods designed so that the completed shaft excavation will have a flat bottom. Ensure that the cutting edges of excavation equipment are normal to the vertical axis of the equipment within a tolerance of ±3/8 in/ft [±30 mm/m] of diameter.

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:

(a) Over drilling the shaft excavation to a larger diameter to permit accurate placement of the reinforcing steel cage with the required minimum concrete cover.

(b) Increasing the number and/or size of the steel reinforcement bars.

(c) Enlargement of the bearing area of the bell excavation within tolerance allowed.

When the tolerances are not met, the Contractor may request design changes in the caps or footings to incorporate shafts installed out of tolerance. The Contractor shall bear the costs of redesign and Unforeseeable Work resulting from approved design changes to incorporate shafts installed out of tolerance. Employ a Specialty Engineer to perform any redesign and who shall sign and seal the redesign drawings and computations. Do not begin any proposed redesign until it 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.

455-22 Load Tests.

When the plans include load testing, perform all load tests in accordance with 455-2 or as shown in the Contract Documents.

455-23 Method of Measurement.

455-23.1 Drilled Shafts: The quantity to be paid for will be the length, in feet [meters], of the reinforced concrete drilled shaft of the diameter shown in the plans, completed and accepted. The length will be determined as the difference between the top of shaft elevation as shown in the plans and the final bottom of shaft elevation as authorized and accepted. When the Contractor elects to provide outside diameter (O.D.) sized casing rather than inside diameter (I.D.) sized casing as allowed in 455-15.7, the pay quantity measured as described above will be multiplied by a factor (F) determined as follows:

$$F = \frac{2D_2 - D_1}{D_2}$$

where:

F= factor to adjust pay quantities to compensate for smaller shafts.
D_1= casing inside diameter specified = shaft diameter specified.
D_2= casing inside diameter provided ($D_2 = D_1$ minus twice the wall thickness).

455-23.2 Drilled Shafts (Unreinforced): The quantity to be paid for will be the length, in feet [meters], of unreinforced concrete drilled shaft of the diameters shown in the plans, completed and accepted. The length will be determined as the difference between the top of shaft elevation as shown in the plans and the final bottom of shaft elevation as authorized and accepted. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor “F” determined as described in 455-23.1.

455-23.3 Unclassified Shaft Excavation: The quantity to be paid for will be the length, in feet [meters], of unclassified shaft excavation of the diameter shown in the plans, completed and accepted, measured along the centerline of the shaft from the ground surface elevation to the plan bottom of shaft elevation authorized and accepted plus up to 15 feet [4.5 meters] or 3 shaft diameters, whichever is deeper, of additional excavation as authorized by the Engineer. When drilled shafts are constructed through fills placed by the Contractor, the original ground surface before the fill was placed will be used to determine the quantity of unclassified shaft excavation. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor “F” determined as described in 455-23.1.

455-23.4 Unclassified Extra Depth Excavation: When excavation is required by the Engineer to extend more than 15 feet [4.5 meters] or 3 shaft diameters, whichever is deeper, below the bottom of the shaft elevation shown in the plans, the work will be considered as Unforeseeable Work.

455-23.5 Drilled Shaft Sidewall Overreaming: The quantity to be paid for will be the length, in feet [meters], of drilled shaft sidewall overreaming authorized, completed and accepted, measured between the elevation limits authorized by the Engineer. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor “F” determined as described in 455-23.1.

455-23.6 Bell Footings: The quantity to be paid for will be the number of bells of the diameter and shape shown in the plans, completed and accepted.

455-23.7 Test Holes: The cost of all test holes will be included in the cost of Drilled Shafts.

455-23.8 Test Bells: The quantity to be paid for will be the number of test bells, completed and accepted.

455-23.9 Core (Shaft Excavation): The quantity to be paid for will be the length, in feet [meters], measured from the bottom of shaft elevation to the bottom of the core-hole, for each authorized core drilled below the shaft excavation, completed and accepted. When the Engineer authorizes ~~Core (Shaft Excavation)~~ *pilot holes* extending through part or all of the shaft, prior to excavation, to some depth below the shaft bottom, the quantity *paid as Core (Shaft Excavation)* will be the length in feet [meters], measured from the top elevation to the bottom elevation authorized by the Engineer, completed and accepted. When SPT tests are substituted for coring *or pilot holes* as provided in 455-15.6, the quantity will be determined as described above ~~for coring~~ *in this ~~s~~Section*.

455-23.10 Casings: The quantity to be paid for will be the length, in feet [meters], of each size casing as directed and authorized to be used. The length will be measured along the casing from the top of the shaft elevation or the top of casing whichever is lower to the bottom of the casing at each shaft location where casing is authorized and used, except as described below when the top of casing elevation is shown in the plans. Casing will be paid for only when the Permanent Casing Method is specified, when the plans show a casing that becomes a permanent part of the shaft, or when the Engineer directs the Contractor to leave a casing in place which then becomes a permanent part of the shaft. No payment will be made for casings which become bound or fouled during shaft construction and cannot be practically removed. The Contractor shall include the cost of all temporary removable casings for methods of construction other than that of the Permanent Casing Method in the bid price for Unclassified Shaft Excavation item.

When the Permanent Casing Method and the top of casing elevation are specified, the casing will be continuous from top to bottom. Authorization for temporary casing will not be given unless the Contractor demonstrates that he can maintain alignment of the temporary upper casing with the lower casing to be left in place during excavation and concreting operations. When artesian conditions are or may be encountered, the Contractor shall also demonstrate that he can maintain a positive water-tight seal between the two casings during excavation and concreting operations.

When the top of casing elevation is shown in the Contract Documents, payment will be from the elevation shown in the plans or from the actual top of casing elevation, whichever is lower, to the bottom of the casing. When the Contractor elects to use an approved special temporary casing system in open water locations, the length to be paid for will be measured as a single casing as provided above.

455-23.11 Protection of Existing Structures: The quantity to be paid for will be at the lump sum price.

455-23.12 Load Tests: The quantity to be paid for will be the number and type of load tests conducted.

455-23.13 Instrumentation and Data Collection: The quantity to be paid for will be at the lump sum price.

455-23.14 Cross-Hole Sonic Logging: *The quantity of the cross-hole sonic logging test set-ups to be paid for will be the number of drilled shafts accepted based on cross-hole sonic logging tests.*

455-24 Basis of Payment.

455-24.1 Drilled Shafts: Price and payment will be full compensation for all drilled shafts, including the cost of concrete*,* ~~and~~ reinforcing steel~~,~~ *and cross-hole sonic logging tubes,* 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.*

455-24.2 Drilled Shafts (Unreinforced): Price and payment will be full compensation for all drilled shafts (unreinforced), including the cost of concrete and all labor, equipment, materials, and incidentals necessary to complete the drilled shaft.

455-24.3 Unclassified Shaft Excavation: Price and payment will be full compensation for the shaft excavation (except for the additional costs included under the associated pay items for casing); removal from the site and disposal of excavated materials; restoring the site as required; cleaning and inspecting shaft excavations; using slurry as necessary; using drilling equipment; blasting procedures, special tools and special drilling equipment to excavate the shaft to the depth indicated in the plans; and furnishing all other labor, materials, and equipment necessary to complete the work in an acceptable manner.

455-24.4 Bell Footings: Price and payment will be full compensation for forming and excavating the bell beyond the diameter of the drilled shaft, furnishing and casting additional concrete necessary to fill the bell outside the shaft together with any extra reinforcing steel required, removing excavated materials from the site, and all other expenses necessary to complete the work.

455-24.5 Test Holes: No separate payment will be made for Test Hole. All cost of Test Holes will be included in the cost of Drilled Shafts.

455-24.6 Test Bells: Price and payment will be full compensation for forming the test bell, providing inspection facilities, backfilling the bell when the test hole is drilled out of position, and all other expenses necessary to complete the work.

455-24.7 Core (Shaft Excavation): Price and payment will be full compensation for drilling and classifying the cores*/pilot hole*, delivering them to the Department, furnishing drilled shaft concrete to fill the core*/pilot* hole, and all other expenses necessary to complete the work. When SPT tests are substituted for ~~coring~~*cores/pilot holes* as provided in 455-15.6, they will be paid for at the price per foot [meter] for coring.

455-24.8 Casings: Price and payment will be full compensation for additional costs necessary for furnishing and placing the casing in the shaft excavation above the costs attributable to the work paid for under associated pay items for Unclassified Shaft Excavation.

455-24.9 Protection of Existing Structures: Price and payment will include all cost of work shown in the plans or described herein for protection of existing structures. When the Contract Documents do not include an item for protection of existing structures, the cost of settlement monitoring as required by these Specifications will be included in the cost of Unclassified Shaft Excavation; however, work in addition to settlement monitoring will be paid for as Unforeseeable Work when such additional work is ordered by the Engineer.

455-24.10 Load Tests: Price and payment will include all costs related to the performance of the load test.

455-24.11 Instrumentation and Data Collection: Price and payment will include all labor, equipment, and materials incidental to the instrumentation and data collection, and, when required, the load test report.

455-24.12 Cross-Hole Sonic Logging: *Price and payment will include all costs related to the performance of the CSL testing and incidentals to the cross-hole sonic test set-up.*

455-24.1~~2~~*3* Payment Items: Payment will be made under:

Item No.	455- 18-	Protection of Existing Structures - lump sum.
Item No.	2455- 18-	Protection of Existing Structures - lump sum.
Item No.	455- 88-	Drilled Shaft - per foot.
Item No.	2455- 88-	Drilled Shaft - per meter.
Item No.	455- 90-	Bell Footings - each.
Item No.	2455- 90-	Bell Footings - each.
Item No.	455- 92-	Test Bells - each.
Item No .	2455- 92-	Test Bells - each.
Item No.	455-107-	Casing - per foot.
Item No.	2455-107-	Casing - per meter.
Item No.	455-111-	Core (Shaft Excavation) - per foot.
Item No.	2455-111-	Core (Shaft Excavation) - per meter.
Item No.	455-119-	Test Loads - each.
Item No.	2455-119-	Test Loads - each.
Item No.	455-122-	Unclassified Shaft Excavation - per foot.
Item No.	2455-122-	Unclassified Shaft Excavation - per meter.
Item No.	455-129-	Instrumentation and Data Collection - lump sum.
Item No.	2455-129-	Instrumentation and Data Collection - lump sum.
Item No.	*455-142-*	*Cross-Hole Sonic Logging* - *each*.
Item No.	*2455-142-*	*Cross-Hole Sonic Logging* - *each*.

D. SPREAD FOOTINGS

455-25 Description.

Construct reinforced concrete spread footing foundations, including dewatering when necessary, excavating to the required limits, compacting the underlying soil as required, and constructing seals when required.

455-26 General Requirements.

Meet the following requirements for all spread footings:

1. Perform excavations, including the removal of all material, of whatever nature, necessary for the construction of spread footings. As used herein, the term "soil" shall constitute any material, whether soil, rock, or other materials.

2. Slope excavations as required, or support them with sheeting, and shore them if necessary, to provide a safe excavation that is adequate for construction purposes and that will adequately protect any existing adjacent structures.

3. Ensure that the foundation soils are firm, stable, and, in the opinion of the Engineer, meet or exceed the design bearing and compressibility requirements before constructing the footings or any required seals. The Department may elect to use any type of test(s) to evaluate the foundation soils that is appropriate in the opinion of the Engineer. Cooperate with the Engineer in the evaluation of the foundation soils, and assist the Engineer as necessary to provide access to the site.

4. The elevation of the bottom of footings or seals and/or the depth of over-excavation shown in the plans is approximate and the Engineer may order, in writing, such changes as may be necessary to secure a satisfactory foundation.

5. Place all spread footing concrete in the dry.

455-27 Protection of Existing Structures.

Protect existing structures in accordance with 455-1.1. Also, if not otherwise provided in the plans, evaluate the need for, design, and provide all reasonable precautionary features to prevent damage, including, but not limited to, the installation of sheet piling, shoring as necessary, maintenance of the water table beneath such structures as nearly as practical to existing conditions, and monitoring and controlling vibrations from construction activities including driving of sheeting or from blasting.

455-28 Dewatering.

The Contractor is responsible for the design, installation, and operation of an adequate dewatering system to dewater excavations for spread footings. Use a well point or well system. Submit a dewatering plan to the Engineer for his records before beginning construction.

Use well points or wells where the piezometric water level is above an elevation 3 feet [1.0 m] below the bottom of the excavation. Maintain the water table 3 feet [1.0 m] or more below the maximum depth of excavation. Provide continuous dewatering until completing construction of the footing and backfill the excavation at least 3 feet [1.0 m] above the piezometric water table elevation. Continue dewatering until the Engineer considers conditions safe to discontinue dewatering. In the event of a dewatering failure, assist the Engineer as required in determining the effects of such a failure on the foundation soils, and take whatever corrective measures are required at no additional expense to the Department. When the Engineer approves the discontinuing of dewatering, decrease the rate of pumping, allowing the water level to rise slowly. Use a rate, in feet per hour [millimeters per hour], that the water table is allowed to rise equal to the total number of feet [millimeters] the water table was lowered, divided by ten hours or a rate of 1 ft/hr [300 mm/h], whichever is less.

Install one piezometer well approximately every 15 feet [4.5 m] of footing perimeter. Provide a minimum of two and a maximum of six piezometers at locations within 2 feet [0.6 m] from the outside of the footing perimeter. Install piezometer wells to a depth at least 10 feet [3 m] below the bottom of footing elevation or as directed by the Engineer. Measure water elevation in the piezometer wells prior to excavation and at 12-hour intervals between excavation and discontinuation of dewatering. Maintain the piezometers in working condition throughout the dewatering process, and repair or replace them when damaged at no expense to the Department.

455-29 Excavations.

455-29.1 Dry Excavations: Dry excavations are excavations that can be completed without the need to lower the piezometric water level. Perform dry excavations when the piezometric water level at the time of construction is and, in the opinion of the Engineer, will remain at least 3 feet [1.0 m] below the bottom of the authorized excavation or over-excavation. Demonstrate to the Engineer that a stable excavation can be made without dewatering. Make adequate provisions to divert surface runoff and to collect and remove any water entering the excavation.

Excavate to the bottom of footing, to the over-excavation limits shown in the plans, or as directed by the Engineer. Save any suitable materials for backfill. Provide areas for the disposal of all unsuitable materials, and dispose of them in a satisfactory method. Compact the foundation soils below the footing as shown in the plans or described herein before constructing the footing.

455-29.2 Dewatered Excavations: Dewatered excavations are excavations made after first lowering the piezometric water level with wellpoints or wells. Perform dewatering as described in 455-28. Excavate in the dry after lowering of the water table.

When dewatering is required, the Contractor may excavate within 3 feet [1.0 m] of the ground water table before dewatering begins if the dewatering system is operating and the Contractor has demonstrated that the water level has been lowered to and maintained at acceptable limits. Where large excavations require stage lowering of the water table (additional wellpoint systems installed at lower elevations), the Contractor may continue excavating as long as the water elevation is maintained at least 3 feet [1.0 m] below the excavation.

Ensure that surface runoff is diverted from the excavation. Compact the foundation soils as shown in the plans or as described herein before constructing the footing.

455-29.3 Wet Excavations: Wet excavations are excavations made below the existing water table without prior dewatering. When the plans show a cofferdam and seal, perform the excavation in the wet. Maintain the water level during excavation at or above the water level outside the cofferdam.

Place the seal directly upon the foundation soils or rock when using wet excavations. Do not compact foundation soils for wet excavations. Ensure that the foundation soils or rock are disturbed as little as practical. Remove all materials that are determined by the Engineer to be loose or disturbed before placing the seal concrete.

455-30 Fill or Backfill.

Only use fill or backfill, including over-excavations below the footing, that is clean cohesionless material, free of rubble, debris, or rocks that would prevent uniform placement and compaction. For backfill materials, use A-1, A-2, or A-3 materials, materials as shown in the plans, or materials approved by the Engineer.

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 AASHTO T 180 for a minimum depth of 2 feet [0.6 m] below the bottom of the excavation or to the depth shown in the plans before backfilling begins. Perform at least one density determination at each footing excavation at a depth of one to 2 feet [0.3 to 0.6 m] below the bottom of the excavation. Compact the backfill in footing excavations which have been over-excavated in 12 inch [300 mm] maximum loose lifts to a density not less than 95% of the maximum density as determined by AASHTO T 180 to the bottom of footing elevation. Perform at least one density determination in each lift of backfill at each footing excavation.

For compaction, use an approved heavy vibratory roller with a static drum weight of at least 4 tons [3.6 metric 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 [450 kg]. The Contractor may compact backfill located more than 15 feet [4.5 m] 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.

455-32 Forming.

Form spread footings if it can not be demonstrated that the natural soil or rock is strong enough to prevent caving during construction. For forms, meet the applicable requirements of 400-5. When forms are not required, meet the requirements of 400-5.4.4.

455-33 Materials.

455-33.1 Concrete: Meet the requirements of Section 346.

455-33.2 Reinforcing Steel: Meet the requirements of Section 415. For spread footing reinforcing steel, use Grade 60 [Grade 420].

455-34 Reinforcing Steel Placement.

Place and fasten reinforcing steel for footings according to the applicable provisions of 415-5.

455-35 Concrete Placement.

455-35.1 Placement: Place all footing concrete in the dry and according to the applicable provisions of Section 400. Do not construct joints in footings.

455-35.2 Finish: After placing and consolidating the concrete, strike-off the top surface to the grades shown in the Contract Documents, leaving the surface smooth and free of undesirable cavities and other defects. Do not provide a special finish unless the footing will be visible after construction, in which case, meet the applicable provisions of Section 400.

455-35.3 Curing: Provide continuous-moisture-curing for footings. For cover materials, use clean sand, sawdust, or other materials meeting the approval of the Engineer. Continuously wet the cover materials for a period of 72 hours.

455-36 Method of Measurement.

455-36.1 Protection of Existing Structures: The quantity to be paid for, when included in the Contract Documents, will be at the Contract lump sum price.

455-36.2 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.

455-36.3 Excavation: No separate payment will be made for backfill or will separate payment be made for excavation above bottom of footing elevation. The cost of this work will be included in the Contract unit price for Concrete (Substructure). For footings with excavation (over-excavation) below the bottom of the footing elevation shown in the plans, the cost of this excavation, backfilling, and compaction will be included in the Contract unit price for Excavation for Structures. The pay quantity will be the volume in cubic yards [cubic meters] bounded by vertical planes 12 inches [300 mm] outside of the limits of the footing and parallel thereto and extending from the bottom of the footing elevation to the authorized bottom of over-excavation or within the pay limits shown in the plans.

455-36.4 Reinforcing Steel: The quantity to be paid for will be the total weight, in pounds [kilograms], determined as described in Section 415.

455-36.5 Concrete: The quantity to be paid for will be the volume of the classes shown in the plans, in cubic yards [cubic meters], determined as described in Section 400.

455-37 Basis of Payment.

455-37.1 Protection of Existing Structures: When separate payment for Protection of Existing Structures is provided, price and payment will be full compensation for all work necessary to evaluate the need for, design of, and to provide the necessary features to protect existing structures, including all cost of work shown in the plans or described herein for protection of existing structures.

When a separate payment for Protection of Existing Structures is not provided, the cost of this work will be included in the Contract unit prices for Excavation for Structures and/or for Concrete (Substructure).

455-37.2 Dewatering: Price and payment will be full compensation for all work related to the successful dewatering of footings, including installing, maintaining, and monitoring piezometer wells. Dewatering will be considered Unforeseeable Work when the Engineer determines that dewatering is required and the plans do not include a Dewatering item.

455-37.3 Excavation: Price and payment will be full compensation for all work related to over-excavating below the bottom of footing elevation, backfill, and compaction as specified.

455-37.4 Reinforcing Steel: Price and payment will be full compensation for all work required to furnish and place the steel as shown in the plans and as specified herein.

455-37.5 Concrete: Price and payment will be full compensation for all work required to construct footings and seals as shown in the plans and described herein.

No separate payment will be made for sheeting and shoring required for excavation and footing construction except when a separate pay item for sheeting and shoring is included in the plans. The cost of all work not specifically mentioned in the other footing items will be included in the price per cubic yard [cubic meter] for substructure Concrete.

455-37.6 Payment Items: Payment will be made under:

Item No. 125- 1- Excavation For Structures - per cubic yard.
Item No. 2125- 1- Excavation For Structures - per cubic meter.
Item No. 400- 2- Class II Concrete - per cubic yard.
Item No. 2400- 2- Class II Concrete - per cubic meter.
Item No. 400- 3- Class III Concrete - per cubic yard.
Item No. 2400- 3- Class III Concrete - per cubic meter.
Item No. 400- 4- Class IV Concrete - per cubic yard.
Item No. 2400- 4- Class IV Concrete - per cubic meter.
Item No. 400- 91- Dewatering For Spread Footings - each.
Item No. 2400- 91- Dewatering For Spread Footings - each.
Item No. 415- 1- Reinforcing Steel - per pound.
Item No . 2415- 1- Reinforcing Steel - per kilogram.
Item No. 455- 18- Protection of Existing Structures - lump sum.
Item No. 2455- 18- Protection of Existing Structures - lump sum.

E. STRUCTURES (OTHER THAN BRIDGE)

FOUNDATIONS - AUGER CAST PILES

455-38 Description.

Furnish and install auger cast piles used for structural support, other than bridge foundations.

455-39 General Requirements.

455-39.1 Contractor’s Operations: Submit an Auger Cast Pile Installation Plan in accordance with 455-47. Prior to the start of production piles, demonstrate to the satisfaction of the Engineer, the dependability of the equipment, techniques, and source of materials by construction of a demonstration pile.

455-39.2 Protection of Existing Structures: Protect existing structures in accordance with 455-1.1.

455-40 Materials.

Meet the following material requirements:

(1) Portland Cement (Types I, II, III, IP, and IS)............Section 921
(2) Fly Ash, Slag and other Pozzolanic Materials for Portland Cement Concrete..Section 929
(3) Fine Aggregate (Sand)* ....Section 902
(4) Admixtures...Section 924
(5) Water...Section 923
(6) Fluidizer ....ASTM C 937

* The Contractor may use any clean sand with 100% passing 3/8 inch [9.5 mm] sieve and not more than 10% passing the 200 mesh [75 µm] sieve. The Engineer will only permit Silica Sand except as provided in 902-5.2.3.

455-41 Grout Mix Proportions.

Use a grout mix consisting of a mixture of Portland cement, fly ash, retarder, fluidizer, sand and water proportioned and mixed to produce a mortar capable of maintaining the solids in suspension without appreciable water gain and which may be pumped without difficulty and fill open voids in the adjacent soils. Proportion these materials to produce a hardened grout of the required strength shown on the plans.

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. Accurately measure all materials by volume or weight as they are fed to the mixer. Place the materials in the mixer in the following order: 1) water, 2) fluidifier, 3) other solids in order of increasing particle sizes.

3. Use a quantity of water and mixing time that will produce a homogenous grout having a consistency of 18 to 24 seconds, or higher if specified by the Engineer, when tested with a flow cone in accordance with ASTM C 939 (3/4 inch [19 mm] diameter outlet), with a frequency at the discretion of the Engineer. 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 70ºF [20ºC]; two hours for temperatures from 70 to 100ºF [20 to 38ºC]. Do not place grout when its temperature exceeds 100ºF [38ºC]. 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 of the cement grout into a thoroughly mixed and uniform mass, free from balls or lumps of cementitious material and capable of discharging the concrete with a satisfactory degree of uniformity. The Engineer’s approval of grout mixers and all other equipment will be conditioned on proper performance during construction of the demonstration pile and subsequent production work.

5. Use a screen no larger than 3/4 inch [19.0 mm] 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 capable of developing displacing pressures at the pump up to 350 psi [2.4 MPa]. ~~Place a minimum volume of grout in the hole of at least 115% of the column of the auger hole.~~

7. Use a grout pump/system equipped with a pressure gauge to accurately monitor the pressure of the grout flow. Test and calibrate the equipment during construction of the demonstration pile to demonstrate flow rate measurement accuracy of ±3% over the range of grouting pressures anticipated during this work. *Provide a pump stroke counter in good working condition on the grout pump.* Also calibrate the equipment any time the Engineer suspects that the grout pump performance has changed.

455-43 Testing Cement Grout.

Make four cubes, 2 by 2 inch [50.8 by 50.8 mm] each, for each 50 yd^3 [38 m^3] of grout placed, per day of pile placement. The Engineer will test two cubes at seven days and two cubes at 28 days. The minimum required strength will be specified on the plans. When a cement grout acceptance strength test falls more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is less deviation from the specified minimum strength, perform one of the following:

(a) Remove and replace the LOT of concrete in question at no additional cost to the Department, or

(b) Submit a structural analysis performed by a Specialty Engineer. If the results of the analysis, approved by the Department, indicate adequate strength to serve the intended purpose with adequate durability, the concrete may remain in place. Otherwise, remove and replace the LOT of concrete in question at no additional cost to the Department.

