Drilled Shaft Inspector CBT

Lesson 8 – Concrete Placement

Welcome to the Drilled Shaft Inspector Course. This is Lesson 8, Concrete Placement.

Learning Objectives

In this lesson, we will take a look at the following objectives:

- Describe typical tremie and pump placement methods.
- Verify Contractor compliance with project documents for concrete placement.
- Utilize the Concrete Placement Log inspection form, determine theoretical concrete volumes, and plot placed concrete volume curves.
- Identify the applicable 455 Specifications

Checklist

This slide shows a checklist of the main items for concrete placement we need to check. Please spend some time reading this list. We will be covering these in this lesson. After reviewing the items, select the continue button or press Shift+N on your keyboard to continue.

Typical Duties during Placement

The typical duties during concrete placement are:

- 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 breaching of tremie.
- Record any unusual events.

We will review these items throughout this lesson.

Let's review this specification which describes the general requirements of concrete. Place concrete in accordance with the applicable portions of Sections 346 and 400, 455-15.2, 455-15.3, 455-15.4, 455-15.5, 455-15.8, 455-15.9, and the requirements herein.

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Most shafts are constructed using either temporary casing or drilling slurry. Concrete for drilled shafts must therefore be designed and placed in such a manner that it can be pumped, dropped or flow through a tremie by gravity to the bottom of the excavation; flow easily through the rebar cage without vibration (so that the concrete is not inadvertently mixed with drilling fluid, ground water or soil); displaces drilling slurry or water and is durable.

Place concrete as soon as possible after completing all excavation, clearing the shaft excavation, inspecting and finding it satisfactory, and immediately after placing reinforcing steel. Continuously place concrete in the shaft to the top of the casing. Continue placing concrete after the casing is full until good quality concrete is evident at the top of the casing.

Place concrete through a tremie or concrete pump using approved methods. After the shaft is overpoured sufficiently to eliminate all contaminated concrete, additional concrete may be added to the shaft without the use of a tremie or pump in accordance with Section 400.

After the Inspector has determined that the shaft has met the cleanliness requirements, the cage is placed. The concrete should be placed as soon as possible.

There are time limits related to the excavation, slurry contact with the shaft walls and of course, the concrete itself.

Note that in this general specification there are two valid methods for placing concrete: Place concrete through a tremie or place with a concrete pump using approved methods. The concrete should be placed continuously until good, fresh concrete flows from the top of the shaft.

If the pressure head is lost during concrete placement for any reason, the Engineer may direct the Contractor to perform integrity testing at no expense to the Department. Immediately after concreting, check the water levels in the CSL access tubes and refill as necessary.

If a “breach” of the tremie occurs, the Inspector can no longer accept the shaft. The Inspector should notify the Contractor of this and inquire as to what is their intention regarding “completion” of the shaft. As discussed in the previous lesson, the CSL tubes were filled with water and capped after the cage was set. Following placement of the concrete, the water in each tub needs to be checked again, and any tube refilled if needed.

455-15.9 – Tremies and Pumps

Let’s review the specification which describes the requirements of concrete for dry excavations. Ensure that the tremie for depositing concrete in a dry drilled shaft excavation consists of a tube of solid construction, a tube constructed of sections which can be added and removed, or a tube of other approved design. Support the tremie so that the free fall of the concrete is less than 5 feet at all times.

Wet Excavations: Construct the tremie or pump line used to deposit concrete beneath the surface of water so that it is water-tight and will readily discharge concrete. Construct the discharge end of the tremie or pump line to prevent water intrusion and permit the free flow of concrete during placement operations. Ensure that the tremie or pump line has sufficient length and weight to rest on the shaft bottom before starting concrete placement.

During placement operations, ensure that the discharge end of the tremie or pump line is within 6 inches of the bottom of the shaft excavation until at least 10 feet of concrete has been placed. Ensure the discharge end of the tremie or pump line is continuously embedded at least 10 feet into the concrete after 10 feet of concrete has been placed and until the casing is over poured sufficiently to eliminate all contaminated concrete.

Ensure that the free fall of concrete into the hopper is less than 5 feet at all times. Do not rapidly raise or lower the tremie to increase the discharge of the concrete. Maintain a continuous flow of concrete and a positive pressure differential of the concrete in the tremie or pump line at all times to prevent water or slurry intrusion into the shaft concrete.

Support the Tremie

This photograph illustrates the support of the tremie so that it can be raised or lowered to control the flow of concrete into the shaft.

This slide shows a photo of a PVC tremie. What could be the issues associated with a PVC tremie pipe? A PVC pipe, since it has to be sealed at the bottom will float in a wet hole. Therefore it will not reach the bottom of the hole.

When the wet method is used, concrete will need to be placed either by a tremie, like the one shown, or by a pump line. Different contractors have different preferences. It is important that placement of concrete begin at the bottom of the hole just as soon as possible after clean-out is finished so as to insert the fluid concrete beneath the water or slurry in the hole and push it out the top. This picture shows a tremie with a hopper.

