Revised November 9, 2006

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION

PROJECT NO.
P.I. NO.

SECTION 524 – DRILLED CAISSON FOUNDATIONS

524.1 General Description

This Work consists of furnishing all labor, materials, equipment, tools and services necessary for construction of drilled caisson foundations and includes all incidentals and additional work in conjunction therewith. Adhere to the Department's Plans, Special Provisions and Standard and Supplemental Specifications for all Work.

524.2 Materials

Use materials that meet the requirements of the Standard Specifications with the following exceptions:

- Use non-air-entrained Class AA concrete with a coarse aggregate size of No. 67 stone and a slump at time of placement of between 7 and 9 inches (175 and 225 mm). Use 10 percent additional cement and a retarder or water reducing agent in all concrete.
- Use Grade 60 (Grade 420) reinforcing bars that conform to ASTM 615 (ASTM A 615M). If wire spirals are used, use spirals that conform to ASTM A 82.
- Use Grade 2 steel casing that conforms to ASTM A 252.
- Use water that conforms to Section 880 of the Standard Specifications.

524.3 Construction Requirements

524.3.01 Personnel

Construct drilled caissons and supervise the work with personnel who are experienced in this type work. Visit and examine the work site and all conditions, and take into consideration all such conditions that may affect the work. At least thirty days prior to beginning drilled caisson work,

submit to the Engineer for review and approval the following proof of the ability of the personnel to construct drilled caisson foundations:

1. Evidence of the successful completion of at least five projects similar in concept and scope to the proposed foundation. Include names, addresses and telephone numbers of the owners' representatives for verification.

2. Résumés of foreman and drilling operators to be employed on this project. Provide evidence showing that the drill operator has experience and knowledge of the drill rig to be used on the project. The Department will be sole judge of the qualifications of the foreman and drill rig operator.

3. A detailed sequence of construction for drilled caisson work that describes all materials, methods and equipment to be used, including, but not limited to the following:

    - casing sizes with proposed top and tip elevations
    - drilling equipment including the manufacturer's specifications on the drill rig
    - methods and equipment for stabilizing and cleaning shaft excavations
    - methods of materials handling and disposal
    - methods and equipment for placing concrete
    - equipment to mix, circulate, contain and de-sand slurry
    - details of tremie or pump line sealing methods
    - details of reinforcement placement, including support and centralization methods

Do not begin drilled caisson construction until the qualifications, construction plan and methods have been approved in writing by the Engineer.

524.3.02 Sequence of Events

1. After the Engineer's acceptance of the qualifications and methods, and prior to construction, attend a meeting with the Engineer to review specifications, discuss details of construction methods and equipment, review contingency plans in the event that problems occur, and other issues.

2. Prior to construction of the load test caisson, demonstrate the adequacy of methods, materials and equipment on a demonstration caisson that will not become part of the completed structure. Excavate this demonstration caisson with the same tools, methods, slurry type, and to the same diameter and maximum depth of the production caissons. Use the same type reinforcing cage and same type slurry that will be used on the load test and production caissons. Do not leave casing in place unless permitted by the Engineer. Construct this demonstration caisson at Bent **X** no closer than five caisson diameters to the existing and proposed bridge foundations, and no further

than ten caisson diameters from the existing and proposed bridge foundations, and to an Elevation **X**.

Include all costs of materials and labor required to construct these caissons in the price bid for demonstration caissons.

3. Prior to constructing the production caissons, perform a load test on a non-production load test caisson. Construct the load test caisson with the same tools, reinforcement, stabilization and excavation methods, and to the same diameter of the production caissons. Construct the load test caisson at Bent **X**, no closer than five caisson diameters to the existing or proposed bridge foundations, and no further than ten caisson diameters from the existing or proposed bridge foundations, and to an Elevation **X.** Install the bottom and mid-range cells at Elevations **X** and **X** respectively.

   Include all costs of materials and labor required to construct and test the load test caisson in the price bid for load test caissons.

4. If the demonstration or load test caisson(s) are constructed in a river, lake, or other open body of water, reinforcement and concrete will not be required above the river or lake bed elevation.

5. After the Engineer has accepted the results of the load tests and set the tip elevations of the production caissons, begin construction of the caissons as detailed in the Plans and Specifications. The Engineer will set the tip elevations of the production caissons no later than twelve calendar days after receiving the completed load test report.

524.3.03 Equipment

Use excavation and drilling equipment with a rated capacity (including power, torque and downward thrust) to excavate a caisson of the maximum specified diameter to a depth of 30 feet (9.1 meters) or 20 percent deeper than the deepest production caisson indicated on the Plans, as measured from the ground or high water surface elevation, whichever is higher.