All low strength cement grout accepted by the Engineer will be subject to reduced payment as follows: $0.80/$yd^3$ for each 10 psi [$1.05/$m^3$ for each 70 kPa] of strength test value below the specified minimum strength.

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. 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 [meters]
RC = Total Reduction in payment, dollars
UC = Unit Cost of pile, dollars /foot [dollars /meter]

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 [1.5 m] and a maximum diameter about the pile centerline, not to exceed 1/2 of the distance to the adjacent pile. Backfill with clean granular backfill materials (A-1, A-3, A-2-4), placed and compacted in maximum

12 inch [300 mm] lifts to at least 95% of maximum dry density as determined by AASHTO T 180. Complete this work to the Engineer's satisfaction prior to auger cast pile construction. Should more than 5 feet [1.5 m] 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, 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 drawings.

6. Clearly mark the auger leads to facilitate monitoring of the incremental drilling & grout placement. Provide individual foot marks with 5 ~~ft~~foot [1.5 m] 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.

~~6~~*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.

~~7~~*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. Commence auger cast pile construction immediately upon 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/minute [300 mm/minute].

~~8~~*9*. Plug the hole in the bottom of the auger while being advanced into the ground. Remove the plug by the grout or with the reinforcing bar.

~~9~~*10*. Pump the grout with sufficient pressure as the auger is withdrawn to 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. Carry a head of at least 5 feet [1.5 m] 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.

~~10~~*11*. Once the grout head has been established, ~~stop or~~ 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* ~~G~~*g*rout ~~should~~ start*s* flowing out from the hole when the cutting head is ~~within~~ *at least* 5 feet [1.5 m] ~~of~~ *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 [1.5 m] to the tip. Place a minimum volume of grout in the hole of at least 105% of the column of the auger hole from a the ground surface to a depth of 5 feet [1.5 m]. Do not include any grout needed to create surplus grout head in* *the volume of grout placed into the hole.* ~~Place a total volume of grout of at least 115% of the theoretical volume for each pile~~ ~~*into the ground, not including any grout needed to create surplus grout head.*~~ If the ~~cutting head reaches the ground surface without any grout~~ ~~*flowing from the hole*~~ *grout does not flow out from the hole when the cutting head is at least 5 feet [1.5 m] 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 [1.5 m] 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.

~~11~~*12*. Assume responsibility for ~~monitoring~~ the grout volume placed ~~and document for each 6.5 feet [2 m] of pile grouted/placed~~. If less than 115% of the theoretical volume of grout is placed in any ~~6.5~~ *5* foot [~~2~~ *1.5* m] increment (~~until the grout head on the auger flighting reaches the ground surface~~ *105% in the top 5 foot [1.5 m] increment*), reinstall the pile by advancing the auger 10 feet [3 m] or to the bottom of the pile if that is less, followed by controlled removal and grout injection.

~~12. Maintain accurate records showing the placement depth of each pile and the amount of material used in each pile. Note any unusual conditions encountered during the installation.~~

~~13~~~~*12*~~*13*. Furnish and install the reinforcing steel and anchoring bolts as shown in the Contract drawings.

~~14~~~~*13*~~*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, unless otherwise approved by the Engineer.

~~15~~~~*14*~~*15*. Leave any temporary supports of/for items placed into a grouted pile (reinforcement template, anchor bolt template, precast column supports, etc.) in place ~~until the grout reaches a minimum of 50% design strength or three days cure time, whichever is earlier~~ *for a minimum of 12 hours after completion of the pile*. Do not place wall panels or other significant loads, before the grout has set a minimum of seven days or reached the 28 day strength.

455-45 Construction Tolerances.

Locate piles as shown on the drawings, or as otherwise directed by the Engineer. Locate pile centers to an accuracy of ±3 inches [±75 mm]. Ensure that the top of pile elevation is within an accuracy of ±3 inches [±75 mm] of the plan elevation.

Locate all precast post, anchor bolts, etc. within the following tolerances unless otherwise shown in the plans: variation from plum (±1/4 inch/post height [±6 mm/post height]); specified elevation (±1/2 inch [±13 mm]); and specified location (±1/4 inch [±6 mm]).

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.

455-47 Auger Cast Pile Installation Plan.

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

1. Name and experience record of auger cast pile superintendent or foreman in responsible charge of auger cast pile operations. Place a person in responsible charge of day to day auger cast pile operations who possesses satisfactory prior experience constructing shafts 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 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. Maintain records of each pile installed, separate from those of the Engineer, showing:

1. Pile location
2. Ground elevation
3. Pile length
4. Tip elevation
5. Pile top elevation
6. Pay length (when piles are paid for separately)
7. Overburden length (length cast above the final grade point)
8. Pile diameter
9. Quantity of grout placed per yard [meter] of pile length
10. Theoretical quantity of grout required
11. Drilling time
12. Grouting time
13. All other pertinent data relative to the pile installation
14. Grout truck time of arrival to the site and batch time
15. Flow cone (consistency) results

455-49 Method of Measurement.

455-49.1 Protection of Existing Structures: The quantity to be paid for, when included in the Contract Documents, will be at the Contract lump sum price.

455-49.2 Auger Cast Pile: The quantity to be paid for will be at the Contract unit price per foot [meter] between tip and required pile top elevations for all piles completed and accepted.

455-50 Basis of Payment.

455-50.1 Protection of Existing Structures: When separate payment for Protection of Existing Structures is provided, price and payment will be full compensation for all work necessary to evaluate the need for, design of, and to provide the necessary features to protect the existing structures, including all cost of work shown in the plans or described herein for protection of existing structures.

When a separate payment for Protection of Existing Structures is not provided, the cost of settlement monitoring will be included in the cost of the structure. Work ordered by the Engineer for protection of existing structures, other than settlement monitoring, will be paid for as Unforeseeable Work.

455-50.2 Auger Cast Piles: Price and payment will be full compensation for all labor, materials, and incidentals for construction of auger cast piles of the sizes and depths indicated on the Contract drawings or otherwise required under this Contract. 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.

455-50.3 Payment Items: Payment will be made under:

Item No.	455- 18-	Protection of Existing Structures - lump sum.
Item No.	2455- 18-	Protection of Existing Structures - lump sum.
Item No.	455-112-	Auger Grouted Piles - per foot.
Item No.	2455-112-	Auger Grouted Piles - per meter.

STRUCTURES FOUNDATIONS.
(REV 8-6-05)

SECTION 455 (Pages 462-533) is deleted and the following substituted:

SECTION 455
STRUCTURES FOUNDATIONS

Index

A. GENERAL

455-1 General Requirement.

The Contractor may examine available soil samples and/or rock cores obtained during the soil boring operations at the appropriate District Materials Office.

455-1.1 Protection of Existing Structures: When the plans require foundation construction operations in close proximity to existing structures, take all reasonable precautions to prevent damage to such structures. The requirements described herein apply to all types of structures (on or off the right-of-way) that may be adversely affected by foundation construction operations (including phase construction) due to vibrations, ground loss, ground heave, or dewatering. Protect utilities as described in-the applicable provisions of Section 7.

Monitor structures for settlement in a manner approved by the Engineer, recording elevations to 0.001 foot [0.5 mm]. Monitor the following structures:

(1) shown in the plans.

(2) within a distance, in feet, of pile driving operations equal to 0.5 times the square root of the impact hammer energy, in foot-pounds [in meters, of pile driving operations equal to 4.14 times the square root of the hammer energy, in kilojoules]. Take required measurements before the initiation of driving and then daily on days when driving occurs or as indicated in the plans and weekly for two weeks after driving has stopped.

(3) within a distance of ten shaft diameters or the estimated depth of excavation, whichever is greater.

(4) within a distance of three times the depth of excavation for the footing.

Obtain the Engineer’s approval of the number and location of monitoring points. Take elevation;

(1) before beginning construction,

(2) daily during the driving of any casings, piling, or sheeting,
(3) weekly for two weeks after stopping driving,
(4) during excavation,
(5) during blasting,
(6) or as directed by the Engineer.

Notify the Engineer of any movements detected and immediately take any remedial measures required to prevent damage to the existing structures.

Employ a qualified Specialty Engineer to survey all structures, or portions thereof, within:

(1) a distance, in feet, of pile driving operations equal to 0.25 times the square root of the impact hammer energy, in foot-pounds [in meters, of pile driving operations equal to 2.07 times the square root of the hammer energy, in kilojoules]

(2) a distance of ten shaft diameters or the estimated depth of excavation, whichever is greater

(3) three times the excavation depth for footings and caps

(4) or as shown in the plans

The Department will make the necessary arrangements to provide right-of-way entry for the Contractor's engineer to survey. Adequately document the condition of the structures and all existing cracks with descriptions and pictures. Prepare two reports documenting the condition of the structures: one report before beginning foundation construction operations and a second report after completing foundation construction operations. The Department will take ownership of both reports. Do not perform pre-driving and post-driving surveys of the condition of bridges owned by the Department except when shown in the Contract Documents.

When shown in the Contract Documents, employ a qualified Specialty Engineer to monitor and record vibration levels during the driving of casings, piling, sheeting, or blasting operations. Provide vibration monitoring equipment capable of detecting velocities of 0.1 in/s [2.5 mm/s] or less.

Upon detecting settlement or heave of 0.005 foot [1.5 mm], vibration levels reaching 0.5 in/s [13 mm/s], levels otherwise shown in the Contract Documents, or damage to the structure, immediately stop the source of vibrations, backfill any open drilled shaft excavations, and contact the Engineer for instructions.

When the plans require excavations for construction of footings or caps, the Contractor is responsible for evaluating the need for, design of, and providing any necessary features to protect adjacent structures. When sheeting and shoring are not detailed in the plans, employ a Specialty Engineer to design the sheeting and shoring, and to sign and seal the plans and specification requirements. Send these designs to the Engineer for his record before beginning construction.

Also, when shown in the Contract Documents or when authorized by the Engineer, install the piling to the depth required to minimize the effects of vibrations or ground heave on adjacent structures by approved methods other than driving (preformed holes, predrilling, jetting, etc.). In the event the Department authorizes the use of preformed pile holes to meet this requirement, the Department will pay for this work as described in 455-5.9.3

Also if not otherwise provided in the plans, the Contractor is responsible for evaluating the need for, design of, and providing all reasonable precautionary features to prevent damage, including, but not limited to, selecting construction methods and procedures that will prevent damaging caving of the shaft excavation and monitoring and controlling the vibrations from construction activities, including driving of casings, driving of sheeting, and blasting.

When shown in the plans or directed by the Engineer, install a piezometer near the right-of-way line and near any structure that may be affected by lowering the ground water when dewatering is required. Monitor the piezometer and record the ground water elevation level daily. Notify the Engineer of any ground water lowering near the structure of 12 inches [300 mm] or more.

455-1.2 Excavation: Complete all excavation of the foundations prior to installing piles or shafts unless otherwise authorized by the Engineer. After completing pile/shaft installation, remove all loose and displaced materials from around the piles/shafts, leaving a clean, solid surface. Compact the soil surface on which concrete is to be placed or which will support the forming system for the concrete to a density not less than 90% of the maximum density as determined by AASHTO T 180, and which will support the load of the plastic concrete without settling or causing the concrete to crack, or as shown in the Contract Documents. The Engineer will not require the Contractor to compact for excavations made below water for seals or when the footing or cap or forming system (including supports) does not rest on the ground surface.

455-1.2.1 Abutment (End Bent) Fill: Place and compact the fill before installing end-bent piling/shafts, except when:

(1) driving specified test piling in end bents or,

(2) the plans show uncased piles through proprietary retaining wall fills.

When installing piles/shafts or casing prior to placing fill, take necessary precautions to prevent displacement of piles/shafts during placing and compacting fill materials within 15 feet [4.5] of the piles/shafts or casing. Reference and check the position of the piles/shafts or casing at three approximately equal intervals during construction of the embankment.

Place embankment material in 6 inch [150 mm] loose lifts in the 15 foot [4.5 m] area around the piles/shafts or casing. Compact embankment material within the 15 foot [4.5 m] area adjacent to the piles/shafts or casing to the required density with compaction equipment weighing less than 1,000 pounds [450 kg]. When installing piles/shafts prior to the completion of the surrounding fills, do not cap them until placing the fills as near to final grade as possible, leaving only the necessary working room for construction of the caps.

Provide permanent casings installed prior to placement of the fill, for all drilled shafts through mechanically stabilized fills (for example, behind proprietary retaining walls) for shafts installed after fill placement. Install temporary casings through the completed conventional fill when permanent casings are not required.

Provide permanent casings, if required, before the fill is placed extending a sufficient distance into the existing ground to provide stability to the casings during construction of the abutment fill.

455-1.3 Cofferdams: Construct cofferdams as detailed in the plans. When cofferdams are not detailed in the plans, employ a Specialty Engineer to design cofferdams, and to sign and seal the plans and specification requirements. Send the designs to the Engineer for his records before beginning construction.

Provide a qualified diver and a safety diver to inspect the conditions of the foundation enclosure or cofferdam when the Contract Documents require a seal for construction. Equip these divers with suitable voice communications, and have them inspect the foundation enclosure and cofferdam periphery including each sheeting indentation and around each piling or drilled shaft to ensure that no layers of mud or other undesirable materials were left above the bottom of seal elevation during the excavation process. Also have the divers check to make sure the surfaces of the piles or drilled shafts are sufficiently clean to allow bond of the concrete down to the minimum bottom of seal elevation. When required, ensure that there are no mounds of stone, shell, or other authorized backfill material left after placement and grading. Assist the Engineer as required to ensure that the seal is placed as specified and evaluate the adequacy of the foundation soils or rock. Correct any deficiencies found by the divers. Upon completion of inspection by the divers, the Department may also elect to inspect the work before authorizing the Contractor to proceed with subsequent construction operations. Furnish the Engineer a written report by the divers indicating the results of their underwater inspection before requesting authorization to place the seal concrete.

455-2 Static Compression Load Tests.

455-2.1 General: Employ a professional testing laboratory, or Specialty Engineer with prior load test experience on at least three projects, to conduct the load test in compliance with these Specifications, to record all data, and to furnish reports of the test results to the Engineer except when the Contract Documents show that the Department will supply a Geotechnical Engineer to provide these services.

Perform the load test by applying a load up to the load required in the Contract Documents or to the failure load, whichever occurs first.

Do not apply test loads to piles sooner than 48 hours (or the time interval shown in the plans) after driving of the test pile or reaction piles, whichever occurs last.

Allow up to four weeks after the last load test for the analysis of the load test data and to provide all the estimated production tip elevations. If the Contractor is willing to construct production foundation elements in areas designated by the Engineer, tip elevations will be determined in these areas beginning seven days after the receipt of the load test data which represents the designated area.

Do not begin static load testing of drilled shafts until the concrete has attained a compressive strength of 3,400 psi [23.5 MPa]. The Contractor may use high early strength concrete to obtain this strength at an earlier time to prevent testing delays.

Load test piles/shafts in the order directed by the Engineer. The Department will furnish certain load test equipment and/or personnel when shown in the plans. Inspect all equipment to be furnished by the Department at least 30 days prior to use, and notify the Engineer of any equipment that is not in satisfactory operating condition. The Department will consider any necessary repairs ordered by the Engineer to place the equipment in satisfactory operating condition as Unforeseeable Work. Provide the remainder of the equipment and personnel needed to conduct the load tests. Unless shown otherwise in the Contract Documents, provide all equipment, materials, labor, and technical personnel required to conduct the load tests, including determination of anchor reaction member depths. In this case, provide a loading apparatus designed to accommodate the maximum load plus an adequate safety factor.

While performing the load test, provide safety equipment, and employ safety procedures consistent with the latest approved practices for this work. Include with these safety procedures adequate support for the load test plates and jack to prevent them from falling in the event of a release of load due to hydraulic failure, test pile/shaft failure, or any other cause.

Include in the bid the cost of transporting load test equipment and instrumentation supplied by the Department from their storage location to the job site and back. Handle these items with care. The Contractor is responsible for the safe return of these items. After completion of the static load tests, return all Department furnished equipment in satisfactory operating condition. Repair all damage to the test equipment furnished by the Department to the satisfaction of the Engineer. Clean all areas of rust on structural steel items, and repaint those areas in accordance with Section 561. Return all load test equipment supplied by the Department within 30 days after completing the load tests.

The Contractor is responsible for the equipment from the time it leaves its storage area until the time it is returned. During this time, insure the equipment against loss or damage for the replacement cost thereof (the greater of $150,000 or the amount shown in the plans) or for the full insurable value if replacement cost insurance is not available.

Notify the Engineer at the preconstruction conference or no later than 30 days before beginning test pile installation of the proposed testing schedule so that items supplied by the Department may be reserved. Notify the Department at least ten working days before pick-up or return of the equipment. During pick-up, the Department will complete a checklist of all equipment placed in the Contractor's possession. The Department will later use this checklist to verify that the Contractor has returned all equipment. Provide personnel and equipment to load or unload the equipment at the Department's storage location. Provide lifting tongs or nylon slings to handle Department owned test girders. Do not perform cutting, welding, or drilling on Department owned girders, jacks, load cells, or other equipment.

455-2.2 Loading Apparatus: Provide an apparatus for applying the vertical loads as described in one of the following:

(1) As shown and described in the Contract Documents.

(2) As supplied by the Contractor, one of the following devices designed to accommodate a load at least 20% higher than that shown in the Contract Documents or described herein for test loads:

(a) Load Applied by Hydraulic Jack Acting Against Weighted Box or Platform: Construct a test box or test platform, resting on a suitable support, over the pile, and load it with earth, sand, concrete, pig iron, or other suitable material with a total weight greater than the anticipated maximum test load. Locate supports for the weighted box or platform at least 6 feet [2 m] or three pile/shaft diameters, whichever is greater, measured from the edge of the pile or shaft to the edge of the supports. Insert a hydraulic jack with pressure gauge between the test pile or shaft and the underside of the reaction beam, and apply the load to the pile or shaft by operating the jack between the reaction beam and the top of the pile or shaft.

(b) Load Applied to the Test Pile or Shaft by Hydraulic Jack Acting Against Anchored Reaction Member: Construct reaction member anchorages as far from the test piles/shafts as practical, but in no case closer than the greater of 3 pile/shaft diameters or 6 feet [2 m] from the edge of the test pile/shaft. Attach a girder(s) of sufficient strength to act as a reaction beam to the upper ends of the anchor piles or shafts. Insert a hydraulic jack with pressure gauges between the head of the test pile/shaft and the underside of the reaction beam, and apply the test load to the pile/shaft by operating the jack between the reaction beam and the pile/shaft head.

If using drilled shafts with bells as reaction member anchorages, locate the top of the bell of any reaction shaft anchorage at least three shaft diameters below the bottom of the test shaft.

(c) Combination Devices: The Contractor may use a combination of devices (a) and (b), as described above, to apply the test load to the pile or shaft.

(d) Other Systems Proposed by the Contractor and Approved by the Engineer: When necessary, provide horizontal supports for loading the pile/shaft, and space them so that the ratio of the unsupported length to the minimum radius of gyration of the pile does not exceed 120 for steel piles, and the unsupported length to the least cross-section dimension does not exceed 20 for concrete piles or drilled shafts. Ensure that horizontal supports provide full support without restraining the vertical movement of the pile in any way.

When required by the Contract Documents, apply a horizontal load to the shaft either separately or in conjunction with the vertical load. Apply the load to the test shaft by hydraulic jacks, jacking against Contractor provided reaction devices. After receiving the Engineer’s approval of the proposed method of load application, apply the horizontal load in increments, and relieve it in decrements as required by the Contract Documents.

455-2.2.1 Modified Quick Test:

(a) Loading Procedure: Apply vertical loads concentric with the longitudinal axis of the tested pile/shaft to accurately determine and control the load acting on the pile/shaft at any time. Place the load on the pile/shaft continuously, in increments equal to approximately 5% of the maximum test load specified until approaching the failure load, as indicated by the measuring apparatus and/or instruments. Then, apply increments of approximately 2.5% until the pile/shaft “plunges” or attains the limiting load. The Engineer may elect to stop the loading increments when he determines the Contractor has met the failure criteria or when a settlement equal to 10% of the pile/shaft width or diameter is reached. Apply each load increment immediately after taking and verifying the complete set of readings from all gauges and instruments. Apply each increment of load within the minimum length of time practical, and immediately take the readings. Complete the addition of a load increment and the completion of the readings within five to 15 minutes. The Engineer may elect to hold the maximum applied load up to one hour.

Remove the load in decrements of about 10% of the maximum test load. Remove each decrement of load within the minimum length of time practical, and immediately take the readings. Complete the removal of a load decrement and the taking of the readings within five to 15 minutes. The Engineer may also require up to two reloading cycles with five loading increments and three unloading decrements.

Record the final recovery of the pile/shaft until movement is essentially complete for a period up to one hour after the last unload interval.

(b) Failure Criteria and Safe-Load: Use the criteria described herein to establish the failure load. The failure load is defined as the load that causes a pile/shaft top deflection equal to the calculated elastic compression plus 0.15 inch [4 mm] plus 1/120 of the pile/shaft minimum width or the diameter in inches [millimeters] for piles/shafts 24 inches [610 mm] or less in width, and equal to the calculated elastic compression plus 1/30 of the pile/shaft minimum width or diameter for piles/shafts greater than 24 inches [610 mm] in width. Consider the safe allowable load of any pile/shaft so tested as either 50% of the maximum applied load or 50% of the failure load, whichever is smaller.

455-2.3 Measuring Apparatus: Provide an apparatus for measuring movement of the test piles/shafts that consists of all of the following devices:

(1) Wire Line and Scale: Stretch a wire as directed by the Engineer between two supports located at a distance at least:

(a) 10 feet [3 m] from the center of the test pile but not less than 3.5 times the pile diameter or width.

(b) 12 feet [3.7 m] from the centerline of the shaft to be tested but not less than three shaft diameters.

Locate the wire supports as far as practical from reaction beam anchorages. At over-water test sites, the Contractor may attach the wire line as directed by the Engineer to the sides of the service platform. Mount the wire with a pulley on one support and a weight at the end of the wire to provide constant tension on the wire. Ensure that the wire passes across the face of a scale mounted on a mirror attached to the test pile/shaft so that readings can be made directly from the scale. Use the scale readings as a check on an average of the dial readings. When measuring both horizontal and vertical movement, mount separate wires to indicate each movement, horizontal or vertical. Measure horizontal movements from two reference wires set normal to each other in a horizontal.

(2) Wooden Reference Beams And Dial Gauges: Attach wooden reference beams as detailed in the plans or approved by the Engineer to independent supports. For piles, install the greater of 3.5 times the pile diameter or width or 10 feet [3 m] from the centerline of the test pile. For drilled shafts install the greater of three shaft diameters or 12 feet [3.7 m] from the centerline of the shaft to be tested. Locate the reference beam supports as far as practical from reaction beam anchorages. For over-water test sites, the Contractor may attach the reference beams as directed by the Engineer between two diagonal platform supports. Attach dial gauges, with their stems resting either on the top of the pile/shaft or on lugs or similar reference points on the pile/shaft, to the fixed beams to record the movement of the pile/shaft head. Ensure that the area on the pile/shaft or lug on which the stem bears is a smooth surface which will not cause irregularities in the dial readings.

For piles, the minimum acceptable method for measuring vertical movement is two dial gauges, each with 0.001 inch [0.025 mm] divisions and with 2 inch [50 mm] minimum travel, placed at 180 degrees or at the diagonal corners of the pile.

For shafts, ensure that three dial gauges, each with 0.001 inch [0.025 mm] divisions and with 2 inch [50 mm] minimum travel, placed at 120 degree intervals around the shaft, are the minimum acceptable method for measuring vertical movement. Ensure that four dial gauges, each with 0.001 inch [0.025 mm] divisions and with 2 inch [50 mm] minimum travel, placed at 90 degree intervals are the minimum required for measuring horizontal movement.

(3) Survey Level: As a check on the dial gauges, determine the elevation of a point near the top of the test pile/shaft (on plan datum) by survey level at each load and unload interval during the load test. Unless approved otherwise by the Engineer, level survey precision is 0.001 foot [0.3 mm]. Alternately, the surveyor may read an engineer's 50 scale attached near the pile/shaft head. Determine the first elevation before applying the first load increment; make intermediate readings immediately before a load increment or an unload decrement, and after the final unload decrement that completely removes the load. Make a final reading at the time of the last recovery reading or as directed by the Engineer.

