465.1 DESCRIPTION

This work consists of all labor, materials, equipment, and services necessary to perform all operations required in the installation of drilled shafts.

465.2 MATERIALS

A. Concrete: Drilled shaft concrete shall conform to the requirements of Section 460, except where modified by this Section.

At least 40 calendar days before constructing drilled shafts, the Contractor shall submit, to the Department Materials Laboratory, sufficient materials, including a water reducer, for a design mix. The concrete mix will be designed to have the following characteristics:

1. Minimum cement content of 780 pounds per cubic yard (465 kilograms per cubic meter) of Type II cement conforming to Section 750;

2. Minimum 28 day compressive strength of 4500 psi (31 MPa);

3. Slump at time of placement shall be between 6" and 8" (150 mm to 200 mm) for concrete that is placed by the free-fall or tremie method. The slump at the time of placement shall be between 7” and 9” (175 mm to 225 mm) for concrete that is pumped through a tremie. In addition, the slump shall be maintained above 4" for four hours from the time of batching regardless of the placement method.

4. Entrained air content of 6.5 % with an allowable tolerance of +1 % to - 1.5 %.

5. The time limitations for Drilled Shaft concrete placement as specified in Section 460.3.H shall be waived except that the interval between batches shall not exceed 30 minutes.

6. Maximum water/cement ratio of 0.44.

The use of a water reducer will be required to achieve the above properties. Water reducers conforming to AASHTO M194 Type C (Accelerating), Type E (Water-Reducing and Accelerating), and Type F (Water-Reducing, High Range) will not be permitted.

B. Casing: Casing shall be smooth steel of sufficient thickness to withstand handling stresses, concrete pressure, and surrounding earth and fluid pressures. The casing shall be of the diameter specified and shall have teeth at the bottom to facilitate proper seating of the casing into the plans specified formation.

C. Access Tubes for Crosshole Sonic Log Testing: Access tubes shall be 2 inch I.D. Schedule 40 steel pipe. The selected pipes must have a round, regular internal diameter free of defects or obstructions, including any at the pipe joints, in order to permit a free, unobstructed passage of the source and receiver probes. The pipes must be watertight and free from corrosion with clean internal and external faces to ensure smooth passage of the probes and to secure a good bond between the concrete and tubes.

The pipes shall each be fitted with a watertight shoe on the bottom and a removable cap on the top.

D. Grout: Grout for filling the access tubes at the completion of the crosshole sonic log tests shall consist of Portland cement, water, and a water reducing admixture and shall be mixed in the following proportions:

Portland Cement Type I or II…	1 Sack (94 lbs.)
Water……	4.5 Gallons Maximum
Water Reducing Admixture…	Manufacturer's Recommendation
Fly Ash (Optional)…	20 pounds Maximum

465.3 CONSTRUCTION REQUIREMENTS

A. Drilled Shaft Installation Plan: Not less than 30 calendar days before beginning drilled shaft construction, the Contractor shall submit an installation plan for approval to the Bridge Design Office, through the Area Engineer. The installation plan shall provide the following information:

1. Provide a list of all proposed equipment to be used and available on site including, but not limited to, cranes, drill augers, pilot bits, bailing buckets, final cleaning equipment, dewatering pumps, tremies, concrete pumps, casing, etc. Include the casing diameter and wall thickness in the equipment list;

2. Details of the overall shaft construction sequence in each bent or group of drilled shafts;

3. Provide a detailed explanation of how the casing is to be installed. It is required that a T-bar be on the project site such that the casing can be twisted into the specified formation to achieve as watertight of a seal as possible. Tamping and/or pounding the casing into the ground will not be allowed;

4. Details of shaft excavation methods to be used;

5. Methods to be used to clean the shaft excavation, including clean out equipment;

6. Details of reinforcement centering devices and their spacing;

7. Details and methods for supporting and lifting reinforcing steel cages;

8. Provide details of the tremie tube that is to be used in the event that a wet excavation is encountered. Include all other details of concrete placement such as free fall (allowed only for shafts 36 inches (915 mm) in diameter or greater), pumping, etc. A tremie tube is required to

be on the project site. Details for the disposal of contaminated concrete from a wet excavation shall also be included;

9. The Contractor shall verify all existing ground and\or water elevations and establish the elevations of any work platforms, etc. that may be used. These elevations shall be included in the drilled shaft installation plan;

B. General Requirements: A drilled shaft preconstruction meeting is required to be held a minimum of 5 working days prior to beginning drilled shaft construction. A representative from the bridge contractor, drilled shaft subcontractor, concrete supplier, Area Office, and Bridge Design Office is required to attend this meeting. The drilled shaft installation plan will be discussed at the meeting and the responsibilities of each of the parties involved clearly identified.