524.3.04 Casing

Use casings if the elevation of the top of the caissons is at or below the ground or expected high water elevation at any time during construction. If casings are used, set the elevation at the top of the casing a minimum of 2 feet (600 mm) above the ground or 4 feet (1200 mm) above the expected high water elevation at the site, whichever is greater. Cut off any permanent casing used as shown on the Plans.

Use casing that is a metal shell of a thickness to withstand handling, internal and external pressures, and that is watertight, smooth and clean. If the elevation of the top of the caisson is below ground level or water level at the time of concrete placement, use an oversize casing from ground elevation to a point below the top of the caisson to prevent soil from caving into the fresh concrete. Do not allow the top of the permanent casing, if required, to extend above the top of the drilled caisson. Use casing in all materials that do not have sufficient strength to safely remain open and stable during and after excavation.

When casing is used, do not use casing with an outside diameter less than the specified diameter of the caisson. That portion of the caisson below the casing may be slightly smaller than the normal outside diameter of the caisson. However, use drilling tools to excavate the caisson below the casing that are no smaller than the Plan diameter of the caisson minus 2 inches (50 mm). Do not leave casing in place unless permitted by the Engineer, and cut off any permanent casing as shown on the Plans.

Provide adequate equipment during concrete placement to prevent pulling up the reinforcing cage during casing extraction. The casing may be pulled in partial stages. Maintain a sufficient head of concrete above the bottom of the casing to overcome hydrostatic pressure. Extract the casing at a slow uniform rate with pull in line with the center of the caisson.

In open-water locations, provide containment at the top of the casing to prevent any material from spilling into the water. Install casing to a depth and in a manner that will produce a positive seal at the bottom of the casing. Do not allow water or other materials, into or out of the excavation area at or below the bottom of the casing.

Do not leave casings in place unless permitted by the Engineer. If casings that are to be removed become bound in the caisson excavation and cannot be practically removed, or if the permanent casing is lowered below the proposed tip elevation, drill the caisson excavation deeper and extend the caisson, including reinforcement, as directed by the Engineer to compensate for loss of capacity due to the presence of the casing. No compensation will be made for the casing remaining in the excavation. The additional length of caisson including excavation, reinforcing steel, concrete and other items incidental to the Work will be paid for at the unit bid price for drilled caissons.

524.3.05 Slurry

Use temporary full-depth casings, mineral or polymer slurry on this project to maintain the stability of the excavations. Manufacture mineral slurry from processed, high-sodium bentonite clays. Use polymer slurry that conforms to the manufacturer's recommendations, that is site specific, and has been used successfully on a minimum of ten projects of similar size and scope. Adjust the percentage and specific gravity of the slurry used so that the stability of the excavation is maintained, and to allow for proper placement of the concrete.

When using mineral slurry, adhere to the following requirements:

1. Premixing: Mix the mineral slurry thoroughly in a clean, separate tank using clean water that meets the requirements of Section 880 of the Standard Specifications prior to placing the slurry in the excavation. Mix the mineral slurry with high-speed pumps for the time recommended by the manufacturer to allow for its complete hydration.

2. Testing: Provide the equipment necessary to sample the slurry at the bottom of the shaft and provide the equipment and materials to perform viscosity, density, pH and sand content tests on these same slurry samples. Perform all tests in the presence of the Engineer. Perform the viscosity, pH and density tests on the slurry taken from the mixing tanks prior to the introduction of the slurry into the excavation.

Conduct all tests at the end of each workday after drilling is completed and at the beginning of each workday before drilling resumes. Perform these tests on slurry samples collected from the depths

and at the times determined by the Engineer to ensure that the slurry within the entire excavation meets these Specifications.

Perform sand content tests on slurry samples taken from the bottom of the shaft after placement of the reinforcing cage, but immediately before pouring concrete. Do not place concrete until all testing produces acceptable results.

a. Viscosity: Produce slurry with a viscosity within the range of 30 to 45 seconds per quart (32 to 48 seconds/liter), as measured by the Marsh Cone Method.

b. Density: Produce slurry with a density within the range of 66 to 73 pounds per cubic foot (1060 to 1170 kilograms per cubic meter). If the sidewalls are unstable, or if artesian flow is present, use a weighing additive to increase the density.

c. pH: Produce slurry with a pH within the range of 8 to 11. The pH of the mineral slurry may be adjusted with the use of soda ash.

d. Sand Content: Measure the sand content of the slurry at the bottom of the shaft by the sand content test just prior to concrete placement. When the sand content at the bottom of the shaft exceeds 4%, clean the bottom of the shaft using desanding or other equipment that is approved by the Engineer.

When using polymer slurry, adhere to the following requirements:

1. Submittals: A minimum of 30 working days prior to the use of polymer slurry, submit the following information to the Engineer:

a. A list of ten projects and locations where the polymer slurry has been successfully used on projects of similar size and scope.

b. Project owner names and contact phone numbers

c. Diameter and depth of drilled caissons used on these projects.

