**KANSAS DEPARTMENT OF TRANSPORTATION**

# SPECIAL PROVISION TO THE STANDARD SPECIFICATIONS, 1990 EDITION

*NOTE: This special provision is generally written in the imperative mood. The subject, "the Contractor" is implied. Also implied in this language are "shall", shall be", or similar words and phrases. The word "will" generally pertains to decisions or actions of the Kansas Department of Transportation.*

## SECTION 706

## DRILLED SHAFTS

**Page 454 Section 706. Delete this Section and replace with this:**

### 706.1 DESCRIPTION

Construct drilled shafts by the cased or uncased method depending upon site conditions and Contract Document requirements.

| BID ITEM | UNIT |
|---|---|
| Drilled Shaft (*) (**) | Linear Foot (meter) |
| Permanent Casing (Set Price) | Linear Foot (meter) |
| Sonic Test (Drilled Shaft) (Set Price) | Each |
| Core Hole (Investigative) | Linear Foot (meter) |

*Size
**Cased (If Contract Documents specify the cased method.)

### 706.2 MATERIALS

**a. Concrete.** Unless otherwise shown in the Contract Documents, provide Grade 4.4 (Grade 30) concrete that complies with the requirements of **Special Provision 90P/M-156 (latest revision).**

Concrete placed by the dry pour cased or uncased method must have a target slump between 6 and 8 inches (152 and 203 mm) with a tolerance of ±1 inch (± 25 mm). Concrete placed by the wet pour cased method must have a slump of 8 inches ±1 inch (203 mm ± 25 mm).

**b. Grout/Flowable Fill.** For backfilling the cross-hole sonic testing pipes and core holes, provide non-shrink cementitious grout (mixed according to the manufacturer's directions) that complies with the requirements of **Special Provision 90P/M-206 (latest version).**

Provide grout or flowable fill for backfilling the annular void space between the temporary and permanent casing that has 28 day strength of 1000 psi (6.9 MPa). Provide a grout consisting of mortar sand, FA-M (**SECTION 1102**) mixed with 2 bags of Type II Portland cement per cubic yard (0.76 cu m), and a water-to-cement ratio of less than 1.

**c. Granular Backfill Material.** Provide granular backfill material for backfilling the annular void space between the temporary and permanent casing that is fine enough to fill the entire volume. The Engineer will accept the granular material based on a visual inspection.

**d. Reinforcing Steel.** Provide steel bars for concrete reinforcement that comply with the requirements of **SECTION 1600**.

**e. Casing.** Provide casing of sufficient thickness to carry the working stresses and loads imposed on the casing during construction. At a minimum, use 14 gage (2.0 mm) corrugated metal pipe (CMP) for the permanent casing.

If required, provide a permanent casing that is less than or equal 1 inch (25 mm) out-of-round, and the deviation of a chord from end to end must be less than or equal 2 inches (51 mm).

The Engineer will accept the casing based on compliance with the specified requirements, and visual inspection for condition.

**f. Pipe for Sonic Testing.** Provide 2 inch (51 mm) diameter steel pipe that complies with the requirements of ASTM A 53, Standard Weight. Provide clean pipe (both internal and external surfaces) with watertight joints. The internal joints must be flush. Provide screw-on watertight shoes, couplers and caps for the pipes.

The Engineer will accept the pipe based on receipt and approval of a Type D certification that complies with the requirements of **SECTION 2600**.

## 706.3 CONSTRUCTION REQUIREMENTS

**a. General.** Drilled shaft lengths shown in the Contract Documents are an estimate from the top of formation elevations determined from borings. Depending upon actual formation elevations at each shaft, the Engineer may adjust the actual length of each drilled shaft as work progresses. If the Engineer changes the drilled shaft lengths, the Contractor will be advised (in writing) of the revised bottom of rock socket elevation.

At least 1 month before constructing the drilled shafts, submit an installation plan to the Engineer for review. Include the following:

- Name and experience record of the drilled shaft superintendent in charge of drilled shaft operations for this project.
- Details of concrete placement, including proposed operational procedures for tremie and pumping methods and method of achieving a sealed tremie or pump.
- List of proposed equipment, such as cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core-sampling equipment, tremies or concrete pumps and casing.

