

DRILLED SHAFTS

Section 465

of

Standard Specifications





What is a Drilled Shaft?

- Type of substructure foundation.
- A cylindrical shaft excavated into the ground and then filled with resteel & concrete.
- Supports loads primarily through skin friction between the concrete and the adjacent soil.
- End bearing generally not considered.
- Typical sizes: 30” to 72” in diameter and can extend 50’ or more into the ground.



What is a Drilled Shaft?

- Drilled shafts require rigorous inspection.
- Initial plan review is a must.
- Should read Section 465 of Standard Specs to clearly understand different types of shaft construction.
- Need to become familiar with procedures in the specs in event problems are encountered.

Casing

- Most drilled shafts require a steel casing to be used to facilitate the shaft excavation.
- The casing is a steel plate rolled and welded to form a large diameter pipe.
- Casings are placed either before, during or after excavation.
- Casings are large enough in diameter to permit the drilling auger to pass through them.
- They should have teeth on the bottom to allow anchoring of the casing into the desired soil formation.







3 Basic Methods of Construction

- Dry Construction Method
- Temporary Casing Method
- Permanent Casing Method

Sometimes a combination of the above types of drilled shaft construction methods is used.



Preparing for Construction:

- Prior to Construction the Contractor needs to address 3 items, required by specification. They are:
 - 1. Concrete Mix Design.
 - 2. Drilled Shaft Installation Plan.
 - 3. Drilled Shaft Preconstruction Meeting.



Drilled Shaft Concrete Mix Design

- Contractor must submit a concrete design mix along with materials, including water reducer, to Central Materials Lab at least 40 days prior to construction, for approval.
- The materials are used by the Lab to verify the Contractor's proposed mix design.

Concrete Mix Requirements

- 28 Day Compressive Strength = 4500 psi
- Slump Range: 6" to 8" for free fall or tremie method
 - 7" to 9" for concrete pumped through a tremie.
 - In addition, slump shall be maintained above 4" for 4 hours after batching (set retarder).
- Entrained Air Content of 5% to 7 1/2%
- Max. Water/Cement Ratio for Design of Mix = 0.44 (*Each established mix design will have a maximum water/cement ratio*)
 - Slump achieved by use of water reducer.
 - Superplasticizers are NOT allowed.
- Minimum Cement Content of 780 lbs/yd³



Drilled Shaft Installation Plan

- Contractor must submit a “Detailed” drilled shaft installation plan 30 days prior to drilled shaft construction.



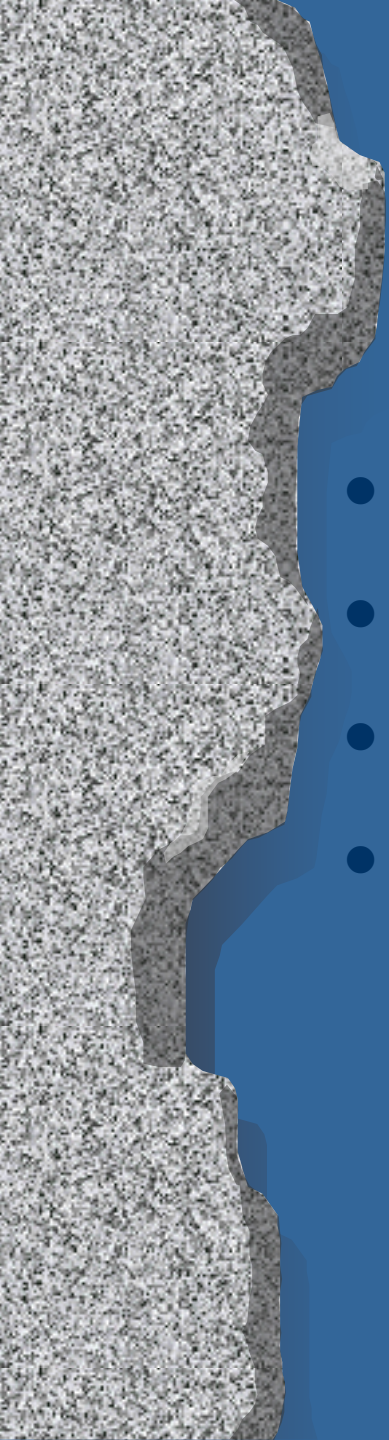
Equipment List

- Cranes
- Drill Augers
- Pilot Bits
- Bailing Buckets
- Cleanout Equipment
- Water Pumps
- Tremies
- Concrete Pumps
- Concrete Chutes
- Steel Casing
 - Diameter
 - Wall Thickness



Construction Sequence and Methods

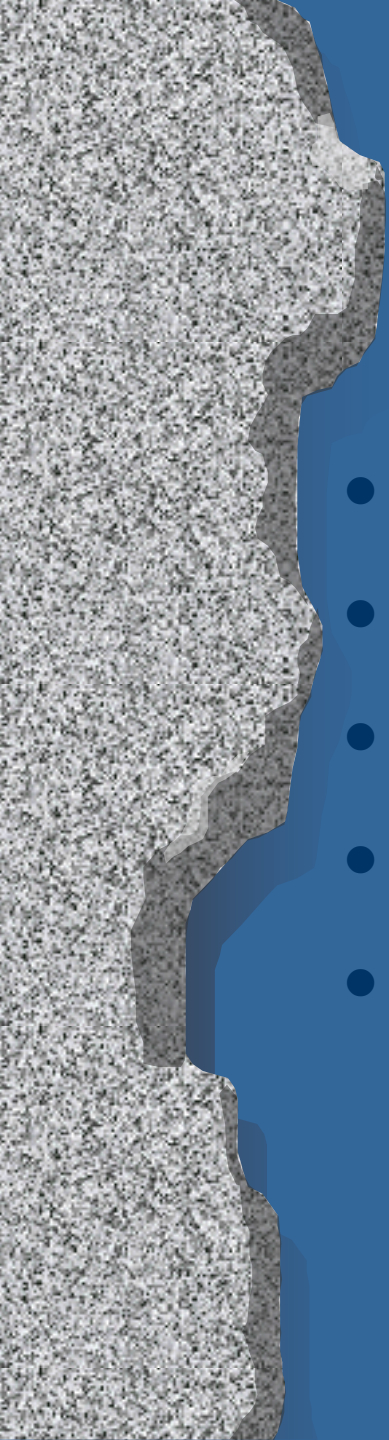
- Sequence of Shaft Construction
- Elevations of Proposed Work Berms or Platforms
 - Contractor is required to verify site conditions prior to installation plan submittal.
- How Casing is to Be Installed
- Method(s) of Excavation

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- Method of Cleaning Out Excavation
 - Details of Resteel Centering Devices
 - Method of Lifting & Supporting Resteel Cage
 - Method(s) of Concrete Placement



Pre-Drilled Shaft Meeting

- Pre-Drilled Shaft Meeting is Mandatory
- 5 Working Days Prior to Construction of Drilled Shafts.



Representatives of the Following are
Required to Attend:

- Bridge Contractor
- Drilling Sub-Contractor
- Concrete Supplier
- Area Office
- Office of Bridge Design and/or Foundations

Purpose

- Drilled shaft construction can be complex.
- There are many unknowns.
- Successful drilled shaft construction depends on everyone involved being fully aware of what each party's responsibilities are.
- Meeting is used to review step-by-step the procedures and construction methods used.
- Possible problem scenarios are reviewed & corrective construction procedures are discussed.



Drilled Shaft Excavation: Dry Construction Method

- Drill the shaft through relatively stiff, stable soil formations in which ground water infiltration is not a problem.
 - Not typically used in SD because of this.
- Clean out bottom of excavation.
- Set the resteel cage in proper position.
- Place concrete.



When Dry Excavations Encounter Caving or Water Bearing Soils:

- Contractor should immediately stop drilling
- The hole should immediately be filled with water to a point above the groundwater elevation.
 - A positive 10 foot head of water should be maintained above the groundwater elevation if possible.



Temporary Casing Method

- Can be used when shafts are drilled through a layer of granular material, before hitting bedrock, causing side wall caving, shaft squeeze or water infiltration.
- The Temporary Casing Method is used when:
 - Excavations, begun by the Dry Construction Method, encounter caving or water bearing soils, or when
 - Specified on the plans.