Do not use the polymer slurry until the Engineer has reviewed and approved the submittal in writing.

2. Manufacturer's Representative: Ensure that a representative of the polymer slurry manufacturer is on site to provide assistance and guidance with the construction of the test excavation (if applicable), the demonstration caisson (if applicable), the load test caisson (if applicable), and the first two production caissons. Ensure that this representative is also available for on-site assistance if problems with the polymer slurry are encountered with the construction of the remaining production caissons. The cost of all on-site assistance and representation will be considered incidental to the cost of the drilled caissons.

3. Premixing: Mix the polymer thoroughly in a clean, separate vessel using clean water that meets the requirements of section 880 of the Standard Specifications prior to placing the slurry in the excavation. Add polymer to water flowing through a hose, across a stationary surface into a vessel. Mix the polymer for the time recommended by the manufacturer to allow the polymer to develop adequate viscosity to be self-suspending.

4. Testing: Provide the equipment necessary to sample the polymer slurry from the bottom of the excavation, from the upper portion of the excavation, and from the slurry supply tank or vessel at regular intervals during the excavation process. Provide the equipment and materials needed to perform density, viscosity, pH, and sand content tests on these slurry samples. Perform all tests in the presence of the manufacturer's representative and the Engineer. Perform the viscosity, pH and density tests on the polymer slurry taken from the mixing tank or vessel prior to the introduction of the polymer slurry into the excavation. After the polymer slurry is in the excavation, perform all tests (i.e. viscosity, density, pH, and sand content) at the bottom and at the upper section of the excavation, at intervals determined by the Engineer. Maintain written records, showing viscosities, pH values, densities, sand content, times, dates, and depth or locations from which samples were taken.

Perform sand content, density, viscosity, and pH during the static period (the period when the polymer slurry is stabilized and shows no further change over a 30-minute interval during which the excavation is completely static), from mid-point of the excavation and from within 24" (610 mm) of the bottom. Do not place concrete until all testing produces acceptable results as follows:

a. Viscosity: Produce polymer slurry with a viscosity within the range of 30 to 125 seconds/quart (32 to 132 seconds/liter) during drilling and less than or equal to 60 seconds/quart (63 seconds/liter) just prior to placing concrete, as measured by the Marsh Cone Method.

b. Density: Produce polymer slurry with a density within the range of 64 lb/ft^3 (1025* kg/m^3) to 67 lb/ ft^3 (1073* kg/m^3). A weighing additive may be used to increase the density of the polymer slurry if the sidewalls are unstable or if artesian flow is present.

c. pH: Produce polymer slurry with a pH within the range of 8 to 11. The pH of the mix water may be adjusted with the use of soda ash.

d. Sand Content: Measure the sand content of the polymer slurry from the bottom and from the upper portion of the excavation just prior to concrete placement. When the sand content at the bottom of the shaft exceeds 1%, clean the bottom of the shaft using desanding or other equipment that is approved by the Engineer.

* When approved by the Engineer, slurry may be used in salt water, and the allowable densities may be increased by 2 lb/ft^3 (32 Kg/m^3).

Use slurry with a temperature of at least 40^o F (4.4^o C) during testing.

524.3.06 Protection of Existing Structures

Monitor structures for settlement that are within a distance of ten shaft diameters or the estimated shaft depth, whichever is greater, in a manner approved by the Engineer. Record elevations to an accuracy of .01 foot (3 mm). Record elevations before construction begins, during the driving of any required casings, during excavation or blasting, or as directed by the Engineer.

Document thoroughly the condition of the structures with descriptions and photographs made both before and after drilled caissons are constructed. Document all existing cracks, and provide copies of all documentation to the Engineer.

At any time settlement of .05 foot (15 mm) or damage to the structure is detected, immediately stop the source of vibrations, backfill any open drilled shaft excavations and contact the Engineer for instructions.

524.3.07 Excavation

Drill and excavate all caissons through whatever substances and to the elevations required. Excavate near the tip elevation in the presence of the Engineer. Stabilize all excavations with slurry to control the excavation diameter and prevent sidewall sloughing, cave-ins or excessive sediment build-up on the excavation bottom. Provide the stabilization prior to excavation.

Use the same tools, stabilization and excavation methods on the production caissons that were used on the accepted demonstration caisson. Construct additional demonstration excavations with no additional cost to the Department, and with no increase in contract time if any changes are made in the tools, excavation and stabilization methods on production caissons from those methods previously demonstrated and accepted.

