Shaft Excavation

Shaft Types and Construction Issues

ODOT MATERIALS & INSPECTION

Dry Shafts
Learning Objectives

- Describe the dry shaft construction process.
- Describe typical/potential construction problems associated with dry shafts.

ODOT MATERIALS & INSPECTION

What is a dry shaft?

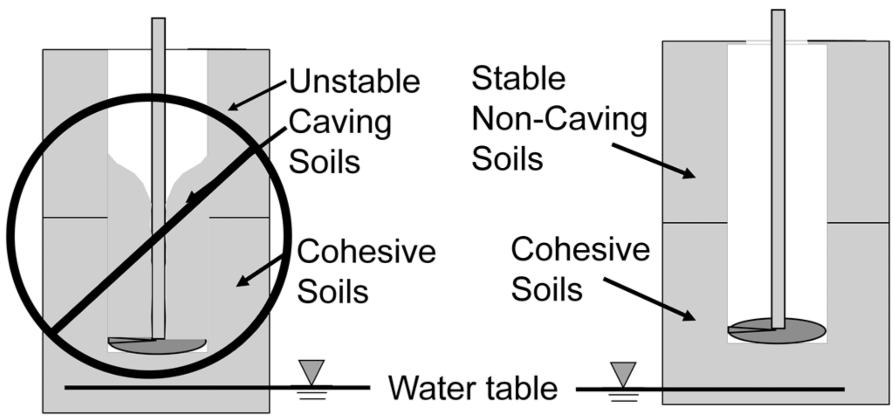
A shaft excavation that can be excavated to its designed depth without the need for side support (slurry or casing).

ODOT MATERIALS & INSPECTION

When Used

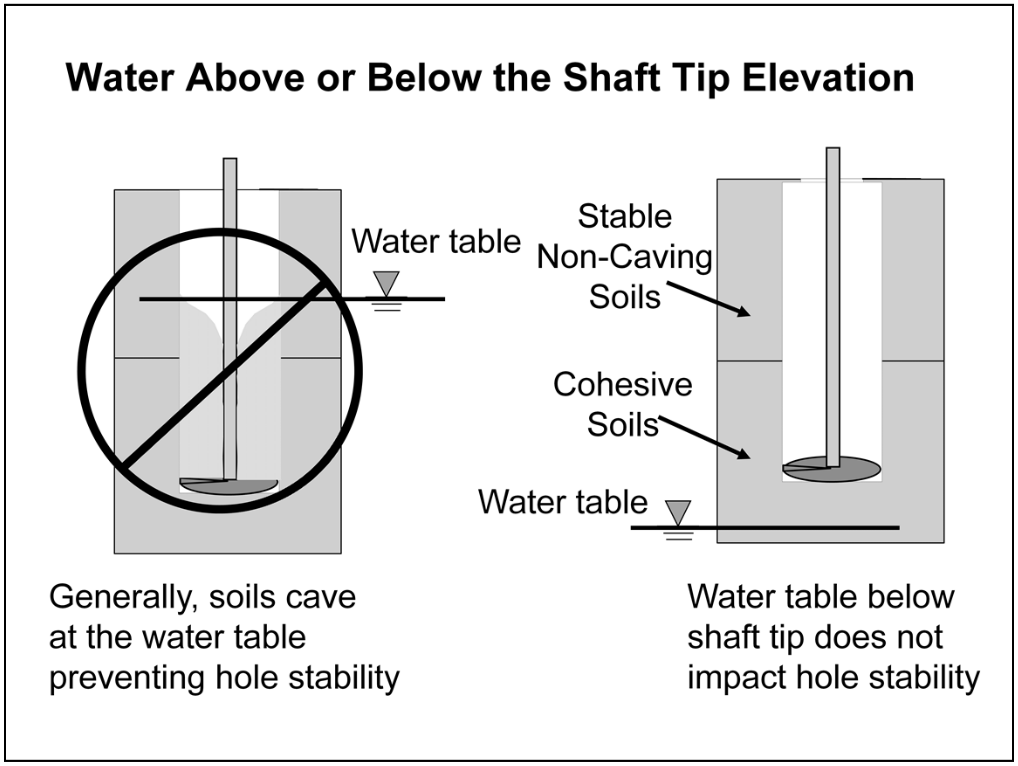
- In place soil/rock will keep the hole walls from collapsing.
- Construction of the shaft can be in relatively dry conditions.

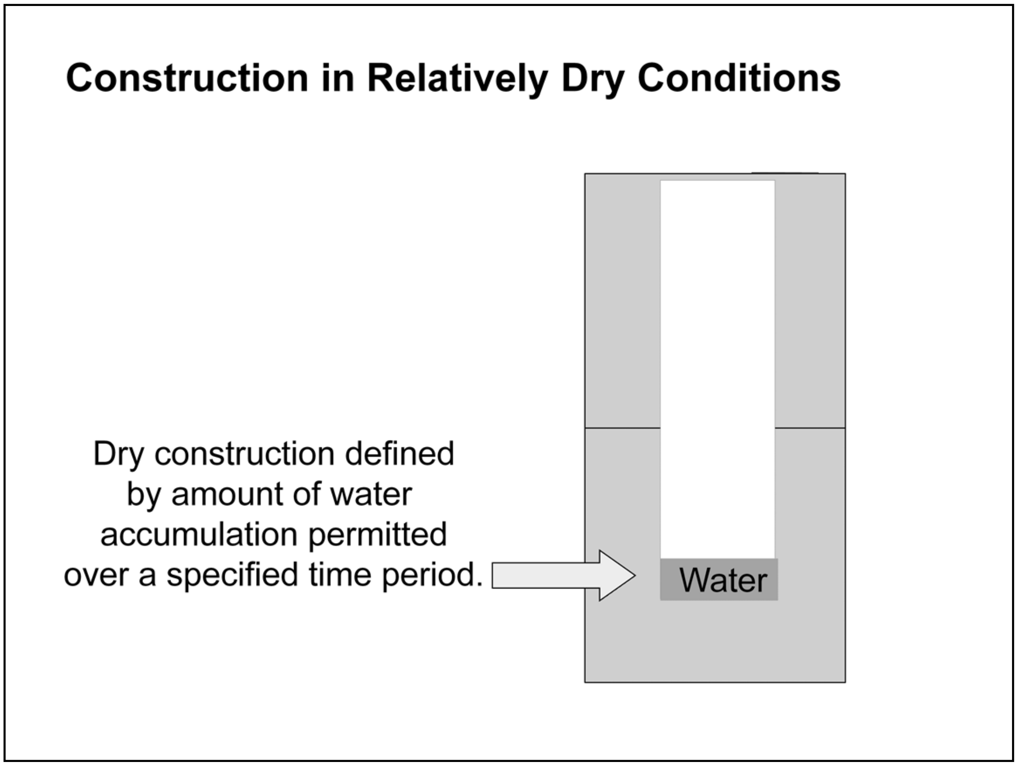
Stable vs. Unstable Soils



Unstable caving soils prevent maintaining hole stability

Stable non-caving soils maintain hole stability


Water Above or Below the Shaft Tip Elevation
Water table
Stable
Non-Caving
Soils
Cohesive
Soils
Water table
Generally, soils cave
at the water table
preventing hole stability
Water table below
shaft tip does not
impact hole stability

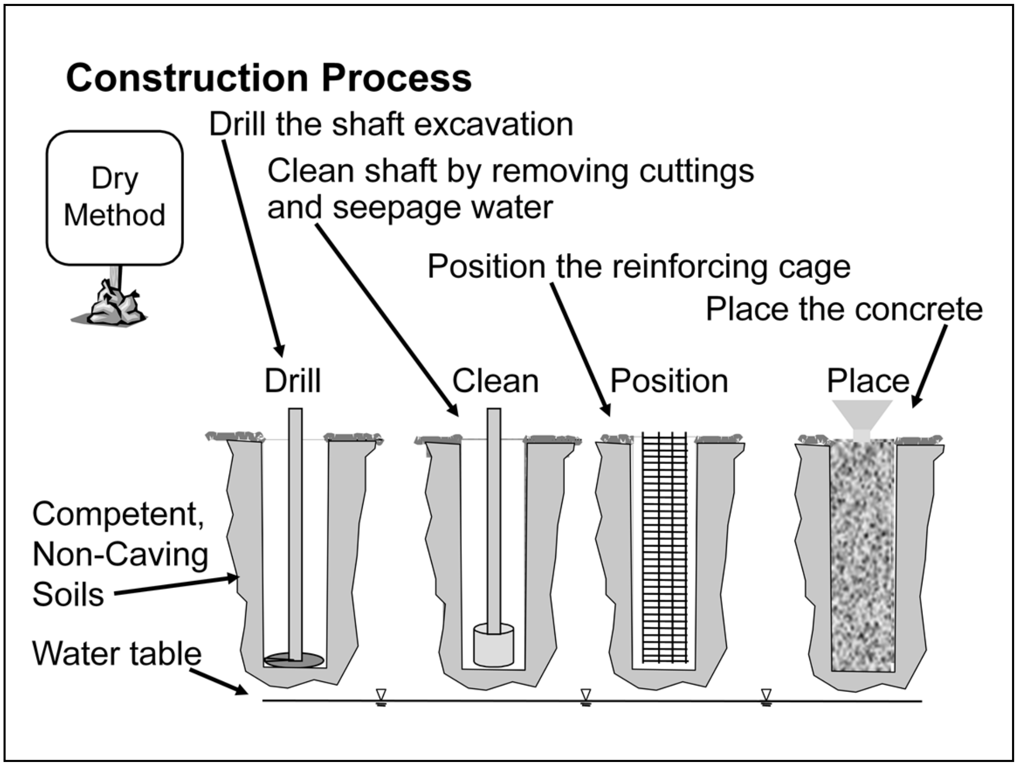


Contractor proposes type of hole in Installation Plan but Mother Nature has the final say. If water accumulates in the hole overnight, could dewater but care should be taken if the water is due to the location of the water table and upon dewatering, could lead to caving. Intent is to not contaminate the concrete and compromise the concrete strength.

00512.47 Concrete – Furnish and place concrete according to the following:

(b) Dry Shaft Concrete Placement – Concrete may be placed by free-fall if all of the following conditions are met:

- No more than 3 inches of water is present in the bottom of the excavation at the beginning of the pour.
- Groundwater seepage into the excavation is at a rate of no more than 12 inches per hour.
- Shaft diameter is greater than or equal to 3 feet.

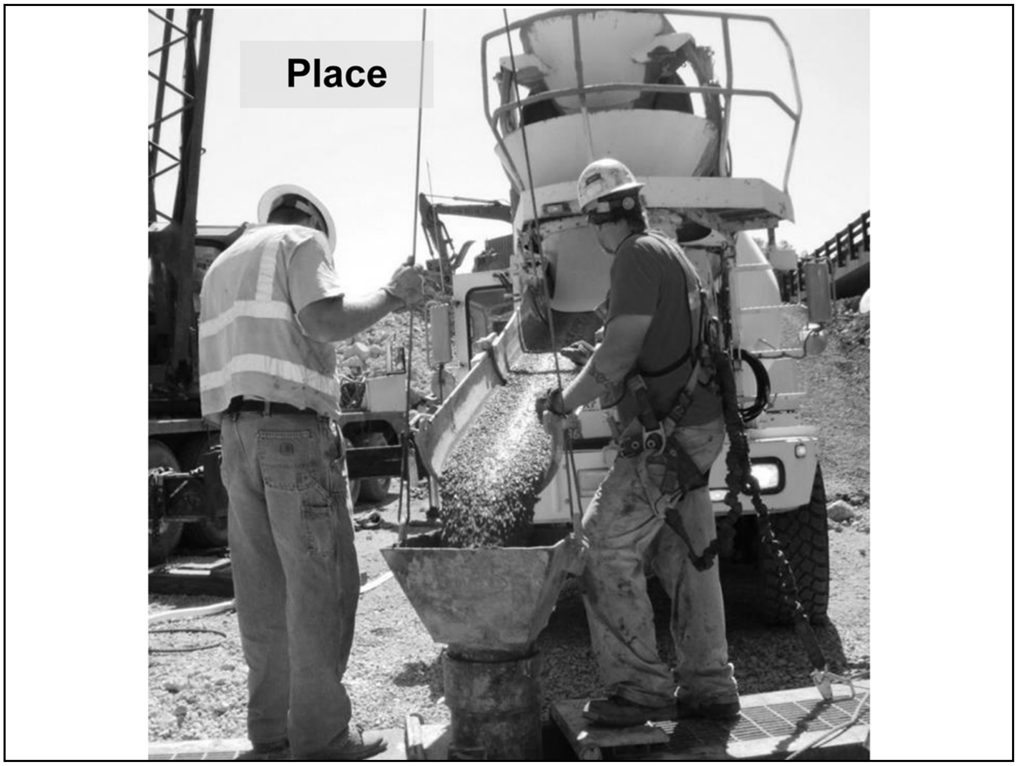

Construction Process
Dry Method
Drill the shaft excavation
Clean shaft by removing cuttings and seepage water
Position the reinforcing cage
Place the concrete
Drill
Clean
Position
Place
Competent, Non-Caving Soils
Water table


Drill

00512.43 Drilled Shaft Excavation – Perform drilled shaft excavation according to the following:

(h) Clean Out - Use appropriate means, such as a cleanout bucket, pump or air lift, to clean the bottom of the drilled shaft excavations. No more than 2 inches of loose or disturbed material will be allowed at the bottom of the excavation for end-bearing drilled shafts. No more than 6 inches of loose or disturbed material will be allowed at the bottom of the excavation for side friction drilled shafts. Assume end-bearing shafts unless otherwise shown or specified. Shaft cleanliness will be determined by the Engineer.