Temp. Casing Method

When the Temporary Casing Method is Specified on the Plans:

- The steel casing is drilled or pushed through the unstable soils prior to the start of excavation.
- All other procedures are the same as previously discussed.



Temp. Casing Method

- A cleanout bucket is used to clean the bottom of the excavation.
- The resteel cage is placed in the proper location.
- Concrete is placed.
- The casing is extracted during concrete placement.



Permanent Casing Method

- A steel casing is drilled or pushed through the unstable material prior to start of excavation.
- The drilled shaft is excavated through the steel casing.
- If water is encountered, a positive head of water is required just the same as was discussed for the Temp. Casing Method

Permanent Casing Method

- The steel casing is left in place.
 - It may sometimes be required to remove portions of the permanent casing after the concrete has attained strength.
 - A cutoff saw, or other approved methods, are required for removal of the casing.
 - Torch-cutting is NOT allowed (unless used before concrete placement)



A Combination of These Methods May Be Used

- The foundation conditions may be such that a casing is required through unstable soil, but the casing is able to be seated into the underlying foundation material such that water infiltration is stopped.
- This results in a casing being used through the unstable material, but the dry construction method is utilized for the remainder of the drilled shaft.



Drilled Shaft Inspection

Preliminary Inspection Prior to
Drilling



Inspection Equipment

- Plans and Specifications
- Rod and Level
- 100 ft. Weighted Tape
- Mirror
- Carpenter's Level



Location of Drilled Shafts

- Verify Location of Stakes
 - Check by more than one method
- Check or Set Offset Stakes
- Set Temporary Bench Mark
 - May be able to establish elevation of one or more of the offset stakes.



Casing

- Check and Record Casing Dimensions
 - Diameter
 - Length
 - Roundness
- Make Sure Casing Length has been Adjusted for Work Berms, Etc.

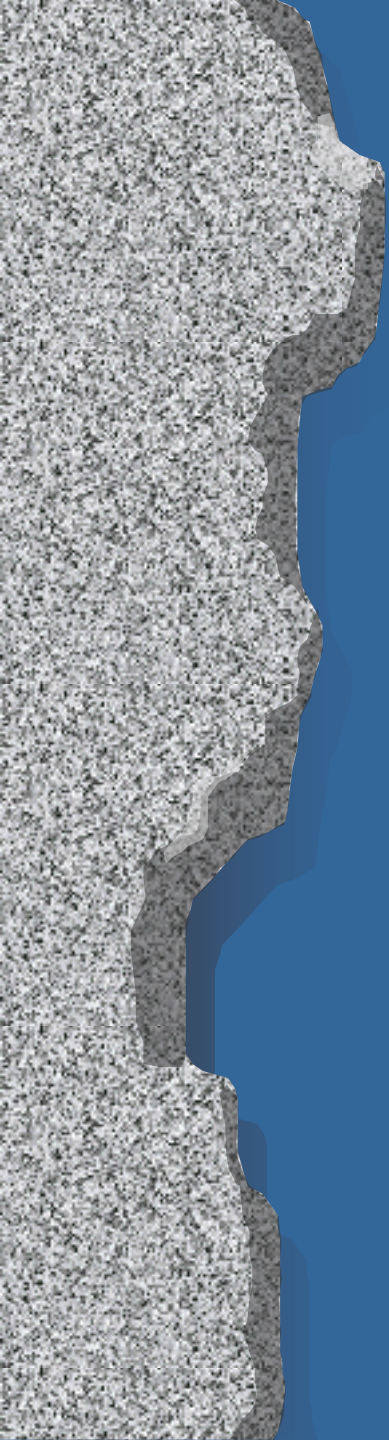


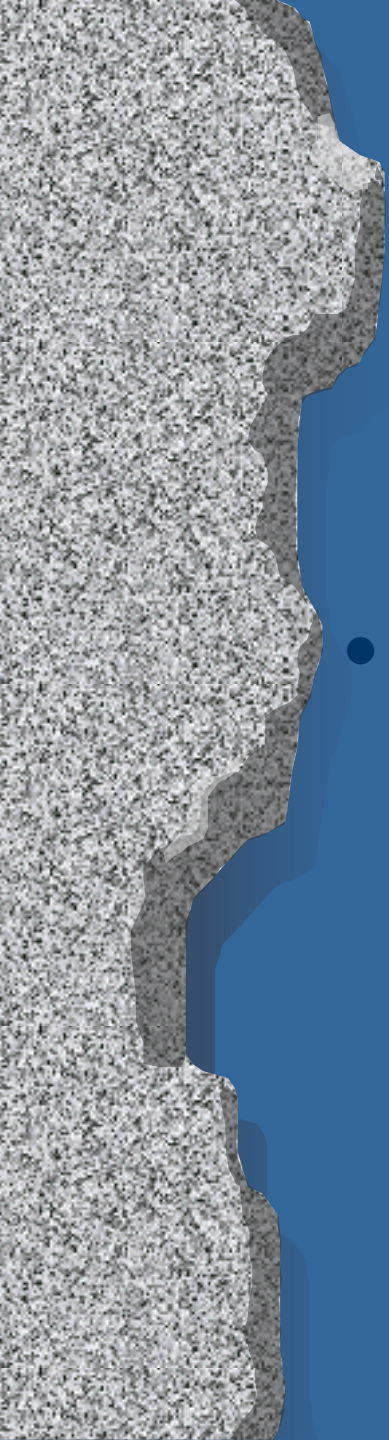
Resteel Cage

Check Resteel Cage for:

- Proper Number, Size, and Grade of Bars
- Proper Diameter and Pitch of Spirals or Hoops
- Proper Splice Lengths
- Adequate Approved Centralizers
- CSL Tubes Correct Spacing and Length
- Length Adequate to Allow for Splice at Construction Joint







Contractor's Equipment

- Verify that all Equipment Listed in the Drilled Shaft Installation Plan is on the Site and is in Good Working Condition.



Mandatory Equipment

- Tremie (Even if concrete is to be pumped)
- T-Bar
- Cleanout Bucket of proper size
- Pilot Bit
- Water Pump
- Weighted Tape









Concrete

- Make Sure Mix Design has been Approved
- Check Inside of Tremie Pipe to Assure it is Clean
 - To function properly, Tremie Pipe must be smooth inside.
 - If concrete was not properly cleaned on previous use, concrete will not flow.

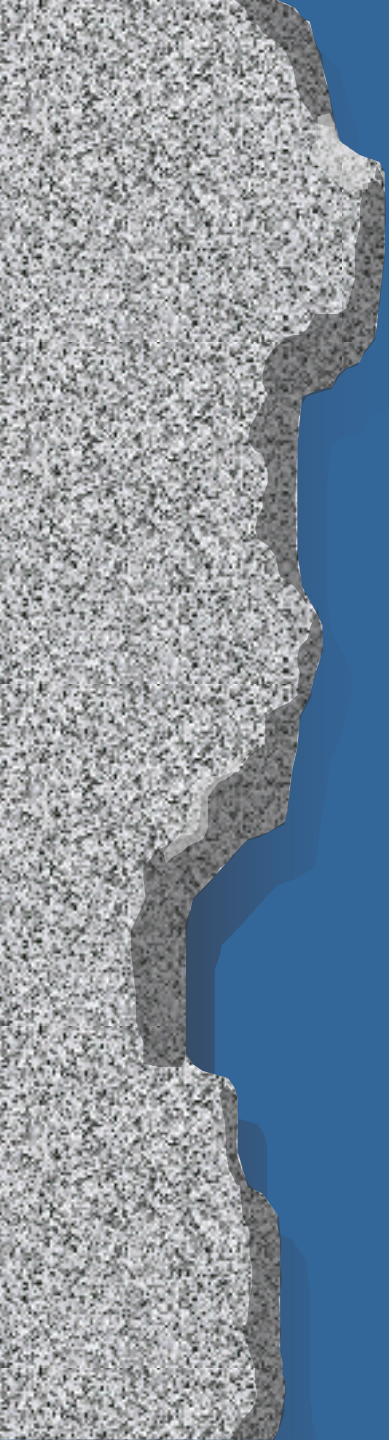


Drilled Shaft Inspection

Setting Casing

Setting of the Casing

- Specifications Require that Casing be Installed using a T-Bar on the Kelly Bar.
- Accurately Setting Casing can be Difficult
 - Re-check location and Plumbness often
 - Check to assure that casing didn't become out-of-round during installation.