When casing is not specifically required on the Plans, fill in any over-excavation with Class AA concrete at no additional cost to the Department. Dispose of excess concrete, grout, displaced water and materials removed from the caisson excavation in areas approved by the Engineer, and in accordance with any Federal, State, or local code or ordinance. Verify the accuracy and existence of all applicable codes, ordinances or other regulations prior to disposing materials.

Maintain the fluid level within the casing at a minimum of 4 feet (1.2 meters) above the level of the expected high water elevation or hydrostatic pressure head, whichever is greater, at all times so that unbalanced hydrostatic and/or soil pressures will not cause the collapse of the drilled caisson sidewalls or bottom. In the event of a sudden and/or significant loss of fluid in the excavation, stop construction until a method to stop fluid loss, or until an alternate construction procedure, has been approved by the Engineer.

Conduct excavation near the tip elevation in the presence of the Engineer for determination of the quality of materials encountered. The Engineer will inspect and approve the bottom of each shaft prior to setting the reinforcing cage and pouring concrete. The Engineer may adjust the caisson tip elevation if unsuitable foundation conditions are encountered at the plan tip elevation. Clean the bottom of the excavation so that it is firm, level, and free of sediment or debris. Use a bailing bucket, air lift, or submersible pump to perform the final cleaning of the excavation.

If the excavation below casing remains open for more than 18 hours, over-ream the sides of the excavation with a grooving tool, over-reaming bucket, or other approved equipment to increase the shaft radius a minimum of ½ inch (12 mm) and a maximum of 3 inches (75 mm). Perform the over-reaming and provide and place additional concrete required at no additional cost to the Department, and with no increase in Contract time.

Do not allow any excavation below casing to remain open longer than 36 hours without commencing concrete placement.

524.3.08 Reinforcing Steel

Assemble a cage of reinforcing steel and place it as a unit immediately prior to concrete placement. Assemble the cage so that the clearance between the cage and side of the caisson will be at least 5 inches (125 mm), and the clearance between the cage and bottom of the caisson will be 3 inches (75 mm).

If the caisson is lengthened, extend all reinforcement to within 3 inches (75 mm) of the bottom. If a splice is required, do not locate the splice in the upper 50 feet (15.2 meters) of the caisson, unless shown on the Plans. Tie hoops or spirals to the caisson and column steel (vertical bars) at 100% of the junctions with double wire figure-eight ties. Do not weld the reinforcing steel. Support the cage from the top in a concentric manner to minimize its slumping downward during concrete placement and/or extracting of the casing.

Check the elevation of the top of the steel cage before and after casing extraction. Any upward movement of the steel not exceeding 2 inches (50 mm) or any downward movement thereof not exceeding 6 inches (150 mm) will be acceptable. Any upward movement of the concrete or displacement of the steel beyond the above limits will be cause for rejection. Tie and support the reinforcing steel in the caisson so that the reinforcing steel will remain within allowable tolerances. Provide all temporary or permanent cage stiffeners, braces, helical ties, jigs, or bands that are required to maintain cage stiffness and shape during the assembly, lifting and placement of the reinforcement cage.

In uncased caissons, use only heavy-duty plastic rollers (wheels). In cased caissons, use heavy-duty non-corrosive plastic rollers (wheels) or steel chairs. Place rollers at a maximum interval of 8 feet (2.4 meters) along the cage to ensure concentric spacing for the entire cage length. Use one roller for each 1 foot (300 mm) of diameter of the cage, with a minimum of four rollers at each interval. Do not use concrete spacer blocks. Use rollers that are constructed of a material approved by the Engineer and that have sufficient bearing surface to provide lateral support to the reinforcing cage.

Use rollers of adequate dimension to provide the annular spacing between the outside of the reinforcing cage and the side of the excavated hole or casing as shown on the Plans. If an oversize casing is used, use rollers that will provide concentric spacing. Use pre-cast concrete or heavy-duty plastic bottom supports (feet/boots) to provide a spacing of 3 inches (75 mm) between the cage and caisson bottom.

524.3.09 Concrete

Mix and place all concrete in accordance with Section 500 of the Specifications where applicable and the requirements herein stated. Place concrete as soon as possible after all excavation is completed and reinforcing placed and supported. Place concrete continuously in the caisson to the top elevation of the caisson.

Place concrete using a gravity feed watertight tremie consisting of a pipe at least 8 inches (200 mm) in diameter with a hopper at the top. Concrete may be placed by pumping through a supply line if the Engineer approves this method. Provide a pump supply line with sections that have watertight couplings. Prevent concrete from mixing with fluid from the excavation within the tremie or pump supply line by sealing the end of the line with a foam plug or other device approved by the Engineer.