Position


Place

Learning Objective
Describe the dry shaft construction process.

What determines if a shaft is constructed in the dry?

ODOT MATERIALS & INSPECTION

00512.47 (b) Dry Shaft Concrete Placement – Concrete may be placed by free-fall if all of the following conditions are met:

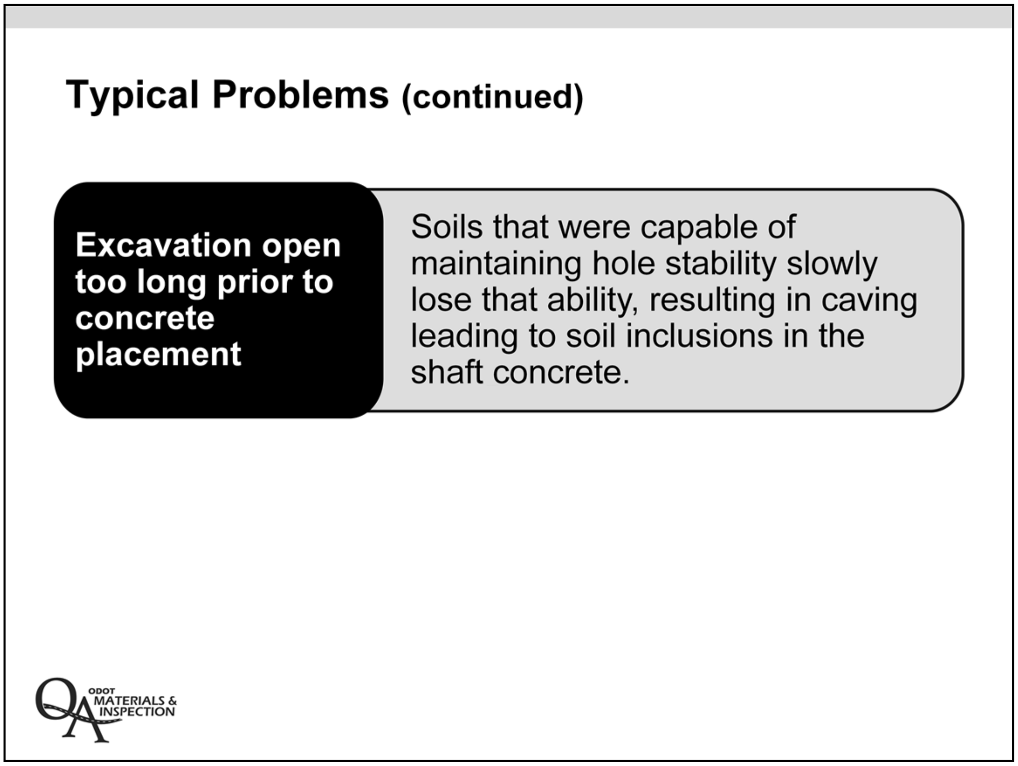
- No more than 3 inches of water is present in the bottom of the excavation at the beginning of the pour.
- Groundwater seepage into the excavation is at a rate of no more than 12 inches per hour.
- Shaft diameter is greater than or equal to 3 feet.

Under free-fall placement, deposit concrete through the center of the reinforcement cage by a method which prevents segregation of aggregates and splashing of concrete on the reinforcement cage. Place concrete so that the free-fall is vertical down the center of the shaft without hitting the sides, the steel reinforcing bars or steel cage bracing.

Typical Problems

Soils are unstable and Contractor attempts to force dry shaft construction	Caving problems will lead to soil inclusions in the shaft concrete thereby affecting shaft integrity.
Water table is too high	Caving problems will lead to soil and sediment inclusions in the shaft concrete thereby affecting shaft integrity.

ODOT MATERIALS & INSPECTION



00512.43 Drilled Shaft Excavation –

Do not leave partially completed shaft excavations open overnight unless they are cased full depth or otherwise stabilized with approved methods. If approved by the Engineer, a partially excavated shaft may be left open overnight, provided that the excavation is:

- Stabilized at the bottom, sides and surface to prevent soil caving or swelling or a reduction of soil strength.
- Covered at the surface to protect the public.

Wet Shafts
Learning Objectives

- Recognize the difference between dry and wet shaft construction
- Describe the wet shaft construction process
- Describe and identify mineral and polymer slurry and other drilling fluids
- Describe typical construction problems associated with wet shafts

ODOT MATERIALS & INSPECTION

What is a wet shaft?

Often called the “slurry-method”, wet shaft construction is when a slurry or water is used to keep the hole stable for the entire depth of the shaft.


When used?

Wet vs. Dry?

- The sides of the hole will not remain stable.
- Accumulated loose material and water cannot be removed.
- Has more than 3″ of accumulated water in the bottom of the shaft at the time of the pour.
- Requires more equipment.
- Requires more Contractor expertise.
- It is more expensive.

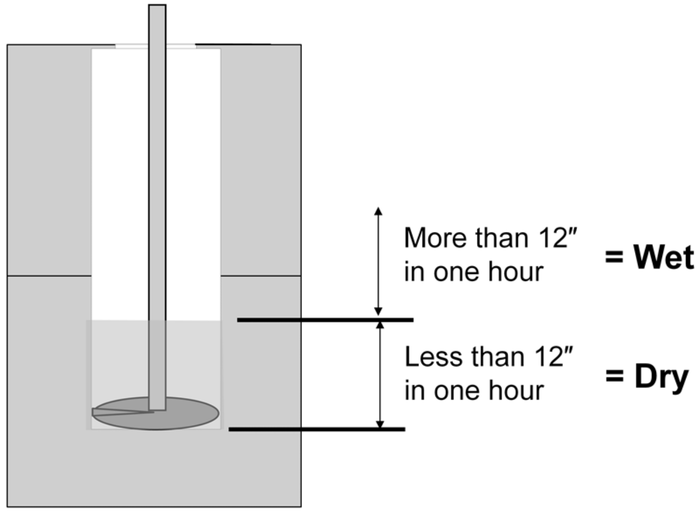
ODOT MATERIALS & INSPECTION

Wet vs. Dry?

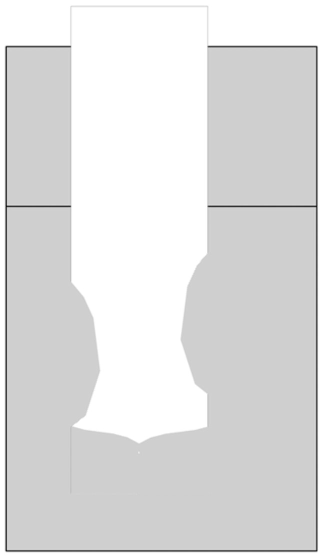
The Inspector cannot visually inspect the shaft and cannot see what is happening underground.

How safe is this site? What's missing?

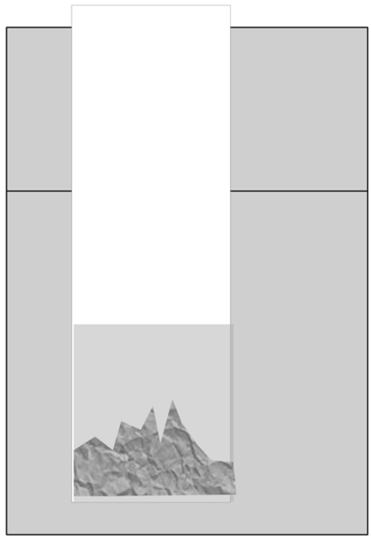
When a dry excavation can not be maintained

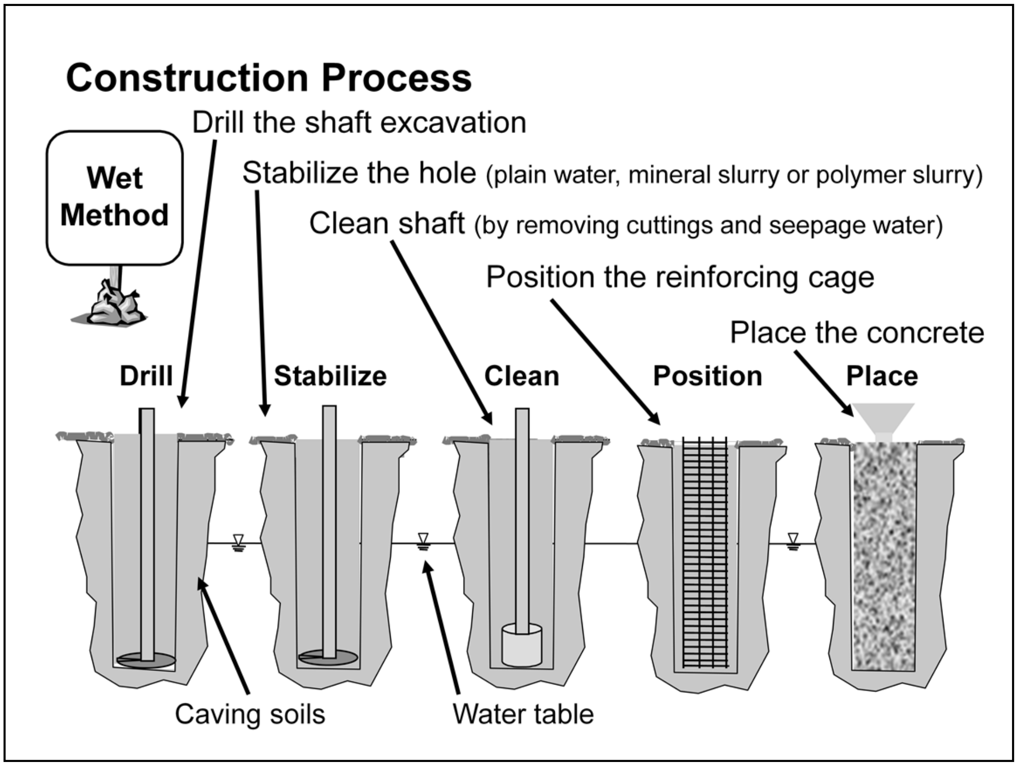


When the sides and bottom of the hole can not remain stable



When loose material and water can not be satisfactorily removed

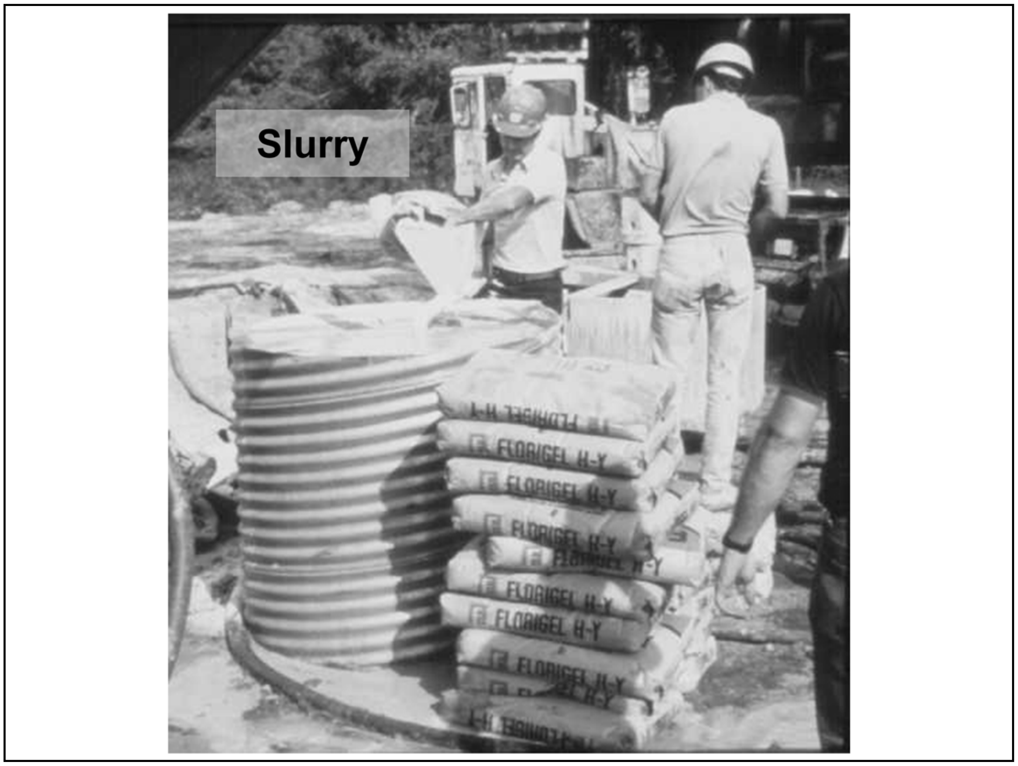



Construction Process
Wet Method
Drill the shaft excavation
Stabilize the hole (plain water, mineral slurry or polymer slurry)
Clean shaft (by removing cuttings and seepage water)
Position the reinforcing cage
Place the concrete
Drill
Stabilize
Clean
Position
Place
Caving soils
Water table

Learning Objective
Recognize the difference between dry and wet shaft construction

What is a significant difference between dry and wet construction to the Inspector?

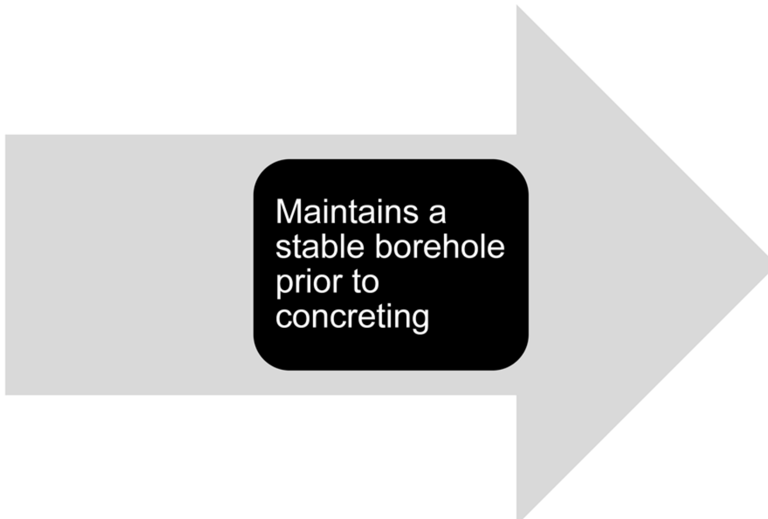
Why do Contractors, in general, try to avoid wet shaft construction?