The Contractor shall perform the excavation for the shafts through the various types of materials that are encountered. The excavation shall be to the dimensions and elevations shown in the plans or as otherwise required by the specifications and special provisions.

Contractor methods and equipment shall be suitable for the intended purpose and materials encountered. All of the equipment listed in the drilled shaft installation plan shall be on the project site prior to the start of work. The following equipment is required to be available for use on the project site at all times during drilled shaft construction:

1. Tremie of sufficient length to reach the bottom of the drilled shaft;

2. T-bar for installing casing;

3. Cleanout bucket of the proper size;

4. Graduated measuring device to determine excavation and/or water depth;

5. Pilot bit capable of drilling through rock;

6. A pump of sufficient capacity to dewater the excavation prior to concrete placement. Dewatering is a requirement prior to concrete placement by the free fall method.

Unless otherwise specified on the plans, the Contractor shall begin drilled shaft excavation using the dry construction method. The Contractor shall use the temporary casing construction method when specified on the plans or when caving soils or ground water is encountered during excavation that is begun by the dry construction method. The permanent casing construction method shall be used only when specified on the plans or approved by the Bridge Design Office.

Upon completion of the excavation of a drilled shaft, a cleanout bucket shall be used to remove all loose material from the bottom of the shaft. After cleanout, the reinforcing steel shall immediately be installed and the concrete placed prior to start of excavation for another drilled shaft.

For drilled shaft concrete pours of 18 cubic yards (14 cubic meters) and less, the Contractor shall have all of the concrete necessary to complete the drilled shaft at the project site and tested prior to placing any concrete in the drilled shaft.

Vibrations caused by any work activities that may be detrimental to the freshly placed concrete will not be allowed for at least 72 hours after placement or until the concrete has attained a minimum compressive strength of 1600 psi (11 MPa). If the Engineer suspects that construction activities may be causing excessive vibration, a 2" X 4" (50 mm X 100 mm) stake shall be driven solidly into the ground adjacent to the freshly placed concrete. A small container of water shall then be placed on top of the stake. If the water surface remains calm, the construction activity will be allowed to continue. When the water surface shows any movement, vibrations are reaching the freshly placed concrete and the construction activities shall be either stopped or altered such that vibrations at the freshly placed concrete are eliminated.

C. Dry Construction Method: The dry construction method consists of drilling the shaft excavation, removing loose material from the excavation and placing the concrete in a relatively dry excavation. The Engineer must be able to inspect the sides and bottom of the excavation before placing the reinforcing steel cage and concrete. The dry construction method shall be approved by the Engineer when the shaft excavation has: a water accumulation rate of three inches or less per hour (75 mm or less per hour); the sides and bottom of the excavation remain stable without detrimental caving, sloughing or swelling; and loose material and water can be removed before inspection and concrete placement.

D. Temporary Casing Construction Method: The temporary casing construction method shall be used when excavations, begun by the dry construction method, encounter water bearing or caving soil formations, or when specified on the plans. If, during dry drilling, the Contractor encounters caving or water bearing soils, the Contractor shall stop drilling and fill the hole with water to a point above the ground water elevation. If practical, a positive 10 foot (three meter) head of water shall be maintained above the ground water elevation. When necessary, a temporary casing may be required to achieve this head. If caving soil is encountered, a sufficient head of water shall be maintained to stop the caving. Once the hole is filled with water, the excavation shall be advanced by drilling to a depth at which an impervious formation is reached. A sufficient head of water shall be maintained during the drilling operation. A temporary casing shall then be placed into the impervious formation by use of a T-bar and twisting the casing into the specified formation to produce a watertight seal at the bottom.