Tremie Method

This picture shows a tremie with a small hopper attached to it. Small hoppers can be an issue because they may allow concrete spillage and falling directly into the shaft.

This picture shows a suspended hopper and bucket as a unit.

The bottom needs to be sealed to prevent water or slurry from rising up in the tremie. This slide shows some sketches of acceptable bottom seals: A built-on hinged seal and the more common seal consisting of a steel plate held in place with “duct” tape with an additional layer of plastic to insure water tightness.

Common Tremie Bottom Seals

The bottom needs to be sealed to prevent water or slurry from rising up in the tremie. This picture shows a typical bottom seal of a tremie consisting of a steel plate held in place with “duct” tape with an additional layer of plastic to insure water tightness.

This picture shows a typical seal at the bottom.

This image shows a traveling plug which is not permitted.

Tremie Checking

This picture shows an inspector verifying the depth of the tremie and that the tremie is not leaking prior to starting concreting operations.

Tremie Method

Here are additional photos of tremie pipes being used for concrete placement.

Free-fall of concrete

Concrete is not to fall unconfined more than 5 feet. This refers to concrete that is not confined within the tremie or its’ hopper. As shown in the photograph, someone was assigned to ensure that the length of the fall of concrete from the bucket to the concrete within the hopper/tremie was not in excess of 5 feet. This is not an appropriate reflection of the specifications and is not safe.

Pump Method

One acceptable method to place concrete in drilled shafts is by the pump method. In the pump method, a concrete pump is frequently used to transport the concrete from a convenient discharge location for the ready-mix trucks to the gravity-fed tremie.

Another frequent use of the concrete pump is to transport the concrete directly into the bottom of the excavation.

Here is another photo of a concrete pumping operation.

In this picture the Contractor is getting ready to pump concrete into a tremie. In this case the pump line does not need to reach the bottom of the shaft but the tremie does. The tremie is sealed and must reach the bottom of the hole prior to the beginning of concreting, as in the regular process of using a tremie pipe. The concrete is pumped and fed by gravity into the tremie.

Pump placement is similar to tremie placement, except that the concrete is forcibly pumped through a steel pump line (slick line). Just as with the tremie method, the bottom of the pump line must stay submerged in the concrete and slowly removed as the concrete level rises. Note that concrete with the same workability that is used for tremie placement is used for pump placement. The high workability is needed to affect proper flow of the concrete once it is deposited in the drilled shaft.

As shown in the photograph, for this pour over, it is easier to move concrete around by pumping it from the trucks (which have been barged out to the bridge location) directly into the drilled shaft. With pumped concrete, it is just as important to keep the concrete and slurry or water separated from one another as it is with concrete placed by tremie. We should note that according to section 400, pump lines must have a minimum diameter of 4 inches.

This is a close-up of concrete being placed by pump in a shaft. The picture shows the top of the shaft where the J rebars can be seen. As we mentioned in the reinforcement lesson, J rebars may present a problem for concreting as it restricts the access to tremie lines. In this case, concreting was performed with a pump line which is smaller than a tremie pipe.

Good Concrete at top of Shaft

It is expected that the first concrete material coming out of the hole will be contaminated. That is why it is very important to overflow until good concrete comes out of the shaft. Question: How does one know good concrete is coming out of the shaft? It should look the same way it looks coming out the concrete truck.

This picture illustrates a concrete pouring operation. Note how the concrete is over poured until good concrete is evident. This is very important because it is expected that the first portions of concrete will be contaminated with soil and the excavation fluid.

Keep in mind that the tremie needs to be lifted up some inches to allow the concrete to start flowing. This creates some contamination in the concrete.

The following video shows the slurry, or fluid in the hole, coming up and overflowing the casing, followed shortly by good clean concrete overflowing the shaft.

In this picture the contractor has opened a window at the top of the casing, to reduce the amount of waste when over pouring. In this case the top of the shaft is several feet below the top of the casing. The window was opened just above the top of the shaft elevation. As you see in this picture, concrete is over poured until good concrete is evident.

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Placement Time Requirements: The elapsed time for placing drilled shaft concrete includes the concrete mixing and transit time, the concrete placement time, the time required to remove any temporary casing that causes or could cause the concrete to flow into the space previously occupied by the casing, and the time to insert any required column steel, bolts, weldments, etc. Maintain a minimum slump of 5 inches throughout the elapsed time.

Provide slump loss tests that demonstrate to the Engineer that the concrete will maintain a 5 inch or greater slump for the anticipated elapsed time before beginning drilled shaft construction.

Note: do not confuse individual truck time limits with this requirement.

Slump Loss Test

The Slump Loss Test is a series of slump tests versus time to determine the ability of a mix design to retain the minimum slump over time. In this test, the slump is checked every 30 minutes after batching until the concrete takes its initial set. The specifications require that the concrete should have a minimum slump of five inches during concrete placement. Once the concrete reaches the 5" slump limit, this defines the available placement time for that mix.