Proper storage: Should be off the ground. Should be contained.

Proper handling: Read MSDS so you know what the appropriate PPE is. Stay upwind during introduction.

What does the slurry do?



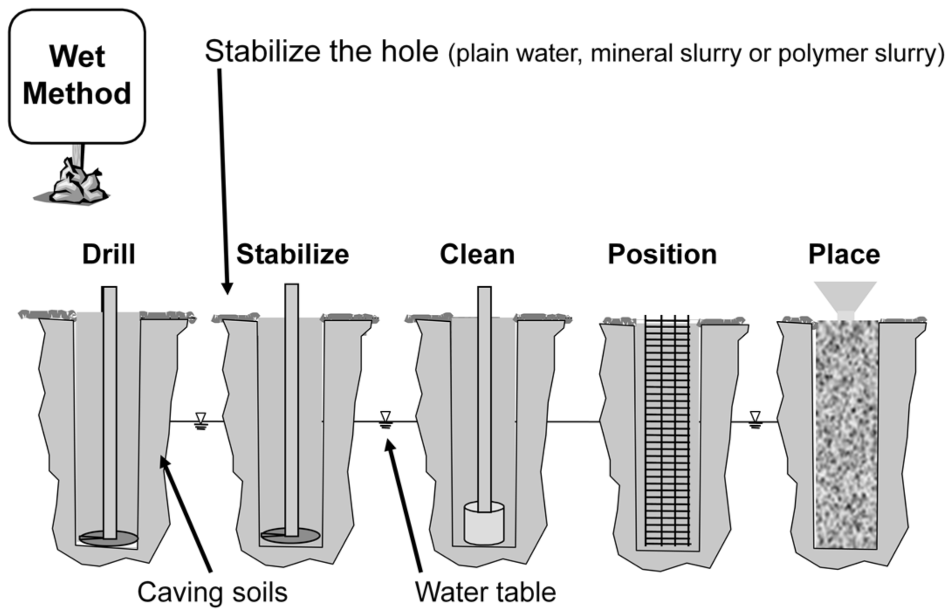
What does the slurry do?

- Maintains a stable borehole prior to concreting
- Retards softening or loosening of the soil while the hole is open

What does the slurry do?

- Maintains a stable borehole prior to concreting
- Retards softening or loosening of the soil while the hole is open
- Facilitates removal of cuttings in “circulation drilling”

Construction Process



Types of Slurry

- Water
- Polymer
  - Must be hydrated
- Natural mineral clays
  - Bentonite, attapulgite and sepiolite
  - Bentonite is the most common
    - Attapulgite and sepiolite are typically used in saltwater environments
  - Must be hydrated

Works by suspending cuttings.

ODOT MATERIALS & INSPECTION

Types of Slurry

Polymers are semi-synthetic or totally synthetic chemical slurries (works by allowing cuttings to settle).

Synthetic Slurries on the Qualified Products List (QPL)

QPL Search

Oregon Department of Transportation

Construction Home

QPL Home

Do fresh search

Results of Search for Qualified Products

You may "drill down" to retrieve more information about a single record by clicking on the "Yes!" next to a row:

More?	Spec No.	Product Name	Category	Manufacturer
Yes!	00512.14	SLURRY PRO CDP	SYNTHETIC SLURRY	KB INTERNATIONAL 423/266-6964
Yes!	00512.14	SUPER MUD	SYNTHETIC SLURRY	PDS COMPANY 562/634-8180
Yes!	00512.14	SHORE PAC	SYNTHETIC SLURRY	CETCO CONSTRUCTION DRILLING
Yes!	00512.14	NOVAGEL	SYNTHETIC SLURRY	GEO-TECH SERVICES 210/587-4758

00512.14 Drilling Slurry – Furnish drilling slurry meeting one of the following requirements:

(b) Synthetic Slurries – Select synthetic slurries from the QPL. Use synthetic slurries according to the manufacturer's recommendations and the Contractor's quality control plan. The sand content of synthetic slurry shall be less than 2.0 percent (API 13B-1, Section 5) prior to final cleaning and immediately prior to concrete placement.

Take Care with Polymers

- "Iffy" in silt-rich soils
- Different products are different chemically
- Specific polymer products should be specified on a site-specific basis
- Need to be premixed

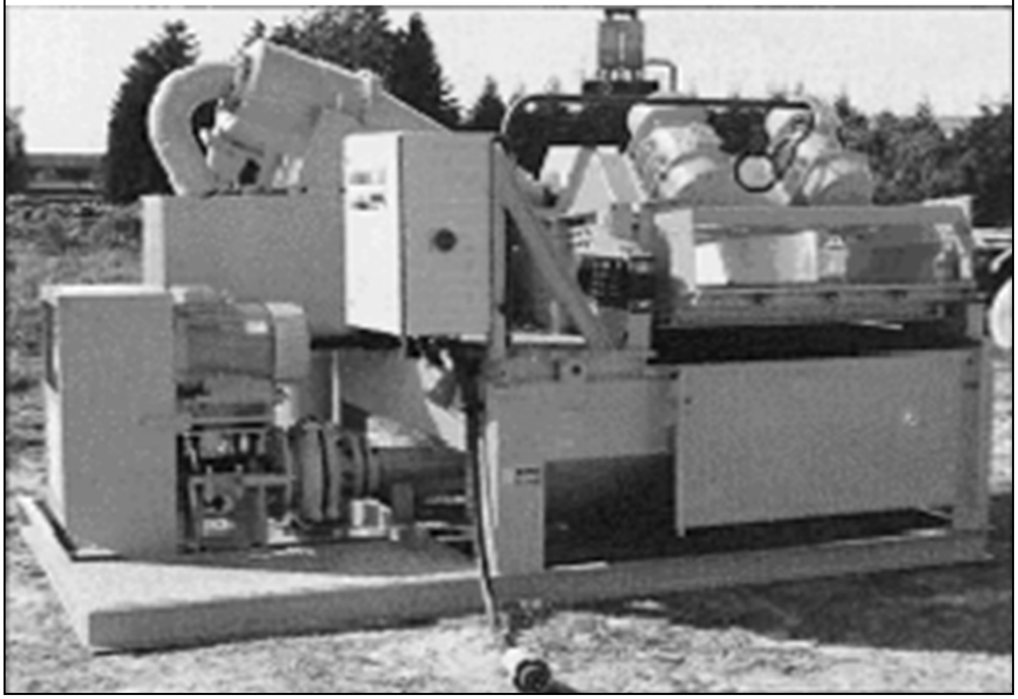
ODOT MATERIALS & INSPECTION

Drilled Shaft Installation plan includes information on the slurry. Check to ensure that the proposed product is being used.

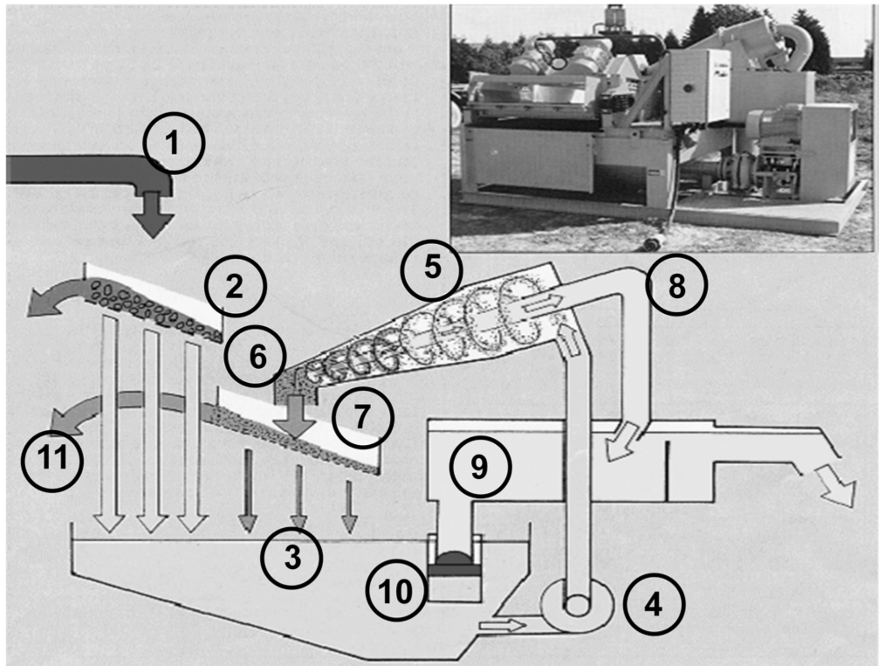
Slurry Comparisons

	Mineral Slurry	Polymer Slurry
Best Application	Cohesionless soils	Clays and argillaceous rock
Mixability	Difficult- must be hydrated for extended time	Easy
Mix Water Sensitivity	Saltwater sensitive	Yes/No
“Caking” Ability	Best	OK
Suspension Ability	Best	OK

Desander



Slurry



The charged slurry passes from the hopper (1) to a scalping vibrating screen (2) which removed fractions >5mm and from there to a storage reservoir (3). A circulating pump (4) pumps it into the cyclone (5) which separates the fines from the slurry. Fine particles are discharged via the cyclone underflow (6) and drop onto vibrating dewatering screen (7), which separates out any fines still remaining in the slurry. The treated slurry is discharged into a holding tank (9) via the cyclone overflow (8), then to a separate outside storage tank. An automatic level control (10), operated by a float, keeps the slurry level in the storage reservoir constant during the desanding process.

Controlling Slurry

Control tests are used to maintain proper slurry condition. Tests are conducted for:

- Density – the slurry weight
- Viscosity – flow: consistency
- pH – acidity:alkalinity
- Sand content
- Slurry testing in conformance with the quality control plan submitted with the Drilled Shaft Installation Plan.

ODOT MATERIALS & INSPECTION

At a minimum, discuss the test results with the contractor’s tester and document in your Daily Report. A better option, is to get copies of the test results from the tester.

00512.14 Drilling Slurry - Furnish drilling slurry meeting one of the following requirements:

(a) Mineral Slurry - Use mineral slurry conforming to the following requirements:

Property	Test	Requirement
Density	Mud Density API * 13B-1, Section 1	64 - 75 lb./cu. ft.
Viscosity	Marsh Funnel and Cup API * 13B-1, Section 2.2	26 - 50 sec./qt.
pH	Glass Electrode, pH Meter, or pH Paper	8 - 11
Sand Content	Sand API * 13B-1, Section 5	4.0 % max.

Maintain slurry temperature at 40 °F or more during testing.

* American Petroleum Institute

(b) Synthetic Slurries - Select synthetic slurries from the QPL. Use synthetic slurries according to the manufacturer's recommendations and the Contractor's quality control plan. The sand content of synthetic slurry shall be less than 2.0 percent (API 13B-1, Section 5) prior to final cleaning and immediately prior to concrete placement.

Add water slurry 00512.14(c)

Add testing frequency of slurry: 00512.43(g). Contractor’s responsibility

00512.14 Drilling Slurry - Furnish drilling slurry meeting one of the following requirements:

(c) Water Slurry - Water may be used as slurry when casing is used for the entire length of the drilled shaft. Use of water slurry without full-length casing will only be allowed with the Engineer's approval. Use water slurry conforming to the following requirements:

Property	Test	Requirement (Maximum)
Density	Mud Weight (Density) API 13B-1, Section 1	70 lb./cu. ft.
Sand Content	Sand API 13B-1, Section 5	2.0 %

Do not use blended slurries.

00512.43 Drilled Shaft Excavation - Perform drilled shaft excavation according to the following:

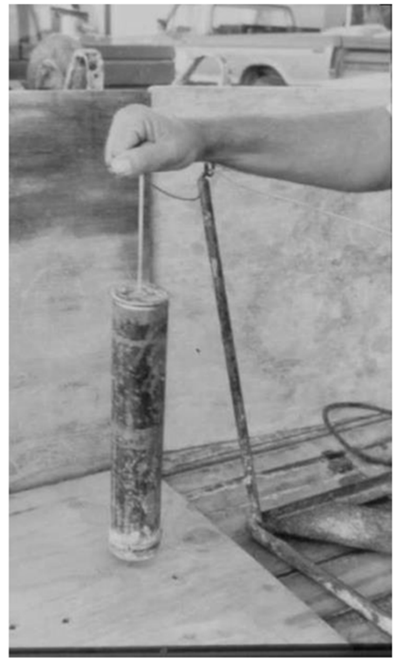
(g) Drilling Slurry Inspection and Testing - Mix and thoroughly hydrate all drilling slurries in an appropriate storage facility. Collect sample sets from the storage facility and perform tests to ensure the slurry conforms to the specified material properties before introduction into the drilled shaft excavation. A sample set shall be composed of samples taken at mid-depth and within 24 inches of the bottom of the storage facility.

Sample and test all slurry in the presence of the Engineer, unless otherwise directed. The sample sets of slurry within the excavation shall consist of samples taken at mid-depth of the excavation and within 24 inches of the bottom of the excavation. Collect and test sample sets during the drilling operation as necessary to ensure the specified properties of the slurry are maintained. Clean, recirculate, de-sand, or replace the slurry as necessary to maintain the specified slurry properties. Final cleaning of the excavation and placement of concrete will not be allowed until the test results indicate the slurry properties are as specified.