Other methods of seating the casing may be used with the Engineer's approval. The casing and the seal at the bottom of the casing shall be watertight. Water shall be pumped out of the temporary casing and the excavation continued using the dry construction method. During concrete placement, the casing shall be withdrawn. If a watertight seal cannot be achieved at the bottom of the casing, the shaft shall be drilled to the final elevation while keeping the hole full of water to maintain an adequate fluid head to control caving. Concrete shall then be placed using proper underwater concrete placement methods.

1. If the Contractor elects to remove a casing and substitute a longer casing through caving soils, the excavation shall be backfilled before a new casing is installed. Other methods may be used

to control the stability of the excavation and protect the integrity of the foundation soils when approved by the Engineer.

2. Temporary casing shall be removed before any of the drilled shaft concrete attains initial set. Before the casing is withdrawn, the level of fresh concrete in the casing shall have sufficient head so all water trapped behind the casing is displaced upward without contaminating or displacing the concrete. When water seepage can not be stopped and water is required to maintain stability of the perimeter of the hole, the concrete shall be placed in the shaft using a tremie or pump. Simultaneously extract the casing and tremie, or pump, at a slow uniform rate. Maintain a sufficient head of concrete above the bottom of the casing to overcome the hydrostatic pressure outside the casing. The bottom of the tremie, or pump, shall always be embedded a minimum of five feet (1500 mm) into the fresh concrete during the extraction.

3. Temporary casing shall be removed at the time of concrete placement. When a casing becomes bound in the excavation, drilled shaft construction shall cease and the Engineer will immediately inform the Bridge Design Office.

E. Permanent Casing Construction Method: The permanent casing construction method shall be used only when specified on the plans or approved by the Bridge Design Office. This method consists of placing a casing to a prescribed depth before excavation begins. If full penetration cannot be attained, the Engineer may require either excavation of material within the embedded portion of the casing and/or excavation of a pilot hole ahead of the casing until the casing reaches the desired penetration. Over reaming to the outside diameter of the casing may be required before placing the casing, as approved by the Engineer.

A T-bar shall be used to twist the permanent casing into the specified formation to achieve a watertight seal at the bottom. Other methods of seating the permanent casing may be used with the Engineer's approval. The casing and the seal at the bottom of the casing shall be watertight.

If the Contractor elects to remove a casing and substitute a longer casing through caving soils, the Engineer may require that the excavation be backfilled before a new casing is installed. Other methods may be used to control the stability of the excavation and protect the integrity of the foundation soils when approved by the Engineer.

If, during dry drilling, the Contractor encounters caving or water bearing soils, the Contractor shall stop drilling and fill the hole with water to a point above the ground water elevation. If practical, a positive 10 foot (three meter) head of water shall be maintained above the ground water elevation. If caving soil is encountered, a sufficient head of water shall be maintained to stop the caving. Once the hole is filled with water, the excavation shall be advanced by drilling. A sufficient head of water shall be maintained during the drilling operation.

Upon completion of drilling, install reinforcing steel and place concrete. After the concrete has attained the specified strength, the section of the casing between the plan shown cutoff elevation and the top shall be removed. When the cutoff elevation is not shown on the plans, the cutoff elevation is assumed to be flowline or ground line as appropriate. The casing shall be cutoff by use of a cutoff saw. Use of an oxyacetylene torch or other methods which produce high heat

damaging the concrete will not be allowed. Casings may only be cutoff and removed when both of the following conditions are met:

1. The drilled shaft concrete has cured for 72 hours according to the specifications.

2. The drilled shaft concrete has attained 2500 psi (17.5 MPa) minimum compressive strength.

F. Excavation and Drilling Equipment: Excavation and drilling equipment shall have adequate capacity including power, torque, and downward force. The excavation and over reaming tools shall be of adequate design, size, and strength to perform the work shown in the plans and described in this specification. When the material encountered cannot be drilled using conventional earth augers and under reaming tools, the Contractor shall provide special drilling equipment including, but not limited to, rock core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to excavate the shaft to the size and depth required. Approval by the Engineer is required before any excavation by blasting is conducted.