- 
- If Casing Needs to be Removed and Replaced with a Longer Casing, the Excavation is Backfilled Before the New Casing is Installed
 - Bottom of Casing Should be Screwed into Foundation Material to Attain Watertight Seal if Possible
 - Top of Casing Should be at the Approved Construction Joint Location
 - Typically 1 foot above groundline







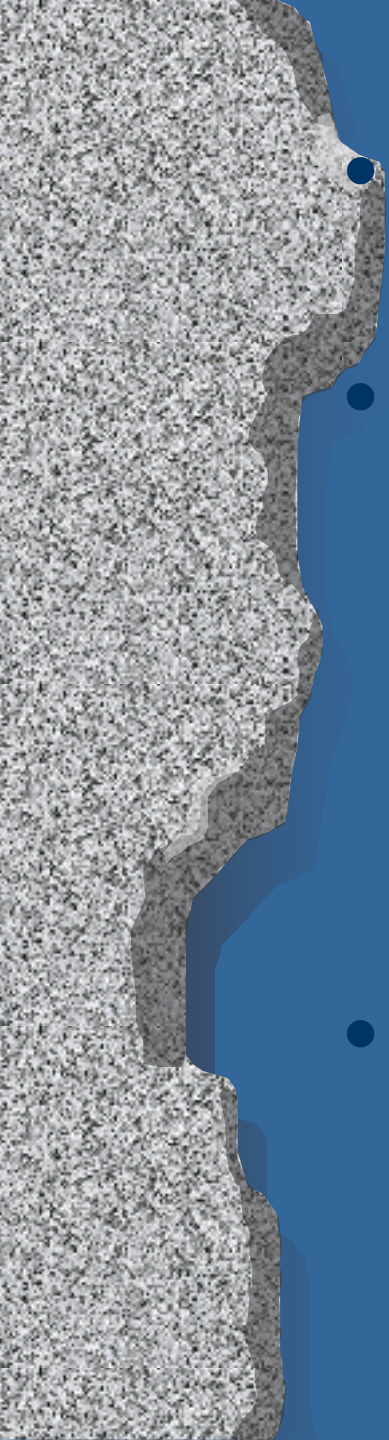
Drilled Shaft Inspection

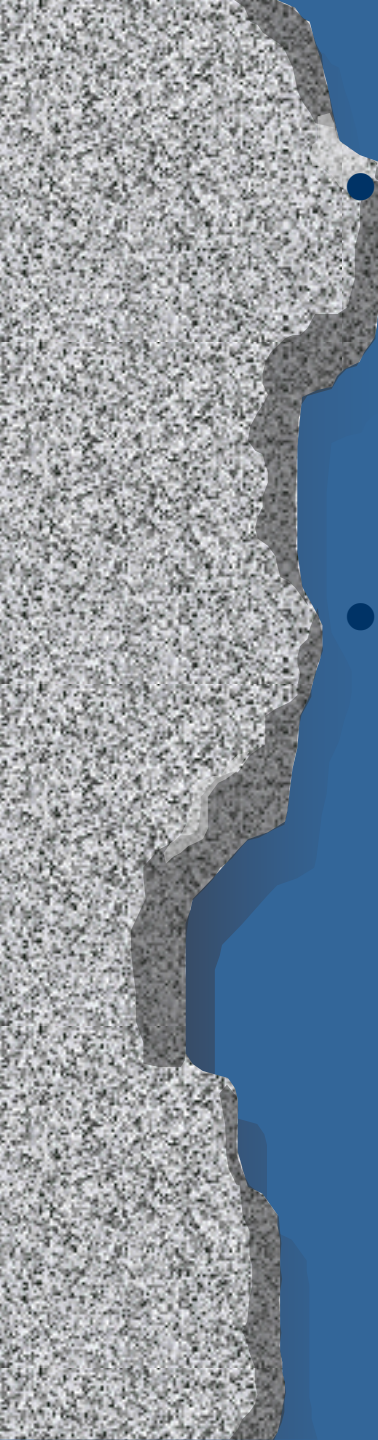
Excavation

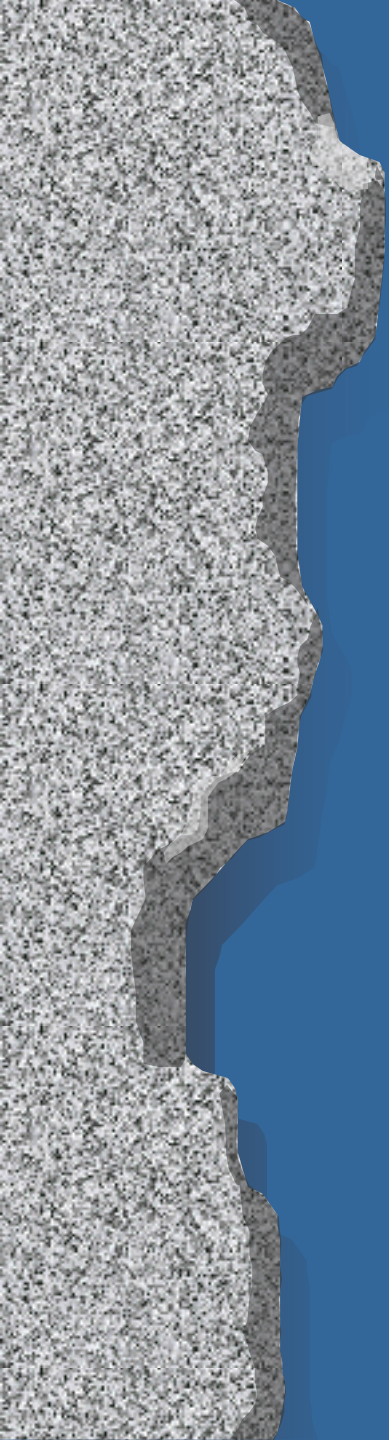


Inspection of Excavation

- Excavation into Frictional Bedrock Should not be Allowed Unless it can be Reasonably Expected that Excavation and Concrete Placement will be Completed the Same Day
- 24 Hour Time Limit
 - Begins upon excavation into frictional bedrock
 - Frictional Bedrock Elevation is designated on plans

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- Record Time that Frictional Bedrock Elevation is Reached
 - Re-Check Location, Plumbness and Depth Often During Excavation
 - Measure from offset stakes for location
 - Use Carpenter's Level on kelly bar for plumbness
 - Use weighted tape to check depth
 - A Mirror Should be Used to Periodically Check Sides of Excavation for Caving or Water Infiltration

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- If Caving or Water Infiltration is Encountered the Contractor Should Immediately Flood the Excavation with Water
 - When the Excavation Reaches Plans Depth, The Contractor Must Clean the Bottom of the Excavation with the Cleanout Bucket
 - Use the mirror to inspect the bottom of the excavation if the excavation is dry
 - If the excavation is wet, require continued use of the cleanout bucket.