For over-water test sites, when shown in the plans or directed by the Engineer, the Contractor shall drive an H pile through a 36 inch [914 mm] casing to provide a stable support for the level and to protect it against wave action interfering with level measurements. Provide a suitable movable jig for the surveyor to stand. Use a jig that has a minimum of three legs, has a work platform providing at least 4 feet [1.2 m] width of work area around the casing, and is approved by the Engineer before use. The described work platform may be supported by the protective casing when approved by the Engineer.

455-2.4 Load Test Instrumentation:

(1) General: The intent of the load test instrumentation is to measure the test load on top of the pile/shaft and, when provided in the Contract Documents, its distribution between side friction and end bearing to provide evaluation of the preliminary design calculations and settlement estimates and to provide information for final pile/shaft length design. Ensure that the instrumentation is as described in the Contract Documents.

When requested by the Engineer, provide assistance during installation of any instrumentation supplied by the Department. Supply 110 V, 60 Hz, 30 A of AC electric power in accordance with the National Electric Code to each test pile/shaft site during the installation of the instrumentation, during the load testing, and during any instrumented redrives ordered by the Engineer.

Place all of the internal instrumentation on the rebar cage before installation in the test shaft. Construct the rebar cage at least two days before it is required for construction of the test shaft. Provide assistance during installation of instrumentation supplied by the Department, including help to string, place, and tie the instrumentation and any assistance needed in moving or repositioning the cage to facilitate installation. Place the rebar cage in one segment complete with its instrumentation. The Engineer may require multiple lift points and/or a suitable "stiffleg" (length of H pile or other suitable section) to get the cage in a vertical position without causing damage to the instrumentation. Successfully demonstrate the lifting and handling procedures before the installing instrumentation.

(2) Hydraulic Jack and Load Cell: Provide hydraulic jack(s) of adequate size to deliver the required test load to the pile/shaft unless shown otherwise in the plans. Before load testing begins, furnish a certificate from a reputable testing laboratory

showing a calibration of gauge readings for all stages of jack loading and unloading for jacks provided. Ensure that the jack has been calibrated within the preceding six months unless approved otherwise. Recalibrate the jack after completing load testing if so directed by the Engineer. Ensure that the accuracy of the gauge is within 5% of the true load.

Provide an adequate load cell approved by the Engineer that has been calibrated within the preceding six months. Provide an approved electrical readout device for the load cell. Before beginning load testing, furnish a certificate from a reputable testing laboratory showing a calibration of readings for all stages of loading and unloading for load cells furnished by the Contractor. Ensure that the accuracy of the load cell is within 1% of the true load.

If the Department supplies the Contractor with the jack and/or load cell, have the equipment calibrated and include the cost in the cost for static load test.

(3) Telltales: When shown in the Contract Documents, provide telltales that consist of an unstressed steel rod placed, with appropriate clearance and greased for reducing friction and corrosion, inside a constant-diameter pipe that rests on a flat plate attached to the end of the pipe at a point of interest shown in the plans. Construct telltales in accordance with details shown in the Contract Documents. Install dial gauges reading to 0.001 inch [0.025 mm] with 1 inch [25 mm] minimum travel as directed by the Engineer to measure the movement of the telltale with respect to the top of the pile/shaft.

(4) Embedded Strain Gauges: When shown in the Contract Documents, provide strain gauges which shall be placed in the test shaft to measure the distribution of the load. Ensure that the type, number, and location of the strain gauges are as shown in the plans or as directed by the Engineer. Use strain gauges that are waterproof and have suitable shielded cable that is unspliced within the shaft.

455-2.5 Support Facilities: Furnish adequate facilities for making load and settlement readings 24 hours per day. Provide such facilities for the instrumented area, and include lighting and shelter from rain, wind, and direct sunlight.

455-2.6 Load Test Personnel Furnished by the Contractor: Provide a certified welder, together with necessary cutting and welding equipment, to assist with the load test setup and to make any necessary adjustments during the load test. Provide personnel to operate the jack, generators, and lighting equipment, and also provide one person with transportation to assist as required during load test setup and conducting of the load tests. Provide qualified personnel, as determined by Specialty Engineer or testing lab, required to read the dial gauges, take level measurements, and conduct the load test, except when the Contract Documents show that the Department will provide these personnel.

455-2.7 Cooperation by the Contractor: Cooperate with the Department, and ensure that the Department has access to all facilities necessary for observation of the conduct and the results of the test.

455-2.8 Required Reports: Submit a preliminary static load test report to the Engineer within five days after completing the load test. When the Contract Documents do not require internal instrumentation, submit the final report within ten days after completing the load test. Furnish the final report of test results for internally instrumented shafts within 30 days after completing the load test. Include in the report of the load test the following information:

(1) A tabulation of the time of, and the amount of, the load and settlement readings, and the load and recovery readings taken during the loading and unloading of the pile/shaft.

(2) A graphic representation of the test results, during loading and unloading of pile/shaft top movement as measured by the average of the dial gauge readings, from wireline readings and from level readings.

(3) A graphic representation of the test results, when using telltales, showing pile/shaft compression and pile/shaft tip movement.

(4) The estimated failure and safe loads according to the criteria described herein.

(5) Remarks concerning any unusual occurrences during the loading of the pile/shaft.

(6) The names of those making the required observations of the results of the load test, the weather conditions prevailing during the load test, and the effect of weather conditions on the load test.

(7) All supporting data including jack and load cell calibrations and certificates and other equipment requiring calibration.

(8) When the Contract Document requires internal instrumentation of the pile/shaft, furnish all of the data taken during the load test together with instrument calibration certifications. In addition, provide a report showing an analysis of the results of axial load and lateral load tests in which soil resistance along and against the pile/shaft is reported as a function of deflection.

Provide the necessary report(s) prepared by the qualified Geotechnical Engineer registered in Florida as a Specialty Engineer responsible for collection and interpretation of the data, except when the Contract Documents show that the Department will provide a Geotechnical Engineer.

455-2.9 Disposition of Loading Material: After completing all load tests, clean, remove all rust and debris from Department equipment, repaint all areas having damage to the paint in accordance with Section 561, and return all load test equipment supplied by the Department to its designated storage area. Repair any structural damage to Department owned equipment to the satisfaction of the Engineer. Notify the Department at least ten working days in advance so that arrangements can be made to unload the equipment. Remove all equipment and materials, which remains the Contractor’s property, from the site. Clean up and restore the site to the satisfaction of the Engineer.

455-2.10 Disposition of Tested Piles/Shafts: After completing testing, cut off the tested piles/shafts, which are not to be incorporated into the final structure, and any reaction piles/shafts at an elevation 24 inches [600 mm] below the finished ground surface. Take ownership of the cut-offs and provide areas for their disposal.

B. PILING

455-3 Description.

Furnish and install concrete, steel, or wood piling including driving, jetting, preformed pile holes, cutting off, splicing, dynamic load testing, and static load testing of piling.

455-4 Classification.

The Department classifies piling as follows:

(1) Treated timber piling.
(2) Prestressed concrete piling.
(3) Steel piling.
(4) Test piling.
(5) Sheet piling.
(a) Concrete sheet piling.
(b) Steel sheet piling.

455-5 General Requirements.

455-5.1 Site Preparation:

455-5.1.1 Predrilling of Pile Holes: Predrilled pile holes are either 4 foot [1.2 m] maximum depth starter holes or holes drilled through embankment/fill material down to the natural ground surface. When using low displacement steel piling such as structural shapes, drive them through the compacted fill without the necessity of drilling holes through the fill except when the requirements for predrilling are shown in the plans. When using concrete or other high displacement piles, drill pile holes through fill, new or existing, to at least the elevation of the natural ground surface. Use the drill diameters listed below for square concrete piles.

12 inch [305mm] square piles.............. 15 inches [380 mm]
14 inch [355 mm] square piles............. 18 inches [460 mm]
18 inch [455 mm] square piles............. 22 inches [560 mm]
20 inch [510 mm] square piles............. 24 inches [610 mm]
24 inch [610 mm] square piles............. 30 inches [760 mm]
30 inch [760 mm] square piles............. 36 inches [910 mm]

For other pile sizes, use the diameter of the drills shown in the plans or approved by the Engineer. Accurately drill the pile holes with the hole centered over the plan location of the piling. Maintain the location and vertical alignment within the tolerances allowed for the piling.

For predrilled holes required through rock or other hard (i.e. debris, obstructions, etc.) materials that may damage the pile during installation, predrill hole diameters approximately 2 inches [50 mm] larger than the largest dimension across the pile cross-section. For predrilled holes which are required through material that caves during driving to the extent that the predrilled hole does not serve its intended purpose, case the hole from the embankment surface to the approximate elevation of the natural ground surface. After driving the piles and obtaining the Engineer’s acceptance, remove the casings unless shown otherwise in the plans and fill the annular space around the piles with concrete sand or other approved clean sand in a manner approved by the Engineer after driving the pile.

In the setting of permanent and test piling, the Contractor may initially predrill holes to a depth up to 4 feet [1.2 m], except that, where installing piles in compacted fill, predrill the holes to the elevation of the natural ground surface. With prior written authorization from the Engineer, the Contractor may predrill holes to depths greater than 4 feet [1.2 m], to minimize the effects of vibrations on existing structures adjacent to the work and/or for other reasons the Contractor proposes. Perform such work the Engineer allows but does not require at no expense to the Department. When the Engineer requires such work, the Department will pay for the additional cost of such work beyond the initial 4 feet [1.2 m] as Preformed Pile Holes as described in 455-5.9.

Fill any voids between the pile and soil remaining after driving through predrilled holes with concrete sand or other approved clean sand.

455-5.1.2 Underwater Driving: Underwater driving is defined as any driving through water which is above the pile head at the time of driving.

When conducting underwater driving, provide a diver equipped with voice communications to aid in placing the hammer back on the pile for required cushion changes or for subsequent redriving, to attach or recover instrumentation the Engineer is using, to inspect the condition of the pile, or for other assistance as required.

Select one of the following methods for underwater driving:

(a) Accomplish underwater driving using conventional driving equipment and piling longer than authorized so that the piling will extend above the water surface during final driving. When choosing this option, furnish a pile hammer that satisfies the requirements of this Section for use with the longer pile.

(b) Accomplish underwater driving using an underwater hammer that meets the requirements of this Section and is approved by the Engineer. When choosing this option, provide at least one pile longer than authorized at each pile group, extending above the water surface at final driving. At each group location, drive the longer pile first. The Engineer will evaluate the adequacy of the underwater driving system. The Engineer may use the pile tip elevation of the longer pile that the Contractor has driven and the Engineer has accepted, to evaluate the acceptability of the piles driven with the underwater hammer.

(c) Accomplish underwater driving using conventional driving equipment with a suitable approved pile follower. When choosing this option, provide at least one pile longer than required at each pile group, extending above the water surface at final driving. At each group location, drive the full length pile first without using the follower. The Engineer will evaluate the adequacy of the follower used for underwater driving. The Engineer may choose to perform a dynamic load test on the first pile the Contractor drives with the follower in each group. The Engineer may use the pile tip elevation of the longer pile, that the Contractor has driven and the Engineer has accepted, to evaluate the acceptability of the piles driven with the follower.

Prior to use, submit details of the follower for the Engineer’s evaluation and approval along with the information required in 455-10. Include the weight, cross-section details, stiffness, type of materials, and dimensions of the follower.

455-5.2 Pile Hammers: Furnish to the Engineer all technical specifications and operating instructions related to hammer equipment. All equipment is subject to satisfactory field performance. Use a variable energy hammer to drive concrete piles. Hammers will be rated based on the theoretical energy of the ram at impact. Supply driving equipment which provides the required resistance at a blow count ranging from 3 blows per inch [3 blows per 25 mm] (36 blows per foot [36 blows per 300 mm]) to 10 blows per inch [10 blows per 25 mm] (120 blows per foot [120 blows per 300 mm]) at the end of initial drive, unless approved otherwise by the Engineer after satisfactory field trial. When the Engineer determines the stroke height or bounce chamber pressure readings do not adequately determine the energy of the hammer, provide and maintain a device to measure the velocity of the ram at impact. Determine the actual hammer energy in the field so that it is consistent with the hammer energy used for each bearing capacity determination.

455-5.2.1 Air/steam: Variable energy air/steam hammers shall be capable of providing at least two ram stroke lengths. The short ram stroke length shall be approximately half of the full stroke for hammers with strokes up to 4 feet [1.2 m] and no more than 2 feet [0.6 m] for hammers with maximum strokes lengths over 4 feet [1.2 m]. Operate and maintain air/steam hammers within the manufacturer's specified ranges. Use a plant and equipment for steam and air hammers with sufficient capacity to maintain, under working conditions, the hammer, volume and pressure specified by the manufacturer. Equip the plant and equipment with accurate pressure gauges which are easily accessible to the Engineer. The Engineer will not accept final bearing on piles the Contractor drives with air/steam hammers unless the Contractor operates the hammers within 10% of the manufacturer's rated speed in blows per minute, unless otherwise authorized by the Engineer.

455-5.2.2 Diesel: Variable energy diesel hammers shall have at least three fuel settings that will produce reduced strokes. Operate and maintain diesel hammers within the manufacturer's specified ranges. Determine the rated energy of diesel hammers using measured ram stroke length multiplied by the weight of the ram for open end hammers and by methods recommended by the manufacturer for closed end hammers.

Equip open-end (single acting) diesel hammers with a scale (jump stick) extending above the ram cylinder to permit the Engineer to visually determine the hammer stroke at all times during pile driving operations. Provide the Engineer with a chart from the hammer manufacturer equating stroke and blows per minute for the open-end diesel hammer to be used. Also provide and maintain in working order for the Engineer's use an approved device to automatically determine and display ram stroke for open-end diesel hammers.

Equip closed-end (double acting) diesel hammers with a bounce chamber pressure gauge, in good working order, mounted near ground level so the Engineer can easily read. Also, provide the Engineer with a chart, calibrated to actual hammer performance within 30 days prior to initial use, equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used.

455-5.2.3 Hydraulic: Variable energy hydraulic hammers shall have at least three hydraulic control settings that provide for predictable stroke control. The shortest stroke shall be a maximum of 2 feet [0.6 m] for the driving of concrete piles. The remaining strokes shall be full stroke and approximately halfway between minimum and maximum stroke.

Determine the hammer energy according to the manufacturer's recommendations. When pressure measuring equipment is required to determine hammer energy, calibrate the pressure gauges before use.

455-5.2.4 Vibratory: Vibratory hammers of sufficient capacity (force and amplitude) may be used to drive steel sheet piles and, with approval of the Engineer, to drive steel bearing piles a sufficient distance to get the impact hammer on the pile (to stick the pile). The Engineer will determine the allowable depth of driving using the vibratory hammer based on site conditions. However, in all cases, use a power impact hammer for the last 15 feet [4.5 m] or more of the final driving of steel bearing piles for bearing determinations after all piles in the bent/pier have been driven with a vibratory hammer. Do not use vibrating hammers to install concrete piles, or to install support or reaction piles for a load test.

455-5.3 Cushions and Pile Helmet:

455-5.3.1 Capblock: Provide a capblock cushion (also called the hammer cushion) as recommended by the hammer manufacturer. Use capblocks constructed of durable manmade materials with uniform known properties. Do not use wood chips, wood blocks, rope, cable, or other material which permit excessive loss of hammer energy. Do not use capblocks constructed of asbestos materials. Obtain the Engineer’s approval for all proposed capblock materials and proposed thickness for use. Maintain capblocks in good condition, and change them when charred, melted, or otherwise significantly deteriorated. The Engineer will inspect the capblock before driving begins and weekly or at appropriate intervals determined by the Engineer based on field trial. Replace or repair any hammer cushion which loses more than 25% of its original thickness, in accordance with the manufacturer's instructions, before permitting further driving.

455-5.3.2 Pile Cushion: Provide a pile cushion that is adequate to protect the pile from being overstressed in compression and tension during driving. Use a pile cushion sized so that it will fully fill the lateral dimensions of the pile helmet. Determine the thickness based upon the hammer-pile-soil system. For driving concrete piles, use a pile cushion made from pine plywood. Alternative materials may be used with the approval of the Engineer. Obtain the Engineer’s approval for all pile cushions. Maintain pile cushions in good condition and change when charred, splintered, excessively compressed, or otherwise deteriorated to the point it will not protect the pile against overstressing in tension and/or compression. Protect cushions from the weather, and keep them dry. Do not soak the cushions in any liquid unless approved by the Engineer. Replace the pile cushion if, during the driving of any pile, the cushion is either compressed more than one-half the original thickness or begins to burn. Provide a new cushion for each pile unless approved otherwise by the Engineer after satisfactory field trial.

Reuse pile cushions in good condition to perform all set-checks and redrives. Use the same cushion to perform the set-check or redrive as was used during the initial driving, unless this cushion is unacceptable due to deterioration, in which case use a similar cushion.

455-5.3.3 Pile Helmet: Provide a pile helmet suitable for the type and size of piling being driven. Use a pile helmet deep enough to adequately contain the required thickness of pile cushion and to assist in maintaining pile-hammer alignment. Use a pile helmet that fits loosely over the pile head and is at least 1 inch [25 mm] larger than the pile dimensions. Use a pile helmet designed so that it will not restrain the pile from rotating.

455-5.4 Leads: Provide pile leads constructed in a manner which offers freedom of movement to the hammer and that have the strength and rigidity to hold the hammer and pile in the correct position and alignment during driving. When using followers, use leads that are long enough and suitable to maintain position and alignment of the hammer, follower, and pile throughout driving.

455-5.5 Followers: Use followers only for underwater driving. Obtain the Engineer's approval for the type of follower, when used, and the method of connection to the leads and pile. Use followers constructed of steel with an adequate cross-section to withstand driving stresses. When driving concrete piles, ensure that the cross-sectional area of the follower is at least 18% of the cross-sectional area of the pile. When driving steel piles, ensure that the cross-sectional area of the follower is greater than or equal to the cross-sectional area of the pile. Provide a pile helmet at the lower end of the follower sized according to the requirements of 455-5.3.3. Use followers constructed that maintain the alignment of the pile, follower, and hammer and still allow the pile to be driven within the allowable tolerances. Use followers designed with guides adapted to the leads that maintain the hammer, follower, and the piles in alignment.

Use information from driving full length piles described in 455-5.1.2 compared to driving piles with the follower and/or dynamic load tests described in 455-5.13 to evaluate the adequacy of the follower and to establish the blow count criteria when using the follower.

455-5.6 Templates: Provide a fixed template, adequate to maintain the pile in proper position and alignment during driving with swinging leads or with semi-fixed leads. For piles on land, locate the template within 5 feet [1.5 m] of cutoff or within 5 feet [1.5 m] of ground line, whichever is less. For piles in water, locate the template within 5 feet [1.5 m] of cutoff or within 5 feet [1.5 m] of the waterline, whichever is less. Do not use floating templates (attached to a barge). Where practical, place the template so that the pile can be driven to cut-off elevation before removing the template. When proposing to use a free hammer, provide a rigid double template that will independently support the pile. Provide free hammers with approved guide extensions that hold the hammer in alignment with the pile to ensure that the hammer blow is applied axially to the pile at all times. When driving piles with a follower using floating equipment, provide a double template or other approved equipment to maintain alignment of the hammer, follower, and pile. Use a double template consisting of a pile template within 5 feet [1.5 m] of cut-off elevation and a second upper support above the water surface for the leads. Where practical, place the template so that the pile can be driven to cut-off elevation before removing the template. Ensure that the individual pile positions of the second upper template are adjustable in size to serve as a guide for both the pile and follower. Ensure that templates do not restrict the vertical movement of the pile.

455-5.7 Water Jets: Use jet pumps, supply lines, and jet pipes that provide adequate pressure and volume of water to freely erode the soil. Do not perform jetting without prior approval by the Engineer or unless allowed by the plans.

Do not perform jetting in the embankment. Where conditions warrant, with approval by the Engineer, perform jetting on the holes first, place the pile therein, then drive the pile to secure the last few feet [meters] of penetration. Only use one jet for prejetting or jetting through piles constructed with a center jet-hole. Use two jets when using external jets. When jetting and driving, position the jets slightly behind the advancing pile tip (approximately 3 feet [0.9 m] or as approved by the Engineer). When using water jets in the driving, determine the pile bearing only from the results of driving after withdrawing the jets, except where using jets to continuously eliminate soil resistance through the scour zone, ensure that they remain in place as directed by the Engineer and operating during pile bearing determination. Where practical, perform jetting on all piles in a pile group before driving begins. When large pile groups or pile spacing and batter make this impractical, or when the plans specify a jet-drive sequence, set check a sufficient number of previously driven piles in a pile group to confirm their capacity after completing all jetting.

455-5.8 Penetration Requirements: Measure the penetration of piles from the elevation of natural ground, scour elevation shown in the plans, or the bottom of excavation, whichever is lower. When the Contract Documents show a minimum pile tip elevation or a minimum depth of penetration, drive the tip of the pile to this minimum elevation or this minimum penetration depth. In all such cases, the Engineer will accept the bearing of a pile only if the Contractor achieves the required bearing when the tip of the pile is at or below the specified minimum tip elevation or depth of penetration and below the bottom of the preformed or predrilled pile hole.

When the plans do not show a minimum depth of penetration, scour elevation, or minimum tip elevation, ensure that the required penetration is at least 10 feet [3 m] into firm bearing material or at least 20 feet [6 m] into soft material unless otherwise permitted by the Engineer. If a scour elevation is shown in the plans, achieve these penetrations below the scour elevation. The Engineer may accept a penetration between 15 and 20 feet [4.5 and 6 m] when there is an accumulation of five consecutive feet [1.5 consecutive meters] or more of firm bearing material. Firm bearing material is any material offering a driving resistance greater than or equal to 30 tons/ft^2 [3 MPa] of gross pile area as determined by the Wave Equation (45-5.11.2). Soft material is any material offering less than these resistances. The gross pile area is the actual pile tip cross-sectional area for solid concrete piles, the product of the width and depth for H piles, and the area within the outside perimeter for pipe piles and voided concrete piles.

Do not drive piles beyond practical refusal (20 blows per inch [25 mm]). To meet the requirements in this Subarticle, provide penetration aids, such as jetting or preformed pile holes, when piles cannot be driven to the required penetration without reaching practical refusal.

If the Contractor encounters unforeseeable, isolated obstructions that the Contractor cannot practically penetrate by driving, jetting, or preformed pile holes, and the Contractor must remove the pile to obtain the required pile penetration, the Department will pay the costs for such removal as Unforeseeable Work.

455-5.9 Preformed Pile Holes:

455-5.9.1 Description: Preformed Pile Holes are holes necessary due to the presence of rock or strong strata of soils which will not permit the installation of piles to the desired penetration by driving or a combination of jetting and driving, or holes determined necessary by the Engineer or when authorized by the Engineer to minimize the effects of vibrations on adjacent existing structures. The Engineer may require preformed holes for any type of pile. Preformed Pile Holes serve as a penetration aid when all other pile installation methods fail to produce the desired penetration and when authorized by the Engineer to minimize the effects of vibrations on adjacent structures. Drive all piles installed in Preformed Pile Holes to determine that the bearing requirements have been met.

Fill all voids between the pile and soil remaining after driving through preformed holes with concrete sand or clean sand.

455-5.9.2 Provisions for Use of Preformed Pile Holes: The Department generally anticipates the necessity for Preformed Pile Holes and includes directions in the Contract Documents. The Department will pay for Preformed Piles Holes when the Contractor establishes that the required results cannot be obtained when driving the load bearing piles with specified driving equipment, while jetting the piles and then driving, or while jetting the piles during driving.

455-5.9.3 Conditions Under Which Payment Will Be Made: The Department will make payment for Preformed Pile Holes where the Contractor demonstrates that such work is necessary to achieve the required penetration of the pile. The Department considers, but does not limit to, the following conditions as reasons for Preformed Pile Holes:

(a) Inability to drive piles to the required penetration with driving and jetting equipment.

(b) To penetrate a hard layer or layers of rock or strong stratum that the Engineer considers not sufficiently thick to support the structure.

(c) To obtain greater penetration into dense (strong) material and into dense material containing holes, cavities or unstable soft layers.

(d) To obtain penetration into a stratum in which it is desired to found the structure.

(e) To minimize the effects of vibrations or heave on adjacent existing structures.

(f) To obtain a penetration up to 20 feet [6 m] except where the Contract Documents show a required pile penetration in excess of 20 feet [6 m].

(g) To minimize the effects of ground heave on adjacent piles.