G. Reinforcing Steel Cage Construction and Placement: The reinforcing steel cage (consisting of longitudinal bars, ties, cage stiffener bars, spacers, and centralizers) shall be completely assembled and placed as a unit into the excavated shaft. Placement of the reinforcing steel cage shall take place immediately after the shaft excavation is inspected and approved by the Engineer and before concrete placement.

The reinforcing steel cage shall be tied and supported in the shaft so the cage will remain within the specified tolerances. Welding of the reinforcing steel cage will not be allowed. Concrete centralizers or other approved noncorrosive centering devices shall be used within one foot (300 mm) of the bottom. Centralizers shall also be used at intervals not exceeding five feet (1500 mm) along the length of the shaft. Each level of centralizers shall be rotated 45 degrees in the horizontal plane relative to the level below. Concrete centralizers shall be constructed of concrete equal in quality and durability to the concrete specified for the shaft. The concrete centralizers shall have the ends beveled to minimize the potential for catching on obstructions during reinforcing steel placement and they shall have a minimum of two tie wires cast in the concrete. Wrapping wires around the concrete centralizers to hold them in place is not an acceptable method of attachment. Any type of steel used as centralizers shall be epoxy coated. The reinforcing steel cage shall not be in contact with the bottom of the shaft.

The elevation of the top of the reinforcing steel cage shall be checked before and after the concrete is placed. If the reinforcing steel cage is not maintained within the specified tolerances, corrections to the cage support shall be made by the Contractor, as required by the Engineer. No additional shafts shall be constructed until the Contractor has modified the reinforcing steel cage support, to prevent vertical movement, in a manner satisfactory to the Engineer.

H. Installation of Crosshole Sonic Log Access Tubes: The Contractor shall install access tubes as detailed in the plans for crosshole sonic log testing in all specified drilled shafts to permit access for the crosshole sonic log test probes. The access tubes shall be evenly spaced and securely attached to the interior of the reinforcement cage of the shaft as shown in the plans. The tubes shall be as near to vertical and parallel as possible. Even moderate bending of the tubes will result in large regional variations of the data. The tubes shall extend from 6 inches above the bottom of

the drilled shaft to at least 4 feet above the construction joint. Under no circumstances should the tubes be allowed to rest on the bottom of the drilled excavation. During placement of the reinforcement cage, care shall be exercised as to not damage the tubes.

After placement of the reinforcement cage, the tubes shall be filled with clean water as soon as possible and the tube tops capped to keep debris out. The tubes must be filled with water and capped either before the pouring of the concrete or no later than 4 hours after the pouring of the concrete, otherwise debonding of the access tubes from the concrete will occur resulting in data which indicates poor quality concrete. Care shall be taken during the removal of the caps from the pipes after installation so as not to apply excess torque, hammering, or other stresses which could break the bond between the tubes and the concrete.

Upon completion of the CSL testing and acceptance of the drilled shaft by the Engineer, the water shall be removed from the access tube and any other drilled holes. The access tubes and the holes shall then be completely filled with grout. The access tubes shall be filled using grout tubes that extend to the bottom of hole. The tubes are to be cut off flush with the top of the drilled shaft.

I. CROSSHOLE SONIC LOG (CSL) TESTING

1. **Testing:** The Contractor shall provide for crosshole sonic log (CSL) testing and analysis on all completed shafts as specified in the plans. The testing and analysis shall be performed by an independent testing organization proposed by the Contractor and approved by the Engineer. The Contractor shall furnish and install access tubes as specified to accommodate the CSL testing.

   The CSL testing shall be performed after the shaft concrete has cured at least 24 hours. Additional curing time prior to testing may be required if the shaft concrete contains admixtures, such as set retarding admixture or water reducing admixture. The additional curing time prior to testing required under these circumstances shall not be grounds for additional compensation or extension of time to the Contractor.

   After placing the shaft concrete and before beginning CSL testing of a shaft, the Contractor shall inspect the access tubes. Each access tube that the test probe cannot pass through shall be replaced, at the Contractor's expense, with a 2 inch diameter hole cored through the concrete for the entire length of the shaft. Location of the core hole shall be determined by the CSL testing firm and shall not damage the shaft reinforcement. Descriptions of inclusions and voids in cored holes shall be logged and a copy of the log shall be submitted to the Engineer. Findings from cored holes shall be preserved, identified as to location, and made available for inspection by the Engineer.