**b. Investigative Core Hole.** At locations shown in the Contract Documents or requested by the Engineer, extract and maintain a core of the foundation material from 4 feet (1.2 m) above the top of the plan tip elevation (discard all material above this elevation) to 6 feet (1.8 m) below the plan tip elevation shown in the Contract Documents. Maintain, protect and label (elevation and location) these samples for review by the Geologist. Provide NX sized, 2.125 inches

(54 mm), core samples organized in descending elevation and stored in standard core cardboard boxes for possible shipment. While drilling, prepare a continuous standard drilling/coring log. The logs will remain with the sample for review. Survey the location of the core hole with the same construction tolerance as **706.3 c. Excavating the Drilled Shaft**. Perform this work, from the existing ground surface elevation, well in advance of the drilled shaft construction.

**c. Excavating the Drilled Shaft.** Prior to constructing drilled shafts, complete excavation for the entire pier.

Locate the top of the shaft within 2 inches (51 mm) of the location shown in the Contract Documents. Unless otherwise shown in the Contract Documents, bore all shafts plumb to within a tolerance of 1 inch per 10 feet (8.3 mm/m) of length of shaft, not to exceed 6 inches (152 mm).

The bottom of the shaft must be nearly flat. The cutting edges of excavation equipment must be normal to the vertical axis of the equipment within a tolerance of ±⅜ inch per foot (31 mm/m) of diameter.

Depending upon site conditions and, requirements in the Contract Documents, construct the drilled shaft by either the cased or uncased method:

(1) Uncased Method. Use this method at locations anticipated to be free of caving soil or excess water inflow into the excavated shaft. If the actual conditions show the shaft is prone to caving soil, or has water inflow that exceeds the dry pour method requirements in **706.3 f. Placing Drilled Shaft Concrete**, <u>use the cased method.</u>

Excavate the shaft <u>without</u> the use of added water or drilling fluid. Completely excavate the shaft in a continuous operation, unless encountering rock or obstructions. Place the concrete without undue delay.

(2) Cased Method. Use this method at locations with caving soil or excess water inflow into the excavated shaft. When the location requires a casing, use either a permanent smooth, thick-walled casing, or a combination of a smooth, thick-walled temporary **<u>and</u>** permanent CMP casing together. All permanent casings must be watertight.

Advancing shaft excavation by stabilizing the hole with drilling fluid is acceptable; however, <u>never</u> allow drilling fluid to get into the rock socket.

The concrete placement method used in a cased shaft depends on the water inflow requirements in **706.3 f. Placing Drilled Shaft Concrete.**

After removal of the overburden, complete the excavation below the top of rock as an uncased core (rock socket) of the diameter shown in the Contract Documents.

Do not excavate closely spaced drilled shafts (3 drilled shaft diameters or less, center to center) until adjacent shafts are completed and cured according to one of the following criteria:

- Shafts have been allowed to set for a minimum of 24 hours after completion of the concrete placement; and developed a compressive strength of 1800 psi (12.5 MPa).
- If the concrete used in the shaft has demonstrated satisfactory results from previous compressive strength tests, the Engineer may allow excavation to proceed when the shaft has cured 72 hours after completion of the concrete placement.

If the plans specify or the Contractor elects to use permanent thick-walled casing for the closely spaced shafts, the Contractor may excavate multiple closely spaced drilled shafts, but

once the concrete is placed, it must be cured according to the criteria above before excavating additional drilled shafts that are closely spaced to the previously constructed drilled shafts.

**d. Placing Reinforcing Steel and Sonic Testing Pipes.** Tie reinforcing steel at all intersections of reinforcement, and place reinforcing steel as a unit for the full length of the shaft prior to placing any concrete by either pour method. Use a minimum of one non-corrosive circular spacer per 30 inches (762 mm) of circumference of the reinforcing steel cage (near the bottom and top, and at intervals not to exceed 10 feet (3 m) vertically). If the shaft is deepened and additional reinforcing steel cage is required, make the splice at the bottom of the steel cage.