Drilled Shaft Inspection

Resteel Placement



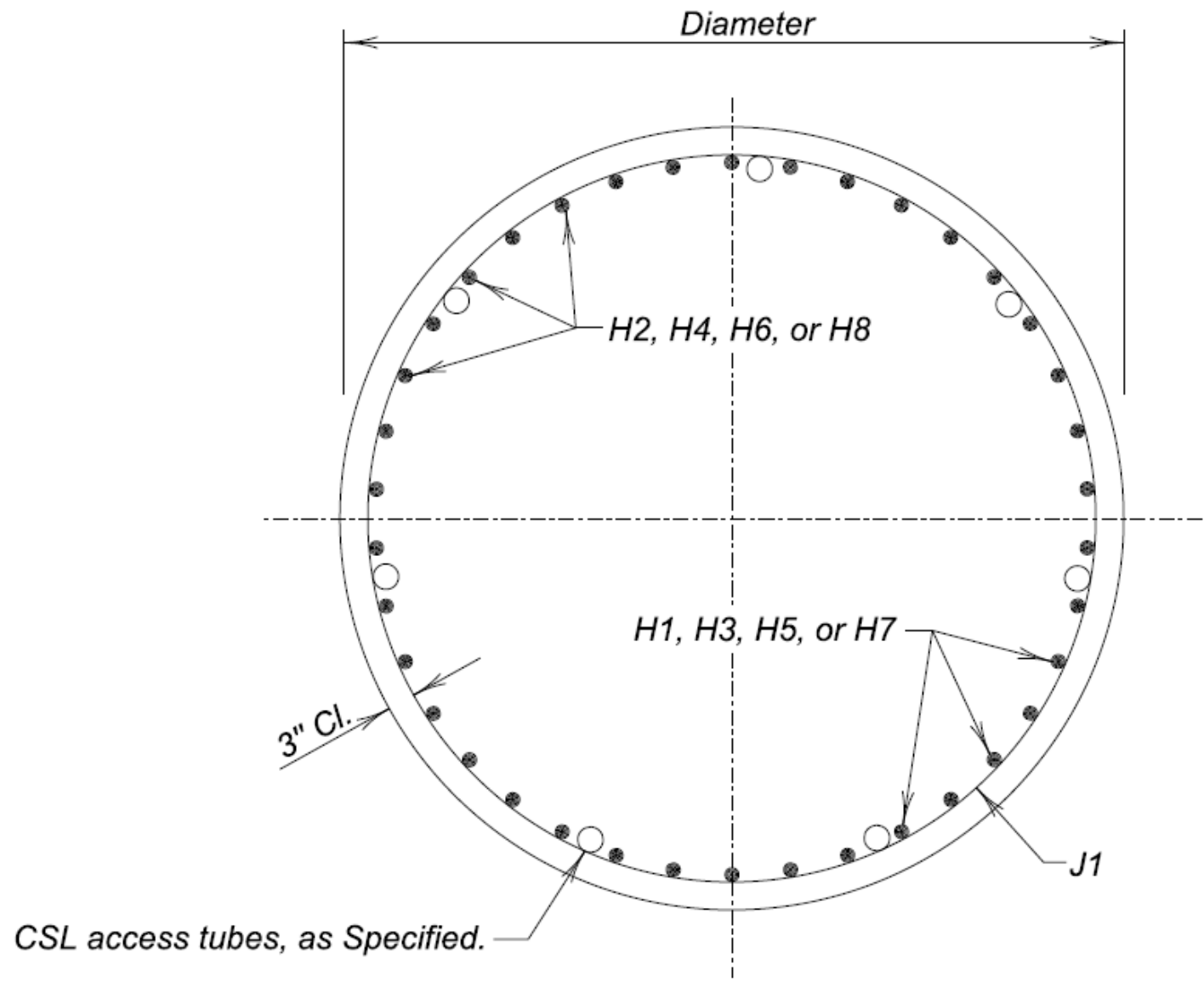
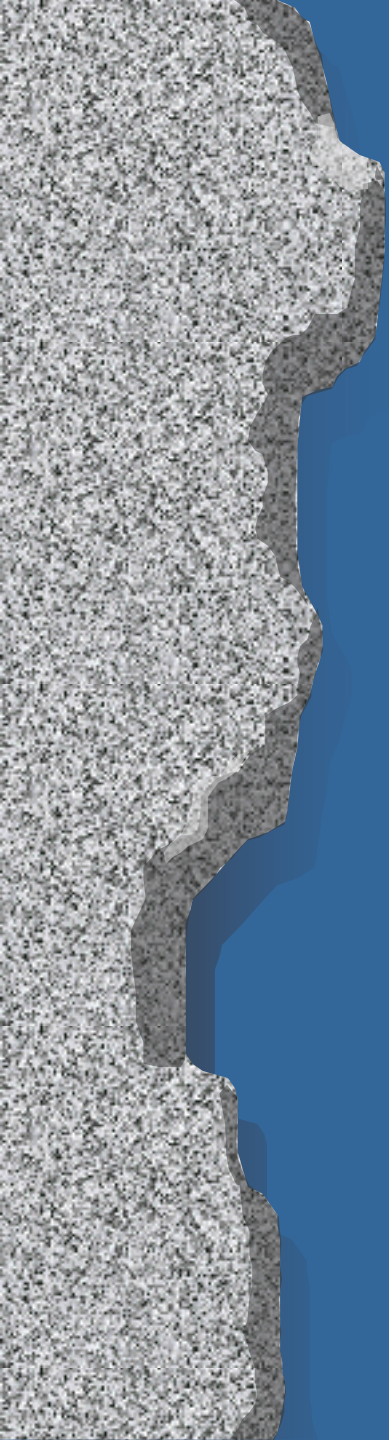
Resteel Placement

- Ensure CSL (Crosshole Sonic Log) tubes are in place before resteel cage is placed
- Extreme Care Needs to be Used in Lifting the Resteel Cage into Place
 - Long Resteel Cages may need to be lifted at more than one point so as not to cause permanent deformation during lifting.

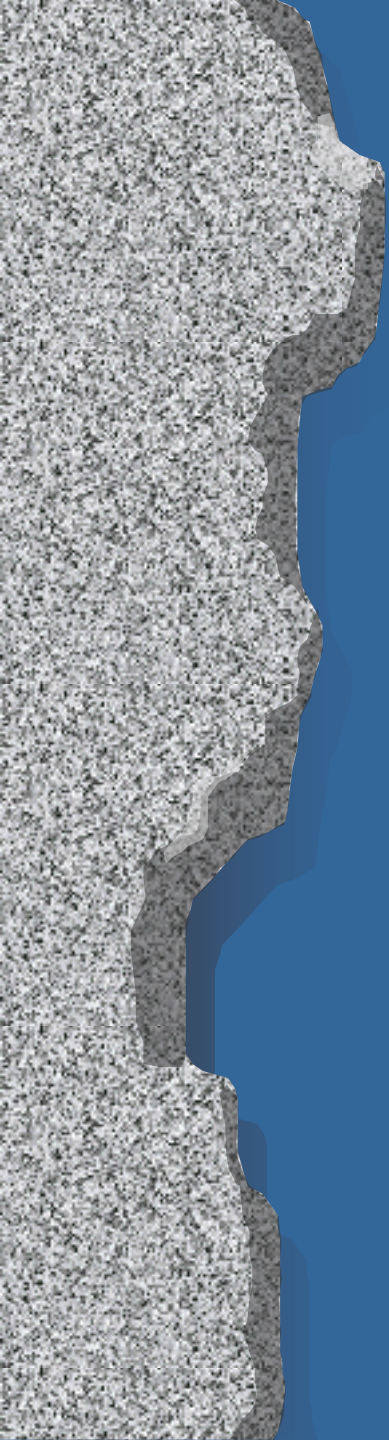


Resteel Placement

- The Resteel Cage Shall be Carefully Lowered into the Excavation
 - If centralizers are knocked off or damaged during resteel placement, the cage shall be raised from the excavation and the centralizers replaced.

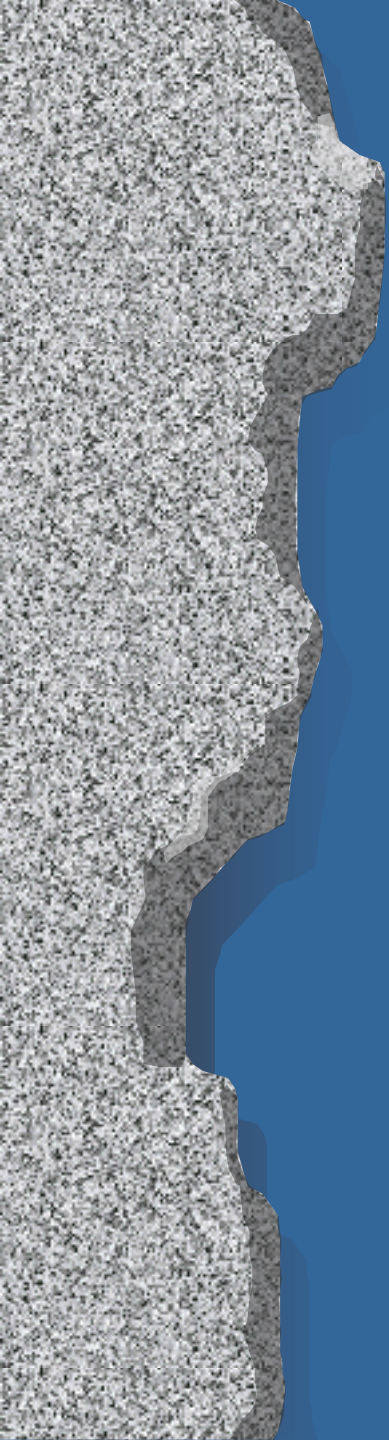


TYPICAL SECTION



Resteel Placement

- The Resteel Cage Shall be Properly Supported Off of the Bottom of the Excavation
 - Held up by use of crane or other equipment
 - Concrete Donut can be attached to bottom of cage