2. **Equipment:** CSL equipment shall consist of the following components;

   A digitizing card for conversion of analog CSL data to digital.

   A microprocessor-based CSL system for recording, processing, analyzing, displaying and log printing of digitally converted CSL data.

Ultrasonic source and receiver probes capable of logging 2 inch I.D. pipes.

An ultrasonic voltage pulser to excite the source combined with a synchronized triggering system to prompt the recording system.

A depth measuring device used to correlate records with depth.

Appropriate filter/amplification and cable systems for CSL testing.

3. **Procedure:** For the CSL test, information on the shaft bottom and top elevations and/or length, along with construction dates should be provided to the testing organization before or at the time of testing. Ultrasonic transmitter/receiver probes are then lowered to the bottom of a pair of access tubes. All slack is removed from the cable in order to assure accurate depth measurements. The two probes are then pulled simultaneously as to maintain a near horizontal ray path between them. Measurement shall be made at 0.2 foot intervals or less as the probes ascend the tube pairs. This process is repeated for all test paths along the outer perimeter as well as across the inner diagonals of the shaft. The data is analyzed and anomalies/defects characterized by longer travel times and lower signal amplitudes should be reported to the Engineer at the time of testing.

4. **CSL Results:** The CSL results shall be presented in report form. Digitized Raw data files shall also be submitted with the report. This report shall contain CSL logs for each tube pair tested combined with an analysis of the first arrival time or compressional wave velocity and signal amplitude of the pulse versus depth. Any anomaly/defect zones shall be discussed in the report where appropriate.

J. CROSSHOLE SONIC LOG TESTING ORGANIZATION AND PERSONNEL

At least seven calendar days prior to beginning shaft construction, the Contractor shall submit the name of the independent testing organization and the names of the personnel conducting the crosshole sonic log tests to the Engineer for approval. The submittal shall include documentation that the qualifications specified below are satisfied. The independent testing organization and the testing personnel shall meet the following minimum qualifications:

1. The testing organization shall have performed crosshole sonic log tests on a minimum of three deep foundation projects in the last two years.

2. Personnel conducting the tests for the testing organization shall have a minimum of one year experience in crosshole sonic log testing and interpretation.

K. ACCEPTANCE OF CSL TESTED DRILLED SHAFTS

The acceptance of each drilled shaft shall be the decision of the Engineer, based on the results of the CSL reports and other information about the shaft placement. De-watering and grouting of the access tubes and any subsequent work above the construction joint of the drilled shaft shall not be done until after the final acceptance of each shaft. The Engineer will determine final acceptance of each shaft, based on the CSL test results and analysis for the tested shafts, and will provide a response to the Contractor within three working days after receiving the test results and

analysis submittal. Rejection of the shaft based on CSL shall require conclusive evidence that a defect exists in the shaft which will result in inadequate or unsafe performance under service loads. If the CSL records are complex or inconclusive the Engineer may require coring or excavation of the shaft to verify shaft conditions. If no defect is encountered, the state shall pay for all coring or excavation costs, including the grouting of all core holes.

In the case that any shaft is determined to be unacceptable, the contractor shall submit a plan for remedial action to the Engineer for approval. Any modifications to the foundation shafts and load transfer mechanisms caused by the remedial action will require calculations and working drawings stamped by a registered professional engineer for all foundation elements affected. All labor and materials required to perform remedial shaft action shall be provided at no cost to the State and with no extension of the contract time.

L. Concrete Placement: The drilled shaft concrete shall be placed immediately after the reinforcing steel cage is placed and shall be placed according to the requirements of this specification and all related specifications. When possible, drilled shaft concrete shall be placed the same working day in which the excavation is done. If it is anticipated that the excavation, reinforcing steel placement, and concrete placement cannot be completed before the end of the working day, the excavation shall not be started until the following day unless otherwise approved by the Engineer. It is required that drilled shaft concrete be placed within 24 hours of the excavation reaching the friction bedrock elevation specified in the plans. In the event that the 24 hour time limitation is exceeded, drilled shaft operations shall cease and the Bridge Design Office shall be immediately notified.

