Drilled Shafts
Section 8

Typical Drilled Shaft

- Axial Load
- Lateral Load
- Depth can vary widely
- Side Resistance
- Base Resistance
- Concrete mix design can vary based on several factors
- Diameter can vary widely
- Reinforcing Steel (Typically required by design)
- Bell - May be used or omitted as desired.
- Bell size varies - No larger than 3 times the shaft diameter at base.
Drilled Shaft Equipment

**Crane Mounted Rigs**

- Large power units attached to crane
- Elevated rotary table to accommodate drill tools
Drilling Equipment Terminology

- **Kelly**
- **Table**
- **Power Unit**
- **Crane**
- **Tool**

Crawler Mounted Rigs

- Larger rigs capable of 12’ diameter holes and 250’ depth
- Smaller rigs are more maneuverable
- Good in low-headroom locations
Light Truck Mounted Rigs

- Smaller jobs such as light and signal poles
- Access road required

Auger Bits and Tools
Earth Augers

Single-Flight
Soil Auger

Soil Teeth
(Blunt/Wide)

Guide Shaft
(“Stinger”)

Earth Augers

Double Flight

Double Cut
Drilling Bucket

This is typical of a drilling bucket used in loose sand, gravel and cobbles.

Boulder Bucket and Auger
Rock Augers

Rock augers are generally used in soft to hard rock formations.

- Tapered geometry
- Conical (bullet) carbide teeth

Rock Bits

Typical rock bits designed for: Hard to Very Hard Rock.

- Circulating bit
- Replaceable roller bits
Core Barrel

Soft Rock

Hard Rock

Cleanout (Muck) Bucket

Typical Cleanout (muck) Bucket:

Used to cleanout cuttings and sediments from bottom of the shaft.
Construction Process

Dry Hole 00512.47 (b)

- No more than 3" of water on bottom of shaft at time of pour.
- Seepage rate of no more than 12" per hour.
- Shaft diameter is greater than or equal to 3 feet.
Drilled Shafts Section 8

Dry-Hole Construction Process

- **“Dry” Hole**
  - Drill the shaft excavation
  - Clean shaft by removing the cuttings & seepage water
  - Position the reinforcing cage
  - Place the concrete

- Competent, non-caving soils
- Water table

Slurry Construction

Slurry is a fluid introduced into the excavation to maintain hole stability.
Clean
Proper cleaning and maintaining slurry level is imperative.

Slurry Process
- "Wet" Hole
- Drill the shaft excavation
- Stabilize the hole (Mineral or Polymer slurry added to the excavation)
- Clean shaft by removing the cuttings & seepage water
- Position the reinforcing cage
- Place the concrete by tremie
- Drill
- Stabilize
- Clean
- Position
- Place

Caving soils
Water table
Slurry Testing Equipment

- pH
- Viscosity Test
- Mud Balance Test
- Sand Content Test

Placing Concrete in “Wet” Holes (Tremie Pipe or Pump Hose)
Placing Concrete

Temporary Casing
Temporary Casing Stabilization

• Used where an open-hole cannot be maintained.
• Used to seal off caving soils below the water table.
• Used where excessive hole deformation occurs (swelling/expansive soils).
• Used where slurry will not work.

Drilled Shaft Construction Process

Drill the shaft excavation (casing may be installed during shaft excavation)
Install casing through caving soils and sealed into relatively impervious material
Clean shaft by removing the cuttings & seepage water
Position the reinforcing cage
Place the concrete and remove temp. casing
Casing Installation Process
(Casing Advancers)

- Hydraulic oscillators/rotators drive and extract casing
- Fitted with special quick coupling joints

Casing Removal
Drilled Shaft Inspector Checklist (1/2)

Drilled Shaft Inspector Checklist (2/2)

Reinforcing Cage

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<tr>
<th>Item</th>
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<th>No</th>
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<tr>
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Reinforcing Shaft Construction and Placement

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Corrosion/Protection

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Notes/Comments

[http://www.section8.com/][1]
Inspector’s Responsibilities on a Drilled Shaft Project

**CONTRACTOR SET UP**
- Responsible to:
  - Check Drilled Shaft Installation Plan
  - Check Contractor Equip.
  - Check hole location
  - Check template
  - Check setup for plumbness, etc.