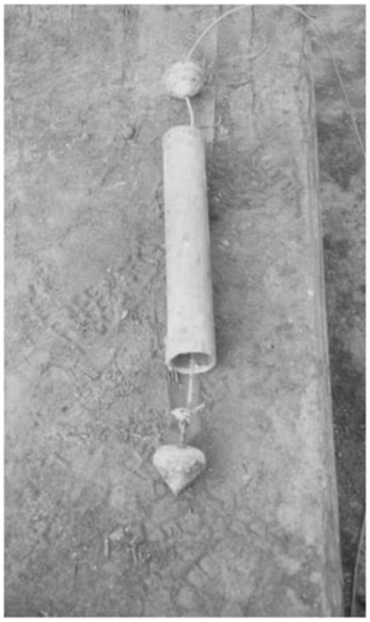
Perform a minimum of two sets of slurry tests per 8 hour work shift, the first test being done at the beginning of the shift. Field conditions may require more frequent testing to ensure acceptable slurry properties.

Slurry Sampling

Sampler



Slurry Sampling
Sampler



.....two consecutive samples produce acceptable values....

00512.14 Drilling Slurry - Furnish drilling slurry meeting one of the following requirements:

(a) **Mineral Slurry** - Use mineral slurry conforming to the following requirements:

Property	Test	Requirement
Density	Mud Density API * 13B-1, Section 1	64 - 75 lb./cu. ft.
Viscosity	Marsh Funnel and Cup API * 13B-1, Section 2.2	28 - 50 sec./qt.
pH	Glass Electrode, pH Meter, or pH Paper	8 - 11
Sand Content	Sand API * 13B-1, Section 5	4.0 % max.

Maintain slurry temperature at 40 °F or more during testing.

* American Petroleum Institute

ODOT 2015 Standard Specification

00512.43 (g) Drilling Slurry Inspection and Testing – Mix and thoroughly hydrate all drilling slurries in an appropriate storage facility. Collect sample sets from the storage facility and perform tests to ensure the slurry conforms to the specified material properties before introduction into the drilled shaft excavation. A sample set shall be composed of samples taken at mid-depth and within 24 inches of the bottom of the storage facility.

Sample and test all slurry in the presence of the Engineer, unless otherwise directed. The sample sets of slurry within the excavation shall consist of samples taken at mid-depth of the excavation and within 24 inches of the bottom of the excavation. Collect and test sample sets during the drilling operation as necessary to ensure the specified properties of the slurry are maintained. Clean, recirculate, de-sand, or replace the slurry as necessary to maintain the specified slurry properties. Final cleaning of the excavation and placement of concrete will not be allowed until the test results indicate the slurry properties are as specified.

Perform a minimum of two sets of slurry tests per eight-hour work shift, the first test being done at the beginning of the shift. Field conditions may require more frequent testing to ensure acceptable slurry properties.

Make copies of all slurry test results available to the Engineer on request.

.....two consecutive samples produce acceptable values....

(b) Synthetic Slurries - Select synthetic slurries from the QPL. Use synthetic slurries according to the manufacturer's recommendations and the Contractor's quality control plan. The sand content of synthetic slurry shall be less than 2.0 percent (API 13B-1, Section 5) prior to final cleaning and immediately prior to concrete placement.

(c) Water Slurry - Water may be used as slurry when casing is used for the entire length of the drilled shaft. Use of water slurry without full-length casing will only be allowed with the Engineer's approval. Use water slurry conforming to the following requirements:

Property	Test	Requirement (Maximum)
Density	Mud Weight (Density) API 13B-1, Section 1	70 lb./cu. ft.
Sand Content	Sand API 13B-1, Section 5	2.0 %

Do not use blended slurries.

ODOT 2015 Standard Specification

00512.43 (g) Drilling Slurry Inspection and Testing – Mix and thoroughly hydrate all drilling slurries in an appropriate storage facility. Collect sample sets from the storage facility and perform tests to ensure the slurry conforms to the specified material properties before introduction into the drilled shaft excavation. A sample set shall be composed of samples taken at mid-depth and within 24 inches of the bottom of the storage facility.

Sample and test all slurry in the presence of the Engineer, unless otherwise directed. The sample sets of slurry within the excavation shall consist of samples taken at mid-depth of the excavation and within 24 inches of the bottom of the excavation. Collect and test sample sets during the drilling operation as necessary to ensure the specified properties of the slurry are maintained. Clean, recirculate, de-sand, or replace the slurry as necessary to maintain the specified slurry properties. Final cleaning of the excavation and placement of concrete will not be allowed until the test results indicate the slurry properties are as specified.

Perform a minimum of two sets of slurry tests per eight-hour work shift, the first test being done at the beginning of the shift. Field conditions may require more frequent testing to ensure acceptable slurry properties.

Make copies of all slurry test results available to the Engineer on request.

How Drilling Slurries Work

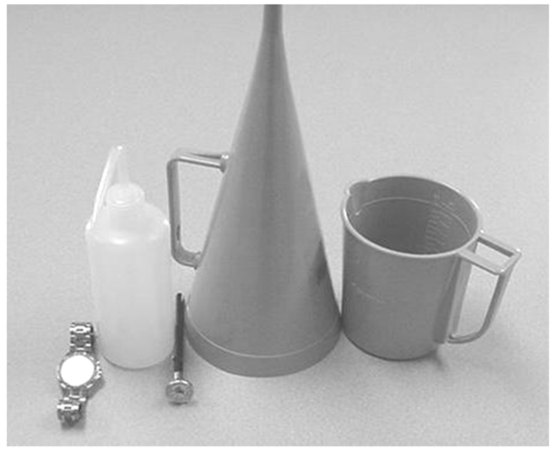
Slurry Type	Mechanisms	Spec 00512.14(a), (b), (c)				Spec 00512.43(f)	Best Application	Caking Ability	Suspension Ability
		Density (lb/cu ft)	Viscosity (sec/qt)	pH	Sand Content (%)	Head above groundwater (ft)			
Water	Hydrostatic Pressure (moderate)	≤ 70	N/A	N/A	≤ 2.0	10	N/A	Low	Low
Synthetic (aka Polymer)	Hydrostatic Pressure (moderate) Cuttings settle, removed from bottom of hole (long chain polymers)	N/A	N/A	N/A	<2.0	10	Cohesive soils (clay) Iffy in silt rich soils	Moderate	Low
Natural Mineral Clay • Bentonite • Attapulgite- SW • Sepiolite -SW	Hydrostatic Pressure (high) Suspends cuttings, removed with circulation drilling	64-75	26-50	8-11	≤4.0	5	Cohesionless soils (sand, low PI silt)	High	High

Note: Potable water has a density of 62.4 lb/ cu ft and a viscosity of 26 sec/qt

Slurry Testing

Viscosity Test

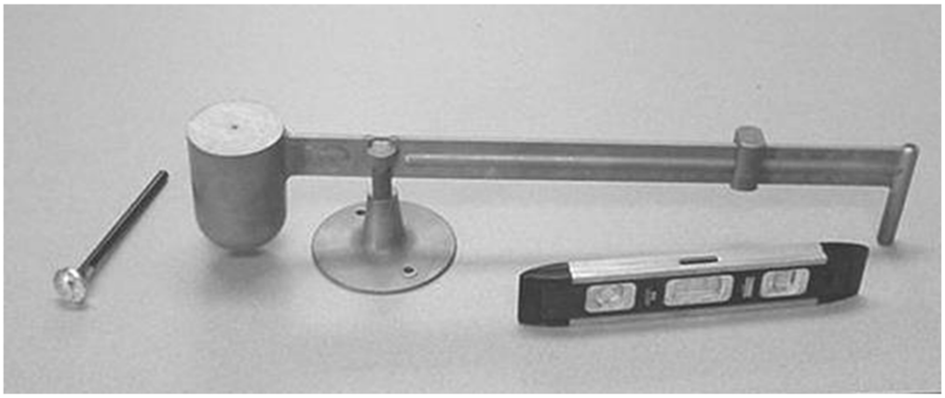
- Also known as Marsh Funnel Test
- Measures the flow rate (i.e., consistency)



The viscosity test is also known as the Marsh Funnel. This test is performed on the pre-mixed slurry prior to introduction in the hole and consists basically of measuring the time required for a prescribed amount of slurry to pass through a plastic funnel with a standard size orifice. The funnel is held in an upright position with the outlet sealed by one’s hand or finger. The test sample is poured through the screen at the top of the funnel until the mud level just reaches the underside of the screen. A stop watch is used to measure the time for a prescribed amount of mud to exit the funnel with the results measured in seconds. As a comparative number, clear water would generally have a test result of 26 seconds.

Mud Balance Test

- Also known as Mud Density Test
- Measures the density (i.e., weight)



The second test prescribed for the pre-mixed slurry, and a test that may also be used for testing samples from the actual excavation, is the density test or mud balance. This device is standardized such that a prescribed amount of mud can be added to a cup attached to a balance arm which rests across a fulcrum. Readings can be taken directly on the scale depending on the weight of mud contained in the cup. The procedures for this test are outlined in the following:

1. Fill the cup with mud to be weighed.
2. Place the lid on the cup and seat it firmly but slowly with a twisting motion. Be sure some mud runs out of the hole in the cap.
3. With the hole in the cap covered with a finger, wash or wipe down all mud from the outside of the cup and arm.
4. Set the knife on the fulcrum and move the sliding weight along the graduated arm until the cup and arm are balanced.
5. Read the density of the mud at the left hand edge of the sliding weight.

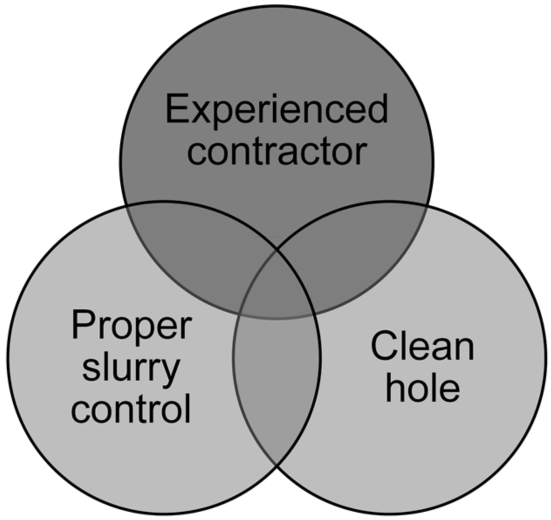
Sand Content Test

- For determining the sand content of the slurry mix
- Reported in volume percent

A more complex test is required when the sand content must be determined. The equipment required for this test consists of a 200 mesh sieve, a small funnel and a sand content tube. The test procedure is prescribed as follows:

1. Fill the sand content tube to the indicated mark with mud. Add water to next mark. Close mouth of the tube and shake vigorously
2. Pour the mixture onto the clean, wet screen. Discard the liquid passing through the screen. Add more water to the tube, shake, and again pour onto the screen. Repeat until the wash water passes through clear. Wash the sand retained on the screen to free it of any remaining mud.
3. Fit the funnel upside down over the top of the screen. Slowly invert the assembly and insert the tip of the funnel into the mouth of the tube. Wash the sand into the tube by spraying a fine spray of water through the screen. (Tapping on the side of the screen with a spatula handle, may facilitate this process). Allow the sand to settle, from the gradations on the tube, read the volume percent of the sand.
4. Report the sand content of the mud in volume percent.

Key elements to quality wet shaft construction are:



Proper Slurry Control Includes:

- Proper dosage and solids content for proper flowability and cake properties
- Thorough mixing / adequate time for hydration (polymer/bentonite)
- Maintenance of head in borehole
- Maintenance of pH, hardness, salts

Problematic Ratings of Slurry Types

Slurry Types	Preparation	Problematic Rating
Bagged commercial bentonite	Properly mixed and hydrated	Fewest
Polymer slurries	Premixed	Some
Polymer slurries	Mixed in hole	Numerous (not recommended)
Water mixed with natural soils	—	Most

Problems with Improper Slurry Control

- Fails to properly suspend and facilitate the removal of sediments and cuttings
- Does not control caving
- Does not control swelling of soils
- Hinders slurry displacement during concrete placement
- Leads to a dirty hole

ODOT MATERIALS & INSPECTION

Problems with Inexperienced Contractor

- Doesn't understand the mechanics of what is happening
- Underestimates the need for slurry
- Uses improper slurry for conditions
- Fails to properly use and control slurry
- Doesn't adequately clean the hole
- Doesn't add slurry soon enough

00512.43 Drilled Shaft Excavation – Perform drilled shaft excavation according to the following:

(f) Drilling Slurry Installation – If synthetic drilling slurry is selected, provide a manufacturer's representative to provide technical assistance at the site prior to use of the slurry, who shall remain at the site during construction and completion of a minimum of one drilled shaft to adjust the slurry mix for the specific site subsurface conditions. After the manufacturer's representative is no longer at the site, provide the approved personnel trained in the use of the synthetic slurry for the remainder of the shaft slurry operations to supervise the proper slurry mix design and quality control procedures.

00512.40 (a), 6th bullet requires manufacturer's representative for synthetic slurry to be named in the Drilled Shaft Installation Plan, and 00512.41, 2nd bullet requires manufacturer's representative for synthetic slurry to attend the coordination meeting and be on site during application.