At the beginning of concrete placement, place the tremie on the bottom of the excavation until the tremie pipe and hopper are filled with concrete. Raise the tremie only enough to induce concrete flow and do not lift it further until the discharge end is immersed at least 10 feet (3 meters) into the deposited concrete. If concrete placement by pumping is used, secure the supply line in place so that the discharge end will not lift off the bottom of the excavation more than 6 inches (150 mm) until at least 10 feet (3 meters) of concrete has been placed. Embed the discharge end of the tremie or pump supply line in the concrete a minimum of 10 feet (3 meters) throughout the remainder of the concrete pour.

Place concrete continuously in the caisson to the top elevation of the caisson until good quality concrete is evident at the top of the caisson, to the satisfaction of the Engineer. Remove any concrete that becomes contaminated with slurry, soil, or other deleterious materials near the top of the caisson and replace it with uncontaminated concrete or chip the contaminated concrete back to sound concrete after the concrete has dried at no additional cost to the Department.

Once concrete placement in the caisson has begun, place all concrete in the caisson within two hours. Adjust the retarder or water reducing agent as approved by the Engineer, for the conditions encountered on the job so that the concrete remains in a workable plastic state throughout the pour. If a longer placement time is needed, provide a concrete design mix that will maintain a minimum 4 inches (100 mm) slump over the longer placement time, as demonstrated by a trial mix and slump loss test to the satisfaction of the Engineer. Repeat the slump loss test as directed by the Engineer when there is an increase of more than 10° Fahrenheit (5.5° Celsius) in ambient temperature from when the trial mix and slump loss tests were performed.

Prepare and cure the top surface of the caisson in accordance with the requirements of Section 500. Locate construction joints as indicated on the Plans. Provide a plan to the Engineer of how the concrete is to be placed and protected at the cut-off elevation to ensure that good quality concrete is placed at the top surface of the caisson. Do not place concrete until the Engineer has approved this plan. Provide a sump to channel displaced water away from the caisson. Do not discharge concrete, contaminated fluids, slurry, soil, or rock into any body of water.

During the twenty-four hour period immediately following the completion of the placement of concrete in the caisson, do not install or extract casing within 50 feet (15 meters) of the completed caisson, and do not excavate any caissons within 15 feet (4.5 meters) of the completed caisson. If the Engineer determines that any construction adversely affects the recently constructed caisson, cease such activities immediately.

Protect any portion of drilled caissons exposed to a body of water from the action of water by leaving the forms in place for a minimum of seven days after pouring the concrete. Remove the forms prior to seven days only if the concrete strength has reached 3000 psi (21 MPa) or greater as tested by cylinder breaks.

524.3.10 Inspection

Provide equipment for checking the dimensions and alignment of each caisson excavation. Check the dimensions and alignment of the excavations in the presence of the Engineer.

524.3.11 Tolerances

Adhere to the following construction tolerances for drilled caissons:

1. Construct the drilled caisson to within 3 inches (75 mm) of the plan position plane, at the top-of-caisson elevation. Adhere to a vertical alignment tolerance of ¼ inch (6 mm) per 12 inches (300 mm) of depth.

2. Place reinforcement in accordance with the requirements of Section 511 of the Standard Specifications and Sub-section 524.3.08. Tie column steel (vertical bars) to hoops and spirals at 100% of the junctions with double wire figure-eight ties.

3. Placed vertical caisson reinforcing bars, including bars extending into columns or footings to within ¼ inch (6 mm) of plan location. Place hoops or spirals to within 1 inch (25 mm) of their specified location. Adhere to a side form clearance of within ¼ inch (6 mm) of plan requirements.

4. Place the construction joint of the top of caissons used as caisson/column intermediate bents to within a tolerance of plus or minus 3 inches (75 mm) of the plan elevation.

5. Provide additional materials and labor necessary to correct out-of-tolerance caissons at no cost to the Department and with no increase in contract time.

524.4 Acceptability

In the event that significant voids are suspected in the concrete that were created during placement, verify the integrity of the caisson using a method that has been approved by the Engineer. If the caisson in question is found to be structurally deficient or out of tolerance in any way, the caisson will not be accepted unless corrective measures as approved by the Engineer are accomplished. Furnish additional materials and work necessary to effect corrections at no cost to the Department and with no increase in contract time.

524.5 Load Test

1. Description: This Work consists of furnishing all labor and materials necessary to conduct a bi-directional load test and to report the results to the Department. Obtain the services of an instrument supplier approved by the Department to conduct the load test. Submit proof that the instrument supplier has successfully conducted at least five load tests using the bi-directional test device (Osterberg Cells or equal) to the Engineer. Use the bi-directional load test device to test separately the shear resistance and end bearing of the caisson by loading the caisson in two directions (upward-shear resistance, downward-base shear and/or end bearing) or by loading the caisson using other approved methods capable of full separation of the upward shear and downward shear and downward base shear and/or end bearing. Use bi-directional test devices that are capable of applying a load of at least **X** tons (MN) at the location of the mid-range cell and **X** tons (MN) at the location of the bottom cell.