**SHAFT EXCAVATION**
- Responsible to:
  - Check Drilled Shaft Installation Plan
  - Check Contractor Equip.
  - Check hole location
  - Check template
  - Check setup for plumbness, etc.

**PLACING STEEL**
- Responsible to:
  - Verify proper steel size, length, etc.
  - Verify proper ties
  - Verify proper spacers and intervals
  - Verify Instrumentation protection

**CONCRETING OPERATION**
- Responsible to:
  - Verify hole cleanliness
  - Monitor concrete volumes
  - Prepare Concrete Placement Log
  - Check Const. Tolerances

**POST INSTALLATION**
- Responsible to:
  - Verify pay quantities
  - Verify Integrity testing
  - Complete required forms
  - Verify Load Tests

**Inspection Forms**
- Drilled Shaft Soil/Rock Excavation Log
- Drilled Shaft Inspection Report
- Concrete Placement Log
- Concrete Volumes Form
Inspector Responsibilities:

- Verify contractor equipment vs. Drilled Shaft Installation Plan
- Verify Concrete Mix Design and Slurry Data

Shaft Excavation, Cleaning & Inspection

Verify Drilled Shaft:

- Location, alignment, vertical tolerance, horizontal tolerance, diameter, depth
- Complete soil and rock excavation logs
- Monitor slurry testing
- Document casing usage; type, length, etc.
- Perform shaft inspection and verify cleanliness
Shaft Depth & Cleanout Requirement

- Depth typically determined and verified by lowering a weighted tape down to the bottom of the shaft after cleaning.
- Depth typically measured and recorded to the nearest 0.1 of a foot.
- Improved cleanout can be achieved with air lifts and submersible pumps vs. cleanout buckets.

Checking Shaft Bottom & Cleanliness

Max. 2” on bottom (end bearing)

Max. 6” on bottom (friction)
Complete the Drilled Shaft Excavation Log

Is the shaft being constructed within the correct location and tolerance (Section 00512.42)?

Plan Position

Vertical Position

3” up to 6’ dia. 6” for over 6’

1.5% (soil)

2% (rock)

4 ft. Builders Square or carpenters level positioned on reference

L
To Check for Vertical Alignment

- Casing
- Depth
- Tolerance
- Tape measure with plumb bob

Drilled Shaft Inspection Report (00512.40(c))
Is the rebar properly tied in accordance with Section 00530.41, Placing and Fastening?

Reinforcing Cage

Longitudinal (vertical) Bars
Spiral Bars
Ties
CSL Inspection Tubes
Does the contractor have the proper spacers for the steel cage? 00512.45 (d)

- Maintain the required concrete cover shown in the plans, between outside of cage and shaft walls.
- Start spacers near the bottom of cage with vertical spacing intervals not exceeding 10 ft.
- Use a minimum of 1 spacer per 30 inches of rebar cage circumference with a minimum of 3 spacers at each interval.
- Standoffs are usually allowed to support the bottom of the cage.

Plastic Roller Spacer
Epoxy Coated Rebar Spacer

Spacer Example

4 ft Drilled Shaft
6” clearance

How many spacers are required on each level?

\[ C = \pi \times D \]

\[ C = 3.14 \times 3' = 9.42' \]

\# of Spacers = 9.42' / 2.5' /Spacer = 3.8

\# of Spacers = 4
Spacer Exercise

8 ft Drilled Shaft
6” clearance
How many spacers are required on each level?

Spacer Exercise Key

C = \pi \times D
C = 3.14 \times 7' = 22.0'
# of Spacers = 22.0' / 2.5' / Spacer = 8.8
# of Spacers = 9
Reinforcing Cage Construction

• Shall be completely assembled prior to placement.
• Placed immediately after inspection and acceptance of shaft.
• Internal stiffeners removed as cage is placed in the borehole.