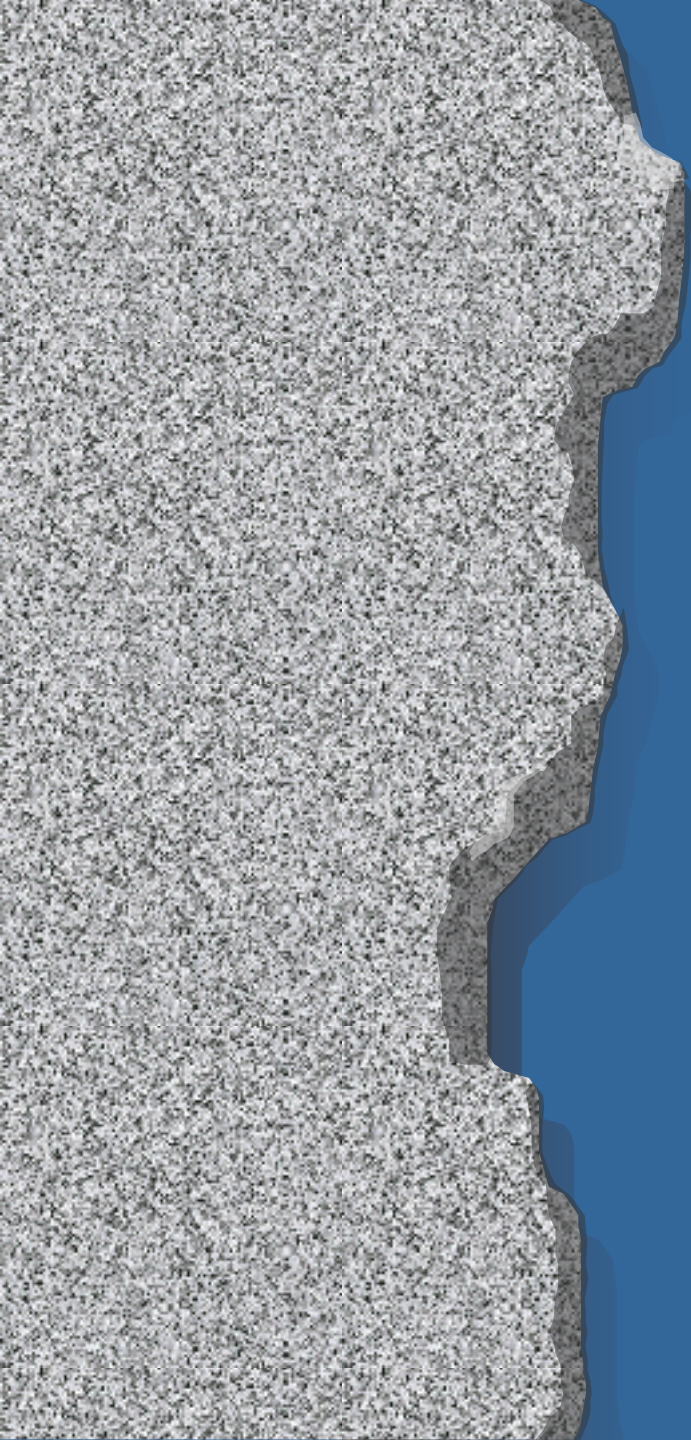
Resteel Placement

- Resteel Cage also Needs to be Tied Down
 - Concrete can “FLOAT” the resteel cage up during concrete placement
 - Do not tie resteel cage to casing. If resteel cage settles or floats during concrete placement, the watertight seal at the bottom of the casing may be broken.



Resteel Placement

- Check Resteel Extension above Construction Joint to Assure Specified Minimum Splice Length



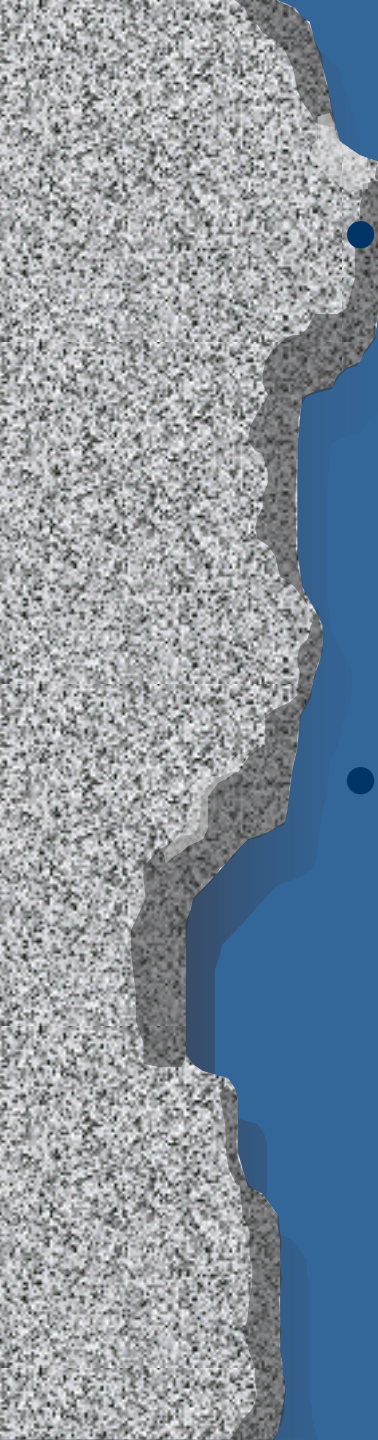
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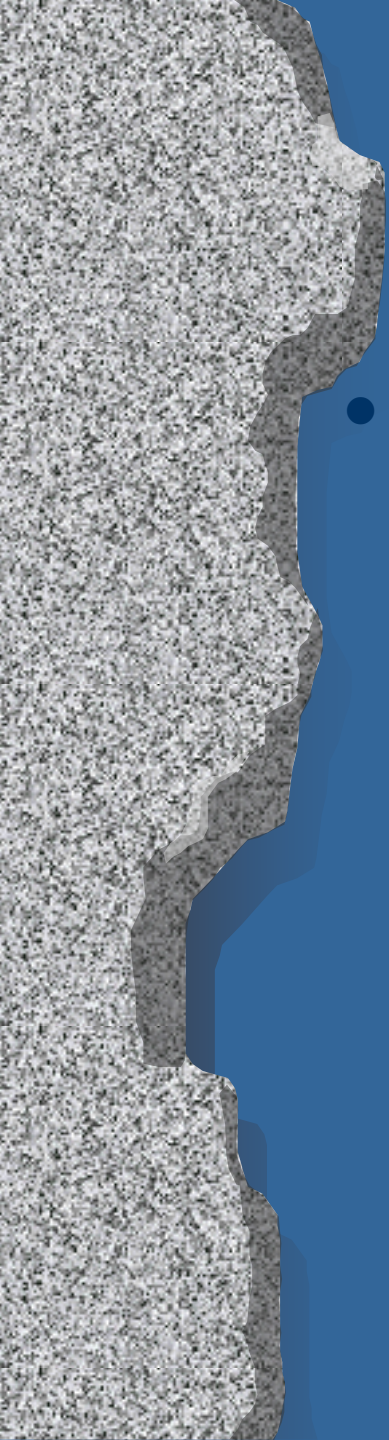
Concrete Placement



Concrete Placement in a Dry Excavation

- Dry Excavation is defined as an excavation in which water accumulates at a rate of no more than 3 inches per hour.