Conduct the load test in conjunction with the instrument supplier and supply material and labor before, during, and after the load test. Instrument the load test caisson as per Sub-section 524.6 (see Figure Nos. 1 and 2 for information). After the completion of the load test, cut off any portion of the caisson to a depth of 12 inches (300 mm) below stream bed elevation.

The tip elevations of the production caissons may be raised or lowered by the Department and will be set by the Engineer based on the results of the load tests no later than fourteen calendar days after the Engineer receives and accepts the completed load test reports.

2. Materials: Supply all materials required to install the load cells and conduct the load test, including, but not limited to the following:

a. Two **X** ton (MN) load cells of the same size for the load test.

b. Fresh water from a source approved by the Engineer for mixing water-soluble oil provided by the instrumentation supplier to form the hydraulic fluid used to pressurize the load cell.

c. Materials sufficient to construct a stable reference beam system for monitoring the deflection of the caisson during testing. Support the reference beam system at a minimum distance of three diameters from the center of the caisson to prevent the beam's disturbance. Where space is restricted, two good-quality, self-leveling surveyor's levels may be used to monitor the caisson movements. In open water areas, protect or brace the test caissons and reference caissons against wave and current action.

d. Materials sufficient to construct a protected area (including provisions such as a tent or shed for protection of the load test equipment and personnel from inclement weather) of size and type required by the Engineer.

e. Electrical power as required for lights, instruments, welding, etc.

f. A beam or pipe system as required by the instrument supplier to support the placement of the load cell and instrumentation pipes and wires when a caisson rebar cage will not be used.

g. Remove materials from the load test caisson at the conclusion of the load test.

3. Equipment: Supply the equipment required to install the load cells, conduct the load test, and remove the load test apparatus as required, including, but not limited to the following:

a. Welding equipment and certified welding personnel, as required, to assemble the test equipment, attach pipes and fittings to the load cells, and prepare the work area.

b. Air compressor of minimum 150 CFM (4.2 CMM) to activate the pump.

c. Cranes or other lifting device for handling the load cells, pipes, and reinforcing cage or alternate instrument support system during the installation of the load cells during the performance of the testing.

d. Equipment and labor sufficient to erect the protected work area and monitoring reference beam system, constructed to the requirements of the Engineer.

e. Suitable operating and reference level platforms, as required for testing over water or in otherwise unstable foundation conditions. Submit to the Engineer for review and approval, a plan for the reference beams and platform system to be used during the load test at least two weeks prior to conducting the load test.

4. Procedure: Construct the load test caisson using the approved caisson installation techniques. Assemble the load cells, pipes and other attachments under the direction of the instrument supplier

Place the load cell assemblies at the bottom of the load test caisson and at other specified locations on the cage. Welding of the rebar to the load cell is permissible.

After the load test caisson excavation has been constructed, inspected and accepted by the Engineer, place a quantity of concrete or grout approximately 6 inches to 12 inches (150 to 300 mm) thick at the base of the caisson by a method approved by the Engineer. Install the load cells and the reinforcing cage assembly in the test shaft under the direction of the instrumentation supplier and the Engineer so that the bottom load cell is resting firmly in/on the concrete/grout bed. Use the utmost care in handling the rebar cage/test equipment assembly so as not to damage the instrumentation during installation. Alternatively, lower the load cells and reinforcing cage assembly as one unit to the near-bottom of the shaft and place a bed of concrete 6 inches to 12 inches (150 to 300 mm) thick placed through a slick line using a concrete pump.

After installation of the load cells, place the concrete in the caisson in the manner specified for similar production caissons. Do not conduct the load test until the minimum compressive strength of the concrete is 3000 psi (21 MPa), as indicated by cylinder breaks. Type III high early cement may be used in the mix to reduce the time between placing concrete and testing if approved by the Engineer

During the period required to perform the load test, do not vibrate casings into place in the foundation area near the load test. However, drilling may continue, provided that such drilling is for caissons located approximately 50 feet (15 meters) or more from the work area. If test apparatus show any signs of negative effects due to construction activities, cease such activities.

After the completion of the load test, and at the direction of the Engineer, remove any equipment, material, waste, etc.

5. Report: Supply the Engineer with five copies of a report of the load test within three calendar weeks after completion of the load test, as prepared by the instrumentation supplier or others approved by the Engineer.

524.6 Load Test Instrumentation Requirements

1. Description: This Work consists of furnishing strain gauges and rod tell-tales, as noted herein, for use in monitoring the load test. Provide and install the gauges and rod tell-tales at the locations directed by the Engineer. Provide shelter over the load test location to protect the gauges and other instrumentation from inclement weather. Replace any instrumentation devices damaged at no additional cost to the Department.