Reinforcing Cage Storage & Handling

• Do not store in contact with soil.
• Keep away from oil or other deleterious materials.
• Provide adequate supports during lifting.
Crosshole Sonic Log (CSL) Access Tubes

Section 00512.15 – Crosshole Sonic Log (CSL) Test Access Tubes:

- Placed per plan.
- CSL tubes to be Schedule 40 steel pipe with minimum I.D. of 1.5 inches.
- Tied securely to the reinforcement cage.
- Water-tight joints and filled with water before or no more than 1 hour after concrete placement.
- Capped top and bottom.
Splicing of Cage

Occasionally, the plans will require the rebar cage to be spliced.

Any splicing of the reinforcement cage requires the approval of the Structural Design Engineer, if not shown in the plans.

Placement of Reinforcement Cage

Proper lifting of cage
Is the steel cage secured from settling and floating during concrete placement?

- Contractor methods for maintaining cage position during construction must be described in the Drilled Shaft Installation Plan.
- Check top of cage elevation before and after concrete placement.
- After concrete placement the top of reinforcement cage **should not exceed:**
  - 6” above plan elevation
  - 6” below plan elevation

Prior to concrete placement, has the slurry been tested in accordance with Section 00512.43(f)?

**Additional Recommended Requirements:**

- Must sample and test slurry prior to placing concrete.
- Need 2 consecutive tests producing acceptable results.
- Concrete cannot be placed until passing test results achieved.
Concrete Sampling and Testing

- Slump
- Air content
- Unit weight
- Temperature
- Concrete cylinders for strength tests

Typically at least one set per shaft and frequencies per MFTP.

Drilled Shaft Concrete
Typical Slump Range
2001.20(c)

All conditions

Target Slump
8 ½"

1.5” Tolerance
12”

1.5” Tolerance
Concrete Placement

- Place concrete **continuously**.
- Place concrete **without** interruption.
- Place concrete from the **bottom** of the hole **to the top**.
- Place concrete until fresh concrete is coming out of the top of shaft, **free of water, soil debris** or other deleterious materials.
Concrete Placement

- No mechanical vibration required.
- Dispose of all displaced water, laitance and waste concrete according to regulations.
- Wet cure the top of shaft for a minimum of seven days.
  00512.47(d)

Concrete Placement

Tremie Method

- Begins at the bottom of the hole.
- Place immediately after cleanout.
Gravity Tremie Placement
8” min Inside dia.

Pump Line Placement

Pump Line
Suction Line
Tremie Concrete Placement

- Discharge end of tremie must be immersed a minimum of 5 ft. in the concrete at all times. 00512.47(c)
- Flow of concrete must be continuous.
- Concrete level in tremie must be above slurry or water level in hole.
- If tremie breaches the shaft is considered defective.

Do Not Breach the Tremie

Marked tremie
Ref. Elev.
Weighted tape measures depth to top of concrete
Concrete being placed
Do not breach the tremie
Free Fall Concrete Placement

00512.47(b)

• Free fall placement only permitted in dry holes.
• Must fall to base of shaft without contacting rebar cage or shaft walls.
• Make sure all cage bracing is removed prior to concrete placement.
• Drop chutes may be use.

Free Fall Method
Drilled Shafts Section 8

00512.47 (a) – Concrete Placement (Time Limits)

• Allow a maximum of 60 minutes between placements.
• No concrete older than 90 minutes from batch time.

Should a delay in concrete placement occur:

• Reduce the placement rate to maintain fresh concrete flow in the shaft.

Permanent Casing Removal

Section 00512.47 (e) Casing Removal –

• Remove the tops of permanent casing to the Top of the Drilled Shaft or the Finished Groundline, whichever is lower, unless otherwise shown or directed.
• Remove the tops of permanent casing for shafts constructed in a permanent body of water to the low water elevation, unless otherwise shown or directed.
Temporary Casing Removal

- Temporary casing
- Fresh concrete
- Top of fresh concrete
- Ground surface
- Level of drilling fluid
- Hydrostatic Water level
- Drilling fluid

5 ft. min. whichever is greater

Drilled Shaft Inspection Report (00512.40(c))
Be alert for rising concrete or cage as casing is being pulled.