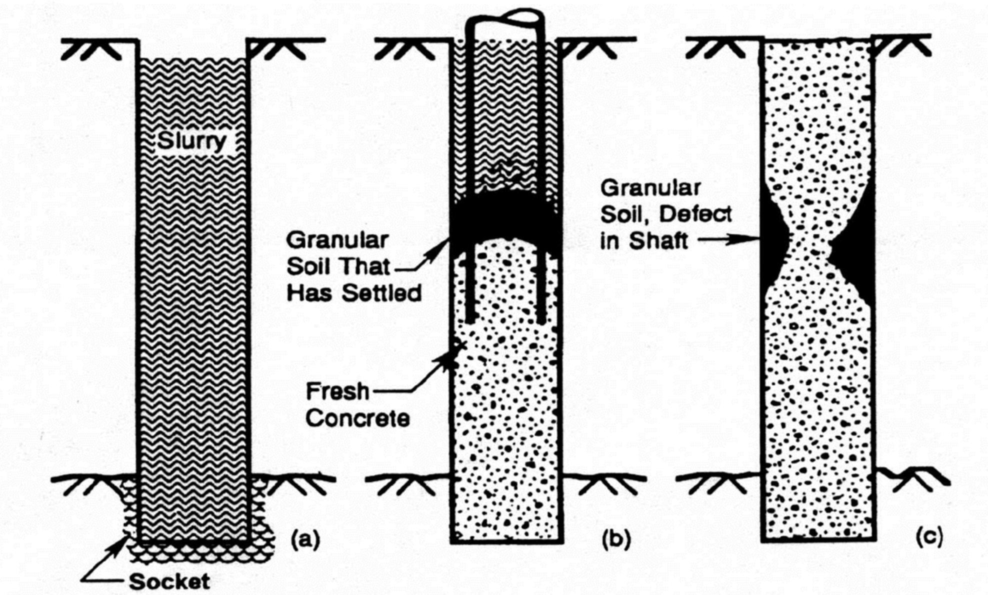
Problems with Dirty Hole

- Leaves cuttings and sediment which prevents good placement of concrete
- Creates voids in the shaft concrete
- Impacts shaft functionality

Other Problems Associated with Slurry

- **Bulge or neck in shaft** – Soft ground zones that were not cased or slurry improperly maintained.
- **Cave in of shaft walls** – Improper use of casing or slurry; failure to use weighting agents in bentonite in running ground water.
- **Excessive mudcake buildup** – Failure to agitate slurry or to place concrete in a timely manner.

Dirty Hole


Slurry
Socket
(a)
Granular
Soil That
Has Settled
Fresh
Concrete
(b)
Granular
Soil, Defect
in Shaft
(c)

Poor Slurry Job

Excellent Slurry Job

Learning Objective

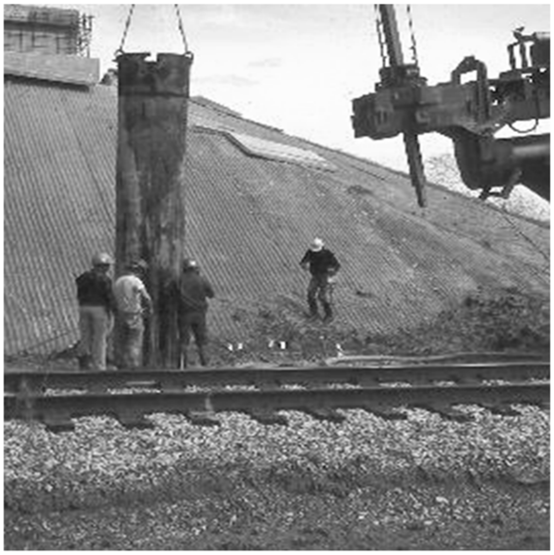
Describe and identify mineral and polymer slurry and other drilling fluids.

What purpose does slurry serve?

ODOT MATERIALS & INSPECTION

Cased Method
Learning Objectives

- Explain why casing is used in both dry and wet holes.
- Describe the cased shaft construction process.
- Describe typical construction problems associated with the use of casing.



When Used?

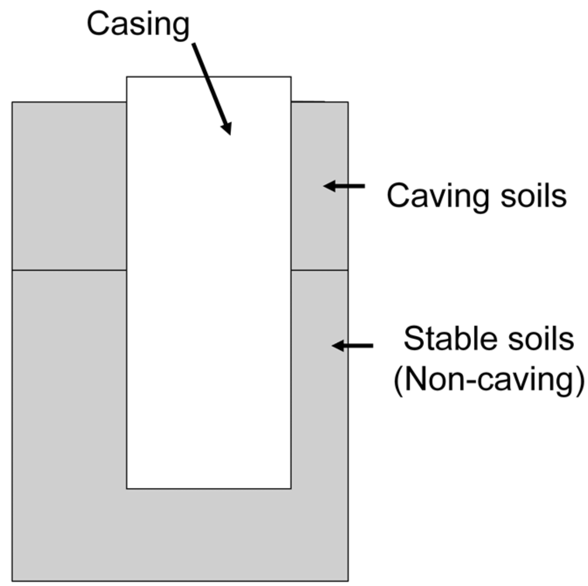
- Where an open hole **cannot** be maintained.
- Where soil or rock deformation will occur.
- Where constructing shafts below the water table or caving soils.

Somewhat Misnamed?

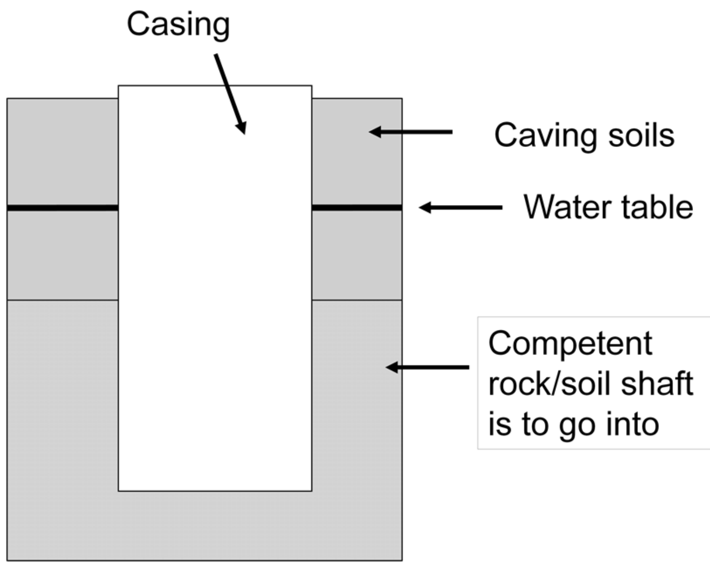
Though called a construction method, the Contractor is installing either wet or dry shafts, and casing is considered another tool by some.

ODOT MATERIALS & INSPECTION

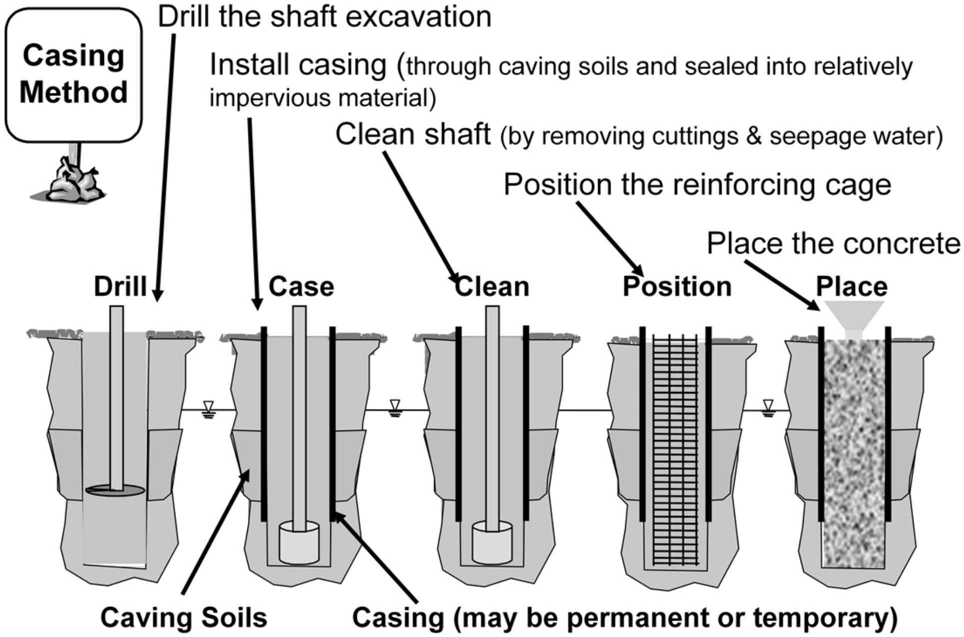
In Dry Holes



In Wet Holes


Casing
Caving soils
Water table
Competent rock/soil shaft is to go into

Construction Process



The Casing Construction Process

Generally the casing method is more expensive and difficult than the dry construction method.

Key elements to quality cased holes are:

- Experienced Contractor
- Good casing material
- Experienced rig operator

Temporary Casing

It is necessary in some construction procedures to seat a temporary casing into an impervious formation such as massive rock. This temporary casing is used to retain the sides of the borehole only long enough for the fluid concrete to be placed. The temporary casing remains in place until the concrete has been poured to a level sufficient to withstand ground and groundwater pressures. The casing is removed alter the concrete is placed. Additional concrete is placed as the casing is being pulled to maintain the pressure balance. Thereafter, the fluid pressure of the concrete is assumed to provide borehole stability.

The wall thickness of temporary casing should be determined by the contractor to ensure stability. Most casing is made of steel, and wall thicknesses usually vary from 0.5 inches upwards, with larger thickness for larger-diameter casings.

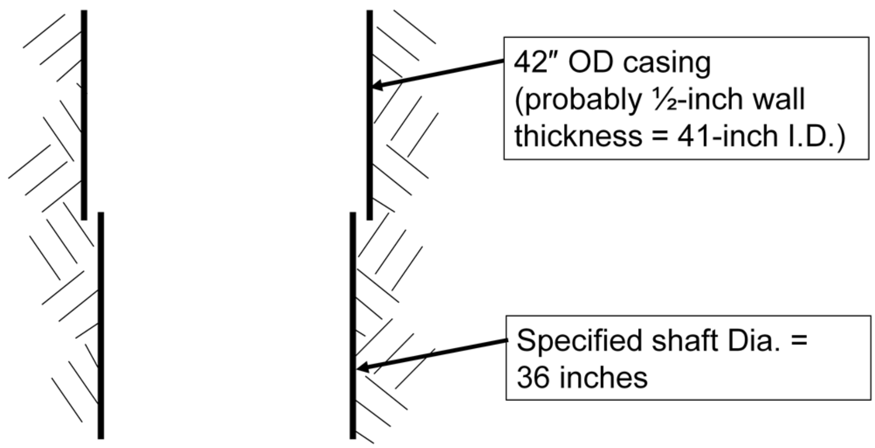
One of the most important uses of casing is to protect workers who most go into the borehole. In the picture above, workers have had to go down the hole to place rock bolts in a large boulder, which was then lifted to the surface. This is a temporary casing.

Most drilled shaft contractors keep a supply of temporary, reusable steel casing in their yard in a variety of lengths and diameters. Most casing is specified according to its outside diameter. If an inside diameter is specified, the Contractor may have to purchase new casing for the project, which would be costly.

Casing comes rolled in outside diameters of 30, 36, 42, 48, etc., inches. Most tools have similar diameters. So to drill a hole with a particular diameter below the casing the contractor will likely need to use a casing 6 in. larger in OD than the hole diameter below the casing.

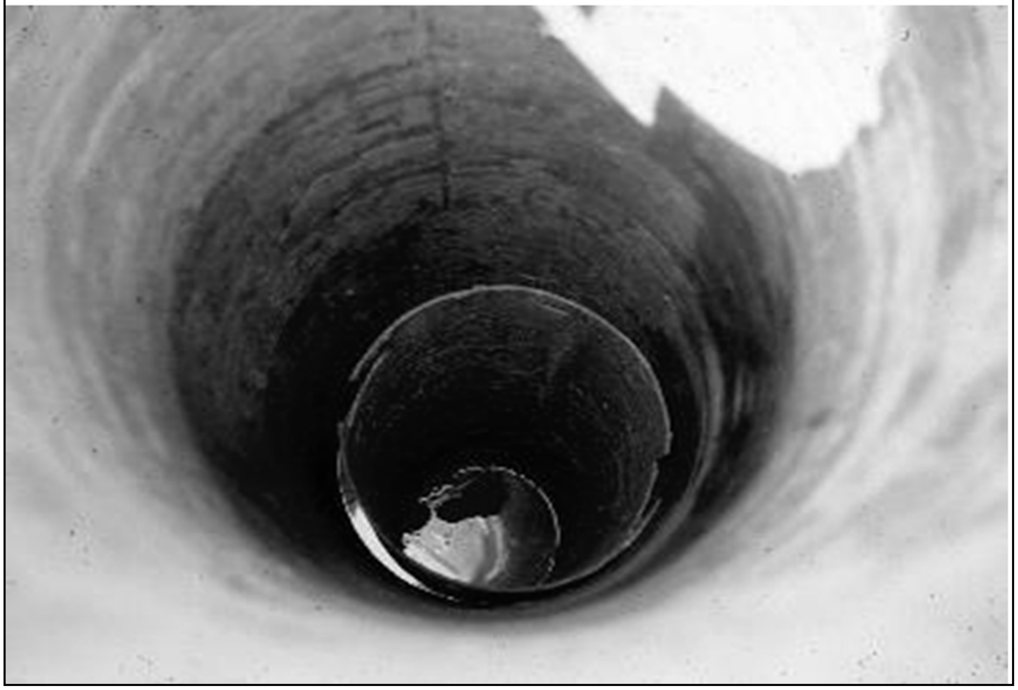
The picture above shows temporary casing stored in a Contractor’s area.