2. Materials: Provide the following type and number of strain gauges and rod tell-tales for the load test:

a. Twelve vibrating wire embedment strain gauges set to measure compression that read to a maximum strain range of at least 3000 microstrains with a sensitivity of 1 microstrain. Provide waterproof gauges supplied with shielded multi-conductor electric cable, and with two connection devices or fasteners of a suitable type to securely join the gauges to a longitudinal reinforcement bar of the drilled caisson rebar cage. Provide access to the drilled caisson rebar cage to allow the instrument supplier to install the strain gauges.

   Install the gauges at intervals of approximately equal spacing throughout the rebar cage, or at the locations directed by the Engineer. Supply sufficient lengths of cable for each gauge to reach from the gauges to approximately 30 feet (10 meters) beyond the top of the casing.

   Perform the monitoring of the strain gauges during the load test. Provide a copy of all the readings to the Engineer at the completion of the load test.

b. Provide six rod tell-tales to measure movement within the drilled caisson. Use rod tell-tales consisting of $^{5}/_{16}$ inch (8 mm) diameter flush-jointed stainless steel threaded rods that can be connected by means of standard threading couplings. Encase the tell-tales within a minimum ½ inch (12 mm) diameter (ID) steel threaded pipe or ¾ inch (19 mm) diameter (ID) PVC flush-joint pipe. Provide and install the PVC or steel pipe. Install the tell-tales at the following points on the rebar cage, or as directed by the Engineer:

   i. Two (2) each at three-quarters of the caisson length from the top.
   ii. Two (2) each at the midpoint of the caisson.
   iii. Two (2) each at one-fourth of the caisson length from the top.

Install and monitor the rod tell-tales. Provide a copy of all the readings to the Engineer at the completion of the load test. Remove the stainless steel rod tell-tales at the completion of the load test.

524.7 Non-destructive testing of drilled caissons

1. Description: This Work consists of furnishing testing services and equipment for conducting Crosshole Sonic Logging (CSL) on drilled caissons, providing and installing pipes, grouting of pipes, and all other equipment necessary to conduct sonic testing.

2. General Requirements: Use the nondestructive testing method called Crosshole Sonic Logging on all caissons including demonstration, load test and production caissons.

Employ an experienced independent testing organization that has been approved by the Engineer to conduct the CSL tests. Conduct the testing a minimum of twenty-four hours after the placement of all concrete in the shaft, but no later than seven calendar days after placement.

After the Engineer has accepted the production caissons, remove all water from CSL-access pipes, and then fill these pipes with grout that the Engineer has approved.

3. Pipe installation: Install six pipes in each production caisson to permit access for CSL testing. Use 1.5 to 2 inch (38 mm to 50 mm) inside diameter schedule 40 steel pipes or PVC pipes that have round, regular internal diameters free of defects or obstructions including any at pipe joints in order to permit the free, unobstructed passage of a 1.35 inch (33 mm) diameter source and receiver probes. In addition, use pipes that are watertight and free from corrosion with clean internal and external faces to ensure passage of the probes and a good bond between the concrete and the pipes.

Fit each pipe with a watertight shoe on the bottom and a removable cap on the top. Securely attach the pipes to the interior of the reinforcement cage with a minimum cover of 3 inches (75 mm). The Engineer may allow the pipes to be installed on the outside of the cage if adequate cover and clearance are available. Install the pipes in each caisson in a regular, symmetric pattern such that each pipe is placed the maximum distance possible from each adjacent pipe, with an equal spacing around the perimeter of the cage. Prior to construction, submit the selection of pipe size and type, and the proposed method to install the pipes to the testing organization and to the Engineer. Do not install the pipes until the Engineer has approved the selection and installation method.

Install the pipes as near to parallel as possible. Extend the pipes 6 inches (150 mm) above the caisson bottom and at least 3 feet (900 mm) above the caisson top. If the caisson top is subsurface, extend the pipes at least 2 feet (600 mm) above the ground or water surface. Use watertight joints at any joints that are required to achieve full-length pipes. Replace any pipes that are damaged during installation with new pipes. Fill the pipes with clean water within 4 hours after concrete placement, and cap the pipe tops to keep debris out of the pipes. Do not apply excess torque, hammering, or other stresses during the removal of caps that could break the bond between the pipes and the concrete.

4. Typical CSL test equipment: Typical CSL test equipment consists of the following components:

a. A microprocessor-based CSL system for display of individual CSL records, analog-digital conversion and recording of CSL data, analysis of receiver responses and printing of CSL logs.

b. Ultrasonic source and receiver probes for 1.5 or 2 inch (38 mm or 50 mm) I.D. pipe, as appropriate.

c. An ultrasonic voltage pulser to excite the source with a synchronized triggering system to start the recording system.

d. A depth measurement device to determine and record depths.

e. Appropriate filter/amplification and cable systems for CSL testing.