Place sonic testing pipes the full length of the shaft from the bottom of the rock socket to at least 12 inches (305 mm) above the top of the shaft concrete. Measure and record the length of the sonic testing pipes and elevation of any pipe joints. If multiple sections of pipe are required to reach the full length, the joints must be watertight and at the same elevation. After installation, fill pipes with potable water and install threaded caps. For accurate test results, pipes must remain watertight until testing is complete.

**e. Final Inspection and Access.** Just prior to placing the concrete, a minimum of 75% of the base of each shaft must have less than ½ inch (13 mm) of sediment at the time of placement of the concrete. The Engineer will determine the shaft cleanliness before concrete placement:

- By visual inspection,
- Underwater inspection using probes.

**f. Placing Drilled Shaft Concrete.** Depending upon site conditions, place concrete by either the dry pour or wet pour method:

- Use the dry pour method if water inflow does not fill the shaft more than 4 inches (102 mm) in depth in a 5 minute period, **and**; the shaft can be dewatered so that no more than 2 inches (51 mm) of water is standing in the shaft when concrete placement starts.
- Use the wet pour method when the above two conditions can not be met.

For both the dry and wet pour method there are common requirements for concrete placed in a cased or uncased shaft:

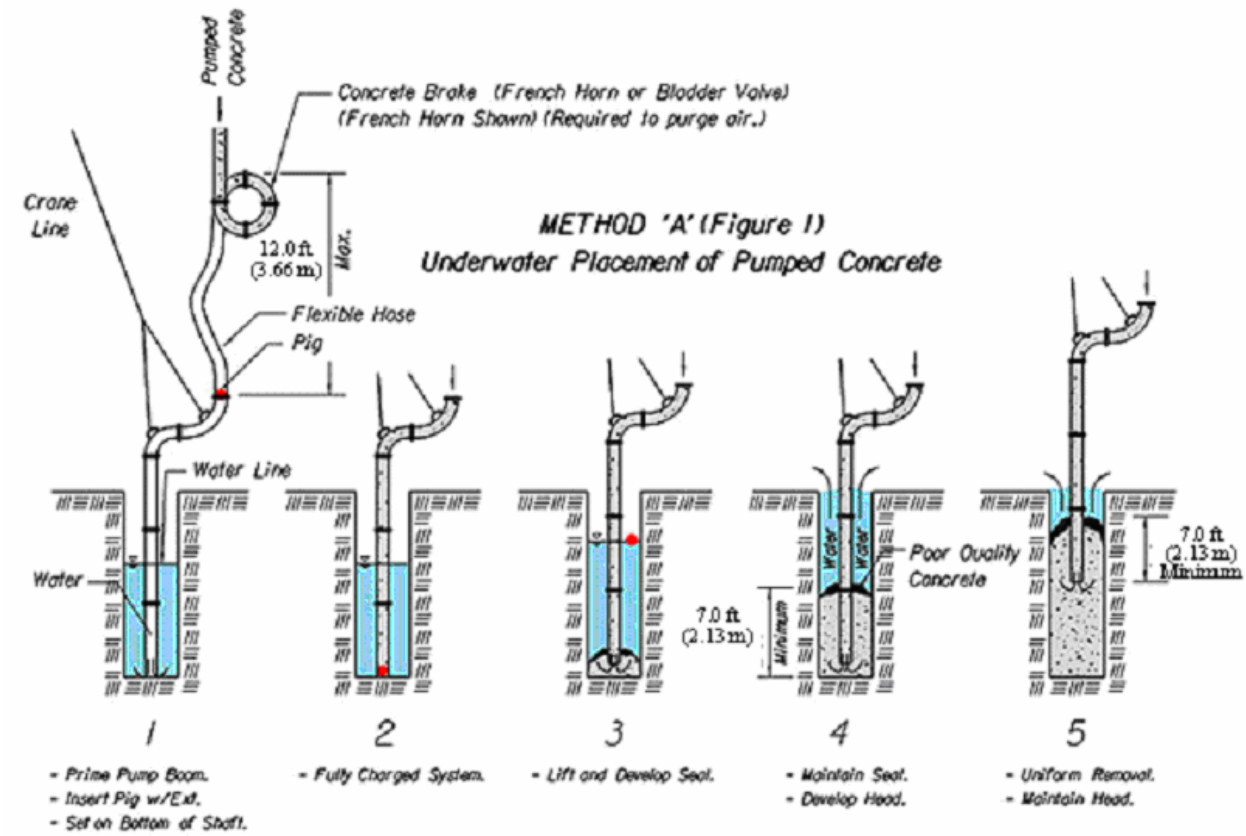
- Place concrete in the shaft with a continuous operation, without construction joints.
- Do not vibrate concrete.
- During concrete placement, determine the top elevation of the fresh concrete and inform the Engineer.
- Use non-aluminum concrete pump discharge tubes and tremie tubes.
- When the concrete reaches the top of the shaft, continue placing concrete (over-pump) to expel any excess water, debris or unsound concrete.