Structural defect produced by interruption in concreting.
Concrete Volumes

Typical Inspector Duties During Placement

- Record start and finish times for placement.
- Record concrete quantity per load/truck.
- Measure and record depth/elevation of top of concrete after each load.
- Plot concrete volume curve.
- Verify placement is continuous.
- Monitor for tremie breaching.
Possible Causes of Curve Irregularities

- As expected
- Less than expected
- As expected
- More than expected
- More than expected
- As expected

Complete the Concrete Placement Log
Complete Concrete Volume Curve

Concrete Volume Curve Example
Calculate Theoretical Volume of Shaft

5’ Dia. Drilled Shaft
50’ Long

Volume = \( \pi r^2 h / 27 \text{cf/cy} \)

\( V = \pi (2.5')^2 (50') / 27 \text{cf/cy} = 36.4 \text{ cy} \)

Theoretical Volume = 36 cy

Convert Field Measurements

6 Truck Loads of 8 cy each:

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<th>Ft</th>
<th>Accum CY</th>
<th>Elev</th>
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Waste = 3 cy
Convert Field Measurements

6 Truck Loads of 8 cy each:

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Waste = 3 cy

Concrete Volume Curve
Possible Causes of Curve Irregularities

- As expected
- Less than expected
- As expected
- More than expected
- As expected
- More than expected
- As expected

Concrete Volume Curve Exercise
Calculate Theoretical Volume of Shaft

6’ Dia. Drilled Shaft
60’ Long

Theoretical Volume of Shaft Key

6’ Dia. Drilled Shaft
60’ Long

Volume = \pi r^2 h / 27 \text{cf/cy}

V = \pi (3')^2 (60') / 27 \text{cf/cy} = 62.8 \text{ cy}

Theoretical Volume = 63 \text{ cy}
### Convert Field Measurements

Each truck holds 7cy and the depth of the concrete after each truck are shown (no waste):

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<td>60</td>
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Plot the concrete curve on the next sheet. What issues may there be?
Complete Curve
Post Construction Activities

Concrete Placement

00512.49 Scheduling and Restrictions

- Do not proceed with additional shafts until the first drilled shaft has been approved and accepted by the Engineer in writing.

- Approval to proceed with constructing subsequent shafts prior to written acceptance of the first shaft will be based on the Engineer’s observations.

- Written notification to proceed or not to proceed will be provided within 24 hours.
Concrete Placement

00512.49 Scheduling and Restrictions – Continued

- Do not proceed with the third drilled shaft until CSL test results have been reviewed and the first shaft approved and accepted by the Engineer in writing.

- After the first drilled shaft on the Project has been accepted, make no significant change in construction methods, equipment or materials used in the construction of subsequent shafts, unless approved by the Engineer.

Top of shaft concrete contaminated
Cage Alignment

Very large defect found by sonic echo test. Probably due to dirty hole.

Typical Problem

No concrete
Post Construction Testing

Cross-hole Sonic Log (CSL) Testing

CSL testing is performed on the first shaft constructed and others as described in SP 0512.

Additional shafts are tested if:

• Construction methods change or
• Shaft construction results in questionable quality shafts.

This is especially true for uncased shafts, excavated below the water level in soils.
Crosshole Sonic Log Testing

Source and Receiver Tools for CSL Test
Crosshole Sonic Log Test Results

**IF AN ANOMALY IS DETECTED:**

The Engineer will determine course of action.

May include:

- Additional CSL testing
- Excavation around shaft to expose defect
- Core drilling
- Down-hole cameras

Whatever the course of action is, the Engineer will review all of the shaft construction records to determine what caused the problem.
Concrete Coring

- Number of holes, locations and depths determined by the Engineer.
- Log the boring like a regular borehole.
- Take photos.
- Record any driller comments on concrete quality.

Core Sample
SAFETY, SAFETY, SAFETY

What's that buzzing sound?
McKenzie & Willamette River Bridges

Drilled Shafts