Concrete placement shall be continuous until the shaft is full and uncontaminated concrete flows out of the top of the shaft, as determined by the Engineer. The use of spud vibrators or other vibrating tools in the drilled shaft concrete will not be permitted.

The free fall method of concrete placement is allowed for shafts 36 inches (915 mm) in diameter or greater provided that all of the following conditions are met:

The water accumulation rate in the excavation is three inches or less per hour (75 mm or less per hour)**;**

There is no caving or sloughing of the excavation;

The excavation is dewatered immediately prior to concrete placement such that there is no more than 3 inches (75 mm) of standing water in the bottom of the excavation;

The concrete placement is directed through a hopper with a drop tube such that the concrete fall is vertical down the center of the shaft and the concrete is not allowed to hit the sides of the shaft or the reinforcing steel cage.

M. Underwater Placement of Concrete:

1. Tremie: The tremie pipe shall be a minimum of 0.25 inch (6.35 mm) thick wall steel pipe, with a minimum inside diameter of 7 3/4 inches (196 mm). The tremie pipe shall be smooth

and thoroughly cleaned of any hardened concrete, rust, and all other contaminants. The tremie pipe shall be marked to allow determination of depth to the mouth of the tremie. Joints between sections of tremie pipe shall be gasketed and bolted to be watertight under placement conditions. Instead of bolted joints, welded joints may be used if a smooth finish is maintained on the inside of the tremie pipe at the weld location.

A crane or other lifting device shall be available to remove the tremie from the water for resealing or horizontal relocation.

Placement of underwater concrete shall be a continuous operation. If an interruption in placement occurs, the interruption shall not exceed 30 minutes without removal of the tremie and restarting the concrete placement according to the paragraph below. An interruption in concrete placement shall not exceed the time for initial set of the concrete. If the concrete attains the initial set before the concrete placement is completed, concrete placement shall cease and the concrete in the shaft shall be rejected and removed from the shaft.

Starting/Restarting of the concrete placement by tremie shall begin by sealing the bottom of the tremie with a watertight seal before placing the tremie into the water. The watertight seal shall prevent water from entering the tremie, yet will be dislodged when concrete flow is initiated. The empty tremie pipe shall be sufficiently heavy to be negatively buoyant when empty. The tremie pipe shall be sealed, lowered to the bottom of the shaft, and completely filled with concrete. Fill the tremie slowly to avoid entrapped air and bridging. When full, the tremie shall be slowly lifted six inches (150 mm) off the bottom to start concrete flow. The concrete supply shall be continuous until soundings indicate the tremie has the required embedment. After being dislodged, the sealing device shall either remain on the bottom or be retrieved by the Contractor.

The mouth of the tremie shall always remain embedded in the fresh concrete a minimum of five feet (1500 mm) unless the tremie is being completely removed from the water. At no time shall the concrete be allowed to fall through water.

A tremie shall not be moved horizontally while concrete is flowing through it. To relocate a tremie, lift it from the water, reseal, relocate, and restart as required above.

All vertical movements of the tremie shall be made slowly and shall be carefully controlled to prevent loss of seal. If loss of seal occurs, placement through that tremie shall be halted immediately. The tremie shall be removed, resealed, replaced, and restarted as directed above.

2. **Concrete Pump:** Concrete pumps can be used for underwater concrete placement if surging of the pump line can be controlled to keep the pump line sufficiently embedded into the fresh concrete. If surging of the line cannot be controlled, a concrete pump shall not be used.

   The pump line shall be not less than four inches (100 mm) in diameter. The portion of the pump line that penetrates the deposited concrete shall be a rigid steel line (pipe).

An approved plug shall be inserted into the pump line, near the pump, in such a way that there is fresh concrete against the plug, with no air or water between the plug and concrete. The plug

shall be advanced down the pump line, using pressure from the concrete pump, to the bottom of the shaft.

Placement shall begin with the pump line within six inches (150 mm) of the bottom of the shaft. After pumping begins, the pump line shall be kept within six inches (150 mm) of the bottom until soundings indicate that the pump line is embedded at least five feet (1500 mm) into fresh concrete. The end of the pump line may be raised with the rising column of concrete as long as the end of the pump line remains embedded at least five feet (1500 mm) into the concrete. At no time shall the concrete be allowed to fall through water.