Telescoping Casing



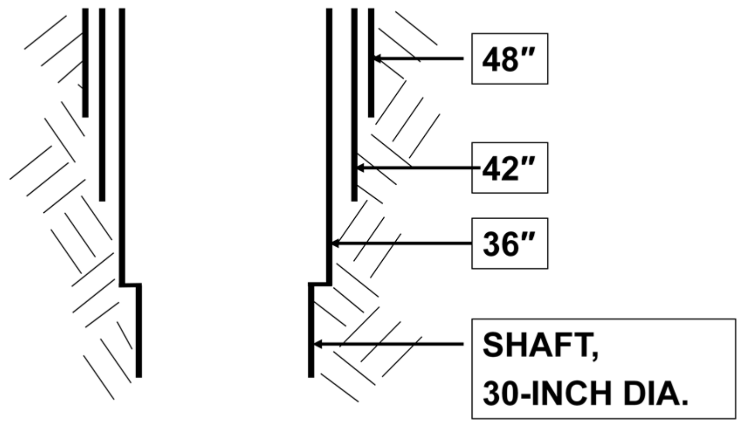
Telescoping casing needs to be approved prior to installation. The documentation is provided in the drilled shaft installation plan.

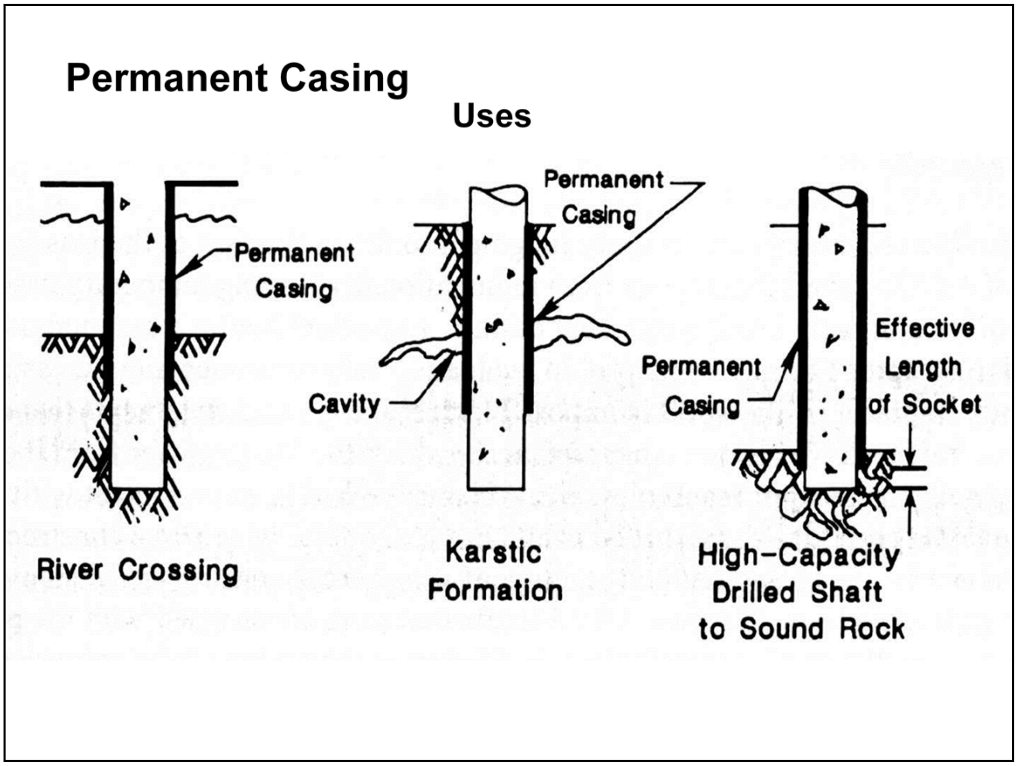
Telescoping Casing



Casing often needs to be inserted into very deep boreholes and/or into very strong geomaterials, which may make it difficult to remove the casings. In such instances, contractors may choose to “telescope” the casing. That is, the first 10 or so feet will be excavated and a large-diameter casing sealed into the geomaterial at the bottom of the hole. A smaller-diameter borehole will then be advanced below the bottom of the casing, and a second casing, of smaller diameter than the first casing, will be sealed into the geomaterial at the bottom of the second-stage borehole. The process can be repeated several times to greater and greater depths until the plan base elevation is reached. With each step, the borehole diameter is reduced, usually by about 6 in. This procedure is often used where the geomaterial to be retained contains boulders.

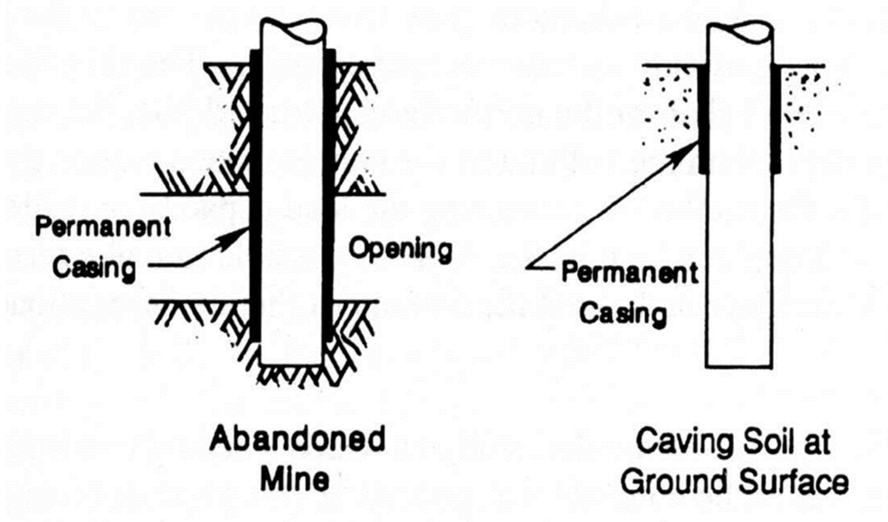
Telescoping Casing



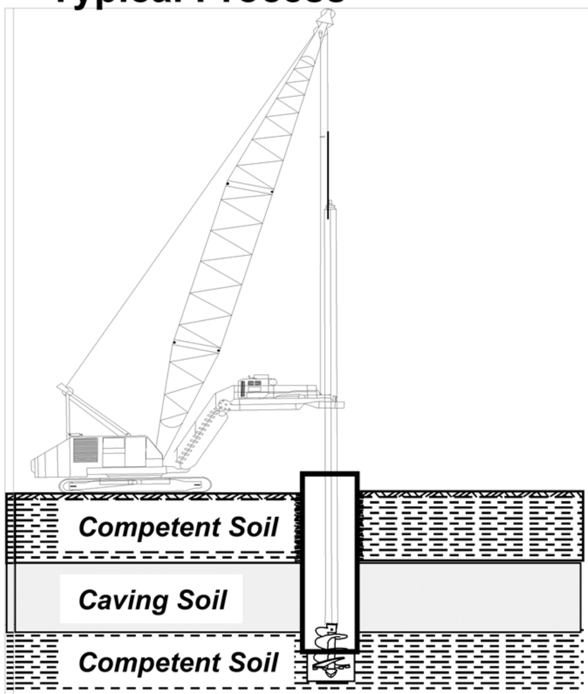


The use of permanent casing is implied by its name; the casing remains and becomes a permanent part of the foundation. An example of the use of permanent casing is when a drilled shaft is to be installed through water and the protruding portion of the casing is used as a form. A possible technique that has been used successfully is to set a template for positioning the drilled shaft, to set a permanent casing through the template with its top above the water and with its base set an appropriate distance below the mudline, to make the excavation with the use of drilling slurry, and to place the concrete through a tremie to the top of the casing. One possible objection to the use of such a technique is that the steel may corrode at the water level and become unsightly.

Permanent Casing Uses (continued)



Typical Process



Introduce slurry (and maintain head) before caving soils are reached

Drill through caving soil

Insert and seal casing

Continue drilling below casing, if needed

Typical Problems with Casing

- Casing not “clean”
- Casing damaged
- Casing not sealed properly
- Casing not structurally adequate
- Getting casing stuck

ODOT MATERIALS & INSPECTION

Want a clean, smooth shaft that is not covered with debris and/or chunks of concrete.

Learning Objectives
Explain why casing is used in both dry and wet holes.

Why is casing used in dry holes?

What are some reasons for casing in wet holes?

ODOT MATERIALS & INSPECTION

Excavation
Learning Objectives

- Describe how to verify checklist questions 16-26
- Determine shaft tip elevations
- Explain methods of assessing and verifying shaft cleanliness
- Describe the typical shaft excavation log forms and their completion

ODOT MATERIALS & INSPECTION

Inspector Duties
Shaft Excavation and Cleaning

Responsible to:

- Classify soils and rock
- Prepare shaft excavation logs
- Verify shaft depth
- Perform shaft inspection
- Validate shaft inspection report
- Verify hole cleanliness
- Document casing use, type, length

QA ODOT MATERIALS & INSPECTION

ODOT Drilled Shaft Inspection Checklist

Shaft Excavation & Cleaning

☐ Yes ☐ No ☐ NA 16. Have the locations for the drilled shafts been accurately located and marked, and both the Contractor and Inspector understand the survey markings?

☐ Yes ☐ No ☐ NA 17. Is the shaft being constructed in the correct location and vertical alignment according to tolerances in Section (00512.42)?

☐ Yes ☐ No ☐ NA 18. Is the slurry level being properly maintained in accordance with 00512.43(f)?

☐ Yes ☐ No ☐ NA 19. Are the proper number and types of tests being performed on the slurry and reported in accordance with 00512.43(g)?

☐ Yes ☐ No ☐ NA 20. Are all excavated materials (spoils) properly contained and disposed of in accordance with 00512.43(a)?

☐ Yes ☐ No ☐ NA 21. If temporary casing is being used, does it meet the requirements of Section 00512.43(c)?

☐ Yes ☐ No ☐ NA 22. Is the shaft of proper depth?

☐ Yes ☐ No ☐ NA 23. Does the shaft bottom meet the clean-out requirements of Section 00512.43(h)?

☐ Yes ☐ No ☐ NA 24. Have the drilled shaft excavation forms been completed?

16. **Have the locations for the drilled shafts been accurately located and marked, and both the Contractor and Inspector understand the survey markings?**

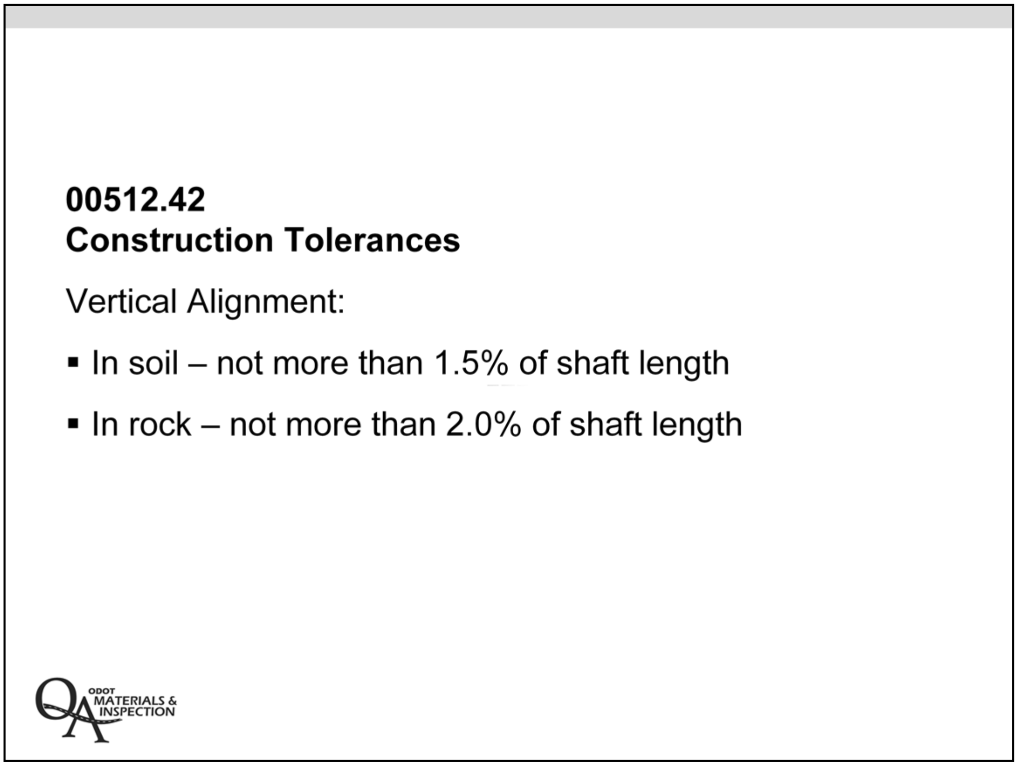
17. Is the shaft being constructed in the correct location and within Section 00512.42 Construction Tolerances?

00512.42
Construction Tolerances

Horizontal Position:

- Diameter < 6 feet equals 3-inch horizontal tolerance
- Diameter > 6 feet equals 6-inch horizontal tolerance

ODOT MATERIALS & INSPECTION



00512.42 Construction Tolerances – Excavate drilled shafts as accurately as possible at the locations shown and within the specified tolerances listed below. Determine the drilled shaft dimensions and alignment with approved methods. The following construction tolerances apply to drilled shafts unless otherwise stated:

Horizontal Position (At the Plan Elevation of the Top of Shaft):

- **Shaft Diameter Less Than or Equal to 6 Feet** – 3-inch horizontal tolerance from the location shown.
- **Shaft Diameter Greater Than 6 Feet** – 6-inch horizontal tolerance from the location shown.