455-5.9.4 Construction Methods: Construct Preformed Pile Holes by drilling, or driving and withdrawing a suitable punch or chisel at the locations of the piles. Construct a hole that is equal to or slightly greater than the pile and of sufficient depth to obtain the required penetration. Carefully form the preformed hole by using a drill or punch guided by a template or other suitable device, and do not exceed the minimum dimensions necessary to achieve the required penetration of the pile. When Preformed Pile Holes are oversized to the extent that the sides of the pile are not in contact with the soil and the pile has inadequate lateral stability, restore lateral stability by filling the space between the pile and the sides of the hole with concrete sand or other approved clean sand. When the plans call for grouting the Preformed Pile Holes, provide the minimum dimension of the pile hole that is 2 inches [50 mm] larger than the largest pile dimension. Construct the holes at the plan position of the pile and the tolerances in location, and ensure that the batter is the same as allowed for the pile.

455-5.9.5 Grouting of Pile Holes: Grout Preformed Pile Holes for bearing piles, when the plans require grouting after driving. Clean the Preformed Pile Holes, and fill them with cement grout as shown in the plans. Use grout that has a minimum compressive strength of 3,000 psi [20 MPa] at 28 days or as specified. Pump the grout through three or more grout pipes initially placed at the bottom of the preformed hole. The Contractor may raise the grout pipes when necessary to prevent clogging and to complete the grouting operations. Maintain the grout pipes below the surface of the previously placed grout. Continue grouting until the grout reaches the ground surface all around the pile. Provide divers to monitor grouting operations when the water depth is such that it is impractical to monitor from the ground surface. When grouting is shown in the plans, include the cost in the price for Piles. In the event that the Engineer determines the Contractor must grout and the required grouting is not shown in the plans, the Department will pay for the grouting work as Unforeseeable Work.

455-5.10 Bearing Requirements:

455-5.10.1 General: Drive piles to provide the bearing capacities required for carrying the loads shown in the plans. For all types of bearing piles, consider the driving resistance as determined by the methods described herein sufficient for carrying the specified loads as the minimum bearing which is accepted for any type of piles. Determine pile bearing using the method described herein or as shown in the plans.

The Engineer may accept a driven pile when the pile has achieved minimum penetration, the blow count is generally increasing and the minimum required bearing capacity obtained for 24 inches [600 mm] of consecutive driving. At his discretion, the Engineer may also accept a driven pile when the minimum penetration is achieved and driving has reached practical refusal in firm material.

455-5.10.2 Blow Count Criteria: The Engineer will determine the number of blows required to provide the required bearing according to the methods described herein. Determine the pile bearing by computing the penetration per blow with less than 1/4 inch [6 mm] rebound averaged through 12 inches [300 mm] each of penetration. When it is considered necessary by the Engineer, the Contractor may determine the average penetration per blow by averaging the penetration per blow through the last 10 to 20 blows of the hammer.

455-5.10.3 Practical Refusal: Practical refusal is defined as 20 blows per inch [20 blows per 25 mm] with the hammer operating at the highest setting or setting determined by the Engineer and less than 1/4 inch [6 mm] rebound per blow. Stop driving as soon as the Engineer determines that the pile has reached practical refusal. The Engineer will generally make this determination within 2 inches [50 mm] of driving. However, the Engineer will in no case approve the continuation of driving at practical refusal for more than 12 inches [300 mm]. When the required pile penetration cannot be achieved by driving without exceeding practical refusal, use other penetration aids such as jetting or Preformed Pile Holes.

455-5.10.4 Set-checks and Pile Redrive:

(a) Set-checks: In the event that the Contractor has driven the pile to approximately 12 inches [300 mm] above cut-off without reaching the required resistance, the Engineer may require the Contractor to interrupt driving at least 15 minutes prior to performing a set-check. A set-check consists of ten hammer blows or 10 inches [250 mm] or more of driving. Provide an engineer’s level or other suitable equipment for elevation determinations to determine accurate pile penetration during the set-checks. There will be no separate payment for an initial set-check. In the event the result of an initial set-check is not satisfactory, the Engineer may direct additional set-checks. For each additional set-check ordered by the Engineer within 72 hours from the end of original driving, the Contractor will be paid an additional quantity of 10 feet [3 m] of Piling. The Engineer may accept the pile as driven when a set-check shows that the

Contractor has achieved the minimum required pile bearing and has met all other requirements of this Section.

(b) Pile Redrive: Pile Redrive consists of redriving the pile after 72 hours from original driving to determine time effects, to reestablish pile capacity due to pile heave, or for other reasons determined by the Engineer. Redrive piles as directed by the Engineer. Redrives may range from ten hammer blows to 12 inches [300 mm] or more of driving.

455-5.10.5 Pile Heave: Pile heave is the upward movement of a pile from its originally driven elevation. Drive the piles in an approved sequence to minimize the effects of heave and lateral displacement of the ground. Monitor piles previously driven in a pile group for possible heave during the driving of the remaining piles. When required by the Engineer, take elevation measurements to determine the magnitude of the movement of piles and the ground surface resulting from the driving process. Redrive all piles that have heaved 1/4 inch [6 mm] or more unless the Engineer determines that the heave is not detrimental to pile capacity. The Department will pay for all work in conjunction with redriving piles due to pile heave under the Pile Redrive item.

455-5.10.6 Piles with Insufficient Bearing: In the case that the Engineer determines that the safe bearing capacity of any pile is less than the required bearing capacity, the Contractor may splice the pile and continue driving or may extract the pile and drive a pile of greater length, or, if so ordered by the Engineer, drive additional piles until reducing the required bearing per pile to the determined bearing capacity of the piles already driven.

455-5.11 Methods to Determine Pile Capacity:

455-5.11.1 General: Dynamic load test will be used to determine pile capacity for all structures or projects unless shown otherwise in the Contract Documents. When necessary, the Engineer may require static load tests to confirm pile capacities. When the Contract Documents do not include items for static load tests, the Engineer will consider all required testing Unforeseeable Work. When considered necessary by the Engineer, adjust the blow count criteria to match the resistance determined from static load tests.

455-5.11.2 Wave Equation:

General: Use Wave Equation Analysis for Piles (WEAP) programs to evaluate the suitability of the proposed driving system (including the hammer, follower, capblock and pile cushions) as well as to estimate the driving resistance, in blows per 12 inches [300 mm] or blows per inch [25 mm], to achieve the pile bearing requirements and to evaluate pile driving stresses.

The Engineer may modify the scour resistance shown in the plans if the dynamic load test is used to determine the actual soil resistance through the scour zone. Also, the Engineer may make modifications in scour resistance when the Contractor proposes drilling and/or jetting to reduce the soil resistance in the scour zone.

Use Wave Equation Analyses to show the hammer is capable of driving to a resistance equal to at least2.0 times the factored design load plus the scour and down drag resistance (if applicable) shown in the Contract Documents, without overstressing the piling in compression or tension and without reaching practical refusal (20 blows per inch [20 blows per 25 mm]). Ensure that the hammer provided also meets the requirements described in 455-5.2.

(b) Required Equipment For Driving: Hammer approval is solely based on satisfactory field trial including PDA, CAPWAP and Wave Equation Analysis. Supply a hammer system that meets the requirements described in the specifications based on the above analysis. Obtain approval from the Engineer for the pile driving system based on satisfactory field performance.

In the event piles require different hammer sizes, the Contractor may elect to drive with more than one size hammer or with a variable energy hammer, provided the hammer is properly sized and cushioned, will not damage the pile, and will develop the required resistance.

(c) Maximum Allowed Pile Stresses:

(1) General: The maximum allowed driving stresses for concrete, steel, and timber piles are given below. In the event Wave Equation analyses show that the hammer will overstress the pile, modify the driving system or method of operation as required to prevent overstressing the pile. In such cases provide additional cushioning or make other appropriate agreed upon changes. For penetration of weak soils by concrete piles, use thick cushions and/or reduced stroke to control tension stresses during driving.

(2) Concrete Piles: Use the wave equation to evaluate the proposed pile cushioning. Use the following equations to determine the maximum allowed pile stresses as predicted by the wave equation, and/or measured during driving when driving prestressed concrete piling:

Non SI Units

$$s_{apc} = 0.7\ f_c' - 0.75\ f_{pe} \qquad (1)$$

$$s_{apt} = 6.5\,(f_c')^{0.5} + 1.05\ f_{pe} \qquad (2a)$$

for piles less than 50 feet long

$$s_{apt} = 3.25\,(f_c')^{0.5} + 1.05\ f_{pe} \qquad (2b)$$

for piles 50 feet long and greater

$s_{apt} = 800$ (2b) within 10 feet of a mechanical splice

where:

s_{apc}= maximum allowed pile compressive stress, psi
s_{apt}= maximum allowed pile tensile stress, psi
f'_c= specified minimum compressive strength of concrete, psi
f_{pe}= effective prestress (after all losses) at the time of driving, psi, taken as 0.8 times the initial prestress force (f_{pe}= 0 for dowel spliced piles).

SI Units

$s_{apc} = 0.7 f_c' - 0.75 f_{pe}$ (1)

$s_{apt} = 0.54 (f_c')^{0.5} + 1.05\ f_{pe}$ (2a) for piles less than 15 m long

$s_{apt} = 0.27 (f_c')^{0.5} + 1.05\ f_{pe}$ (2b) for pile over 15 m long and greater

$s_{apt} = 5.52$ (2c) within 3 m of a mechanical splice

where:

s_{apc}= maximum allowed pile compressive stress, MPa
s_{apt}= maximum allowed pile tensile stress, MPa
f_c'= specified minimum compressive strength of concrete, MPa
f_{pe}= effective prestress (after all losses) at the time of driving, MPa, taken as 0.8 times the initial prestress force (f_{pe}= 0 for dowel spliced piles).

(3) Steel Piles: Ensure the maximum allowed pile compression and tensile stresses as predicted by the Wave Equation, and/or measured during driving are no greater than 0.9 times the yield strength (0.9 f_y) of the steel.

(4) Timber Piles: Ensure the maximum allowed pile compression and tensile stresses as predicted by the wave equation, and/or measured during driving are no greater than 3.6 ksi [25 MPa] for Southern Pine and Pacific Coast Douglas Fir and 0.9 of the ultimate parallel to the grain strength for piles of other wood.

455-5.11.3 Temporary Piles: Submit for the Engineers approval, a Wave Equation analysis signed and sealed by a Specialty Engineer which establishes the driving criteria for temporary piles. The required driving resistance is equal to the design (service) load multiplied by the appropriate factor of safety plus the scour and down drag resistance shown in the plans (no safety factor is required) or the ultimate bearing capacity shown in the plans, whichever is higher.

The factor of safety applied to the design (service) load is:

2.0....................... when static load tests are required.
2.5...........................when the Pile Driving Analyzer ....and Wave Equation Analysis are required.
3.0 when only the Wave Equation Analysis is required.

455-5.11.4 Dynamic Load Tests: Dynamic load testing consists of predicting pile capacity from blows of the hammers during drive and/or redrive of an instrumented pile.

455-5.11.5 Static Load Tests: Static load testing consists of applying a static load to the pile to determine its capacity. Use The Modified Quick Test Procedure in accordance with 455-2.2.1.

455-5.11.6 Fender Pile Installation: For piles used in fender systems, regardless of type or size of pile, either drive them full length or jet the piles to within

2 feet [600 mm] of cutoff and drive to cutoff elevation to seat the pile. The Engineer will not require a specific driving resistance unless noted in the plans. Use methods and equipment for installation that do not damage the piles. If the method or equipment used causes damage to the pile, modify the methods or equipment at no expense to the Department.

455-5.12 Test Piles:

455-5.12.1 Description: Drive piles of the same cross-section and type as the permanent piles shown in the plans, in order to determine any or all of the following:

(a) the installation criteria for the piles.

(b) the nature of the soil.

(c) the lengths of permanent piles required for the work.

(d) the driving resistance characteristics of the various soil strata.

(e) the amount of work necessary to obtain minimum required pile penetration.

(f) the ability of the driving system to do the work.

(g) the need for point protection.

Because test piles are exploratory in nature, drive them harder (within the limits of practical refusal), deeper, and to a greater bearing resistance than required for the permanent piling.Except for test piles which are to be statically (or Statnamically) load tested, drive test piles their full length or to practical refusal. Build up test piles which have been driven their full length and have developed only minimal required bearing, and proceed with further driving.

As a minimum, unless otherwise directed by the Engineer, do not cease driving of test piles until obtaining the required bearing capacity continuously, where the blow count is increasing, for 10 feet [3 m] unless reaching practical refusal first. For test piles which are to be statically (or Statnamically) load tested, ignore this minimum and drive these piles as anticipated for the production piles.

When test piles attain practical refusal prior to attaining minimum penetration, perform all work necessary to attain minimum penetration and the required bearing. Where practical, use water jets to break the pile loose for further driving. Where jetting is impractical, extract the pile and install a Preformed Pile Hole through which driving will continue. The Department will consider the work of extracting the pile to be Unforeseeable Work.

When driving test piles other than low displacement steel test piles, have water jets as specified in 455-5.7 and preforming equipment available at the site, ready for use, before the test pile driving begins.

The Engineer may elect to interrupt pile driving up to four times on each test pile, two times for 15 minutes and two additional times within 72 hours of initial driving to determine time effects during the driving of test piles at no additional cost to the Department. If set-checks are determined necessary by the Engineer after 72 hours from the end of initial driving, each set-check will be paid for as Pile Redrive.

Install instruments on test piles when dynamic load tests are included in the plans or when directed by the Engineer.

455-5.12.2 Location of Test Piles: Drive all test piles in the position of permanent piles at the designated locations. Ensure that all test piles designated to be statically load tested are plumb. In the event that all the piles are battered at a static load test site, the Engineer will designate an out-of-position location for driving a plumb pile for the static load test.

455-5.12.3 Equipment for Driving: Use the same hammer and equipment for driving test piles as for driving the permanent piles. Also use the same equipment to redrive piles.

455-5.12.4 Ground Elevations: At the time of driving test piles, furnish the Engineer with elevations of the original ground and template at each pile or pile group location. Note the highest and lowest elevation at each required location and the ground elevation at all the test piles. Present the elevations in plotted and tabular form and submit with the test pile data.

455-5.13 Dynamic Load Tests: The Engineer will take dynamic measurements during the driving of piles designated in the plans or authorized by the Engineer as Dynamic Load Test Piles. Install instruments on test piles and selected permanent piles for dynamic load testing. When the Contract Documents include Dynamic Load Tests, all test piles will have dynamic load tests. The Engineer will perform Dynamic Load Tests to evaluate any or all of the following:

1. Evaluate suitability of Contractor’s driving equipment, including hammer, capblock, pile cushion, and any proposed follower.
2. Determine pile capacity.
3. Determine pile stresses.
4. Determine energy transfer to pile.
5. Determine distribution of soil resistance.
6. Evaluate soil variables including quake and damping.
7. Evaluate hammer-pile-soil system for Wave Equation analyses.
8. Evaluate pile installation problems.
9. Other.

Attach instruments (strain transducers to measure force and accelerometers to measure acceleration) with screws to the pile for dynamic load testing. To allow the Engineer to perform dynamic load testing, supply 110 V, 60 Hz, 30 A of AC electric power to operate an electric drill and to operate the pile driving analyzer equipment. When required in the plans, also provide a suitable shelter within 50 feet [15 m] and within view of the test location to protect the equipment from the elements. Ensure that this shelter is 7 feet [2 m] high and 8 by 8 feet [2.5 by 2.5 m] in plan. Provide a suitable man basket, having a working area of at least 4 by 4 feet [1.2 by 1.2 m] with 4 foot [1.2 m] high safety rails all around, to be lifted by the crane, for use as required, to provide access to the top of the pile. Supply a stable platform which is satisfactory, in the opinion of the Engineer, for reference of the pile penetration.

Make each pile to be dynamically tested available to drill holes for attaching instrumentation and for wave speed measurements. Support the pile with timber blocks placed at appropriate intervals. Ensure that the pile is in a horizontal position and does not contact adjacent piles. Provide a sufficient clear distance at the sides of the pile for drilling the holes. The Engineer will furnish the equipment, materials, and labor necessary for drilling holes and taking the wave speed measurements. If the Engineer directs dynamic load testing of piles already driven, provide the Engineer safe access to the top of the piles for drilling the attachment holes. After placing the leads provide the

Engineer reasonable means of access to the piles to attach the instruments and for removal of the instruments after completing the pile driving.

The Engineer will monitor the stresses in the piles with the dynamic test equipment during driving to ensure the Contractor does not exceed the maximum allowed stresses. If necessary, add additional cushioning, replace the cushions, or reduce the hammer stroke to maintain stresses below the maximum allowable. If dynamic test equipment measurements indicate non-axial driving, immediately realign the driving system. If the cushion is compressed to the point that a change in alignment of the hammer will not correct the problem, add cushioning or change the cushion as directed by the Engineer.

Drive the pile to the required penetration and resistance or as directed by the Engineer. The Engineer may elect to interrupt driving for up to two waiting periods, 60 minutes each (set-checks) during the initial driving of the pile. Dynamic load testing of a pile may average up to two hours longer than for driving an uninstrumented pile.

When directed by the Engineer, perform instrumented redrives. Do not use a cold diesel hammer for a redrive unless in the opinion of the Engineer it is impractical to do otherwise. Generally, warm up the hammer by driving another pile or applying at least 20 blows to a previously driven pile or to timber mats placed on the ground.

455-5.14 Pile Lengths:

455-5.14.1 Test Pile Length: Provide the length of test piles shown in the plans or as directed by the Engineer.

455-5.14.2 Production Pile Length: When shown in the plans, the lengths are based on information available during design and are approximate only. The Engineer will determine final pile lengths in the field which may vary significantly from the lengths or quantities shown in the plans.

455-5.14.3 Authorized Pile Lengths: The authorized pile lengths are the lengths determined by the Engineer based on all information available before the driving of the permanent piles, including, but not limited to, information gained from the driving of test piles, dynamic load testing, static load testing, supplemental soil testing, etc. When authorized by the Department, soil freeze information obtained during set checks and pile redrives may be used to determine authorized pile lengths for sites with extreme soil conditions. These lengths represent the lengths the Department has assumed will remain in the completed structure. The Contractor may elect to provide piling with lengths longer than authorized to suit his method of installation or schedule. When the Contractor elects to provide longer than authorized pile lengths, the Department will pay for the furnished length as either the originally authorized length or the length between cut-off elevation and the final accepted pile tip elevation, whichever is the longer length.

Within 30 days after driving all the test piles, completing all load tests, completing all redrives, and receiving all test reports, the Engineer will furnish the Contractor an itemized list of authorized pile lengths and driving criteria. Use these lengths for furnishing the permanent piling for the structure. If the Contractor is willing to start his pile driving operations in phases designated by the Engineer, and if the Contractor so requests in writing at the beginning of the test pile program, the Department will furnish pile lengths and driving criteria for these designated phases within seven days after driving all the test piles, completing all load tests, completing all redrives, and receiving all test reports for those designated phases.

On multiple phase projects, the Engineer will not furnish pile lengths on subsequent phases until completing the piling on initial phases.

455-5.15 Allowable Driving Tolerances:

455-5.15.1 General: Meet the tolerances described in this Subarticle to the piles that are free standing without lateral restraint (after the template is removed). After the piles are driven, do not move the piles laterally to force them to be within the specified tolerances. The Contractor may move battered piles laterally to overcome the dead load deflections caused by the pile's weight. When this is necessary, submit calculations signed and sealed by a Specialty Engineer to the Engineer that verify the amount of dead load deflection prior to moving any piles.

455-5.15.2 Position: Ensure that the final position of the pile head at cut-off elevation is no more than 3 inches [75 mm] from the plan position indicated in the plans.

455-5.15.3 Axial Alignment: Ensure that the axial alignment of the driven piles does not deviate by more than 1/4 in/ft [20 mm/m] from the vertical or batter line indicated in the plans.

455-5.15.4 Elevation: Ensure that the final elevation of the pile head is no more than 1 1/2 inches [38 mm] above, or more than 4 inches [100 mm] below, the elevation shown in the plans. Do not embed the pile less than 6 inches [150 mm] below the elevation shown in the plans unless a minimum penetration requirement is shown.

455-5.15.5 Deviation From Above Tolerances: When the Contractor has failed to meet the above tolerances, the Contractor may request design changes in the pile caps or footings to incorporate piles driven out of tolerance. Bear the expense of redesign and Unforeseeable Work resulting from approved design changes to incorporate piles driven out of tolerance. Employ a Specialty Engineer to perform any redesign and who shall sign and seal the redesign drawings and computations. Do not begin any proposed redesign until it has been reviewed for acceptability and approved by the Engineer.

455-5.16 Disposition of Pile Cut-offs, Test Piles, and Load Test Materials:

455-5.16.1 Pile Cut-offs:

(a) Steel Piling: Unless shown otherwise in the plans, the Department will retain ownership of cut-off sections, or portions of cut-off sections, and unused piling 20 feet [6 m] long or longer that are not damaged. Deliver them to the Department's nearest maintenance yard. Ensure that sections of piles delivered to the maintenance yard are straight and undamaged. Cut off the damaged portions prior to delivery. Take ownership of cut-off sections less than 20 feet [6 m] long. Remove them from the job, and dispose of them.

(b) Other Pile Types: Upon completion of all work under the Contract in connection with piling, unless shown otherwise in the plan, take ownership of any unused cut-off lengths remaining, and remove them from the right-of-way. Provide areas for their disposal.

455-5.16.2 Test Piles: Where so directed by the plans or the Engineer, cut off, or build-up as necessary, test piles, and leave them in place as permanent piles. Extract and replace test piles driven in permanent position and found not suitable for use at no expense to the Department. Pull, or cut off at an elevation 2 feet [0.6 m] below the ground surface or bottom of proposed excavation, test piles driven out of permanent position, and dispose of the removed portion of the test pile.

When test piles are required to be driven in permanent pile positions, the Contractor may elect to drive the test pile out of position, with the approval of the Engineer, provided that a replacement pile is furnished and driven by the Contractor at no expense to the Department in the position that was to be occupied by the test pile. Under this option, the Department will pay for the test pile in the same manner as if it were in permanent position.

Unless otherwise directed in the plans or by the Engineer, retain ownership of test piles that are pulled or cut off and provide areas for their disposal.

455-6 Timber Piling.

455-6.1 Description: Drive timber piles constructed of round timber of the kind and dimensions specified in the plans at the locations and to the elevations shown in the plans, or as directed by the Engineer.

455-6.2 Materials: Meet the timber piling requirements of Section 953. Treat the piles according to the applicable provisions of Section 955. Treat all cuts and drilled holes in accordance with 470-3.

455-6.3 Preparation for Driving:

455-6.3.1 Caps: Protect the heads of timber piles during driving, using a cap of approved type, that will distribute the hammer blow over the entire cross-section of the pile. When necessary, cut the head of the pile square before beginning pile driving.

455-6.3.2 Collars: Provide collars or bands to protect piles against splitting and brooming at no expense to the Department.

455-6.3.3 Shoes: Provide piles shod with metal shoes, of a design satisfactory to the Engineer, at no expense to the Department. Shape pile tips to receive the shoe and install according to the manufacturer's directions.

455-6.4 Storage and Handling: Store and handle piles in the manner necessary to avoid damage to the piling. Take special care to avoid breaking the surface of treated piles. Do not use cant dogs, hooks, or pike holes when handling and storing the piling.

455-6.5 Cutting Off: Saw off the tops of all timber piles at the elevation indicated in the plans. Saw off piles which support timber caps to the exact plane of the superimposed structure so that they exactly fit it. Withdraw and replace broken, split, or misplaced piles.

455-6.6 Build-ups: The Engineer will not permit splices or build-ups for timber piles. Extract piles driven below plan elevation and drive a longer pile.

455-6.7 Pile Heads:

455-6.7.1 Piles with Timber Caps: On piles wider than the timber caps, dress off to a slope of 45 degrees the part of the pile head projecting beyond the sides of the cap. Coat the cut surface with the required preservative over which place a sheet of copper, of a weight of 10 oz/ft^2 [3 kg/m^2] or greater, meeting the requirements of ASTM B 370. Provide a cover that measures at least 4 inches [100 mm] more in each dimension greater than the diameter of the pile. Bend the cover down over the pile and fasten the edges with large head copper nails or three wraps of No. 12 [2 mm] copper wire.

455-6.7.2 Fender and Bulkhead Piles: First paint the heads of fender piles and of bulkhead piles with preservative and then cover with copper as provided above for piles supporting timber caps.

455-7 Prestressed Concrete Piling.

455-7.1 Description: Provide prestressed concrete piles that are manufactured, cured, and driven in accordance with the requirements of the Contract Documents. Provide piles full length without splices when transported by barge or transported by truck without the need of a special over length permit. When piles are of a length which requires a special over length permit to transport and splicing is desired, provide minimal splices. Include the cost of the splices in the cost of the pile.

455-7.2 Manufacture: Fabricate piles in accordance with Section 450.