(1) Dry Pour Method. Use a centering device to deposit concrete so the falling concrete will not come into contact with vertical and horizontal reinforcing steel and wire supports. Extend the centering device a minimum of 8 feet (2.4 m) into the shaft to control the fall. For a cased shaft, concrete may free fall to the bottom. For an uncased shaft the maximum fall for concrete is 5 feet (1.5 m).

(2) Wet Pour Method. Prior to starting concrete placement, allow the water level in the shaft to reach its static level. Place concrete with either a sealed (watertight) tremie tube or pump with a rigid and watertight extension tube. In either case use a device (i.e. commercially available pig or flap gate) that prevents water from entering the tube while charging with concrete. The commercially available pig must be at least 110% the diameter of the tube. Also, clearly label the outside of the tremie and pump tubes in 12 inch (305 mm) increments (starting at the bottom).

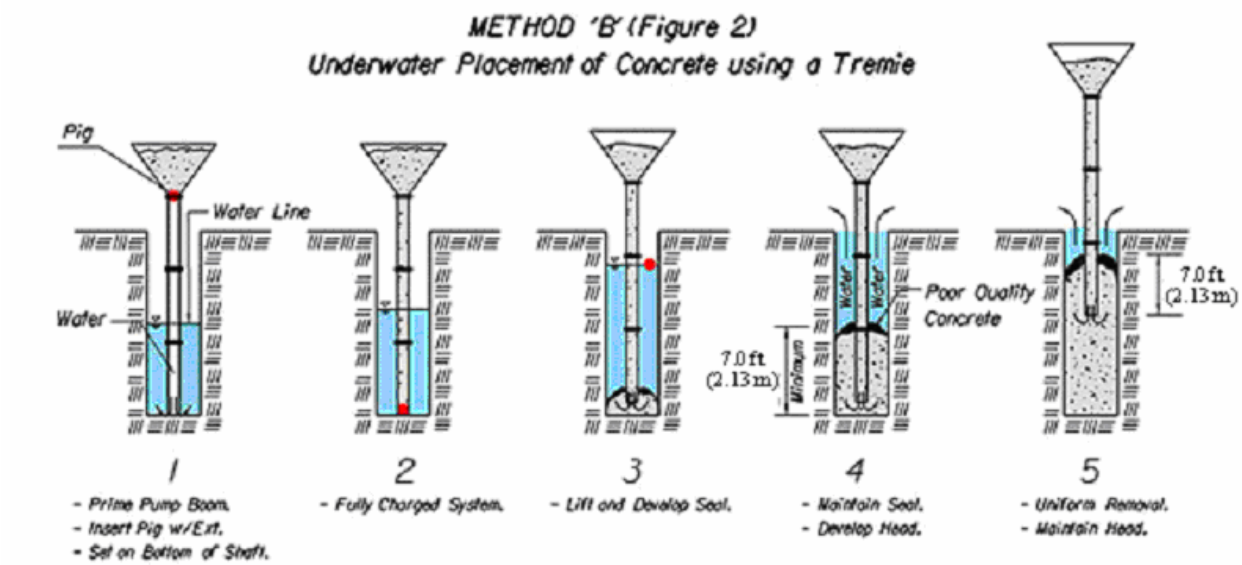
Lower the rigid tube into the shaft so the bottom of the tube is resting on the bottom of the rock socket, and fully charge the system (tube and hopper or pumping system). Once the system is fully charged, raise the tube off the bottom of the rock socket by 1 tube diameter, and allow the concrete to seal the discharge end of the tube. Keep the tube at this elevation until a minimum of 7 feet (2.1 m) head of concrete is developed. During concrete placement, always maintain a minimum of 7 feet (2.1 m) head of concrete. Prior to raising the tube, determine the top elevation of the fresh concrete and inform the Engineer.