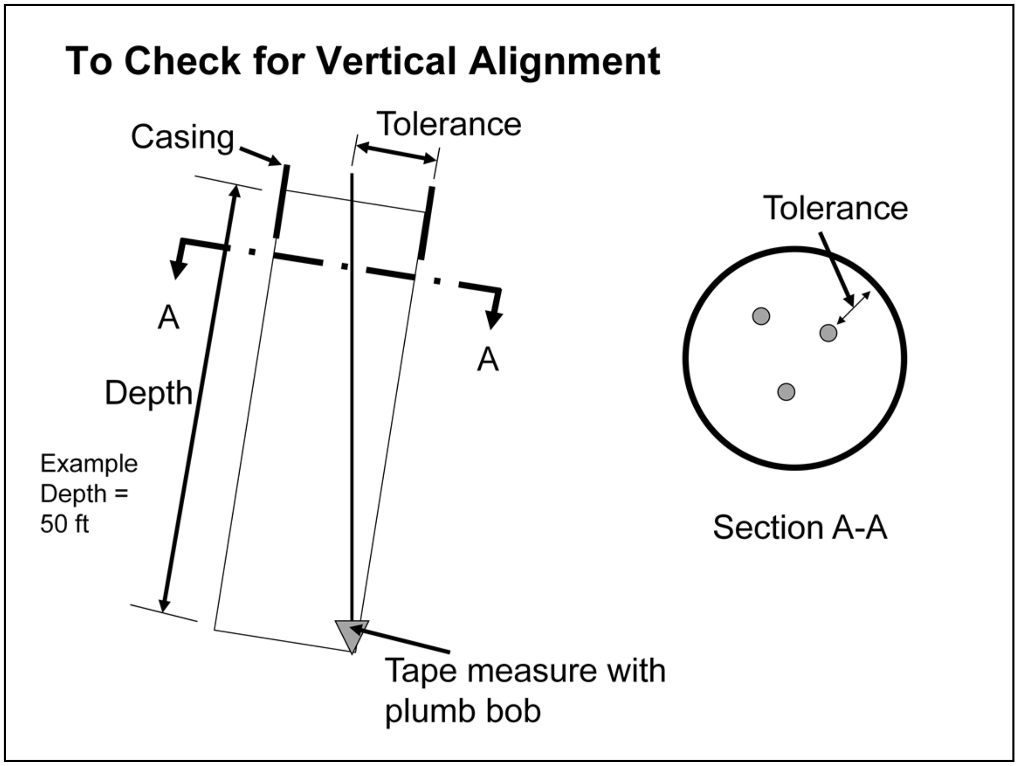
Top Elevation of Shaft Concrete:

- **Top Elevation Above Water** – Minus 3 inches to plus 1 inch from the plan top of shaft elevation.
- **Top Elevation Under Water** – Minus 3 inches to plus 6 inches from the plan top of shaft elevation.

Vertical Alignment in Soil – May not vary from the plan alignment by more than 1.5% of the shaft length.

Vertical Alignment in Rock – May not vary from the plan alignment by more than 2% of the shaft length.

Top of Steel Reinforcement – Plus or minus 6 inches from the plan top of steel reinforcement elevation.



Plump Bob Method

If you know the vertical tolerance, which we do (1.5% for soil and 2.0% for rock) then you can use this method to determine vertical tolerance of plumb shafts.

Assume shaft in illustration is 50 ft. in depth, and is in soil.

1. Determine Tolerance; 1.5%., therefore, 1.5% x 50 ft. = 0.75 ft = 9″
2. Measure in from casing towards center of shaft 9″ – lower plumb bob
3. When plumb bob makes contact, note measurement.
4. Do this at several locations around shaft.
5. In our scenario, any measurement less than 50 ft. would indicate and out of alignment shaft.

Note – we are assuming the shaft is clean and there is no significant accumulation of sediment or cuttings on the bottom.

18. **Is the slurry level being properly maintained in accordance with 00512.43(f)?**

00512.43(f) Drilling Slurry Installation

- Mineral slurries – no less than 5 feet above groundwater level
- Synthetic or water – no less than 10 feet above groundwater level

19. Are the proper number and types of tests being performed on the slurry and reported in accordance with 00512.43(g)?

00512.43(g) Drilling Slurry Inspection and Testing

- Samples taken at mid depth and within 24 inches of excavation bottom.
- Perform minimum of 2 sets per 8-hour work shift.
- Tests may be collected as often as necessary to ensure specified properties are maintained.

ODOT MATERIALS & INSPECTION

20. Are all excavated materials (spoils) properly contained and disposed of in accordance with 00512.43(a)?

- Dispose of materials removed from the shaft excavation according to 00290.20.
- Comply with all applicable federal, state, and local laws.
- Waste materials become the property of the Contractor.

ODOT MATERIALS & INSPECTION

21. If temporary casing is being used, does it meet the requirements of Section 00512.43?

00512.43(c) Temporary Casing

- Provide temporary casing according to the approved installation plan and of sufficient quantities to meet the needs of the anticipated construction method.

ODOT MATERIALS & INSPECTION

(c) Temporary Casing - Provide temporary casing according to the approved installation plan and of sufficient quantities to meet the needs of the anticipated construction method. Where the peak horizontal ground acceleration coefficient for the 1,000 year return period used for seismic design of the structure is less than or equal to 0.16 g (acceleration due to gravity), temporary telescoping casing may be used for the drilled shafts, subject to the following conditions:

- Submit the request to use temporary telescoping casing to the Engineer for approval. Specify the diameters and lengths of the temporary telescoping casing and the shafts where use is requested.
- The minimum diameter of the shaft shall be as shown on the plans.
- Backfill all voids between the temporary telescoping casing and the plan shaft dimensions with a material that approximates the geotechnical properties of the subsurface soils, or with concrete as approved.
- Use temporary telescoping casing material conforming to 00512.13.

Common Problems

- **Temporary casing that cannot be removed** – In some cases, specially squeezing ground conditions, the crane handling the casing doesn't have the power to pull the casing.
- **Horizontal separation or severe necking** – This shaft problem can occur if the temporary casing has concrete adhering to it when pulled.

Commentary

Temporary casing is commonly installed through an unstable deposit in an overreamed hole by the wet method and sealed in an underlying impervious layer. This procedure traps drilling fluid between the casing and the borehole wall. This trapped drilling fluid must be displaced upward along the outside of the casing during casing extraction if the load support capacity of this deposit is to be mobilized and the structural integrity of the shaft is to be ensured.

Positive upward displacement of drilling fluid can only be achieved if an adequate head of fluid concrete fills the casing when the seal is broken during casing extraction. In general, the head of concrete should be kept at or above hydrostatic ground water level during casing extraction. This requires adding concrete during extraction, as the volume to fill the overreamed hole is greater than the casing volume. Casing should never be pulled after the concrete begins to set due to probable entrapment of drilling fluid in the shaft concrete and probable separation of the concrete within the shaft.

22. Is the shaft of proper depth?

- Generally determined and verified by lowering a weighted tape down to the bottom of the shaft after cleaning or Contractor's marks on the kelly.
- Typically measured and recorded to the nearest 0.1 foot from the supplied reference.
- Shaft is to be constructed to the elevation shown in the plans or as revised by the EOR.

ODOT MATERIALS & INSPECTION

Is the shaft of proper depth?

Safety – what are the concerns?

00512.42 Construction Tolerances

Frequently check the plumbness, alignment, and dimensions of the shaft during construction. Correct all out-of-tolerance shaft excavations and completed shafts to the satisfaction of the Engineer. Materials and work necessary to complete corrections for out-of-tolerance drilled shafts will be at the Contractor’s expense, and no extension of the Project completion date will be granted. Materials and work necessary to complete corrections for out-of-tolerance drilled shafts resulting from the removal of unexpected drilled shaft obstructions will be paid for according to 00195.20.

Is the shaft of proper depth?

00512.43 Drilled Shaft Excavation – Perform drilled shaft excavation according to the following:

(a) General – Excavate drilled shafts to the dimensions and elevations shown or as directed. Provide and maintain stabilized drilled shaft sidewalls and bottoms for the full depth of the excavation, using approved materials, equipment and methods. If caving or other unstable conditions occur during any construction procedure, stop further construction, notify the Engineer, and stabilize the shaft excavation by approved methods and submit a revised installation plan which addresses the problem and prevents further instability. Do not continue with shaft construction until any damage which occurred has been repaired according to the Specifications and until receiving the Engineer’s approval of the revised shaft installation plan.

If the Engineer has reason to believe that the drilled shaft excavation techniques or workmanship have been deficient, so that the integrity of any excavation is in question, work on that drilled shaft may be stopped. Drilled shaft excavation will not be allowed to resume until the deficient excavation techniques or workmanship have been changed to the Engineer’s satisfaction.

23. Does the shaft bottom meet the cleanout requirements of Section 00512.43(h)?

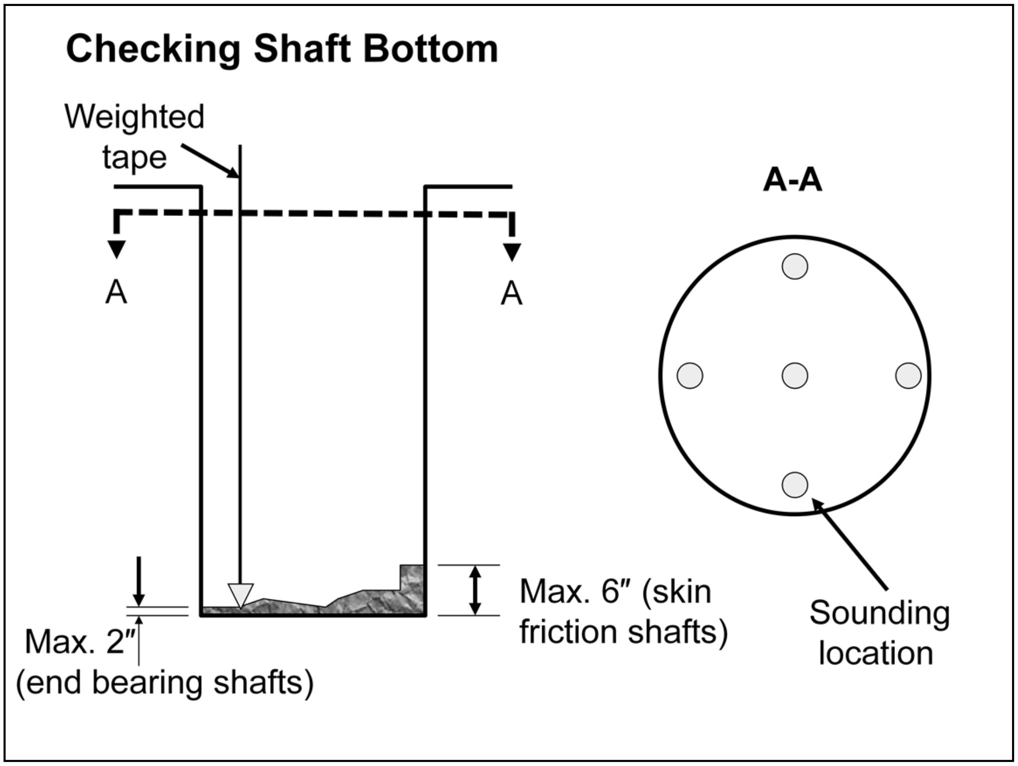
00512.43(h) Cleanout

- **End Bearing Shafts:** No more than 2 inches of loose or disturbed material at bottom
- **Side Friction Shafts:** No more than 6 inches of loose or disturbed material at bottom

ODOT MATERIALS & INSPECTION

00512.43 (h) Clean Out – Use appropriate means, such as a cleanout bucket, pump or air lift, to clean the bottom of the drilled shaft excavations. No more than 2 inches of loose or disturbed material will be allowed at the bottom of the excavation for end-bearing drilled shafts. No more than 6 inches of loose or disturbed material will be allowed at the bottom of the excavation for side friction drilled shafts. Assume end-bearing shafts unless otherwise shown or specified. Shaft cleanliness will be determined by the Engineer.

Notify the Engineer of completion of each drilled shaft excavation to permit inspection before proceeding with construction. Measure final shaft depths with a suitable weighted tape or other approved method after final cleaning to determine that the shaft bottom meets the requirements in the Contract. Do not proceed with shaft construction until the bottom cleanliness requirements have been met and the bottom (shaft tip) elevation is approved.



Keep track of the information on Drilled Shaft Excavation Log.