455-7.3 Storage and Handling:

455-7.3.1 Time of Driving Piles: Drive prestressed concrete piles at any time after the concrete has aged at least seven days and the concrete compressive strength is equal to or greater than the specified 28 day compressive strength.

455-7.3.2 Storage: Support piles on adequate dunnage both in the prestress yard and at the job site in accordance with the locations shown in the plans to minimize undue bending stresses or creating a sweep or camber in the pile.

455-7.3.3 Handling: Handle and store piles in the manner necessary to eliminate the danger of fracture by impact or of undue bending stresses in handling or transporting the piles from the forms and into the leads. In general, lift concrete piles by means of a suitable bridge or slings attached to the pile at the locations shown in the plans. Construct slings used to handle piles of a fabric material or braided wire rope constructed of six or more wire ropes which will not mar the corners or the surface finish of the piles. Do not use chains to handle piles. During transport, support concrete piles at the lifting locations shown in the plans or fully support them throughout 80% or more of their length. In handling piles for use in salty or brackish water, exercise special care to avoid damaging the surface and corners of the pile. If an alternate transportation support arrangement is desired, submit calculations, signed and sealed by the Specialty Engineer, for approval by the Engineer prior to transporting the pile. Calculations must show that the pile can be transported without exceeding the bending moments calculated using the support locations shown in the plans.

455-7.4 Cracked Piles: The Engineer will reject any pile that becomes cracked in handling to the point that a transverse or longitudinal crack extends through the pile, shows failure of the concrete as indicated by spalling of concrete on the main body of the pile adjacent to the crack, or which in the opinion of the Engineer will not withstand driving stresses. The Engineer will not reject any pile for the occasional minor surface hairline cracking caused by shrinkage or tensile stress in the concrete from handling.

Do not drive piling with irreparable damage, which is defined as any cracks that extend through the pile cross-sectional area that are, or will be, below ground or water level at the end of driving. Such cracks are normally evidenced by emitting concrete dust during their opening and closing with each hammer blow. Remove and replace broken piles or piles cracked to the extent described above at no expense to the Department. The Engineer will accept cracks less than 0.005 inch [0.15 mm] which do not extend through the pile. Using approved methods, cut off and splice or build-up to cut-off elevation piles with cracks greater than 0.005 inch [0.15 mm] at the pile head or above ground or water level, and piles with cracks above ground or water level which extend through the cross-sectional area of the pile. The Engineer, at his discretion, may require correction of pile damage or pile cracks by cutting down the concrete to the plane of sound concrete below the crack and rebuilding it to cut-off elevation, or the Engineer may reject the pile. Extract and replace rejected piles that cannot be repaired, at no expense to the Department.

Take appropriate steps to prevent the occurrence of cracking, whether due to handling or driving. When cracking occurs during driving take immediate steps to prevent additional cracking by using thicker cushions or reducing the ram stroke length. Revise handling and transporting equipment and procedures as necessary to prevent cracking during handling and transportation.

455-7.5 Preparation for Transportation: Cut any strands protruding beyond the ends of the pile flush with the surface of the concrete using an abrasive cutting blade before transporting the piles from the casting yard.

Cut the metal handling devices cast into the concrete back to a minimum depth of 1 inch [25 mm] and patch with an approved epoxy mortar, mixed, applied and cured in accordance with the manufacturer's recommendations before transporting the piles from the casting yard.

455-7.6 Method of Driving: Unless otherwise directed, drive piles by a hammer or by means of a combination of water jets and hammer. When using jets in combination with a hammer, withdraw the jets and drive the pile by the hammer alone, to secure final penetration and to rigidly fix the tip end of the pile. Keep jets in place if they are being used to continuously eliminate the soil resistance in the scour zone.

455-7.7 Extensions and Build-ups Used to Increase Production Lengths:

455-7.7.1 General: Where splices and build-ups for concrete piles are necessary, such splices and build-ups to be driven, or those21 feet [6.4 m] or longer, are to be prestressed precast sections. Ensure that build-ups less than21 feet [6.4 m] in length and not to be driven consist of a non-prestressed reinforced section meeting the requirements of 455-7.7.3. The Contractor may construct build-ups less than 2 feet [0.6 m] in length in accordance with 455-11.8. When splicing a prestressed precast section onto the original pile and, after driving, the length of spliced section below cut-off elevation is4 feet [1.2 m] or less, remove the pile concrete to the cut-off elevation and leave the dowels in place to be incorporated into the cap as directed by the Engineer. The Contractor may cut the length of dowels which becomes exposed to a length of 48 inches [1,220 mm] from the plane of pile-splice.

These requirements are not applicable to specially designed piling. Make splices for special pile designs as shown in the plans.

455-7.7.2 Extensions to be Driven or Those 21 feet [6.4 m] or Longer: Construct extensions to be driven or extensions 21 feet [6.4 m] or longer in length in accordance with the details shown in the plans and in a manner including the requirements, sequences, and procedures outlined below:

(a) Cast a splice section in accordance with Section 450 with the dowel steel in the correct position and alignment.

(b) Drill dowel holes using an approved steel template that will position and align the drill bit during drilling. Drill holes a minimum of 2 inches [50 mm] deeper than the length of the dowel to be inserted.

(c) Clean the drilled dowel holes by inserting a high pressure air hose to the bottom of the hole and blowing the hole clean from the bottom upward.

Eliminate any oil, dust, water, and other deleterious materials from the holes and the concrete surfaces to be joined.

(d) Mix the adhesive components in accordance with the manufacturer's directions. Do not mix sand or any other filler material with the epoxy components unless it is prepackaged by the manufacturer for this specific purpose. Use adhesives meeting the requirements of Section 926 for Type B Epoxy Compounds.

(e) After ensuring that all concrete surfaces are dry, fill the dowel holes with the adhesive material.

(f) Place forms around joints between the pile sections.

(g) Insert the dowels of the spliced section into the adhesive filled holes of the bottom section and position the spliced section so that the axes of the two sections are in concentric alignment and the ends of the abutting sections are spaced 1/2 inch [15 mm] apart. The Contractor may use small steel spacers of the required thickness provided they have 3 inches [75 mm] or more of cover after completing the splice. Fill the space between the abutting sections completely with the adhesive.

(h) Secure the spliced sections in alignment until the adhesive is cured in accordance with the manufacturer's directions for the time appropriate with the prevailing ambient temperatures. Do not utilize the crane to secure the pile extension during the adhesive cure time. Utilize alignment braces to maintain the proper pile alignment during the epoxy cure time.

(i) After curing is completed, remove alignment braces and forms and clean and dress the spliced area to match the pile dimensions.

455-7.7.3 Precast Reinforced Build-ups: Construct Precast Reinforced Build-ups in accordance with the requirements of this Subarticle, Section 346, and Section 400. Provide the same material for the form surfaces for precast build-ups as was used to form the prestressed piles. Use concrete of the same mix as used in the prestressed pile and dimension the cross-section the same as piling being built up. Install build-ups as specified in 455-7.7.2(b) through 455-7.7.2(i). Apply to the build-ups the same surface treatment or sealant applied to the prestressed piles. The Department will make payment for authorized build-ups at the respective Contract unit prices per foot [meter] for Prestressed Concrete Piling.

455-7.8 Pre-Planned Splices: When the contractor elects to use piles which are spliced together to obtain the authorized production length, splices shall be made by the doweled splice method contained in the plans or may be made using proprietary splices which are listed on the Department's QPL. Splice test piles in the same manner as the production piles. Include in the pile installation plan, the chosen method of splicing and the approximate locations of the splice. Generally, place the splice at approximately the midpoint between the estimated pile tip and the ground surface, considering scour if applicable. Stagger the splice location between adjacent piles by a minimum of 10 feet [3 meters]. Obtain the Engineer's approval prior to constructing any pile sections. Construct piles which are to be spliced using the doweled splice with preformed dowel holes in the bottom section and embedded dowels in the upper section. Provide splices constructed using doweled splice shown in the plans or a mechanical pile splice, listed on the Department's QPL. Mechanical pile splices shall be capable of developing the following capacities in the pile section unless shown otherwise in the plans and capable of being installed without damage to the pile or splice:

a) Compressive strength = (Pile Cross sectional area) x (28 day concrete strength)

b) Tensile Strength = (Pile Cross sectional area) x 900 psi [6.21 MPa]

Non SI Units	
Pile Size (inches)	Bending Strength (kip-feet)
18	245
20	325
24	600
30	950

SI Units	
Pile Size (mm)	Bending Strength (KN-m)
455	330
510	440
610	815
760	1,290

455-7.9 Pile Cut-offs: After the completion of driving, cut piles off which extend above the cut-off elevation with an abrasive saw. Make the cut the depth necessary to cleanly cut through the prestressed strands. Take ownership and dispose of cut-off sections not used elsewhere as allowed by this Section.

455-8 Steel Piling.

455-8.1 Description: Furnish, splice, drive, and cut off structural steel shapes to form bearing piles. Include in this work the installation of bracing members of structural steel by bolting or welding, construction of splices and the filling of pipe piles with the specified materials.

455-8.2 Material: For the material in rolled steel piles, pile bracing, scabs, wedges, and splices, meet the requirements for structural steel as specified in 962-2, Miscellaneous Steel.

455-8.3 Pile Splices: Order and use the full authorized pile length where practicable. Do not splice to obtain authorized lengths less than 40 feet [12 m] except when shown in the plans. When approved by the Engineer, perform splicing to obtain authorized lengths between 40 and 60 feet [12 and 18 m]. The Engineer will permit splicing to obtain authorized lengths in excess of 60 feet [18 m].

Where the pile length authorized is not sufficient to obtain the required bearing value or penetration, order an additional length of pile and splice it to the original length.

Make all splices in accordance with the plan details. Payment for pile splicing will be limited as specified in 455-11.8.

455-8.4 Welding: Make all welded connections to steel piles by electric arc welding, in accordance with details shown in the plans and in compliance with the requirements of 460-6, except 460-6 (1) and 460-6 (2). Only visual inspection methods will be used to inspect pile welds.

455-8.5 Pile Heads and Tips: Cut off all piles at the elevation shown in the plans. If using a cutting torch, make the surface as smooth as practical.

Where foundation material is so dense that the Contractor cannot drive the pile to the required penetration and firmly seat it without danger of crumpling the tip, reinforce the tips with approved cast steel point protectors as shown in the plans or required by the Engineer. Construct point protectors in one piece of cast steel meeting the requirements of ASTM A 27, Grade 65-35 [ASTM A 27M, Grade 450-240] heat treated to provide full bearing for the piles. Attach points by welding according to the recommendations of the manufacturer.

455-8.6 Pile Bent Bracing Members: Place structural steel sway and cross bracing, and all other steel tie bracing, on steel pile bents and bolt or weld in place as indicated in the plans. Where piles are not driven into position in exact alignment as shown in the plans, the Engineer may require the use of fills and shims between the bracing and the flanges of the pile. Furnish and place all fills and shims required to square and line up faces of flanges for cross bracing at no additional expense to the Department.

455-8.7 Painting: Paint exposed parts of steel piling, wedging, bracing, and splices in accordance with the provisions for painting structural steel as specified in Section 561, except as might be otherwise specified in the plans.

455-8.8 Storage and Handling: While handling or transporting the piles from the point of origin and into the leads, store and handle in the manner necessary to avoid damage due to bending stresses. In general, lift steel piles by means of a suitable bridge or a sling attached to the pile at appropriate points to prevent damage. Lift the pile from the horizontal position in a manner that will prevent damage due to bending of the flanges and/or web.

455-8.9 Filling Pipe Piles: When required by the plans, fill pipe piles with the specified materials. Use clean concrete sands and concrete meeting the requirements of Section 346. Place concrete in pipes containing water using methods in accordance with 455-15.9 with modified tremie and pump line sizes. Concrete may be placed directly into pipes which are dry. Construct and place reinforcement cages in accordance with 455-16. Reinforcement cages may be installed before concrete placement or after concrete placement is completed if proper alignment and position is obtainable.

455-9 Sheet Piling.

455-9.1 Description: Leave permanent piling in place as part of the finished work and generally remove temporary piling after each construction phase.

455-9.2 Materials: Meet the following requirements:

Concrete with Air Entrainment......................................Section 346
Bar Reinforcement...Section 931
Prestressing Reinforcement ....Section 933
Steel Sheet Piles..Section 962*

*For temporary steel sheet piles meet the requirements specified in the plans.

455-9.3 Steel Sheet Piling: Drive steel sheet piling and cut off true to line and grade. Install steel sheet piling with a suitable hammer. Remove and replace any section damaged during handling and installation at no additional expense to the Department.

455-9.3.1 Method of Installation: Where rock or strong material is encountered such that the sheet piles cannot be set to grade by driving, remove the strong material by other acceptable means, such as excavation and backfilling or by punching. When the plans do not indicate the existence of rock or strong material, work of removing or punching the strong material or rock will be paid for as Unforeseeable Work.

455-9.4 Concrete Sheet Piling:

455-9.4.1 Description: Ensure that Concrete Sheet Piling is of prestressed concrete construction and manufactured, cured, and driven in accordance with the requirements of the Contract Documents. Use these piles in bulkheads and abutments and at other locations as shown in the plans.

455-9.4.2 Manufacture of Piles: Ensure that the piles are fabricated in accordance with Section 450.

455-9.4.3 Method of Installation: Jet concrete sheet piling to grade where practical. The Engineer will require a minimum of two jets. Provide water at the nozzles of sufficient volume and pressure to freely erode material adjacent to the piles. Where encountering rock or strong material, such that the sheet piles cannot be set to grade by jetting, remove the strong materials by other acceptable means, such as excavation and backfilling or by punching with a suitable punch. When the plans do not indicate the existence of rock or strong material and the piles cannot be set by jetting, the Department will pay for the work of removing or punching the strong material or rock as Unforeseeable Work.

455-9.4.4 Grouting and Caulking: Concrete sheet piles are generally detailed to have tongues and grooves on their lower ends, and double grooves on their upper ends. Where so detailed, after installation, clean the grooves of all sand, mud, or debris, and fully grout the grooves. Use approved plastic bags (sheaths) which will meet the shape and length of the groove to be grouted to contain the plastic grout within the double grooves. Provide grout composed of one part cement and two parts sand. The Contractor may use clean local sand or beach sand in this grout. In lieu of sand-cement grout, the Contractor may use Class I concrete, using small gravel or crushed stone coarse aggregate. Deposit the grout through a grout pipe placed within a watertight plastic sheath (bag) extending the full depth of the double grooves and which, when filled, completely fills the slot formed by the double grooves.

455-9.5 Storage and Handling: Handle and store all sheet piles in a manner to prevent damage. Handle long sheet piles with fabric slings or braided wire rope constructed of six or more wire ropes placed at appropriate lift points to prevent damage due to excessive bending.

455-10 Pile Installation Plan.

455-10.1 General: Complete the Pile Driving Installation Plan form provided by the Engineer. Return the Pile Driving Installation Plan information to the Engineer at the preconstruction conference or no later than 30 days before driving the first pile. Ensure the Pile Driving Installation Plan information includes the following:

1. List and size of proposed equipment including cranes, barges, driving equipment, jetting equipment, compressors, and preformed pile hole equipment. Include manufacturer’s data sheets on hammers.

2. Methods to determine hammer energy in the field for determination of pile capacity. Include in the submittal necessary charts and recent calibrations for any pressure measuring equipment.

3. Detailed drawings of any proposed followers.

4. Detailed drawings of templates.

5. Details of proposed load test equipment and procedures, including recent calibrations of jacks and required load cells.

6. Sequence of driving of piles for each different configuration of pile layout.

7. Proposed schedule for test pile program and production pile driving.

8. Details of proposed features and procedures for protection of existing structures.

9. Required shop drawings for piles, cofferdams, etc.

10. Methods and equipment proposed to prevent displacement of piles during placement and compaction of fill within 15 feet [4.5 m] of the piles.

11. Methods to prevent deflection of battered piles due to their own weight and to maintain their as-driven position until casting of the pile cap is complete.

12. Proposed pile splice locations and details of any proprietary splices anticipated to be used.

455-10.2 Acceptance of Equipment and Procedures: All equipment and procedures are subject to satisfactory field performance. Make any required changes that may result from unsatisfactory field performance. The Engineer will give final acceptance after the Contractor makes necessary modifications. Do not make any changes in the driving system after acceptance without authorization of the Engineer. A hammer repaired on site or removed from the site and returned is considered to have its performance altered (efficiency increased or decreased), which is considered a change in the driving system and is subject to a Dynamic Load Test in accordance with 455-5.13 at no additional cost to the Department.

455-11 Method of Measurement (All Piling).

455-11.1 Treated Timber Piling: The quantity to be paid for will be the length, in feet [meters], furnished, placed, and accepted according to the authorized lengths list, including any additions and excluding any deletions thereto, as approved by the Engineer.

455-11.2 Prestressed Concrete Piling:

455-11.2.1 General: The quantity to be paid for will be the length, in feet [meters], of Prestressed Concrete Piling furnished, driven and accepted according to the authorized lengths list, including any additions and excluding any deletions thereto, as approved by the Engineer.

455-11.2.2 Furnished Length: The furnished length of precast concrete piles will be considered as the overall length from head to tip. Final pay length will be based on the casting length as authorized in accordance with 455-5.14.3 subject to provisions of 455-11.2.3 through 455-11.2.12, 455-11.8 and 455-11.9.

455-11.2.3 Build-ups: The lengths of pile build-ups authorized by the Engineer, measured from the plane of cutback or the joint between the sections, to head of build-up, will be included in the quantities of Piling.

455-11.2.4 Piles Requiring Cut-offs: No deduction from the length, in feet [meters], of Piling will be made if cut-offs are required after the pile has been driven to satisfactory bearing.

455-11.2.5 Piles Driven Below Cut-off Elevation: Where a pile is driven below cut-off elevation and satisfactory bearing is obtained so that no further driving is required, the length of pile driven will be measured from cut-off elevation to tip of the pile.

455-11.2.6 Driving of Splice: If a pile is driven below cut-off and satisfactory bearing is not obtained, and additional driving is required after construction of a satisfactory splice, an additional 10 feet [3.0 m] of piling will be paid for the additional driving. This compensation for driving of splice, however, will not be allowed for test piles that are spliced and redriven.

455-11.2.7 Replacing Piles: In the event a pile is broken or otherwise damaged to the extent that the damage is irreparable, in the opinion of the Engineer, the Contractor shall extract and replace the pile at no additional expense to the Department. In the event that a pile is mislocated by the Contractor, the Contractor shall extract and replace the pile at no expense to the Department except when a design change proposed by the Contractor is approved by the Department as provided in 455-5.15.5.

In the event that a pile is driven below cut-off without obtaining the required bearing, and the Engineer elects to have the pile pulled and a longer pile substituted, it will be paid for as Unforeseeable Work. In the event a pile is damaged or mislocated, and the damage or mislocation is determined to be the Department's responsibility, the Engineer may elect to have the pile extracted, and it will be paid for as Unforeseeable Work. If the extracted pile is undamaged and driven elsewhere the pile will be paid for at 30% of the Contract unit price for Piling. When the Department determines that it is responsible for damaged or mislocated pile, and a replacement pile is required, compensation will be made under the item for Piling, for both the original pile and replacement pile.

The Contractor may substitute a longer pile in lieu of splicing and building-up a pile. In this event, the Contractor will be paid for the original authorized length of the pile, plus any additional length furnished by the Contractor up to the authorized length of the build-up, as Piling. No payment will be made for extracting the original pile furnished or will any payment be made for a pile splice.

455-11.2.8 Underwater Driving: When the Contractor selects one of the optional underwater driving methods, payment will be made by selecting the applicable method from the following:

(a) Using a pile longer than the authorized length: Payment for piling will be made only for the authorized length at that location unless the length of pile from cut-off elevation to the final tip elevation is greater than the authorized length, in which case payment for piling will be made from cut-off elevation to final tip elevation. No payment will be made for pile splice, when this option is selected, unless the pile is physically spliced and the splice is driven below cut-off elevation to achieve bearing. When making and driving a pile splice below cut-off elevation to achieve bearing, the length to be paid for piling will be the length between cut-off elevation and final pile tip elevation.

(b) Using an underwater hammer: Payment for piling and pile splices will be in accordance with 455-11.2.1 through 455-11.2.7 and 455-11.2.10. The Contractor shall furnish additional lengths required to provide the full length confirmation pile at no expense to the Department. Payment for piling for the full length confirmation pile will be the authorized length of the pile, unless the length driven below cut-off elevation is greater than the authorized length, in which case the length to be paid for will be the length between cut-off elevation and the final tip elevation. Splices in confirmation piles will be paid for only when the splice is driven below cut-off elevation.

(c) Using a pile follower: When a pile follower is used with a conventional pile driving system, the method of payment will be the same as shown above in 455-11.2.10(b).

455-11.2.9 Set-Checks/Test Piles: As described in 455-5.12.1, there will be no separate payment for the initial four set-checks performed within 72 hours of initial driving. For each additional set-check performed within 72 hours of initial driving, an additional quantity of 10 feet [3.0 m] piling will be paid.

455-11.2.10 Set-Check/Production Piles: As described in 455-5.10.4(a), there will be no separate payment for one initial set-check. For each additional set-check performed within 72 hours from the end of initial driving, an additional quantity of 10 feet [3.0 m] of piling will be paid.

455-11.3 Steel Piling:

455-11.3.1 General: The quantity to be paid for will be the length, in feet [meters], of Steel Piling furnished, spliced, driven and accepted, up to the authorized length, including any additions and excluding any deletions thereto as approved by the Engineer.

455-11.3.2 Point Protectors: The quantity to be paid for will be each for the total of point protectors authorized, furnished, and properly installed.

455-11.4 Test Piles: The quantity to be paid for of test piles of various types, will be the length, in feet [meters], of Test Piling furnished, driven and accepted, according to the authorized length list, and any additions or deletions thereof as approved by the Engineer.

Where a test pile is left in place as a permanent pile, it will be paid for only as Test Piles. Any extensions necessary to continue driving the pile for test purposes, as authorized by the Engineer, will be paid for as Test Piles. Other build-ups made only to incorporate the pile into the structure as a permanent pile will be included in the quantities of regular Piling and will not be paid for as Test Piling.

455-11.5 Dynamic Load Tests: The quantity to be paid for will be the number of dynamic load tests as shown in the plans or authorized by the Engineer, actually applied to piles, completed and accepted in accordance with the Contract Documents. Dynamic load tests may be applied to test piles and/or production piles.

No separate payment will be made for dynamic load tests used to evaluate the Contractor’s driving equipment. This will generally be done on the first test pile or production pile driven on a project with each combination of proposed hammer and pile size and/or a separate pile to evaluate any proposed followers, or piles driven to evaluate proposed changes in the driving system.

The price for Dynamic Load Tests will include all costs related to dynamic testing as described in 455-5.13 including the initial instrumented drive, up to two set-checks, and two additional instrumented set-checks within 72 hours after the initial driving of a dynamic load test pile. In the event the Engineer requires an instrumented redrive of a pile previously instrumented more than 72 hours after initial driving, it will be paid for at 1/2 the bid price for a Dynamic Load Test.

455-11.6 Steel Sheet Piling: The quantity to be paid for will be the plan quantity area, in square feet [square meters], measured from top of pile elevation to the bottom of pile elevation and longitudinally along the top of the sheet piles as shown in the plans. Sheet piling used in cofferdams and to incorporate the Contractor's specific means and methods, and not ordered by the Engineer, will be paid for as required in Section 125.

455-11.7 Concrete Sheet Piling: The quantity to be paid for will be the product of the number of such piles satisfactorily completed, in place, times their lengths in feet [meters] as shown in the plans or authorized by the Engineer. This quantity will be based upon piles 2 1/2 feet [0.75 m] wide.

When the Engineer approves, the Contractor may furnish the concrete sheet piling in widths wider than shown in the plans; then the number of piles shall be the actual number of units completed times the width used divided by the width in the plans.

455-11.8 Pile Splices: Authorized splices in concrete piling, steel piling and test piling, which are made for the purpose of obtaining greater lengths than originally authorized by the Engineer, or to incorporate test piling in the finished structure, or for further driving of test piling, will be paid for as described in 455-12.12. No separate payment will be made for splices required to obtain the authorized length.

For concrete piles, where the head of the pile to be spliced is not more than 2 feet [0.6 m] below the elevation of cut-off, the Contractor, if he so elects, may cast the pile build-up with the cap, under the following conditions:

(a) Reinforcing steel and pile dimensions will conform in every respect to a standard splice.

(b) Reinforcing steel used for the build-up will be paid for as an overrun in the Contract quantity for substructure reinforcing steel.

(c) Concrete used for the build-up will be paid for as an overrun in the Contract quantity for substructure concrete.