For wet pours, follow the steps listed in the previous paragraph, regardless of the Method (A, B or C) used to place concrete in the shaft:

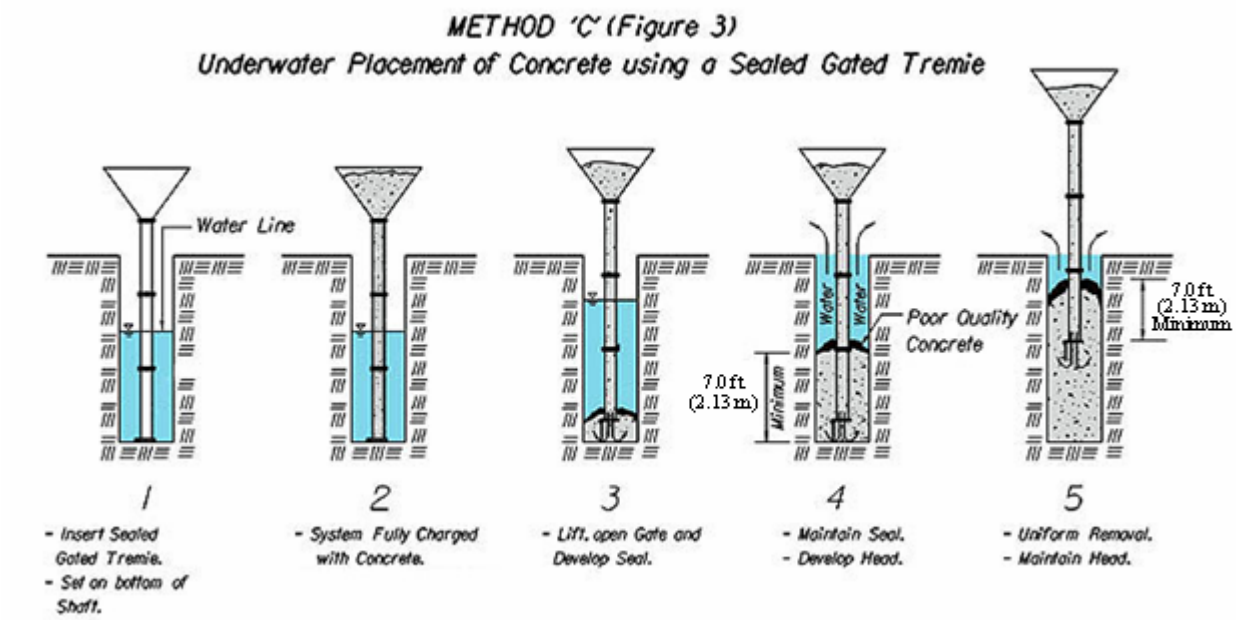



**Method A (Figure 1):** Use a pump and extension tube, with a pig separating the ground water and concrete, to place concrete into the shaft. Install a concrete brake (e.g. bladder valve or French horn) at the end of the pump boom to purge the air from the pump line.

Insure the boom is fully charge with concrete (no air gaps), then install the pig in the top of the extension tube.