©RCWilliams

Shaft Inspection Device (SID)

Setting up the SID

SID into Shaft

On-Site Monitoring

Other SIDs

Inside 36″ rock socket

Clay-filled cavity in sidewall of 36″ rock socket

24. Have the drilled shaft excavation forms been completed?

DRILLED SHAFT EXCAVATION LOG

PROJECT: OR138W: Dodge Cr./Calapooya Cr. Bridge Replacements	BRIDGE NO.: 20861	CONTRACT NO.: 14292
BENT: / STATION: "L" 1156+47.5	SHAFT NO.: 1	SHAFT DIAMETER: 8.0'
SHAFT CONTRACTOR: Inland Foundation Specialties	INSPECTED BY: John Kelley	CERTIFICATION NO.: 43452 / DATE: 7/28 & 7/29/11

DATE/TIME EXCAVATED — START 7/28/2011 @ 16:00 FINISH: 7/29/2011 @ 15:20

TYPE OF CONSTRUCTION: ☐ DRY ☑ WET

ELEVATIONS

Reference Elev.	
Grd. Surface Elev.	373.03'
Water Table Elev.	369.03'
Top Shaft Elev.	366.21'
Msd Top Rock Elev.	366.0'
Msd Avg. Shaft Bot Elev.	321.01'

DIMENSIONS

Soil Auger Dia.	6.0'/8.0'
Soil Shaft Length	7.03'
Rock Auger Dia.	6.0'/8.0'
Rock Socket Length	44.9'
Construc. Shaft Length	51.3'

DRILLING SLURRY

Slurry Type & Manufacturer:

Slurry Meets Specifications? Y N

CLEANOUT METHOD

Bucket X Airlift ___ Pump ___

Other:

BOTTOM INSPECTION

Visual X Tape/Probe X

Record 5 depths to the bottom of finished shaft:

1 321.01, 2 321.0, 3 321.01, 4 321.01, 5 321.03

Ave. Shaft Bottom Elev.: 321.01 ft

Meet Cleanout Specification? (Y) N

Meet Alignment Specifications? (Y) N

CASING INFORMATION (if applicable)

	Casing (Temp / Perm)	Casing (Temp / Perm)	Casing (Temp / Perm)
Type	Steel		
OD (in.)	8.575'		
Thickness	.75'		
Top Elev.	372.31'		
Length:	8.0'		

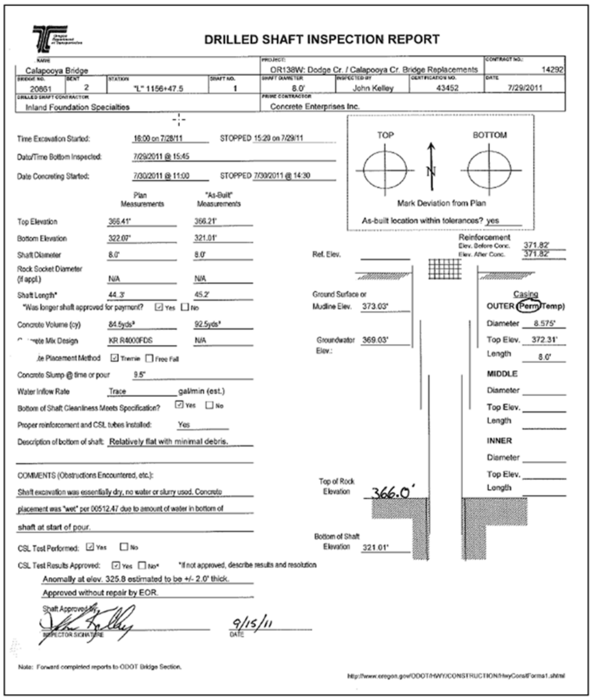
Record and describe all materials encountered during drilled shaft excavation, water table information, depths of seepage and seepage rates, obstructions encountered, equipment used and equip. breakdowns (use additional sheets if necessary).

DEPTH	ELEVATION	START	FINISH	SOIL OR ROCK MATERIAL DESCRIPTION AND NOTES	LOG
4.0'	369.03'			Water seepage noted on two sides of the shaft.	
7.03'	366.0'			Mudstone encountered for the remainder of the shaft.	

INSPECTOR SIGNATURE: John Kelley DATE: 9/15/11

NOTES: Excavation advanced with alternating between a 5.0' and 8.0' auger. Shaft excavation was essentially dry, no water or slurry added. The excavation within the mudstone bedrock was much more stabel than anticipated by the engineer of record (E.O.R.).

A full size version of this document is included in Appendix C along with other examples of completed excavation forms.



DRILLED SHAFT INSPECTION REPORT

NAME	PROJECT	CONTRACT NO.
Calapooya Bridge	OR138W: Dodge Cr. / Calapooya Cr. Bridge Replacements	14292

BRIDGE NO.	BENT	STATION	SHAFT NO.	SHAFT DIAMETER	INSPECTED BY	CERTIFICATION NO.	DATE
20861	2	"L" 1156+47.5	1	8.0'	John Kelley	43452	7/29/2011

DRILLED SHAFT CONTRACTOR	PRIME CONTRACTOR
Inland Foundation Specialties	Concrete Enterprises Inc.

Time Excavation Started: 16:00 on 7/28/11 STOPPED 15:20 on 7/29/11

Date/Time Bottom Inspected: 7/29/2011 @ 15:45

Date Concreting Started: 7/30/2011 @ 11:00 STOPPED 7/30/2011 @ 14:30

	Plan Measurements	"As-Built" Measurements
Top Elevation	366.41'	366.21'
Bottom Elevation	322.07'	321.01'
Shaft Diameter	8.0'	8.0'
Rock Socket Diameter (if appl.)	N/A	N/A
Shaft Length*	44.3'	45.2'
Concrete Volume (cy)	84.5yds³	92.5yds³
Concrete Mix Design	KR R4000FDS	N/A

*Was longer shaft approved for payment? ☑ Yes ☐ No

Concrete Placement Method ☑ Tremie ☐ Free Fall

Concrete Slump @ time or pour 9.5"

Water Inflow Rate Trace gal/min (est.)

Bottom of Shaft Cleanliness Meets Specification? ☑ Yes ☐ No

Proper reinforcement and CSL tubes installed: Yes

Description of bottom of shaft: Relatively flat with minimal debris.

COMMENTS (Obstructions Encountered, etc.):

Shaft excavation was essentially dry, no water or slurry used. Concrete placement was "wet" per 00512.47 due to amount of water in bottom of shaft at start of pour.

CSL Test Performed: ☑ Yes ☐ No

CSL Test Results Approved: ☑ Yes ☐ No* *If not approved, describe results and resolution

Anomally at elev. 325.8 estimated to be +/- 2.0' thick.

Approved without repair by EOR.

Shaft Approved by: [signature] INSPECTOR SIGNATURE 9/15/11 DATE

TOP BOTTOM N

Mark Deviation from Plan

As-built location within tolerances? yes

Reinforcement Elev. Before Conc. 371.82'

Elev. After Conc. 371.82'

Ref. Elev.

Ground Surface or Mudline Elev. 373.03'

Groundwater Elev.: 369.03'

Top of Rock Elevation 366.0'

Bottom of Shaft Elevation 321.01'

Casing

OUTER (Perm/Temp) — Perm circled

Diameter 8.575'

Top Elev. 372.31'

Length 8.0'

MIDDLE

Diameter

Top Elev.

Length

INNER

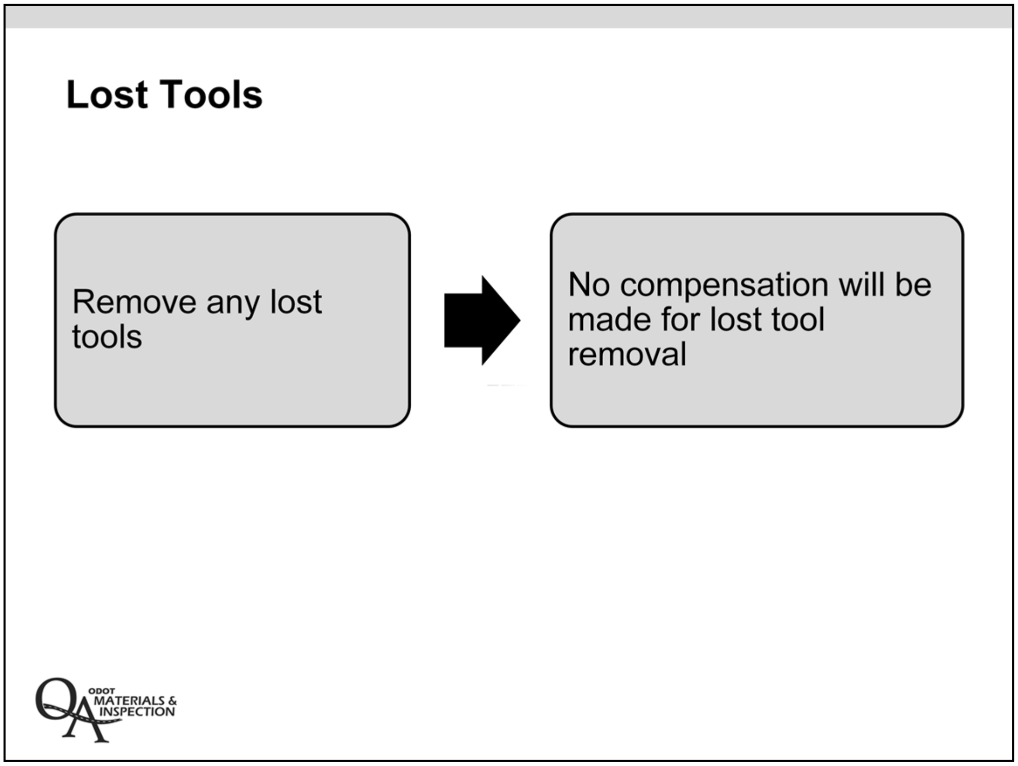
Diameter

Top Elev.

Length

Note: Forward completed reports to ODOT Bridge Section.

http://www.oregon.gov/ODOT/HWY/CONSTRUCTION/HwyConstForms1.shtml



ODOT 2015 Standard Specification

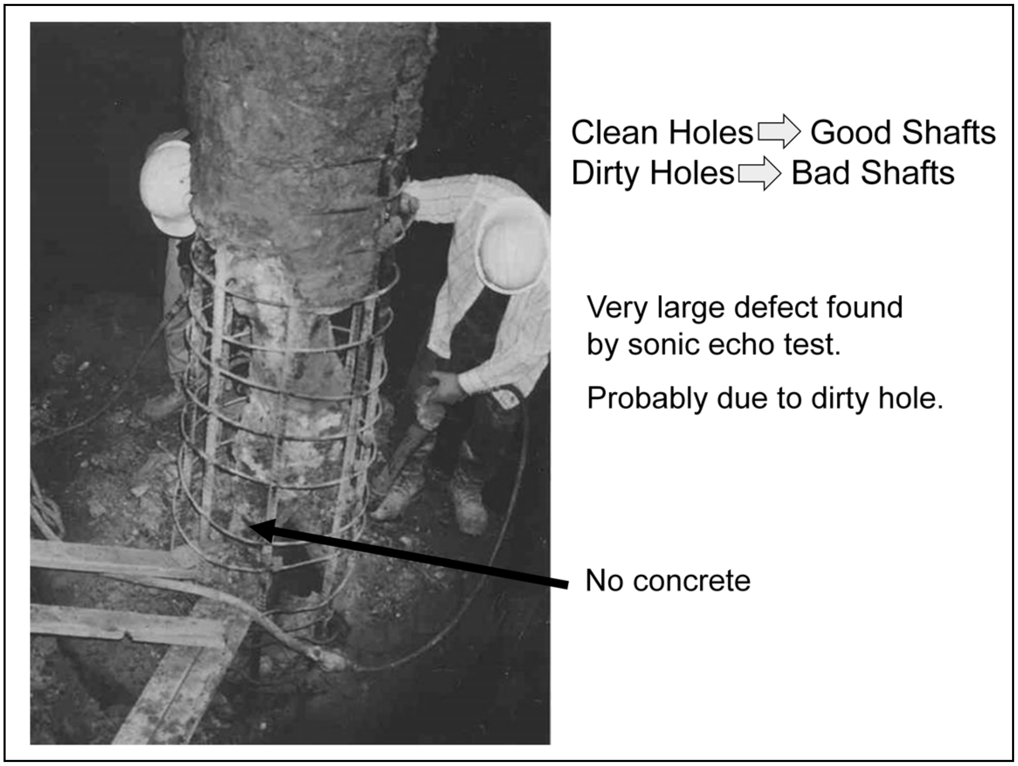
00512.43 Drilled Shaft Excavation – Perform drilled shaft excavation according to the following:

(e) Lost Tools – Promptly remove drilling tools lost in the excavation. Lost tools will not be considered unexpected obstructions and shall be removed without additional compensation. Drilling tools lost during the course of removing unexpected drilled shaft obstructions will be paid according to 00195.20.

Learning Objective
Explain methods of assessing and verifying shaft cleanliness

The maximum depth of sediment or debris permitted anywhere on the shaft bottom is ___?

Describe a common non-intrusive method of determining shaft cleanliness.



This is a photograph of a defect on a highway bridge after contaminated concrete had been chipped away. A severe defect of this size can be detected with almost certainty by the sonic echo method.

Shaft Excavation Quiz

1. What is perhaps the most important step in getting a good shaft?
   a. Casing the drilled shaft.
   b. Keeping all water out of the hole.
   c. Cleaning the hole (excess cuttings).
   d. Constructing a vertical rebar cage.

2. The Dry shaft method shall only be approved when the shaft demonstrates that less than _____ inches of water accumulate above the base over a one hour period when no pumping is permitted.
   a. 4
   b. 6
   c. 8
   d. 12

3. What constitutes the need for a wet shaft with respect to concrete placement?
   a. Caving Hole
   b. Excessive accumulated water
   c. Contractor preference
   d. A and B
   e. B and C

4. In Wet shaft construction, which of the following is perhaps the most critical element in getting a good shaft?
   a. A clean hole prior to casing
   b. A clean hole prior to concreting
   c. The use of temporary casing

5. The specified maximum sand content for polymer slurries at the base of the shaft just prior to concreting is ___?
   a. 1%
   b. 2%
   c. 3%
   d. 4%

More Questions on back…

6. Of the following slurries, for which must the Contractor submit a detailed report specific to the project?
    a. Polymer
    b. Water
    c. Blended
    d. Mineral

7. What is the allowable horizontal tolerance for plan position for a ≤ 6 ft diameter shaft?
    a. 3″
    b. 4″
    c. 5″
    d. 6″

8. The maximum depth of sediment or debris permitted anywhere on the end bearing shaft bottom is ___?
    a. 1″
    b. 2″
    c. 3″
    d. 4″

9. Shaft cleanliness is important for…
    a. End-bearing shafts
    b. Side-friction shafts
    c. Both of the above
    d. None of the above

Prepared 1/23/2012