(d) 9 feet [2.7 m] of piling, will be paid for as compensation for drilling and grouting the dowels and all other costs for which provision has not otherwise been made.

(e) No payment for the build-up will be made under the item for Piling.

455-11.9 Pile Redrive: The quantity to be paid for will be the number of redrives, each, authorized by the Engineer. Pile Redrive is defined in 455-5.10.4(b). Payment for any pile redrive ordered by the Engineer will consist of 20 feet [6.0 m] of additional piling. The size of the pile redriven will be the same size as the furnished item for payment.

Pile Redrive will be paid under any of the following conditions:

(a) When the Engineer directs the Contractor to redrive a pile to determine its capacity as described in 455-5.10.4.

(b) When the Engineer orders the Contractor to redrive piles to reestablish their capacity as the result of pile heave as described in 455-5.10.5.

455-11.10 Pile Extraction: Piles authorized to be extracted by the Engineer and successfully extracted as provided in 455-11.2.9 will be paid for as Unforeseeable Work. 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.

455-11.11 Protection of Existing Structures: The quantity to be paid for will be at the Contract lump sum price. When the Contract Documents do not include an item for protection of existing structures, the cost of settlement monitoring as required by these Specifications will be included in the cost of the piling items; however, work in addition to settlement monitoring will be paid for as Unforeseeable Work when such additional work is ordered by the Engineer.

455-11.12 Static Load Tests: The quantity to be paid for will be the number of static load tests of the designated tonnages, each, as shown in the plans or authorized by the Engineer, actually applied to piles, completed and accepted in accordance with the plans and these Specifications.

455-11.13 Preformed Pile Holes: The quantity to be paid for will be the length in feet (meters) of completed Preformed Pile Holes acceptably provided, complete for the installation of the bearing piles, regardless of the type of pile installed therein. Only those holes authorized to be paid for, as provided in 455-5.9.3, will be included in the measurement for payment. The Engineer will authorize payment for Preformed Pile Holes only when the pile has been placed in proper position and has achieved the required penetration.

455-12 Basis of Payment (All Piling).

455-12.1 Treated Timber Piling: Price and payment will be full compensation for furnishing all materials, including collars, metal shoes, copper cover sheets, preservatives and tar, and for wrapping pile clusters with wire cable, where so shown in the plans.

455-12.2 Prestressed Concrete Piling: Price and payment will be full compensation for the cost of furnishing and placing all reinforcing steel, predrilled holes, furnishing the material for and wrapping pile clusters with wire cable where so shown in the plans and grouting of preformed pile holes when shown in the plans. Payment will be made in two increments: 70% of the unit price for Prestressed Concrete Piling for each foot (meter) fabricated and accepted as stockpiled materials, and 30% of the unit price for Prestressed Concrete Piling for the entire authorized length upon completion of driving.

455-12.3 Steel Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing Steel Piling, including welding and painting as specified and the cost of predrilling pile holes described in 455-5.1.1. The cost of any sand or concrete fill and reinforcing steel in pipe piles will be included in the price for Steel Piling. Payment will be made in two increments: 70% of the unit price for Steel Piling for each foot (meter) fabricated and accepted as stockpiled materials, and 30% of the unit price for Steel Piling for the entire authorized length upon completion of driving.

Bracing and other metal parts attached to or forming a part of piling or bracing and not otherwise classified, will be measured and paid for as provided in Section 460.

455-12.4 Test Piles: Price and payment will be full compensation for all incidentals necessary to complete all the work of this item except splices, build-ups, pile extractions and preformed pile holes authorized by the Engineer and paid for under other pay items or payment methods. The cost of all additional work not listed above necessary to ensure required penetration and attain required bearing of the test piles will be included in the price bid per foot [meter] of Test Pile, including driving and all other related costs. Payment will be made in two increments: 70% of the unit price for Test Piles for each foot (meter) fabricated and accepted as stockpiled materials, and 30% of the unit price for Test Piles for the entire authorized length upon completion of driving.

455-12.5 Dynamic Load Tests: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.6 Steel Sheet Piling: Price and payment will be full compensation for all labor, equipment, and materials required for furnishing and installing steel sheet piling including preformed holes, but will not include furnishing and placing anchors when an anchored wall system, temporary or permanent, is designed and detailed in the plans. In such cases, furnishing and installing anchors will be paid for separately. For installations designed by the Contractor, the cost of furnishing and installing anchors will be incidental to the cost of steel sheet piling. For temporary installations, removal of the sheet piling, anchors, and incidentals will be included in the cost per square foot [square meter] for Steel Sheet Piling (Temporary).

455-12.7 Concrete Sheet Piling: Price and payment will be full compensation for furnishing all materials, including reinforcing steel, grouting, preformed holes and installation.

455-12.8 Preformed Pile Holes: There will be no separate pay item for Preformed Pile Holes. Payment will be made as the unit price for Piling of the applicable pile type (excluding sheet pile) for 30% of each linear foot (meter) of hole which is preformed when authorized by the Engineer. Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.9 Protection of Existing Structures: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.10 Point Protectors: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.11 Static Load Tests: Price and payment will be full compensation for all labor, equipment, and materials required to perform this work.

455-12.12 Pile Splices: The quantity of this item will be determined as provided in 455-11.8. Payment for each Steel Pile Splice authorized by the Engineer will be made as 20 feet [6 m] of additional steel piling. Payment for each Concrete Pile Splice authorized by the Engineer will be made as 30 feet [9 m] of additional prestressed concrete piling.

455-12.13 Prestressed Concrete Pile Cut-Off: There will be no separate pay item for pile cut-off. Payment for each cut-off will be made as 5 feet [1.5 m] of additional piling furnished.

455-12.14 Payment Items: Payment will be made under:

Item No .	455- 2-	Treated Timber Piling - per foot.
Item No .	2455- 2-	Treated Timber Piling - per meter.
Item No.	455- 14-	Concrete Sheet Piling - per foot.

Item No. 2455- 14- Concrete Sheet Piling - per meter.
Item No. 455- 18- Protection of Existing Structures - lump sum.
Item No. 2455- 18- Protection of Existing Structures - lump sum.
Item No . 455- 34- Prestressed Concrete Piling – per foot.
Item No. 2455- 34- Prestressed Concrete Piling – per meter.
Item No. 455- 35- Steel Piling – per foot.
Item No. 2455- 35- Steel Piling – per meter.
Item No. 455-119- Test Loads- each.
Item No. 2455-119- Test Loads- each.
Item No. 455-120- Point Protection - each.
Item No. 2455-120- Point Protection - each.
Item No. 455-133- Steel Sheet Piling - per square foot.
Item No. 2455-133- Steel Sheet Piling - per square meter.
Item No. 455-137- Dynamic Load Tests - each.
Item No. 2455-137- Dynamic Load Tests - each.
Item No. 455-143- Test Piles (Prestressed Concrete) – per foot.
Item No. 2455-143- Test Piles (Prestressed Concrete) – per meter.
Item No. 455-144- Test Piles (Steel) – per foot.
Item No. 2455-144- Test Piles (Steel) – per meter.
Item No. 455-145- Test Piles (Concrete Cylinder) – per foot.
Item No. 2455-145- Test Piles (Concrete Cylinder) – per meter.

C. DRILLED SHAFTS

455-13 Description.

Construct drilled shaft foundations consisting of reinforced, or unreinforced when indicated in the plans, concrete drilled shafts with or without bell footings.

455-14 Materials.

455-14.1 Concrete: For all concrete materials, meet the requirements of Section 346. Use concrete that is specified in the plans.

455-14.2 Reinforcing Steel: Meet the reinforcing steel requirements of Section 415. Ensure that reinforcing steel is in accordance with the sizes, spacing, dimensions, and the details shown in the plans.

455-15 Construction Methods and Equipment.

455-15.1 General Requirements:

455-15.1.1 Templates: 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 not require a template for shafts drilled on land provided the Contractor demonstrates satisfactorily to the Engineer that shaft position and alignment can be properly maintained. The Engineer will require a fixed template, adequate to maintain shaft position and alignment during all excavation and concreting operations, for shafts drilled on land when the Contractor fails to demonstrate satisfactorily that he can properly maintain shaft position and alignment without use of a template.

455-15.1.2 Drilled Shaft Installation Plan: At the preconstruction conference submit a drilled shaft installation plan 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. Mineral 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, etc.

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

4. Details of shaft excavation methods and drilling log procedures.

5. Details of slurry, including proposed methods to mix, circulate, desand, test methods, and proposed testing laboratory to document test results.

6. Details of proposed methods to clean shaft after initial 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. Provide 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. Details of any required cross-hole-sonic logging (CSL) tubes, test equipment, procedures and proposed CSL Specialty Engineer to perform, log, analyze, 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. Details of environmental control procedures used to prevent loss of slurry or concrete into waterways or other protected areas.

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

16. Other information shown in the plans or requested by the Engineer.

The Engineer will evaluate the drilled shaft installation plan 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 of the equipment and procedures chosen before field operations begin. The Engineers acceptance is not a guarantee that the chosen methods and equipment are capable of obtaining the required results, this responsibility lies with the Contractor.

455-15.1.3 General Methods & Equipment: Perform the excavations required for the shafts and bell footings, through whatever materials encountered, to the dimensions and elevations shown in the Contract Documents, using methods and equipment suitable for the intended purpose and the materials encountered. Provide equipment capable of constructing shafts supporting bridges to a depth equal to the deepest shaft shown in the plans plus 15 foot [4.5 m] or plus three times the shaft diameter, whichever is greater, except when the plans require equipment capable of constructing shafts to a deeper depth. Provide equipment capable of constructing shafts supporting non-bridge structures, including mast arms, signals, signs and light supports to a depth equal to the deepest shaft shown in the plans plus 5 feet [1.5 m].

Construct drilled shafts according to the Contract Documents using generally either the dry method, wet method, casing method, or permanent casing method as necessary to produce sound, durable concrete foundation shafts free of defects. Use the permanent casing method only when required by the plans or authorized by the Engineer. When the plans describe a particular method of construction, use this method except when permitted otherwise by the Engineer after field trial. When the plans do not describe a particular method, propose a method on the basis of its suitability to the site conditions and submit it for approval by the Engineer.

Set a suitable temporary removable surface casing. The minimum surface casing length is the length required to prevent caving of the surface soils and to aid in maintaining shaft position and alignment. The Engineer may require predrilling with slurry and/or overreaming to the outside diameter of the casing to install the surface casing at some sites.

455-15.2 Dry Construction Method: Use the dry construction method only at sites where the ground water table and soil conditions, generally stiff to hard clays or rock above the water table, make it feasible to construct the shaft in a relatively dry excavation and where the sides and bottom of the shaft are stable and may be visually inspected by the Engineer prior to placing the concrete.

In applying the dry construction method, drill the shaft excavation, remove accumulated seepage water and loose material from the excavation and place the shaft concrete in a relatively dry excavation.

Use the dry construction method only when shaft excavations, as demonstrated in a test hole, have 12 inches [300 mm] or less of seepage water accumulated over a four hour period, the sides and bottom remain stable without detrimental caving, sloughing, or swelling for a four hour period, and the loose material and water can be satisfactorily removed prior to inspection and prior to placing concrete. Use the wet construction method or the casing construction method for shafts that do not meet the requirements for the dry construction method.

Provide temporary surface casings to aid shaft alignment and position and to prevent sloughing unless the Engineer determines by demonstration that the surface casing is not required.

455-15.3 Wet Construction Method: Use the wet construction method at all sites where it is impractical to provide a dry excavation for placement of the shaft concrete.

The wet construction method consists of drilling the shaft excavation below the water table, keeping the shaft filled with fluid (mineral slurry, natural slurry or water), desanding and cleaning the mineral slurry and final cleaning of the excavation by means of a bailing bucket, air lift, submersible pump or other approved devices and placing the shaft concrete (with a tremie or concrete pump extending to the shaft bottom) which displaces the water or slurry during concreting of the shaft excavation. Provide temporary surface casings to aid shaft alignment and position and to prevent sloughing of the top of the shaft except when the Engineer declares that the surface casing is not required.

Where drilled shafts are located in open water areas, construct the shafts by the wet method using exterior casings extending from above the water elevation into the ground to protect the shaft concrete from water action during placement and curing of the concrete. Install the exterior casing in a manner that will produce a positive seal at the bottom of the casing so that there is no intrusion or extrusion of water or other materials into or from the shaft excavation.

Expandable or split casings that are removable are not permitted for use below the water surface.

455-15.4 Temporary Casing Construction Method: Use the temporary casing method at all sites where it is inappropriate to use the dry or wet construction methods without the use of temporary casings other than surface casings. In this method, the hole is advanced through caving material by the wet method as described above. When a formation is reached that is nearly impervious, place a casing in the hole and seal in the nearly impervious formation. Proceed with drilling as with the wet method to the projected depth. Proceed with the placement of the concrete as with the dry method except withdraw the casing after placing the concrete. In the event seepage conditions prevent use of the dry method, complete the excavation and concrete placement using wet methods.

Where drilling through materials having a tendency to cave, advance the excavation by drilling in a mineral slurry. In the event that a caving layer or layers are encountered that cannot be controlled by slurry, install temporary removable casing through such caving layer or layers. The Engineer may require overreaming to the outside diameter of the casing. Take whatever steps are required to prevent caving during shaft excavation including installation of deeper casings. If electing to remove a casing and replace it with a longer casing through caving soils, adequately stabilize the excavation with slurry or backfill the excavation. The Contractor may use soil previously excavated or soil from the site if backfilling the excavation. The Contractor may use other approved methods which will control the size of the excavation and protect the integrity of the foundation soils to excavate through caving layers.

Before withdrawing the casing, ensure that the level of fresh concrete is at such a level that the fluid trapped behind the casing is displaced upward. As the casing is withdrawn, maintain the level of concrete within the casing so that fluid trapped behind the casing is displaced upward out of the shaft excavation without mixing with or displacing the shaft concrete.

The Contractor may use the casing method, when approved by the Engineer, to construct shafts through weak caving soils that do not contribute significant shaft shear resistance. In this case, place a temporary casing through the weak caving soils before beginning excavation. Conduct excavation using the dry construction method where appropriate for site conditions and the wet construction method where the dry construction method is not appropriate. Withdraw the temporary casing during the concreting operations unless the Engineer approves otherwise.

455-15.5 Permanent Casing Construction Method: Use the permanent casing method when required by the plans. In this method, place a casing to the prescribed depth before beginning excavation. If the Contractor cannot attain full penetration, the Engineer may direct the Contractor to excavate through the casing and advance the casing until reaching the desired penetration. In some cases the Engineer may require the Contractor to overream the outside diameter of the casing before placing the casing.

Cut the casing off at the prescribed elevation upon reaching the proper construction sequence and leave the remainder of the casing in place.

455-15.6 Excavations: When pilot holes and/or load tests are performed, the Engineer will use the pilot hole and/or load test results to determine the authorized tip elevations and/or the authorized installation criteria of the drilled shafts. The resulting shaft tip elevations may vary from the Tip Elevations presented in the plans. Extend drilled shaft excavations deeper by extra depth excavation when the Engineer determines the material encountered while drilling the shaft excavation is unsuitable and/or is not the same as anticipated in the design of the drilled shaft.

455-15.6.1 Pilot Hole: When pilot holes are shown in the plans core a pilot hole, prior to shaft excavation, in accordance with ASTM D 2113 Standard Practice for Diamond Core Drilling for Site Excavation using a double or triple wall core barrel through part or all of the shaft, to a depth of 3 times the diameter of the drilled shaft below the tip elevation shown in the plans, as directed by the Engineer. The Engineer may require the Contractor to cut any core to a total depth below the bottom of the drilled shaft excavation of up to 5 times the diameter of the drilled shaft. Maintain a drilling log during pilot hole operations that contains information such as the description of and top and bottom elevation of each stratum encountered, depth of penetration, drilling time in each of the various strata, material description, and remarks. Classify, measure, and describe core samples in the drilling log. Furnish two copies of the drilling log, signed by a designated representative of the Contractor to the Department.

455-15.6.2 Cores: Take cores when shown in the plans or directed by the Engineer to determine the character of the material directly below the shaft excavation. Cut the cores with an approved core barrel to a minimum depth of 3 times the diameter of the drilled shaft below the bottom of the drilled shaft excavation after completing the shaft excavation, as directed by the Engineer. The Engineer may require the Contractor to cut any core to a total depth below the bottom of the drilled shaft excavation of up to 5 times the diameter of the drilled shaft. Maintain a drilling log during coring operations that contains information such as the description of and top and bottom elevation of each stratum encountered, depth of penetration, drilling time in each of the various strata; classify, measure, and describe core samples in the drilling log. Furnish two copies of the drilling log, signed by a designated representative of the Contractor to the Department.

For cores or pilot holes, use only a double or triple wall core barrel designed:

(a) to cut a core sample from 4 to 6 inches [100 to 150 mm] in diameter,

(b) so that the sample of material cored can be removed from the shaft excavation and the core barrel in an undisturbed state, and

(c) with sufficient length to provide core samples from a depth of 5 times the diameter of the drilled shaft below the bottom of the drilled shaft excavation, as directed by the Engineer.

The Engineer will inspect the cores and determine the depth of required excavation. When considered necessary by the Engineer, take additional cores. Place the core samples in suitable containers, identified by shaft location, elevation from and to, and job number, and deliver to the Department within 48 hours after cutting. When called for in the plans, substitute Standard Penetration Tests (SPT) for coring. In such cases, supply these tests at no additional cost per foot [meter] to the Department above that bid for core (shaft excavation).

Provide areas for the disposal of unsuitable materials and excess materials as defined in 120-5 that are removed from shaft excavations, and dispose of them in a manner meeting all requirements pertaining to pollution.

When shown in the plans, excavate bells to form a bearing area of the size and shape shown. Bell outlines varying from those shown in the plans are permissible provided the bottom bearing area equals or exceeds that specified. If the diameter of the bell exceeds three times the shaft diameter, drill the excavation deeper as directed and form a new bell footing. Excavate bells by mechanical methods.

Furnish the additional drilled shaft concrete over the theoretical amount required to complete filling any excavations for bells and shafts which are larger than required by the plans or authorized by the Engineer, at no expense to the Department.

455-15.7 Casings: Ensure that casings are metal, or concrete when indicated in the plans, of ample strength to withstand handling and driving stresses and the pressure of concrete and of the surrounding earth materials, and that they are smooth and water tight. Ensure that the inside diameter of casing is not less than the specified size of shaft except as provided below. The Department will not allow extra compensation for concrete required to fill an oversize casing or oversize excavation.

The Engineer will allow the Contractor to supply casing with an outside diameter equal to the specified shaft diameter (O.D. casing) provided he supplies additional shaft length at the shaft tip. Determine the additional length of shaft required by the following relationship:

$$Additional\ length = \frac{(D_1 - D_2)L}{D_2}$$

where:

D_1= casing inside diameter specified = shaft diameter specified
D_2= casing inside diameter provided ($D_2 = D_1$ minus twice the wall thickness).
L= authorized shaft length below ground for temporary casing methods or below casing for permanent casing methods.

Bear all costs relating to this additional length including but not limited to the cost of extra excavation, extra concrete, and extra reinforcing steel.

Remove all casings from shaft excavations except those used for the Permanent Casing Method. Ensure that the portion of casings installed under the Permanent Casing Method of construction below the shaft cut-off elevation remains in position as a permanent part of the Drilled Shaft. The Contractor may leave casings if in the opinion of the Engineer the casings will not adversely affect the shaft capacity in place. When casings that are to be removed become bound in the shaft excavation and cannot be practically removed, drill the shaft excavation deeper as directed by the Engineer to compensate for loss of capacity due to the presence of the casing. The Department will not compensate for the casing remaining. The Department will pay for the additional length of shaft under Item No. 455-88 [Item No. 2455-88] and the additional excavation under Item No. 455-125 [Item No. 2455-125].

When the shaft extends above ground or through a body of water, the Contractor may form the portion exposed above ground or through a body of water, with removable casing except when the Permanent Casing Method is specified (see 455-23.10). When approved, the Contractor may form drilled shafts extending through a body of water with permanent or removable casings. However, for permanent casings, remove the portion of metal casings between an elevation 2 feet [0.6 m] below the lowest water elevation or 2 feet [0.6 m] below ground whichever is higher and the top of shaft elevation after the concrete is cured. Dismantle casings removed to expose the concrete as required above in a manner which will not damage the drilled shaft concrete. Dismantle removable casings in accordance with the provisions of 455-17.5.

Generally when removal of the temporary casing is required, do not start the removal until completing all concrete placement in the shaft. The Engineer will permit movement of the casing by rotating, exerting downward pressure, and tapping it to facilitate extraction, or extraction with a vibratory hammer. Extract casing at a slow, uniform rate with the pull in line with the axis of the shaft. Withdraw temporary casings while the concrete remains fluid.

When conditions warrant, the Contractor may pull the casing in partial stages. Maintain a sufficient head of concrete above the bottom of the casing to overcome the hydrostatic pressure of water outside the casing. At all times maintain the elevation of the concrete in the casing high enough to displace the drilling slurry between the outside of the casing and the edge of the hole while removing the casing.

The Contractor may use special casing systems in open water areas, when approved, which are designed to permit removal after the concrete has hardened. Design special casings so that no damage occurs to the drilled shaft concrete during their removal.

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

455-15.8.1 Slurry: When mineral slurry is used in an excavation, use only processed attapulgite or bentonite clays. The Engineer will not allow polymer slurries. Use 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, delay the construction of that foundation until an alternate construction procedure has been approved.

Thoroughly premix the mineral slurry with clean fresh water prior to introduction into the shaft excavation. Ensure that the percentage of 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 these Specifications. 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/or 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 qualified professional soil testing laboratory approved by the Engineer to perform control tests using suitable apparatus on the mineral slurry mixture to determine the following parameters:

(a) Freshly mixed mineral slurry: Measure the density of the freshly mixed mineral slurry regularly as a check on the quality of the suspension being formed using a measuring device calibrated to read within ±0.5 lb/ft^3 [±8 kg/m^3].

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

Non SI Units		
Item to be measured	Range of Results at 68ºF	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	28 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

SI Units		
Item to be measured	Range of Results at 20ºC	Test Method
Density	1030 to 1170 kg/m^3 (in fresh water environment) 1060 to 1200 kg/m^3 (in salt water environment)	Mud density balance: FM 8-RP13B-1
Viscosity	28 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(s) 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.

Perform tests to determine density, viscosity, and pH value to establish a consistent working pattern, taking into account the mixing process and blending of freshly mixed mineral slurry and previously used mineral slurry. Perform a minimum of four sets of tests to determine density, viscosity, and pH value during the first 8 hours mineral slurry is in use.

When the results show consistent behavior, discontinue the tests for pH value, and only carry out tests to determine density and viscosity during each four hours mineral slurry is in use. If the consistent working pattern changes, reintroduce the additional tests for pH value for the time required to establish consistency of the test values within the required parameters.

(c) Furnish reports of all mineral slurry tests required above, signed and sealed by a Specialty Engineer, representing the soil testing laboratory to the Department on completion of each drilled shaft.

(d) The Department may perform comparison tests as determined necessary during the mineral slurry operations.

During construction, maintain the level of mineral slurry in the shaft excavation within the excavation and at a level not less than 4 feet [1.2 m] above the highest expected piezometric water pressure along the depth of a shaft.

At any time the wet construction method of stabilizing excavations fails, in the opinion of the Engineer, to produce the desired final result, discontinue this method of construction, and propose modifications in procedure or alternate means of construction for approval.

455-15.8.1.1 Exceptions for Shafts for Miscellaneous Structures: Testing of the slurry prior to introduction into the shaft excavation is not required for drilled shafts up to 60 inches [1.5 m] in diameter installed to support mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures.

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

Take samples of the fluid in the shaft from the base of the shaft and at intervals not exceeding 10 feet [3 m] up the shaft, using an approved sampling tool. 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 455-15.8.1. except as follows:

The Engineer will not require tests for pH or viscosity when mineral slurry has not been introduced into the shaft excavation.

When using mineral slurry, engage an approved soil testing laboratory to provide a CTQP qualified drilled shaft inspector, or provide an experienced person approved by the Engineer to perform slurry testing. The Department may also perform comparison tests. Provide equipment for such comparison tests when requested by the Engineer.

455-15.9 Tremies and Pumps:

455-15.9.1 General: The requirements of the applicable provisions of Section 400- will apply when using a tremie or a pump to place drilled shaft concrete.

455-15.9.2 Dry Excavations: Ensure that the tremie for depositing concrete in a dry drilled shaft excavation consists of a tube of solid construction, a tube constructed of sections which can be added and removed, or a tube of other approved design. The Contractor may pass concrete through a hopper at the top of the tube or through side openings as the tremie is retrieved during concrete placement. Support the tremie so that the free fall of the concrete is less than 5 feet [1.5 m] at all times. If the free falling concrete causes the shaft excavation to cave or slough, control the movement of concrete by reducing the height of free fall of the concrete and/or reducing the rate of flow of concrete into the excavation.