Placement of concrete shall be a continuous operation. Interruptions of placement shall not exceed 30 minutes or the time of initial set of the concrete whichever is shorter. If the time of initial set is exceeded, the concrete shall be rejected and removed from the shaft.

If the pump line is allowed to come out of, or is removed from the concrete once placement has begun, placement though the pump line shall be restarted. A watertight seal shall be installed on the end of the pump line. The line shall then be filled with concrete before the pump line is lowered into the water. The pump line shall be filled in such a way as to eliminate air or water in the line. Once filled, the pump line shall be embedded a minimum of five feet (1500 mm) into the concrete and pumping resumed. The sealing device shall be retrieved by the contractor after pumping has been restarted.

N. Construction Tolerances: The following tolerances apply to drilled shafts:

The drilled shaft shall be within one twelfth of the shaft diameter or 3 inches (75 mm), whichever is less, of the plan shown horizontal position, at the plan elevation of the top of the shaft.

The bottom of the shaft shall be drilled to the plan shown elevation, within a tolerance of plus or minus six inches (150 mm).

The vertical alignment of the shaft excavation shall not vary from the plan alignment by more than one fourth inch per foot of depth or three inches (20 mm per 1000 mm of length or 75 mm), whichever is less.

After all concrete is placed, the top of the reinforcing steel cage shall be no more than six inches (150 mm) above nor more than three inches (75 mm) below plan position.

The diameter of the completed shaft shall be the plan diameter with a tolerance of minus zero inch, plus two inches (minus zero mm, plus 50 mm).

The top of the shaft shall be built to plan elevation with a tolerance of plus or minus one inch (25 mm). The plan shown elevation of the top of shaft shall not be changed without prior permission from the Bridge Design Office.

Excavation equipment and methods shall be designed so the completed shaft excavation will have a relatively flat bottom.

465.4 METHOD OF MEASUREMENT

A. Class A45 (A31) Concrete, Drilled Shaft: The plan quantity shall be the quantity paid for unless a change is ordered in writing. If a change is ordered, measurement will be according to neat line dimensions specified in the change and quantities computed to the nearest 0.1 cubic yard (0.1 cubic meter).

B. Drilled-In-Foundation Excavation: The plan quantity shall be the quantity paid for unless a change is ordered in writing. If a change is ordered, measurement will be according to the neat line dimensions specified in the change and quantities computed to the nearest 0.1 cubic yard (0.1 cubic meter).

C. Permanent Casing: The length of casing from the plan shown cutoff elevation to the bottom of the casing unless otherwise specified in the plans. Permanent Casing shall be measured to the nearest 0.1 linear foot (0.1 meter), for each specified size of casing.

D. Crosshole Sonic Log (CSL) Test: will be measured by the number of shafts tested. CSL testing will only be measured once per shaft tested.

465.5 BASIS OF PAYMENT

A. Class A45 (A31) Concrete Drilled Shaft: The accepted quantities of concrete will be paid for at the contract unit price per cubic yard (cubic meter). Payment will be full compensation for labor, equipment, tools, materials, and all incidentals required. All costs for furnishing, installing, cutting off, and grouting the CSL access tubes will be incidental to the unit price bid for Class A45 (31) Concrete Drilled Shaft. Payment will be for plan quantity regardless of the amount placed. If a change is ordered, payment will be for the changed quantity at the contract unit price.

B. Drilled-In-Foundation Excavation: The accepted quantities of excavation shall be paid for at the contract unit price per cubic yard (cubic meter). Payment will be full compensation for labor, equipment, tools, materials, and all incidentals required, including blasting equipment and temporary casings. Payment will be for plan quantity regardless of the amount placed. If a change is ordered, payment will be for the changed quantity at the contract unit price

C. Permanent Casing: The accepted quantities of casing will be paid for at the contract unit price per linear foot (meter), for each specified size. Payment will be full compensation for labor, equipment, tools, materials, and all incidentals required.

D. Crosshole Sonic Log (CSL) Test: The accepted quantity of cross sonic log tests will be paid at the contract unit price per each test. Payment will be full compensation for all labor, equipment, tools, materials, services, and incidentals required to perform the tests and analyze the results. Payment will be made only once per shaft tested.