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- The Excavation is to be Dewatered Immediately Prior to Concrete Placement
 - No more than 3 inches of water allowed in bottom of excavation
 - For Drilled Shafts 36 inches in Diameter or Less, Concrete Shall be Placed Through a Drop Tube that Extends to the Bottom of the Excavation
 - Typically, the tremie is used

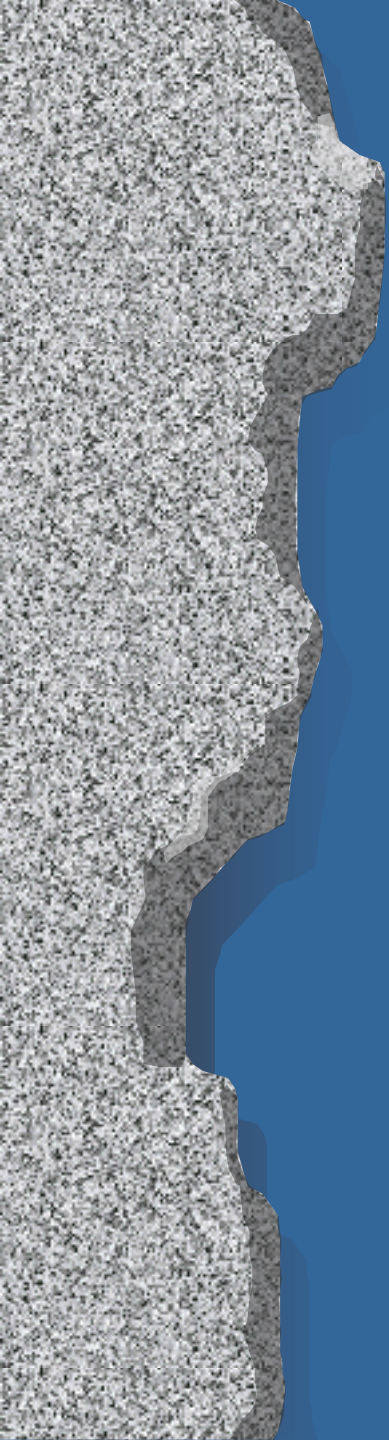
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- For Drilled Shafts 36 Inches in Diameter or Larger, Concrete May be Placed by the Free-Fall Method
 - A hopper with a drop tube is required to assure that the concrete is dropped down the center of the excavation so as not to fall through any resteel.





Concrete Placement in a Wet Excavation

- Concrete Must be Placed Underwater Utilizing the “Tremie Method”
 - This can be achieved either by use of a tremie or a concrete pump

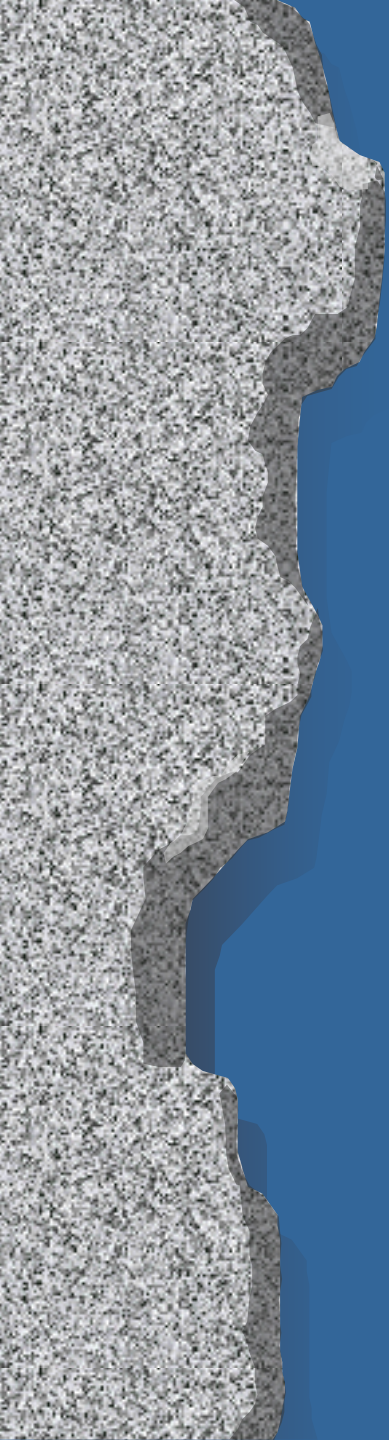


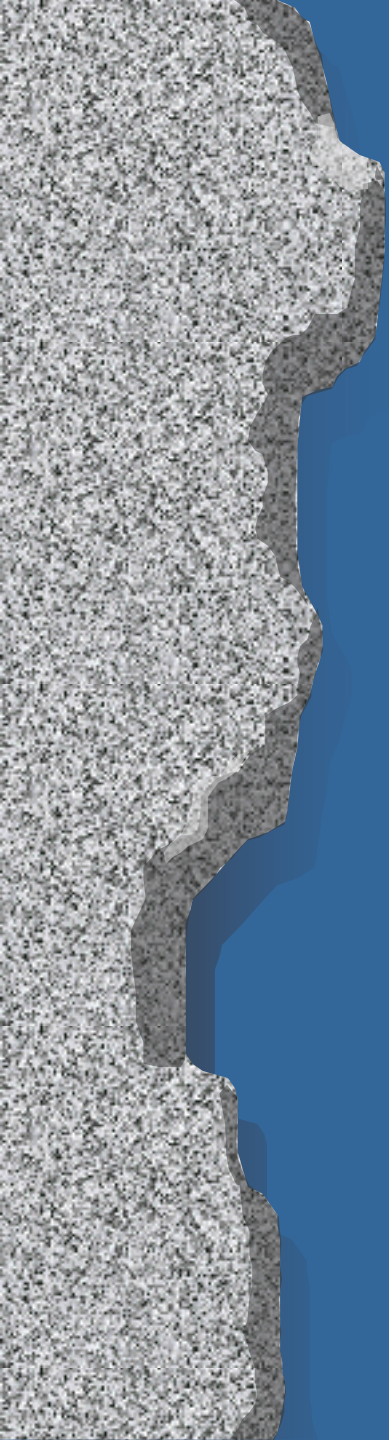


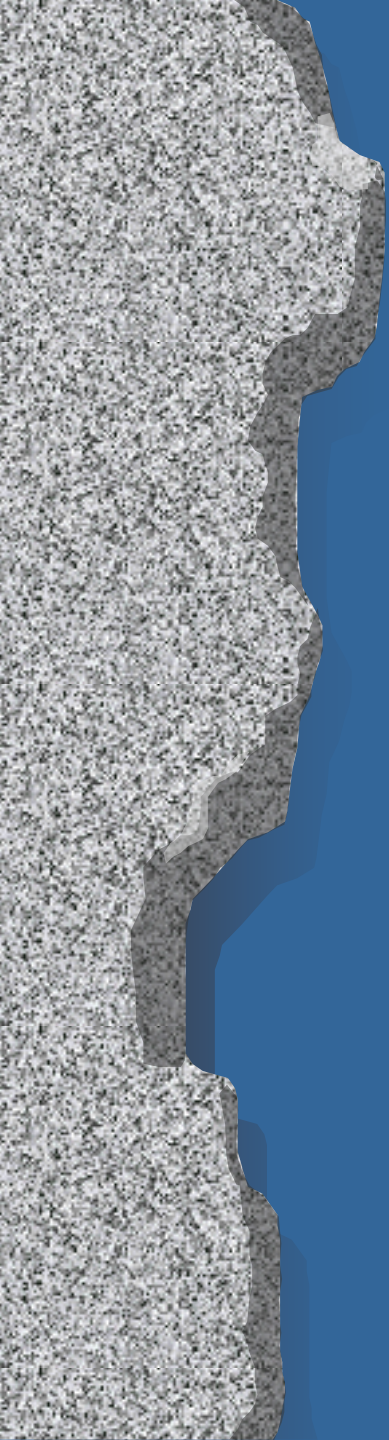


Tremie Method

- Excavation is Partially or Fully Filled with Water
- Mark Tremie at Five Foot Intervals
- The End of the Tremie is Plugged
 - The pig(a foam ball) is placed in the pump and pumped into the shaft to separate the concrete from water in the shaft
 - The pump line needs to be at least 4” diameter and be steel for the length of the shaft

- 
- The Empty Plugged steel pump line is Lowered to the Bottom of the Excavation
 - As the pump is started slowly lift the pump line as the shaft fills making sure the line is imbedded in fresh concrete at least 5 feet



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- Process Continues Until all Water has Been Displaced and Enough Concrete has Run Out of the Shaft Such that Only Uncontaminated Concrete Remains.
 - Concrete Placement Should be Performed in One Continuous Operation.