**Method B (Figure 2):** Use a tremie tube, with a pig separating the ground water and concrete, to place concrete into the shaft. Once the tremie tube is resting on the bottom of the shaft, install the pig just below the hopper in the top of the tremie tube. Fully charge the tremie tube and hopper (forcing the pig to the bottom of the tremie tube), then raise the tremie tube by 1 tremie diameter and seal the discharge end of the tremie tube with the fresh concrete.




**Method C (Figure 3):** Use a tremie tube, with a sealed gate separating ground water and concrete, to place concrete in the shaft. Fully charge the tremie tube and hopper, then raise the tremie tube by 1 tremie diameter and seal the discharge end of the tremie tube with the fresh concrete.

On all wet pours, regardless of the method used, the Engineer will make a set of cylinders (in addition to normal concrete cylinder sampling requirements) from the top of the shaft after completing over-pumping to verify a compressive strength of 1800 psi (12.5 MPa) before proceeding with subsequent substructure (i.e. columns, abutments, etc.) construction.

Prior to constructing the portion of the substructure that attaches to the drilled shaft, thoroughly clean the top of the drilled shaft to facilitate the bond at the cold joint.

**g. Raising Temporary Casing.** Do not remove the temporary casing until the shaft is completed and cured:

- Allowed to set for a minimum of 24 hours after completion of the concrete placement; and developed a compressive strength of 1800 psi (12.5 MPa).
- Or, provided the concrete used in the shaft has demonstrated satisfactory results from previous compressive strength tests, the Engineer will allow extraction of the temporary casing to proceed when the shaft has cured 72 hours after completion of the concrete placement.

However, immediately after completing concrete placement in the permanent casing, it is acceptable to raise and hold the temporary casing the embedment depth plus 6 inches (152 mm).

Before completely raising the temporary casing, backfill the annular space between the two casings according to **706.3 j. Backfill.**

**h. Curing.** Cure the exposed surfaces of the shafts according to the requirements of **DIVISION 700 Special Provision 90P/M-91 (latest revision)**, except do not use liquid membrane curing.

Cure all cylinders in the field, alongside and under the same conditions as the concrete they represent.

**i. Sonic Testing.**

(1) General. Conduct the sonic testing between 2 and 21 days after the drilled shaft is completed. The Engineer has the option to require additional testing at designated locations.

Secure the services of an independent, experienced testing organization to take the cross-hole sonic logging measurements. Submit to the Engineer for approval, the testing organization's record of experience, a written description of the testing procedures, operation manuals for the testing equipment, and samples of previous test results indicating both sound and defective concrete.

(2) Sonic Logging Equipment. Provide sonic logging equipment capable of identifying any faults, honey combing or poor concrete at KDOT specified operating settings:

- A time base that will provide the "zero signal" and "first arrival" are 2 to 3 divisions apart on the horizontal axis.
- Select an amplitude signal that fills ⅔ to ¾ of the screen vertically.
- Set the gain on 2.0.

Provide test results on thermal or graphical printouts with the vertical scale representing the vertical position along shaft, and the horizontal scale representing the propagation time.

(3) Sonic Logging Test Procedure. Conduct the sonic logging test procedure between all possible combinations of pipes (i.e. 4 pipes have 6 different combinations, 5 pipes have 10 different combinations, 6 pipes have 15 different combinations, 7 pipes have 21 different combinations, 8 pipes have 28 different combinations, etc.) If the sonic testing detects faults, the Engineer may require retesting with the probes in the same or different horizontal plane.

Immediately prior to testing, insure the pipes are free from blockages and filled with water. Determine the elevation of the top of the drilled shaft and the top of each pipe. Plumb each pipe to determine the depth, and provide the information to the Engineer.

Configure sonic logging to settings in **706.3 i (2) Sonic Logging Equipment**.

Use a winch to simultaneously raise the probes from the bottom of the pipes at a rate less than 12 inches per second (0.3 m/sec). Before switching on the analyzer, take all slack out of the cables.