5. CSL logging procedures: Before the placement of concrete, plumb one pipe per shaft and record the pipe length, including a notation of the stickup of the pipe above the caisson tips. Provide the information on the caisson bottom and top elevations and/or length, along with construction dates to the Engineer and the testing organization before the CSL tests. Conduct the CSL tests between pairs of pipes. Allow the approved testing organization to determine which pairs of pipes are to be tested. Typically, perimeter and/or major diagonals are tested. Conduct additional testing in the event anomalies are detected at no additional cost to the Department

Conduct the CSL tests with the source and receiver probes in the same horizontal plane unless test results indicate potential defects, in which case the questionable zone may be further evaluated with angled tests (source and receiver vertically offset in the pipes). Perform all CSL measurements at depth intervals of 0.2 feet (60 mm) or less, beginning from the bottom of the pipes to the top of each caisson. Pull the probes simultaneously, starting from the bottom of the pipes, over a depth-measuring device. Removed any slack from the cables prior to pulling, to provide for accurate depth measurements of the CSL records. Report any defects indicated by longer pulse-arrival times and significantly lower amplitude/energy signals to the Engineer, and conduct further tests as required by the Engineer to evaluate the extent of such defects. Additional non-destructive testing methods that may be used to evaluate possible defects include Singlehole Sonic Logging, Gamma-Gamma Nuclear Density Logging, and/or Surface Sonic Echo, and Impulse Response Tests.

6. CSL testing results: Supply five copies of the CSL tests in the form of a written report to the Engineer that includes the CSL logs with the following analysis:

a. Initial pulse arrival time versus depth.

b. Pulse energy/amplitude verses depth.

Provide a CSL log for each pipe pair tested with any defect zones indicated on the logs and discussed in the test report, as appropriate.

7. Evaluation of CSL test results: The Engineer will evaluate the CSL test results and determine whether or not the drilled caisson is acceptable.

If the Engineer determines that the drilled caisson is unacceptable based on the CSL tests, replace or core the caisson to allow further evaluation of the caisson. Perform either option at the direction of the Engineer, at no additional cost to the Department.

8. Core drilling of drilled shaft concrete: Core the tested caissons that are determined to be unacceptable by the CSL tests to determine the quality of the concrete. Obtain core samples from each defective caisson for the full depth of the caisson. Perform this work at no additional cost to the Department, and with no increase in contract time.

Retain an accurate log of cores and store the cores in a crate that is properly marked showing the caisson depth at each interval of core recovery. Transport the cores and five copies of the coring logs to the Engineer. After the Engineer has accepted the production caissons, fill these core holes with grout that the Engineer has approved.

524.8 Measurement

1. **Demonstration caisson:** The demonstration test of procedures will include any material, labor, equipment, etc. required for the assembly and installation of the demonstration drilled caisson. All related work to be paid for under this Specification will be performed under the direction of the Engineer. Include all costs associated with the installation and removal of the demonstration caisson in the bid price for the demonstration caisson.

2. **Instrumentation:** No separate measurement for payment will be made for providing and installing strain gauges and rod tell-tales, or for work, equipment, tools, and incidentals to monitor the strain gauges or rod tell-tales.

3. **Load Test:** The load test will include any material, labor, equipment, etc. required for the assembly and installation of the non-production load test caisson. All related work to be paid for under this Specification will be performed under the direction of the Engineer. Include all costs associated with the installation, removal, and performance of the initial load test on the non-production caisson in the price bid for the load test. No additional payment will be made for instrumentation, load testing, or providing reports.

4. **Drilled caisson:** The length of accepted caisson foundation is measured in linear meter of caisson in place in the completed work. The length is measured from the final approved bottom elevation to the top of the caisson elevation detailed in the plans.

5. **Crosshole sonic logging:** No separate measurement for payment will be made for performing CSL testing, providing testing services and equipment, providing and installing CSL pipes, grouting the CSL pipes, or any other associated costs that are necessary to conduct sonic testing. Include the cost of this Work in the contract bid price for the drilled caissons.

524.9 Payment

Drilled in place caisson foundations are paid for at the unit price bid per linear foot (meter) complete and in place as specified. The payment is full compensation for all excavation, furnishing and placement of reinforcing steel, slurry, and concrete in the caisson, all temporary and permanent casing, disposal of excavated materials, and the cost of furnishing all tools, safety devices, labor, equipment and all other necessary items to complete the work.

Payment will be made under:

Item No. 524-0010 DRILLED CAISSON……..PER LINEAR FOOT (METER)

Item No. 524-0300 LOAD TEST CAISSON……PER EACH

Item No. 524-0500 DEMONSTRATION CAISSON……..PER EACH