Restarting a Tremie

- If a problem is encountered and Restarting is Required the tremie must be used:
 - The pump line is inadvertently raised such that the minimum 5 foot embedment is not maintained.
 - There is a delay in concrete placement of more than 30 minutes.
 - The pump line plugs.



Tremie Pipe Requirements

- Must be Steel
 - Do not allow the use of Aluminum
- 7.5” Min. Inside Diameter
- 1/4” Min. Wall Thickness
- Watertight Joints
 - Gasketed & Bolted
 - Welded
- Smooth Interior Free of Hardened Concrete



Steps to Restart a Tremie

- Measure and Record Depth to Top of Concrete.
- Remove pump line
- Put Plug on End of Tremie
- Push Empty Plugged Tremie into Concrete to a Minimum Depth of 5 Feet Below Measured Depth
- Follow Same Procedure as to Begin Placement



Work Adjacent to Fresh Concrete

- Drilling Operations and Free-Fall of Concrete in Adjacent Shafts Can Result in Vibrations Damaging Freshly Placed Concrete
 - This can be monitored by driving a stake into the ground near the fresh concrete and setting a glass of water on top of the stake
 - If ripples appear on the water, operations should be stopped
 - Should not resume these operations for at least 72 hours after concrete placement or until the concrete attains a minimum compressive strength of 1600 psi.



Construction Tolerances

Horizontal Position

- $1/12$ Shaft Dia. or 3 Inches, Whichever is Less

Bottom of Shaft Elevation

- Plus or Minus 6 Inches

Vertical Alignment

- $1/4$ Inch per Foot Depth or 3 Inches, Whichever is less



Diameter of Shaft

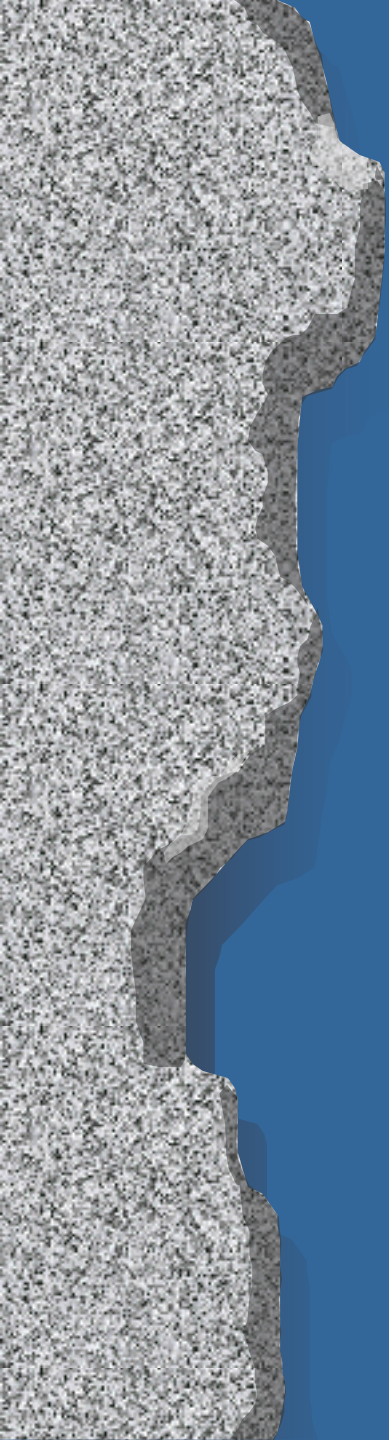
– Plus 2 Inches

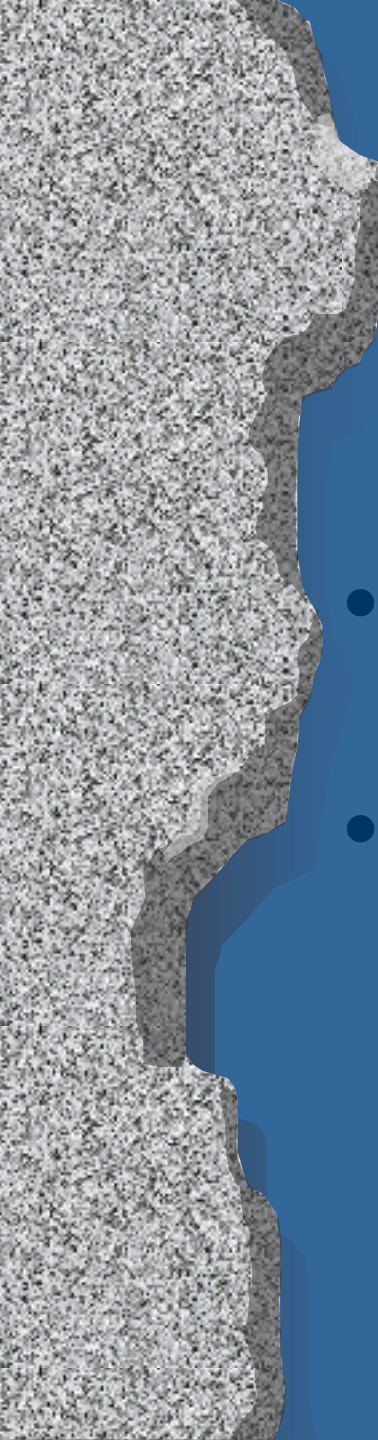
Top of Shaft Elevation

– Plus or Minus 1 Inch

Bottom of shaft shall be relatively flat.

Consideration Needs to Be Given to the Fact
that the Shafts May be an Extension of the
Column Which Require More Stringent
Construction Tolerances.