455-15.9.3 Wet Excavations: Construct the tremie or pump line used to deposit concrete beneath the surface of water so that it is water-tight and will readily discharge concrete. Construct the discharge end of the tremie or pump line to prevent water intrusion and permit the free flow of concrete during placement operations. Ensure that the tremie or pump line has sufficient length and weight to rest on the shaft bottom before starting concrete placement. Ensure that the discharge end of the tremie or pump line is entirely immersed in concrete at all times during placement operations. Ensure that the free fall of concrete into the hopper is less than 5 feet [1.5 m] at all times. Support the tremie so that it can be raised to increase the discharge of concrete and lowered to reduce the discharge of concrete. The Engineer will not allow rapid raising or lowering of the tremie to increase the discharge of the concrete. Maintain a continuous flow of concrete and a positive pressure differential of the concrete in the tremie or pump line at all times to prevent water or slurry intrusion into the shaft concrete.

455-15.10 Excavation and Drilling Equipment:

455-15.10.1 General: All shaft excavation is Unclassified Shaft Excavation. The Engineer will require Drilled Shaft Sidewall Overreaming when inspections show it to be necessary. These terms are defined in 455-15.10.2, 455-15.10.3, and 455-15.10.4, respectively.

Use excavation and drilling equipment having adequate capacity, including power, torque, and crowd (downthrust), and excavation and overreaming tools of adequate design, size, and strength to perform the work shown in the plans or described herein. When the material encountered cannot be drilled using conventional earth augers and/or underreaming tools, provide special drilling equipment, including but not limited to rock augers, core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to continue the shaft excavation to the size and depth required. In the event blasting is necessary, obtain all necessary permits. The Contractor is responsible for the effects of blasting on already completed work and adjacent structures. The Engineer must approve all blasting.

455-15.10.2 Unclassified Shaft Excavation: Unclassified Shaft Excavation is defined as all processes required to excavate a drilled shaft of the dimensions shown in the Contract Documents to the depth indicated in the plans plus 15 feet [4.5 meters] or plus 3 shaft diameters, whichever is deeper, completed and accepted. Include in the work all shaft excavation, whether the material encountered is soil, rock, weathered rock, stone, natural or man-made obstructions, or materials of other descriptions.

455-15.10.3 Unclassified Extra Depth Excavation: Unclassified Extra Depth Excavation is defined as all processes required to excavate a drilled shaft of plan dimensions which is deeper than the limits defined as Unclassified Shaft Excavation.

455-15.10.4 Drilled Shaft Sidewall Overreaming: Drilled Shaft Sidewall Overreaming is defined as the unclassified excavation required to roughen its surface or to enlarge the drilled shaft diameter due to softening of the sidewalls or to remove excessive buildup of slurry cake when slurry is used. Increase the shaft radius a minimum of 1/2 inch [15 mm] and a maximum of 3 inches [75 mm] by overreaming. The Contractor may accomplish overreaming with a grooving tool, overreaming bucket, or other approved equipment.

Meet the limit for depth of sidewall overreaming into the shaft sidewall material and the elevation limits between which sidewall overreaming is required.

455-15.11 Inspection of Excavations:

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:

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

(b) Check the dimensions and alignment of casing when inserted in the excavation.

(c) Insert a casing in shaft excavations temporarily for alignment and dimension checks.

(d) 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.

455-15.11.2 Depth: Generally reference the depth of the shaft during drilling to appropriate marks on the Kelly bar or other suitable methods. Measure final shaft depths with a suitable weighted tape or other approved methods after final cleaning.

455-15.11.3 Shaft Inspection Device: The Engineer, when shown in the plans, will furnish and use an inspection device comprised of a television camera sealed inside a water-tight jacket to inspect the bottoms of the shafts. The Engineer may also use a sidewall sampler attached to the inspection device to sample the sides of the shafts. Cooperate with the Engineer in using this inspection device, including placing the inspection device in position for inspection and removing it after the inspection. Furnish 110 V single phase current (minimum 30 A service), 220 V single phase current (minimum 15A service), and a 150 psi [1.0 MPa] compressor (8 cfm [0.0038 m^3/s] minimum) to operate the device. Include all cost related to the inspection device in the cost of drilled shaft items.

Provide the projected drilled shaft construction schedule to the Engineer at the preconstruction conference so that the inspection device may be scheduled. Include in the bid the cost of transporting the inspection device from its storage location to the job site and back.

Assume responsibility for the device from the time it leaves its storage area until the time it is returned. During this time, insure the device against loss or damage for the replacement cost thereof (the greater of $400,000 or the amount shown in the plans) or for the full insurable value if replacement cost insurance is not available.

Return the device in good working condition to its proper location within 30 days after completing the drilled shafts. Notify the Department at least ten working days before returning the inspection device.

455-15.11.4 Shaft Cleanliness Requirements: Adjust cleaning operations so a minimum of 50% of the bottom of each shaft will have less than 1/2 inch [13 mm] of sediment at the time of placement of the concrete. Ensure the maximum depth of sedimentary deposits or any other debris at any place on the bottom of the shaft excavation does not exceed 1 1/2 inches [40 mm]. The Engineer will determine shaft cleanliness by visual inspection for dry shafts, using divers or an inspection device or other methods the Engineer deems appropriate for wet shafts.

When using slurry, meet the requirements of 455-15.8 at the time of concrete placement.

455-15.11.4.1 Exceptions for Shafts for Miscellaneous Structures: Ensure the depth of sedimentary deposits or other debris does not exceed 1 inch [25 mm] over the bottom of the shaft when installing drilled shafts up to 60 inches [1.5 m] in diameter installed to support mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures.

455-15.11.5 Time of Excavation: Any unclassified excavation work lasting more than 36 hours (measured from the beginning of excavation for all methods except the Permanent Casing Method, which begins at the time excavation begins below the casing) before placement of the concrete may require overreaming the sidewalls to the depth of softening or removing excessive slurry cake buildup as indicated by samples taken by the sidewall sampler or other test methods employed by the Engineer. Ensure that the minimum depth of overreaming the shaft sidewall is 1/2 inch [13 mm] and the maximum depth is 3 inches [75 mm]. Provide any overreaming required at no expense to the Department when exceeding the 36-hour limit unless the time limit is exceeded solely to accomplish excavating deeper than the elevation shown in the plans as ordered by the Engineer. The Department will pay the Contractor for authorized overreaming resulting from softening or excessive filtercake buildup which is indicated by sidewall samples or other test methods employed by the Engineer during the initial 36-hour time period. The Department will pay the Contractor for authorized overreaming when sidewall samples indicate softening or excessive filter cake buildup in shaft excavations which exceed the 36-hour time limit in order to accomplish excavating deeper than the elevation shown in the plans as ordered by the Engineer.

When using mineral slurry, adjust excavation operations so that the maximum time that slurry is in contact with the bottom 5 feet [1.5 m] of the shaft (from time of drilling to concreting) does not exceed 12 hours. If exceeding the 12-hour time limit, overream the bottom 5 feet [1.5 m] of shaft at no additional expense to the Department prior to performing other operations in the shaft.

455-15.11.5.1 Excavation Time for Shafts for Miscellaneous Structures: For drilled shafts up to 60 inches [1.5 m] in diameter installed to support mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures, all references to a 36-hour time limit is changed to a 12-hour time limit.

455-16 Reinforcing Steel Construction and Placement.

455-16.1 Cage Construction and Placement: Completely assemble and place as a unit the cage of reinforcing steel, consisting of longitudinal bars, ties, and cage stiffener bars, immediately after the Engineer inspects and accepts the shaft excavation and immediately prior to placing concrete. Tie all intersections of drilled shaft reinforcing steel with cross ties or “figure 8” ties. Use double strand ties or ties with larger tie wire when necessary. The Engineer will give final approval of the cage construction and placement subject to satisfactory performance in the field.

455-16.2 Splicing Cage: If the bottom of the constructed shaft elevation is lower than the bottom of the shaft elevation in the plans, extend a minimum of one half of the longitudinal bars required in the upper portion of the shaft the additional length. Continue the tie bars for the extra depth, spaced on 2 foot [0.6 m] centers, and extend the stiffener bars to the final depth. The Contractor may lap splice these bars or use unspliced bars of the proper length. Do not weld bars to the planned reinforcing steel unless shown in the Contract Documents.

455-16.3 Support, Alignment, and Tolerance: Tie and support the reinforcing steel in the shaft so that the reinforcing steel will remain within allowable tolerances as specified in 455-8 and Section 415.

Use concrete wheels or other approved noncorrosive spacing devices near the bottom, within 3 feet [1 m] of the top, and intervals not exceeding 15 feet [4.5 m] along the shaft 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 [750 mm] of circumference of cage with a minimum of three at each level. Provide concrete spacers, constructed as shown in the Contract Documents, at the bottom of the drilled shaft reinforcing cage to maintain the specified distance between the bottom of the cage and the bottom of the shaft is maintained. Use the number of bottom spacers as shown in the Contract Documents. Use spacers constructed of approved material equal in quality and durability to the concrete specified for the shaft. The Engineer will approve spacers subject to satisfactory performance in the field.

Check the elevation of the top of the steel cage before and after placing the concrete. If the rebar cage is not maintained within the specified tolerances, correct it as directed by the Engineer. Do not construct additional shafts until modifying the rebar cage support in a manner satisfactory to the Engineer.

455-16.4 Cross-Hole Sonic Logging (CSL) Tubes: Install CSL access tubes full length in all drilled shafts from the tip of shaft to a point high enough above top of shaft to allow cross-hole-sonic-logging testing, but not less than 30 inches [750 mm] 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 must be Schedule 40 steel with a minimum inside diameter of 1.5 inches [38 mm]. 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. Repair or replace any unserviceable tube prior to concreting. 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 and configuration of crosshole 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 [915 mm to 1.220 m]	4	90 degrees apart
Greater than 48 inches	1 tube per 12 inches [305 mm] of Shaft Diameter	360 degrees divided by the Number of Tubes

Shaft Diameter	Number of Tubes Required	Configuration around the inside of Circular Reinforcing Cage
[1.220 m]		

Insert simulated or mock probes in each cross-hole-sonic 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 damaged tubes as in a manner acceptable to the Engineer prior to concreting.

455-17 Concrete Placement.

455-17.1 General: Place concrete in accordance with the applicable portions of Sections 346 and 400, Standard Operating Procedures for Quality Control of Concrete, Subarticles 455-15.2, 455-15.3, 455-15.4, 455-15.5, 455-15.8, 455-15.9, and the requirements herein.

Place concrete as soon as possible after completing all excavation, cleaning the shaft excavation, inspecting and finding it satisfactory, and immediately after placing reinforcing steel. Continuously place concrete in the shaft to the top elevation of the shaft. Continue placing concrete after the shaft is full until good quality concrete is evident at the top of the shaft. Place concrete through a tremie or concrete pump using approved methods.

If the pressure head is lost during concrete placement for any reason, the Engineer may direct the Contractor to perform integrity testing at no expense to the Department.

Immediately after concreting, check the water levels in the CSL access tubes and refill as necessary. If tubes become unserviceable, core new holes in the drilled shaft as directed by the Engineer.

455-17.2 Placement Time Requirements: The elapsed time for placing drilled shaft concrete includes the concrete mixing and transit time, the concrete placement time, and the time required to remove any temporary casing that causes or could cause the concrete to flow into the space previously occupied by the casing. Maintain a minimum slump of 4 inches [100 mm] throughout the elapsed time. Use materials to produce and maintain the required slump through the elapsed time that meets the class of concrete specified. Provide slump loss tests that demonstrate to the Engineer that the concrete will maintain a 4 inch [100 mm] or greater slump for the anticipated elapsed time before beginning drilled shaft construction.

455-17.3 Forms: When the top of shaft elevation is above ground, form the portion of the shaft above ground with a removable form or another approved method to the dimensions shown in the plans.

When the shaft extends above the ground through a body of water, the Contractor may form the portion through the water with removable forms except when the Permanent Casing Method is specified.

When approved, the Contractor may form the portion through the water with permanent forms, provided the forms are removed from 2 feet [0.6 m] below the lowest water elevation to the top of shaft elevation.

455-17.4 Riser Blocks: The Contractor may cast a riser block of equal diameter as the column and of a maximum height of 6 inches [150 mm] at the top of the completed shaft. When this option is chosen, extend any dowel steel above the top of shaft an additional 6 inches [150 mm].

455-17.5 Curing: Cure the top surface in accordance with the applicable provisions of Section 400, and construct any construction joint area as shown in the plans. Protect portions of drilled shafts exposed to a body of water from the action of water by leaving the forms in place for a minimum of seven days after casting the concrete. The Contractor may remove forms prior to seven days provided the concrete strength has reached 2,500 psi [17 MPa] or greater as evidenced by cylinder breaks.

455-17.6 Non-Destructive Testing of Drilled Shaft Integrity:

455-17.6.1 Cross-Hole Sonic Logging (CSL) Tests: Perform all CSL testing in accordance with ASTM 6760. In bridge bents or piers containing one column with one or two drilled shafts, or two columns with one or more of the columns supported by only one drilled shaft, test all drilled shafts in the bent or pier using CSL. For all other drilled shafts, perform CSL testing only on drilled shafts selected by the Engineer. The minimum number of shafts tested is the number of shafts indicated in the plans. At his/her discretion, the Engineer may increase the number shafts tested as deemed necessary.

Engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer must have a minimum three (3) years experience of CSL testing and have a Florida Licensed Professional Engineer supervising the collection and interpretation of data. The Contractor shall provide all necessary 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.

After acceptance of production shafts by the Engineer, remove all water from the access tubes or core holes and fill the tubes or core holes with a structural non-shrink grout approved by the Engineer.

455-17.6.1.1 Equipment: Furnish Cross-Hole-Sonic logging test equipment as follows:

(1) Include ultrasonic transmitter and receiver probes for 1.5 inch or 2.0 inch I.D. pipe, as appropriate, which produce measurements with consistent signal strength and arrival time in uniform, good quality concrete with all tube spacings on the project.

(2) Include a microprocessor based data acquisition system for display, storage, and transfer of data. Graphically display First pulse Arrival Time (FAT) during data acquisition.

(3) Electronically measure and record the relative position (depth) of the probes in the tubes with each CSL signal.

(4) Print the CSL logs for report presentation.

(5) Provide report quality plots of CSL measurements that identify each individual test.

(6) Electronically store each CSL log in digital format, with shaft identification, date, time and test details, including the transmitter and receiver gain.

455-17.6.1.2 Procedure: Perform Cross-hole sonic logging between 72 hours and 25 calendar days of shaft concrete placement and after the concrete compressive strength exceeds 3,000 psi. 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 CSL testing. 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.

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 2.5 inches [64 mm] 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.

Report any anomalies indicated by longer pulse arrival times and significantly lower amplitude/energy signals to the Engineer and conduct further tests as required to evaluate the extent of possible defects. Conduct offset CSL measurements between all tube pair combinations in any drilled shafts with 20% or greater in velocity reduction. 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: +45, +22.5 (source below receiver), and -45, -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. Provide offset CSL logs and 3-D tomographic analysis of all CSL data at no additional cost to the Department in the event 20% or greater in velocity reductions are detected.

455-17.6.1.3 Required Reports: Present the CSL testing and analysis results to the Engineer in a 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 3-D tomographic analysis using all offset data, and include color coded 3-D tomographic images in the report.

455-17.6.1.4 Evaluation of CSL Test Results: The Engineer will evaluate the CSL test results and determine whether or not the drilled shaft construction is acceptable. Drilled shafts with velocity reduction exceeding 20% are not acceptable.

455-17.6.1.5 Coring and/or Repair of Drilled Shafts: If the Engineer determines a drilled shaft is unacceptable based on the CSL tests and tomographic analyses, core the shaft to allow further evaluation and repair, or replace the shaft. 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 3-D tomographic analysis of offset and horizontal CSL data. 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. Transport the cores, along with five (5) copies of the coring log to the Engineer. Perform strength testing by an AASHTO certified lab on portions of the cores that exhibit questionable concrete as determined by the Engineer. If the drilled shaft offset CSL testing, 3-D tomographic analyses 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 3D tomographic imaging as described in this Section. Engage a Specialty Engineer to perform gamma-gamma density logging to verify the integrity of the shaft outside the reinforcing cage in the same locations offset CSL data was/is required. Submit all results to the Engineer within 5 days of test completion for approval. Perform all work described in this Section at no additional cost to the Department, and with no increase in contract time.

455-18 Test Holes.

The Engineer will use the construction of test holes to determine if the methods and equipment used by the Contractor are sufficient to produce a shaft excavation meeting the requirements of the Contract Documents. During test hole excavations, the Engineer will evaluate the ability to control dimensions and alignment of excavations within tolerances; to seal the casing into impervious materials; to control the size of the excavation under caving conditions by the use of mineral slurry or by other means; to properly clean the completed shaft excavation; to construct excavations in open water areas; to establish elevations for belling; to determine the elevation of ground water; to place reinforcing steel and concrete meeting the requirements of these Specifications within the prescribed time frame; and to execute any other necessary construction operation. Revise the methods and equipment as necessary at any time during the construction of the test hole when unable to satisfactorily carry out any of the necessary operations described above or when unable to control the dimensions and alignment of the shaft excavation within tolerances.

Drill test holes out of permanent position at the location shown in the plans or as directed by the Engineer. Ensure the diameter and depth of the test hole or holes are the same diameter and maximum depth as the production drilled shafts. Reinforce the test hole unless otherwise directed in the Contract Documents. Fill the test hole with concrete in the same manner production drilled shafts will be constructed. Backfill test holes which are not filled with concrete with suitable soil in a manner satisfactory to the Engineer. Leave concreted test holes in place, except remove the top of the shaft to a depth of 2 feet [0.6 m] below the ground line. Use the same procedure for shafts constructed in water. Restore the disturbed areas at the sites of test holes drilled out of position as nearly as practical to their original condition. When the Contractor fails to demonstrate to the Engineer the adequacy of his methods or equipment, and alterations are required, make appropriate modifications and provide additional test holes at no expense to the Department. Include the cost of all test holes in the cost of the Drilled

Shafts. Make no changes in methods or equipment after initial approval without the consent of the Engineer.

A separate test hole is not required for drilled shafts installed under mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures. The first production shaft will serve as a test hole for determining acceptability of the installation method.

455-19 Test Bells.

Ream the bells at specified test holes to establish the feasibility of belling in a specific soil strata. Use the diameter and shape of the test bell shown in the plans or as approved in writing.

455-20 Construction Tolerances.

Meet the following construction tolerances for drilled shafts:

(a) Ensure that the top of the drilled shaft is no more than 3 inches [75 mm] laterally from the position indicated in the plans.

(b) Ensure that the vertical alignment of the shaft excavation does not vary from the alignment shown in the plans by more than 1/4 in/ft [20 mm/m] of depth.

(c) After placing all the concrete, ensure that the top of the reinforcing steel cage is no more than 6 inches [150 mm] above and no more than 3 inches [75 mm] below plan position.

(d) Ensure that the reinforcing cage is concentric with the shaft within a tolerance of 1 1/2 inches [40 mm]. Ensure that concrete cover is 6 inches ± 1 1/2 inches [150 ± 40 mm] unless shown otherwise in the plans.

(e) All casing diameters shown in the plans refer to I.D. (inside diameter) dimensions. However, the Contractor may use casing with an outside diameter equal to the specified shaft diameter if the extra length described in 455-15.7 is provided. In this case, ensure that the I.D. of the casing is not less than the specified shaft diameter less 1 inch [25 mm]. When approved, the Contractor may elect to provide a casing larger in diameter than shown in the plans to facilitate meeting this requirement. When casing is not used, ensure that the minimum diameter of the drilled shaft is 1 inch [25 mm] less than the specified shaft diameter. When conditions are such that a series of telescoping casings are used, provide the casing sized to maintain the minimum shaft diameters listed above.

(f) Excavate the bearing area of bells to the plan bearing area as a minimum. Ensure that the diameter of the bells does not exceed three times the specified shaft diameter. The Contractor may vary all other plan dimensions shown for the bells, when approved, to accommodate his equipment.

(g) Ensure that the top elevation of the drilled shaft concrete has a tolerance of +1 and - 3 inches [+25 and -75 mm] from the top of shaft elevation shown in the plans.

(h) The dimensions of casings are subject to American Petroleum Institute tolerances applicable to regular steel pipe.

(i) Use excavation equipment and methods designed so that the completed shaft excavation will have a flat bottom. Ensure that the cutting edges of excavation equipment are normal to the vertical axis of the equipment within a tolerance of ±3/8 in/ft [±30 mm/m] of diameter.

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:

(a) Over drilling the shaft excavation to a larger diameter to permit accurate placement of the reinforcing steel cage with the required minimum concrete cover.

(b) Increasing the number and/or size of the steel reinforcement bars.

(c) Enlargement of the bearing area of the bell excavation within tolerance allowed.

When the tolerances are not met, the Contractor may request design changes in the caps or footings to incorporate shafts installed out of tolerance. The Contractor shall bear the costs of redesign and Unforeseeable Work resulting from approved design changes to incorporate shafts installed out of tolerance. Employ a Specialty Engineer to perform any redesign and who shall sign and seal the redesign drawings and computations. Do not begin any proposed redesign until it 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.

455-22 Load Tests.

When the plans include load testing, perform all load tests in accordance with 455-2 or as shown in the Contract Documents.

455-23 Method of Measurement.

455-23.1 Drilled Shafts: The quantity to be paid for will be the length, in feet [meters], of the reinforced concrete drilled shaft of the diameter shown in the plans, completed and accepted. The length will be determined as the difference between the top of shaft elevation as shown in the plans and the final bottom of shaft elevation as authorized and accepted. When the Contractor elects to provide outside diameter (O.D.) sized casing rather than inside diameter (I.D.) sized casing as allowed in 455-15.7, the pay quantity measured as described above will be multiplied by a factor (F) determined as follows:

$$F = \frac{2\,D_2 - D_1}{D_2}$$

where:

F= factor to adjust pay quantities to compensate for smaller shafts.
D_1= casing inside diameter specified = shaft diameter specified.
D_2= casing inside diameter provided (D_2 = D_1 minus twice the wall thickness).

455-23.2 Drilled Shafts (Unreinforced): The quantity to be paid for will be the length, in feet [meters], of unreinforced concrete drilled shaft of the diameters shown in the plans, completed and accepted. The length will be determined as the difference between the top of shaft elevation as shown in the plans and the final bottom of shaft elevation as authorized and accepted. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor “F” determined as described in 455-23.1.

455-23.3 Unclassified Shaft Excavation: The quantity to be paid for will be the length, in feet [meters], of unclassified shaft excavation of the diameter shown in the plans, completed and accepted, measured along the centerline of the shaft from the ground surface elevation to the plan bottom of shaft elevation authorized and accepted plus up to 15 feet [4.5 meters] or 3 shaft diameters, whichever is deeper, of additional excavation as authorized by the Engineer. When drilled shafts are constructed through fills placed by the Contractor, the original ground surface before the fill was placed will be used to determine the quantity of unclassified shaft excavation. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor “F” determined as described in 455-23.1.

455-23.4 Unclassified Extra Depth Excavation: When excavation is required by the Engineer to extend more than 15 feet [4.5 meters] or 3 shaft diameters, whichever is deeper, below the bottom of the shaft elevation shown in the plans, the work will be considered as Unforeseeable Work.

455-23.5 Drilled Shaft Sidewall Overreaming: The quantity to be paid for will be the length, in feet [meters], of drilled shaft sidewall overreaming authorized, completed and accepted, measured between the elevation limits authorized by the Engineer. When the Contractor elects to use O.D. casing, the quantity as determined above will be multiplied by the factor “F” determined as described in 455-23.1.

455-23.6 Bell Footings: The quantity to be paid for will be the number of bells of the diameter and shape shown in the plans, completed and accepted.

455-23.7 Test Holes: The cost of all test holes will be included in the cost of Drilled Shafts.

455-23.8 Test Bells: The quantity to be paid for will be the number of test bells, completed and accepted.

455-23.9 Core (Shaft Excavation): The quantity to be paid for will be the length, in feet [meters], measured from the bottom of shaft elevation to the bottom of the core-hole, for each authorized core drilled below the shaft excavation, completed and accepted. When the Engineer authorizes pilot holes extending through part or all of the shaft, prior to excavation, to some depth below the shaft bottom, the quantity paid as Core (Shaft Excavation) will be the length in feet [meters], measured from the top elevation to the bottom elevation authorized by the Engineer, completed and accepted. When SPT tests are substituted for coring or pilot holes as provided in 455-15.6, the quantity will be determined as described above in this Section.