(4) Record of Testing. After completing sonic testing, provide the Engineer the test results (recorded on thermal or graphical printouts) with the profiles referenced to the top of the pipe elevation. Inform the Engineer on site of any faults, honeycombing or poor concrete detected by a fainting of the signals and a sudden lengthening of the propagation time. Diagram (horizontal and vertical cross sections) any defects found within the shaft to identify the location, width and thickness of the defect. Within 1 week of conducting the sonic test, provide the Engineer a report (stamped by a licensed Professional Engineer) of the results and recommendations for acceptance or correction of each drilled shaft.

If the sonic logging inspection indicates defective concrete, drill cores (NX size, 2.125 inches (54 mm) or larger) at locations directed by the Engineer. Provide the Engineer core samples labeled with their location and relative elevation. If the concrete is defective, submit in writing to the Engineer a proposal to repair the drilled shaft. The Engineer must approve the proposal before repairs commence. Subsequent to completing repairs, fill core holes by pressure grouting with non-shrink grout described in 7**06.2 b. Grout/Flowable Fill**. Use a pipe extending to the bottom of the hole to fill it from the bottom to the top.

After completing sonic testing and final acceptance of the drilled shaft, fill the sonic testing pipes with non-shrink grout. If the Contractor can expel enough water from sonic testing pipes so there is 2 feet (0.60 m) or less of standing water in the sonic testing pipe, grout may free fall to the bottom of the pipe. If more than 2 feet (0.6 m) remains in the bottom of the sonic testing pipe, use a tremie tube extending to the bottom of the sonic testing pipe to prevent the grout from free falling through the water.

**j. Backfill.**

When a temporary casing and a permanent casing are used, backfill the annular space (between casings) with the material specified in the Contract Documents:

- Granular material fine enough to fill the entire volume; or
- Grout or flowable fill described in **706.2 b. Grout/Flowable Fill.** If the Contract Documents do not specify a material, use the granular material. When the Contract Documents specify grout/flowable fill, fill the annular space with grout/flowable fill to the top of the casing, then completely remove the temporary casing:

- If the annular space contains water, use a pump with an extension pipe or tremie (extending to the bottom of the annular space) to fill the annular space.
- If the annular space is dry, the grout/flowable fill can free fall to the bottom of the shaft.

After extracting the temporary casing fill the rest of the annular space with granular material.

**706.4 MEASUREMENT AND PAYMENT**

The Engineer will measure accepted drilled shafts by the linear foot measured to the nearest 0.01 lin. ft. (m) and paid to the nearest 0.1 lin. ft. (m) from the bottom of the rock socket to the top of the completed drilled shaft. Unless the overall length of a drilled shaft changes by more than 20%, the Engineer will not consider a request for additional compensation.

The Engineer will measure the accepted permanent casing by the linear foot measured to the nearest 0.01 lin. ft. (m) and paid to the nearest 0.1 lin. ft.(m), if a permanent casing is necessary, but not specified in the Contract Documents. The Engineer will not measure the permanent casing if:

- the Contract Documents required a permanent casing.
- the Contractor uses the casing for their convenience.
- the casing is a temporary casing.

The Engineer will measure each completed and accepted sonic test, at locations designated in the Contract Documents and added locations, per shaft (i.e. sonic logging between all possible combinations of pipes represents a single sonic test). If the sonic testing indicates defective concrete in the drilled shaft, the Engineer will measure the first sonic test for payment, and the Contractor is responsible for subsequent sonic testing of that shaft.

The Engineer will measure the investigative core hole by the linear foot (m) to the nearest 0.1 linear foot. (m), from the existing ground surface to 6 feet (1.8 m) below the drilled shaft tip elevation.

Payment for "Drilled Shafts" and "Core Hole (Investigative)" at the Contract unit prices, and "Sonic Test" and "Permanent Casing" at the Contract set price is full compensation for the specified work.

If the Engineer lengthens the drilled shaft during construction, the Engineer will measure and pay for additional reinforcing steel according to the requirements of **Section 703**.

If the sonic testing indicates defective concrete in the shaft, and the Engineer requests cores from the shaft, the Engineer will not measure the cores for payment if the cores reveal defective concrete. If the cores reveal sound concrete, the Engineer will pay for the cores as "Extra Work" according to the provisions of **DIVISION 100**.

04-01-04 BD (BS)(BM)