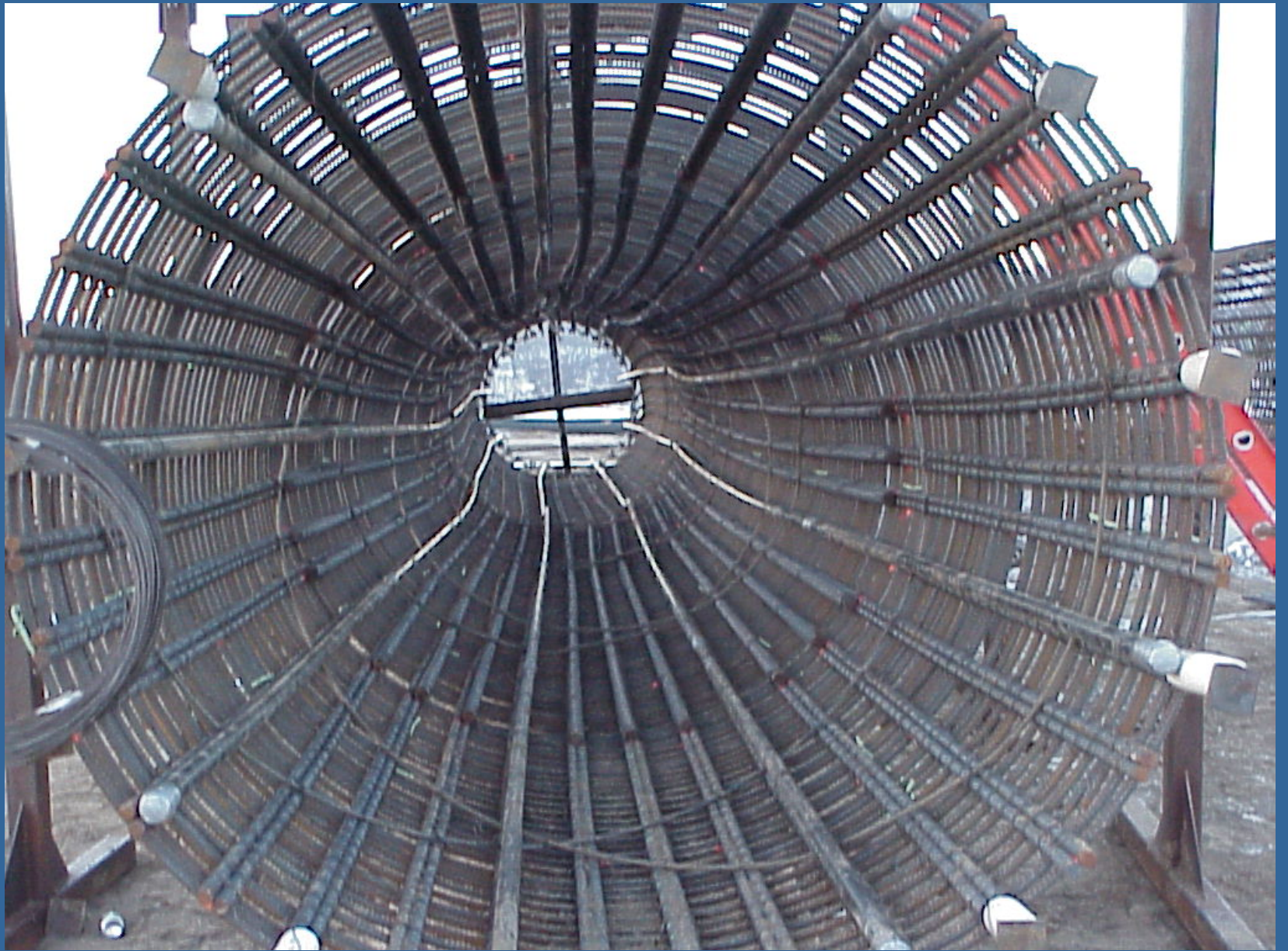
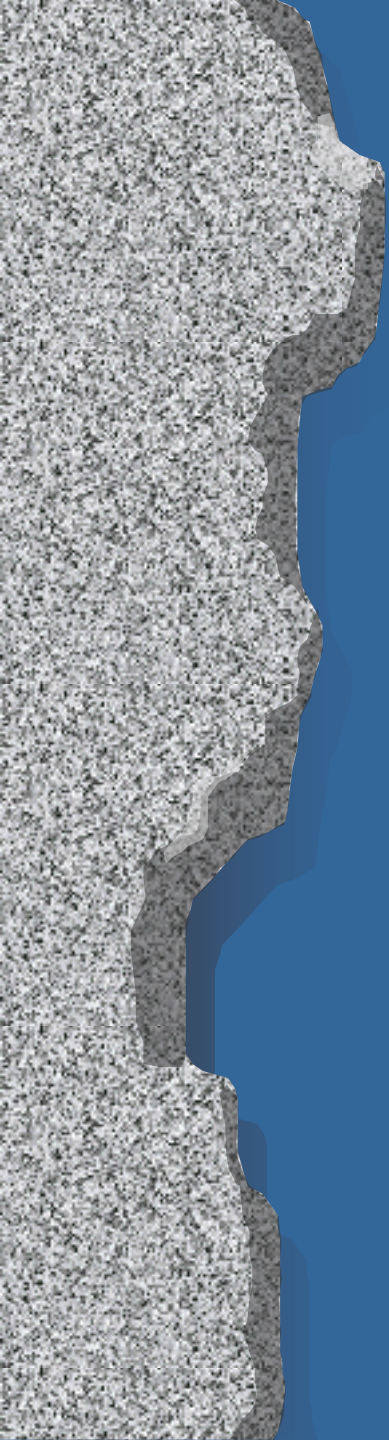


Drilled Shaft Construction Report (DOT Form 297)

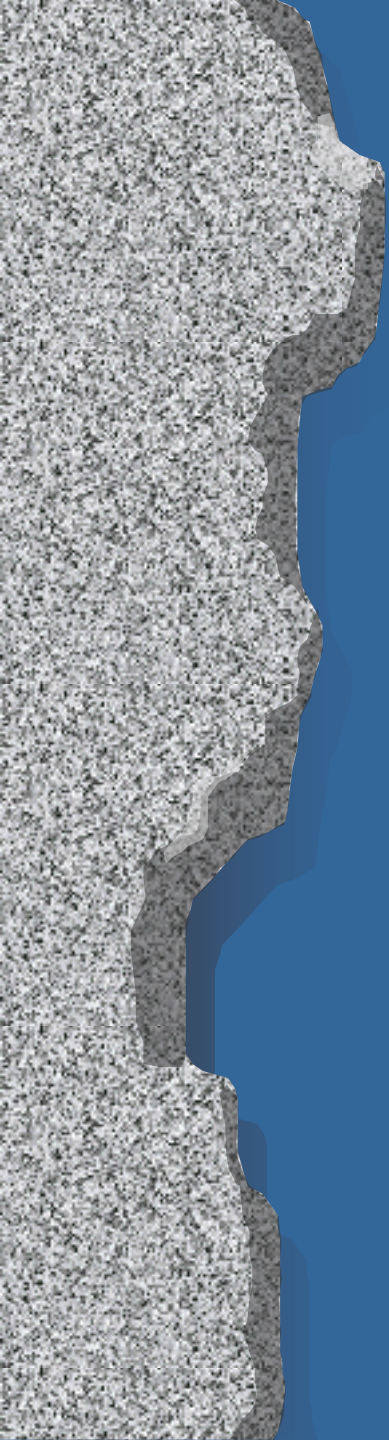
- Should be Completed for Each Drilled Shaft Constructed
- All Events of the Drilled Shaft Construction Should be Thoroughly Documented on the Form

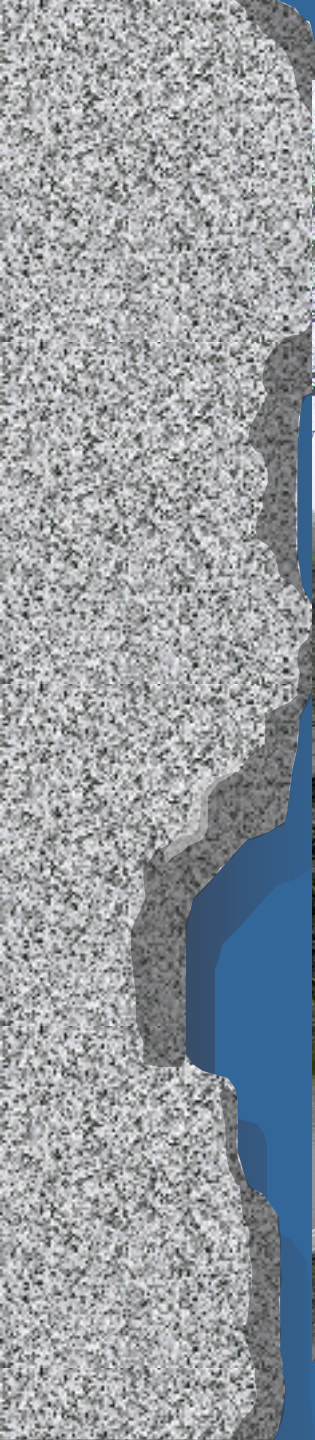
CSL Testing

- Cross Hole Sonic Log (CSL): Test that determines the integrity of the newly placed drilled shaft concrete.
- Test requires an ultrasonic pulse to pass through the concrete through water filled access tubes.
- Access tubes are secured to the inside of the rebar cage, and should extend 4 feet above construction joint and be within 3 inches of the bottom of the rebar cage and are cast in the concrete during placement.











CSL Testing

- Concrete quality is based on the relationship between pulse velocities and the receiver response energy.
- High velocities indicate sound quality concrete.



CSL Testing

- Testing will be done by an independent testing organization proposed by the Contractor and approved by the DOT.
- Acceptance of the drilled shaft will be the decision of the DOT (Foundations Office), based on the results of the CSL reports and other information about the shaft placement.



CSL Testing

- In the case that any shaft is determined to be unacceptable, the Contractor shall submit a plan of remedial action for approval.
- All costs to perform this remedial action will be at no cost to the State.

CSL Testing

- CSL testing will be used on all single column bents or when drilled shaft construction is suspect.
- If drilled shaft construction goes well, no CSL testing will be required.
- After final acceptance of a shaft, the access tubes shall be de-watered, cut off at construction joint and grouted full according to the plans.
- Any CSL questions?