455-23.10 Casings: The quantity to be paid for will be the length, in feet [meters], of each size casing as directed and authorized to be used. The length will be measured along the casing from the top of the shaft elevation or the top of casing whichever is lower to the bottom of the casing at each shaft location where casing is authorized and used, except as described below when the top of casing elevation is shown in the plans. Casing will be paid for only when the Permanent Casing Method is specified, when the plans show a casing that becomes a permanent part of the shaft, or when the Engineer directs the Contractor to leave a casing in place which then becomes a permanent part of the shaft. No payment will be made for casings which become bound or fouled during shaft construction and cannot be practically removed. The Contractor shall include the cost of all temporary removable casings for methods of construction other than that of the Permanent Casing Method in the bid price for Unclassified Shaft Excavation item.

When the Permanent Casing Method and the top of casing elevation are specified, the casing will be continuous from top to bottom. Authorization for temporary casing will not be given unless the Contractor demonstrates that he can maintain alignment of the temporary upper casing with the lower casing to be left in place during excavation and concreting operations. When artesian conditions are or may be encountered, the Contractor shall also demonstrate that he can maintain a positive water-tight seal between the two casings during excavation and concreting operations.

When the top of casing elevation is shown in the Contract Documents, payment will be from the elevation shown in the plans or from the actual top of casing elevation, whichever is lower, to the bottom of the casing. When the Contractor elects to use an approved special temporary casing system in open water locations, the length to be paid for will be measured as a single casing as provided above.

455-23.11 Protection of Existing Structures: The quantity to be paid for will be at the lump sum price.

455-23.12 Load Tests: The quantity to be paid for will be the number and type of load tests conducted.

455-23.13 Instrumentation and Data Collection: The quantity to be paid for will be at the lump sum price.

455-23.14 Cross-Hole Sonic Logging: The quantity of the cross-hole sonic logging test set-ups to be paid for will be the number of drilled shafts accepted based on cross-hole sonic logging tests.

455-24 Basis of Payment.

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 tubes, 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.

455-24.2 Drilled Shafts (Unreinforced): Price and payment will be full compensation for all drilled shafts (unreinforced), including the cost of concrete and all labor, equipment, materials, and incidentals necessary to complete the drilled shaft.

455-24.3 Unclassified Shaft Excavation: Price and payment will be full compensation for the shaft excavation (except for the additional costs included under the associated pay items for casing); removal from the site and disposal of excavated materials; restoring the site as required; cleaning and inspecting shaft excavations; using slurry as necessary; using drilling equipment; blasting procedures, special tools and special drilling equipment to excavate the shaft to the depth indicated in the plans; and furnishing all other labor, materials, and equipment necessary to complete the work in an acceptable manner.

455-24.4 Bell Footings: Price and payment will be full compensation for forming and excavating the bell beyond the diameter of the drilled shaft, furnishing and casting additional concrete necessary to fill the bell outside the shaft together with any extra reinforcing steel required, removing excavated materials from the site, and all other expenses necessary to complete the work.

455-24.5 Test Holes: No separate payment will be made for Test Hole. All cost of Test Holes will be included in the cost of Drilled Shafts.

455-24.6 Test Bells: Price and payment will be full compensation for forming the test bell, providing inspection facilities, backfilling the bell when the test hole is drilled out of position, and all other expenses necessary to complete the work.

455-24.7 Core (Shaft Excavation): Price and payment will be full compensation for drilling and classifying the cores/pilot hole, delivering them to the Department, furnishing drilled shaft concrete to fill the core/pilot hole, and all other expenses necessary to complete the work. When SPT tests are substituted for cores/pilot holes as provided in 455-15.6, they will be paid for at the price per foot [meter] for coring.

455-24.8 Casings: Price and payment will be full compensation for additional costs necessary for furnishing and placing the casing in the shaft excavation above the costs attributable to the work paid for under associated pay items for Unclassified Shaft Excavation.

455-24.9 Protection of Existing Structures: Price and payment will include all cost of work shown in the plans or described herein for protection of existing structures. When the Contract Documents do not include an item for protection of existing structures, the cost of settlement monitoring as required by these Specifications will be included in the cost of Unclassified Shaft Excavation; however, work in addition to settlement monitoring will be paid for as Unforeseeable Work when such additional work is ordered by the Engineer.

455-24.10 Load Tests: Price and payment will include all costs related to the performance of the load test.

455-24.11 Instrumentation and Data Collection: Price and payment will include all labor, equipment, and materials incidental to the instrumentation and data collection, and, when required, the load test report.

455-24.12 Cross-Hole Sonic Logging: Price and payment will include all costs related to the performance of the CSL testing and incidentals to the cross-hole sonic test set-up.

455-24.13 Payment Items: Payment will be made under:

Item No.	455- 18-	Protection of Existing Structures - lump sum.
Item No.	2455- 18-	Protection of Existing Structures - lump sum.
Item No.	455- 88-	Drilled Shaft - per foot.
Item No.	2455- 88-	Drilled Shaft - per meter.
Item No.	455- 90-	Bell Footings - each.
Item No.	2455- 90-	Bell Footings - each.
Item No.	455- 92-	Test Bells - each.
Item No .	2455- 92-	Test Bells - each.
Item No.	455-107-	Casing - per foot.
Item No.	2455-107-	Casing - per meter.
Item No.	455-111-	Core (Shaft Excavation) - per foot.
Item No.	2455-111-	Core (Shaft Excavation) - per meter.
Item No.	455-119-	Test Loads - each.
Item No.	2455-119-	Test Loads - each.
Item No.	455-122-	Unclassified Shaft Excavation - per foot.
Item No.	2455-122-	Unclassified Shaft Excavation - per meter.
Item No.	455-129-	Instrumentation and Data Collection - lump sum.
Item No.	2455-129-	Instrumentation and Data Collection - lump sum.
Item No.	455-142-	Cross-Hole Sonic Logging - each.
Item No.	2455-142-	Cross-Hole Sonic Logging - each.

D. SPREAD FOOTINGS

455-25 Description.

Construct reinforced concrete spread footing foundations, including dewatering when necessary, excavating to the required limits, compacting the underlying soil as required, and constructing seals when required.

455-26 General Requirements.

Meet the following requirements for all spread footings:

1. Perform excavations, including the removal of all material, of whatever nature, necessary for the construction of spread footings. As used herein, the term "soil" shall constitute any material, whether soil, rock, or other materials.

2. Slope excavations as required, or support them with sheeting, and shore them if necessary, to provide a safe excavation that is adequate for construction purposes and that will adequately protect any existing adjacent structures.

3. Ensure that the foundation soils are firm, stable, and, in the opinion of the Engineer, meet or exceed the design bearing and compressibility requirements before constructing the footings or any required seals. The Department may elect to use any type of test(s) to evaluate the foundation soils that is appropriate in the opinion of the Engineer. Cooperate with the Engineer in the evaluation of the foundation soils, and assist the Engineer as necessary to provide access to the site.

4. The elevation of the bottom of footings or seals and/or the depth of over-excavation shown in the plans is approximate and the Engineer may order, in writing, such changes as may be necessary to secure a satisfactory foundation.

5. Place all spread footing concrete in the dry.

455-27 Protection of Existing Structures.

Protect existing structures in accordance with 455-1.1. Also, if not otherwise provided in the plans, evaluate the need for, design, and provide all reasonable precautionary features to prevent damage, including, but not limited to, the installation of sheet piling, shoring as necessary, maintenance of the water table beneath such structures as nearly as practical to existing conditions, and monitoring and controlling vibrations from construction activities including driving of sheeting or from blasting.

455-28 Dewatering.

The Contractor is responsible for the design, installation, and operation of an adequate dewatering system to dewater excavations for spread footings. Use a well point or well system. Submit a dewatering plan to the Engineer for his records before beginning construction.

Use well points or wells where the piezometric water level is above an elevation 3 feet [1.0 m] below the bottom of the excavation. Maintain the water table 3 feet [1.0 m] or more below the maximum depth of excavation. Provide continuous dewatering until completing construction of the footing and backfill the excavation at least 3 feet [1.0 m] above the piezometric water table elevation. Continue dewatering until the Engineer considers conditions safe to discontinue dewatering. In the event of a dewatering failure, assist the Engineer as required in determining the effects of such a failure on the foundation soils, and take whatever corrective measures are required at no additional expense to the Department. When the Engineer approves the discontinuing of dewatering, decrease the rate of pumping, allowing the water level to rise slowly. Use a rate, in feet per hour [millimeters per hour], that the water table is allowed to rise equal to the total number of feet [millimeters] the water table was lowered, divided by ten hours or a rate of 1 ft/hr [300 mm/h], whichever is less.

Install one piezometer well approximately every 15 feet [4.5 m] of footing perimeter. Provide a minimum of two and a maximum of six piezometers at locations within 2 feet [0.6 m] from the outside of the footing perimeter. Install piezometer wells to a depth at least 10 feet [3 m] below the bottom of footing elevation or as directed by the Engineer. Measure water elevation in the piezometer wells prior to excavation and at 12-hour intervals between excavation and discontinuation of dewatering. Maintain the piezometers in working condition throughout the dewatering process, and repair or replace them when damaged at no expense to the Department.

455-29 Excavations.

455-29.1 Dry Excavations: Dry excavations are excavations that can be completed without the need to lower the piezometric water level. Perform dry excavations when the piezometric water level at the time of construction is and, in the opinion of the Engineer, will remain at least 3 feet [1.0 m] below the bottom of the authorized excavation or over-excavation. Demonstrate to the Engineer that a stable excavation can be made without dewatering. Make adequate provisions to divert surface runoff and to collect and remove any water entering the excavation.

Excavate to the bottom of footing, to the over-excavation limits shown in the plans, or as directed by the Engineer. Save any suitable materials for backfill. Provide areas for the disposal of all unsuitable materials, and dispose of them in a satisfactory method. Compact the foundation soils below the footing as shown in the plans or described herein before constructing the footing.

455-29.2 Dewatered Excavations: Dewatered excavations are excavations made after first lowering the piezometric water level with wellpoints or wells. Perform dewatering as described in 455-28. Excavate in the dry after lowering of the water table.

When dewatering is required, the Contractor may excavate within 3 feet [1.0 m] of the ground water table before dewatering begins if the dewatering system is operating and the Contractor has demonstrated that the water level has been lowered to and maintained at acceptable limits. Where large excavations require stage lowering of the water table (additional wellpoint systems installed at lower elevations), the Contractor may continue excavating as long as the water elevation is maintained at least 3 feet [1.0 m] below the excavation.

Ensure that surface runoff is diverted from the excavation. Compact the foundation soils as shown in the plans or as described herein before constructing the footing.

455-29.3 Wet Excavations: Wet excavations are excavations made below the existing water table without prior dewatering. When the plans show a cofferdam and seal, perform the excavation in the wet. Maintain the water level during excavation at or above the water level outside the cofferdam.

Place the seal directly upon the foundation soils or rock when using wet excavations. Do not compact foundation soils for wet excavations. Ensure that the foundation soils or rock are disturbed as little as practical. Remove all materials that are determined by the Engineer to be loose or disturbed before placing the seal concrete.

455-30 Fill or Backfill.

Only use fill or backfill, including over-excavations below the footing, that is clean cohesionless material, free of rubble, debris, or rocks that would prevent uniform placement and compaction. For backfill materials, use A-1, A-2, or A-3 materials, materials as shown in the plans, or materials approved by the Engineer.

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 AASHTO T 180 for a minimum depth of 2 feet [0.6 m] below the bottom of the excavation or to the depth shown in the plans before backfilling begins. Perform at least one density determination at each footing excavation at a depth of one to 2 feet [0.3 to 0.6 m] below the bottom of the excavation. Compact the backfill in footing excavations which have been over-excavated in 12 inch [300 mm] maximum loose lifts to a density not less than 95% of the maximum density as determined by AASHTO T 180 to the bottom of footing elevation. Perform at least one density determination in each lift of backfill at each footing excavation.

For compaction, use an approved heavy vibratory roller with a static drum weight of at least 4 tons [3.6 metric 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 [450 kg]. The Contractor may compact backfill located more than 15 feet [4.5 m] 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.

455-32 Forming.

Form spread footings if it can not be demonstrated that the natural soil or rock is strong enough to prevent caving during construction. For forms, meet the applicable requirements of 400-5. When forms are not required, meet the requirements of 400-5.4.4.

455-33 Materials.

455-33.1 Concrete: Meet the requirements of Section 346.

455-33.2 Reinforcing Steel: Meet the requirements of Section 415. For spread footing reinforcing steel, use Grade 60 [Grade 420].

455-34 Reinforcing Steel Placement.

Place and fasten reinforcing steel for footings according to the applicable provisions of 415-5.

455-35 Concrete Placement.

455-35.1 Placement: Place all footing concrete in the dry and according to the applicable provisions of Section 400. Do not construct joints in footings.

455-35.2 Finish: After placing and consolidating the concrete, strike-off the top surface to the grades shown in the Contract Documents, leaving the surface smooth and free of undesirable cavities and other defects. Do not provide a special finish unless the footing will be visible after construction, in which case, meet the applicable provisions of Section 400.

455-35.3 Curing: Provide continuous-moisture-curing for footings. For cover materials, use clean sand, sawdust, or other materials meeting the approval of the Engineer. Continuously wet the cover materials for a period of 72 hours.

455-36 Method of Measurement.

455-36.1 Protection of Existing Structures: The quantity to be paid for, when included in the Contract Documents, will be at the Contract lump sum price.

455-36.2 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.

455-36.3 Excavation: No separate payment will be made for backfill or will separate payment be made for excavation above bottom of footing elevation. The cost of this work will be included in the Contract unit price for Concrete (Substructure). For footings with excavation (over-excavation) below the bottom of the footing elevation shown in the plans, the cost of this excavation, backfilling, and compaction will be included in the Contract unit price for Excavation for Structures. The pay quantity will be the volume in cubic yards [cubic meters] bounded by vertical planes 12 inches [300 mm] outside of the limits of the footing and parallel thereto and extending from the bottom of the footing elevation to the authorized bottom of over-excavation or within the pay limits shown in the plans.

455-36.4 Reinforcing Steel: The quantity to be paid for will be the total weight, in pounds [kilograms], determined as described in Section 415.

455-36.5 Concrete: The quantity to be paid for will be the volume of the classes shown in the plans, in cubic yards [cubic meters], determined as described in Section 400.

455-37 Basis of Payment.

455-37.1 Protection of Existing Structures: When separate payment for Protection of Existing Structures is provided, price and payment will be full compensation for all work necessary to evaluate the need for, design of, and to provide the necessary features to protect existing structures, including all cost of work shown in the plans or described herein for protection of existing structures.

When a separate payment for Protection of Existing Structures is not provided, the cost of this work will be included in the Contract unit prices for Excavation for Structures and/or for Concrete (Substructure).

455-37.2 Dewatering: Price and payment will be full compensation for all work related to the successful dewatering of footings, including installing, maintaining, and monitoring piezometer wells. Dewatering will be considered Unforeseeable Work when the Engineer determines that dewatering is required and the plans do not include a Dewatering item.

455-37.3 Excavation: Price and payment will be full compensation for all work related to over-excavating below the bottom of footing elevation, backfill, and compaction as specified.

455-37.4 Reinforcing Steel: Price and payment will be full compensation for all work required to furnish and place the steel as shown in the plans and as specified herein.

455-37.5 Concrete: Price and payment will be full compensation for all work required to construct footings and seals as shown in the plans and described herein.

No separate payment will be made for sheeting and shoring required for excavation and footing construction except when a separate pay item for sheeting and shoring is included in the plans. The cost of all work not specifically mentioned in the other footing items will be included in the price per cubic yard [cubic meter] for substructure Concrete.

455-37.6 Payment Items: Payment will be made under:

Item No.	125-	1-	Excavation For Structures - per cubic yard.
Item No.	2125-	1-	Excavation For Structures - per cubic meter.
Item No.	400-	2-	Class II Concrete - per cubic yard.
Item No.	2400-	2-	Class II Concrete - per cubic meter.
Item No.	400-	3-	Class III Concrete - per cubic yard.
Item No.	2400-	3-	Class III Concrete - per cubic meter.

Item No. 400- 4- Class IV Concrete - per cubic yard.
Item No. 2400- 4- Class IV Concrete - per cubic meter.
Item No. 400- 91- Dewatering For Spread Footings - each.
Item No. 2400- 91- Dewatering For Spread Footings - each.
Item No. 415- 1- Reinforcing Steel - per pound.
Item No . 2415- 1- Reinforcing Steel - per kilogram.
Item No. 455- 18- Protection of Existing Structures - lump sum.
Item No. 2455- 18- Protection of Existing Structures - lump sum.

E. STRUCTURES (OTHER THAN BRIDGE)

FOUNDATIONS - AUGER CAST PILES

455-38 Description.

Furnish and install auger cast piles used for structural support, other than bridge foundations.

455-39 General Requirements.

455-39.1 Contractor's Operations: Submit an Auger Cast Pile Installation Plan in accordance with 455-47. Prior to the start of production piles, demonstrate to the satisfaction of the Engineer, the dependability of the equipment, techniques, and source of materials by construction of a demonstration pile.

455-39.2 Protection of Existing Structures: Protect existing structures in accordance with 455-1.1.

455-40 Materials.

Meet the following material requirements:

(1) Portland Cement (Types I, II, III, IP, and IS)............Section 921
(2) Fly Ash, Slag and other Pozzolanic Materials for Portland Cement Concrete..Section 929
(3) Fine Aggregate (Sand)* ....Section 902
(4) Admixtures...Section 924
(5) Water...Section 923
(6) Fluidizer ....ASTM C 937

* The Contractor may use any clean sand with 100% passing 3/8 inch [9.5 mm] sieve and not more than 10% passing the 200 mesh [75 µm] sieve. The Engineer will only permit Silica Sand except as provided in 902-5.2.3.

455-41 Grout Mix Proportions.

Use a grout mix consisting of a mixture of Portland cement, fly ash, retarder, fluidizer, sand and water proportioned and mixed to produce a mortar capable of maintaining the solids in suspension without appreciable water gain and which may be pumped without difficulty and fill open voids in the adjacent soils. Proportion these materials to produce a hardened grout of the required strength shown on the plans.

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. Accurately measure all materials by volume or weight as they are fed to the mixer. Place the materials in the mixer in the following order: 1) water, 2) fluidifier, 3) other solids in order of increasing particle sizes.

3. Use a quantity of water and mixing time that will produce a homogenous grout having a consistency of 18 to 24 seconds, or higher if specified by the Engineer, when tested with a flow cone in accordance with ASTM C 939 (3/4 inch [19 mm] diameter outlet), with a frequency at the discretion of the Engineer. 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 70ºF [20ºC]; two hours for temperatures from 70 to 100ºF [20 to 38ºC]. Do not place grout when its temperature exceeds 100ºF [38ºC]. 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 of the cement grout into a thoroughly mixed and uniform mass, free from balls or lumps of cementitious material and capable of discharging the concrete with a satisfactory degree of uniformity. The Engineer's approval of grout mixers and all other equipment will be conditioned on proper performance during construction of the demonstration pile and subsequent production work.

5. Use a screen no larger than 3/4 inch [19.0 mm] 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 capable of developing displacing pressures at the pump up to 350 psi [2.4 MPa]. 7. Use a grout pump/system equipped with a pressure gauge to accurately monitor the pressure of the grout flow. Test and calibrate the equipment during construction of the demonstration pile to demonstrate flow rate measurement accuracy of ±3% over the range of grouting pressures anticipated during this work. Provide a pump stroke counter in good working condition on the grout pump. Also calibrate the equipment any time the Engineer suspects that the grout pump performance has changed.

455-43 Testing Cement Grout.

Make four cubes, 2 by 2 inch [50.8 by 50.8 mm] each, for each 50 yd^3 [38 m^3] of grout placed, per day of pile placement. The Engineer will test two cubes at seven days and two cubes at 28 days. The minimum required strength will be specified on the plans. When a cement grout acceptance strength test falls more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is less deviation from the specified minimum strength, perform one of the following:

(a) Remove and replace the LOT of concrete in question at no additional cost to the Department, or

(b) Submit a structural analysis performed by a Specialty Engineer. If the results of the analysis, approved by the Department, indicate adequate strength to serve the intended purpose with adequate durability, the concrete may remain in place. Otherwise, remove and replace the LOT of concrete in question at no additional cost to the Department.

All low strength cement grout accepted by the Engineer will be subject to reduced payment as follows: \$0.80/yd^3 for each 10 psi [\$1.05/m^3 for each 70 kPa] of strength test value below the specified minimum strength.

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. 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 [meters]
RC = Total Reduction in payment, dollars
UC = Unit Cost of pile, dollars /foot [dollars /meter]

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 [1.5 m] and a maximum diameter about the pile centerline, not to exceed 1/2 of the distance to the adjacent pile. Backfill with clean granular backfill materials (A-1, A-3, A-2-4), placed and compacted in maximum 12 inch [300 mm] lifts to at least 95% of maximum dry density as determined by AASHTO T 180. Complete this work to the Engineer's satisfaction prior to auger cast pile construction. Should more than 5 feet [1.5 m] 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, 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 drawings.

6. Clearly mark the auger leads to facilitate monitoring of the incremental drilling & grout placement. Provide individual foot marks with 5 foot [1.5 m] 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. Commence auger cast pile

construction immediately upon 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/minute [300 mm/minute].

9. Plug the hole in the bottom of the auger while being advanced 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 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. Carry a head of at least 5 feet [1.5 m] 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 [1.5 m] 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 [1.5 m] to the tip. Place a minimum volume of grout in the hole of at least 105% of the column of the auger hole from a the ground surface to a depth of 5 feet [1.5 m]. 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 [1.5 m] 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 [1.5 m] 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 [1.5 m] increment (105% in the top 5 foot [1.5 m] increment), reinstall the pile by advancing the auger 10 feet [3 m] 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.

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, unless otherwise approved by the Engineer.

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 the grout has set a minimum of seven days or reached the 28 day strength.

455-45 Construction Tolerances.

Locate piles as shown on the drawings, or as otherwise directed by the Engineer. Locate pile centers to an accuracy of ±3 inches [±75 mm]. Ensure that the top of pile elevation is within an accuracy of ±3 inches [±75 mm] of the plan elevation.

Locate all precast post, anchor bolts, etc. within the following tolerances unless otherwise shown in the plans: variation from plum (±1/4 inch/post height [±6 mm/post height]); specified elevation (±1/2 inch [±13 mm]); and specified location (±1/4 inch [±6 mm]).

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.

455-47 Auger Cast Pile Installation Plan.

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

1. Name and experience record of auger cast pile superintendent or foreman in responsible charge of auger cast pile operations. Place a person in responsible charge of day to day auger cast pile operations who possesses satisfactory prior experience constructing shafts 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 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. Maintain records of each pile installed, separate from those of the Engineer, showing:

1. Pile location
2. Ground elevation
3. Pile length
4. Tip elevation
5. Pile top elevation

6. Pay length (when piles are paid for separately)
7. Overburden length (length cast above the final grade point)
8. Pile diameter
9. Quantity of grout placed per yard [meter] of pile length
10. Theoretical quantity of grout required
11. Drilling time
12. Grouting time
13. All other pertinent data relative to the pile installation
14. Grout truck time of arrival to the site and batch time
15. Flow cone (consistency) results

455-49 Method of Measurement.

455-49.1 Protection of Existing Structures: The quantity to be paid for, when included in the Contract Documents, will be at the Contract lump sum price.

455-49.2 Auger Cast Pile: The quantity to be paid for will be at the Contract unit price per foot [meter] between tip and required pile top elevations for all piles completed and accepted.

455-50 Basis of Payment.

455-50.1 Protection of Existing Structures: When separate payment for Protection of Existing Structures is provided, price and payment will be full compensation for all work necessary to evaluate the need for, design of, and to provide the necessary features to protect the existing structures, including all cost of work shown in the plans or described herein for protection of existing structures.

When a separate payment for Protection of Existing Structures is not provided, the cost of settlement monitoring will be included in the cost of the structure. Work ordered by the Engineer for protection of existing structures, other than settlement monitoring, will be paid for as Unforeseeable Work.

455-50.2 Auger Cast Piles: Price and payment will be full compensation for all labor, materials, and incidentals for construction of auger cast piles of the sizes and depths indicated on the Contract drawings or otherwise required under this Contract. 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.

455-50.3 Payment Items: Payment will be made under:

Item No.	455- 18-	Protection of Existing Structures - lump sum.
Item No.	2455- 18-	Protection of Existing Structures - lump sum.
Item No.	455-112-	Auger Grouted Piles - per foot.
Item No.	2455-112-	Auger Grouted Piles - per meter.