The Slump Loss Test provided by the Contractor for the Mix being used is the "clock" for the concreting of the shaft. For the test shown in this slide, the results indicate that the maximum time the mix could maintain a 5 inch slump would be 4 hours 40 minutes.

For this mix, the contractor will have 4 hours 40 minutes to complete all the concrete pouring operations. This includes from the time the concrete is batched (water added to the mix) to the finishing of the shaft (typically the removal of casing) and corresponds to the elapsed time as defined in the previous slide.

By not exceeding the maximum elapsed time defined for 5 inches slump we indirectly ensure that the concrete will maintain a minimum slump of 5 inches during the pouring operations. We need to maintain this requirement to make sure the concrete will flow through the steel elements and properly cover the reinforcement and that the bond between concrete and the steel elements will not be impacted.

The Inspector needs to accurately record the starting time and the finish time of the placement along with the amount of concrete placed. Slump loss requirements are specified in Section 346-3.2.

Slump Requirements

Now, let's read an important excerpt from section 346-6.4 regarding slump requirements. Plastic Property Tolerances: Do not place concrete with a slump more than plus or minus 1.5 inches from the target slump value specified in Table 2. Reject concrete with slump or air content that does not fall within the specified tolerances and immediately notify the concrete production facility that an adjustment of the concrete mixture is required. This refers to slump of the concrete as it arrives to the site.

For drilled shafts the target slump value is 8.5 inches. Again this refers to the slump of the concrete in the truck as it arrives to the site. The 5.0 inches minimum slump requirement we mentioned earlier refers to the concrete at any time in the shaft during pouring.

Now, let's read an important excerpt from section 346-3.2 regarding slump testing and elapsed time: Test each load of concrete for slump to ensure the slump is within the limits of 346-6.4. If the elapsed time during placement exceeds the slump loss test data, cast cylinders to verify the strength.

Provide an engineering analysis performed by a Professional Engineer, registered in the State of Florida, knowledgeable in the area of foundations, to determine if the shaft is structurally sound and there are no voids in the drilled shaft concrete. At the direction of the Engineer, excavate the drilled shaft for inspection. Obtain approval from the Engineer before placing any additional shafts. Note in the previous specification that a slump test is required for each load of concrete.

Transit Time

Now, let's read an important excerpt from section 346-7.2.1 regarding transit times. Transit Time: Ensure compliance with Table 6 between the initial introduction of water into the mix and completely discharging all of the concrete from the truck: For trucks with an agitator for example, the concrete load has a transit time limit of 90 minutes.

Placement Time: All the concrete in a load must be in its final placement position a maximum of 15 minutes after the transit time has expired unless a time extension is approved in advance by the Engineer. Note the additional 15 minutes time after the transit time limit of table 6.

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Let's Review the specification regarding forms. When the shaft extends above the ground through a body of water, the Contractor may form the portion through the water with removable forms except when the Permanent Casing Method is specified. When approved, the Contractor may form the portion through the water with permanent forms, provided the forms are removed from 2 feet below the lowest water elevation to the top of shaft elevation.

Let us Review the Curing specification. Cure the top surface in accordance with the applicable provisions of Section 400, and construct any construction joint area as shown in the plans. Protect portions of drilled shafts exposed to a body of water from the action of water by leaving the forms in place for a minimum of seven days after casting the concrete. The Contractor may remove forms prior to seven days provided the concrete strength has reached 2,500 psi or greater as evidenced by cylinder breaks.

Common Concreting Problems

We will now look at some of the things that can happen during the concreting phase of construction.

Do Not Breach the Tremie

Let's discuss 'breaching" of the tremie. The tremie is sealed initially and lowered to the bottom of the hole. The tremie tube is then filled with concrete. The tremie is lifted about a foot to open the seal and allow the concrete to flow out rapidly. Thereafter, the bottom orifice of the tremie must remain below the top of concrete level in the shaft.

Tremie bottom level is monitored from markings on the side of the tremie, while concrete level is determined by using a weighted tape. The tremie is lifted as necessary to maintain the free flow of concrete. It should not be rapidly raised and lowered because of the danger of mixing slurry with the concrete. The need to rapidly raise and lower the tremie is an indication that the concrete is losing slump too rapidly, that the inside surface of the tremie is too rough or the tremie is too small to allow free flow of the concrete.

The markings on the tremie reflect the depth to the bottom of the tremie relative to the reference. A weighted tape is used to measure the depth to the top of the concrete relative to a reference elevation. The difference between the two measurements provides the depth the tremie is submerged in the concrete. Note in the right sketch how the tremie has raised and breached, out of concrete, with concrete coming out of bottom of tremie. This is not good.

Hook and J Bars

J and hook bars represent a problem in the form of tremie access and casing removal to the Contractor. This picture illustrates how J bars may create an access problem for the concreting operations.

This picture illustrates how hook bars represent a problem for the casing removal to the Contractor.

Rising Cage

The photograph here shows the Contractor attempting to drive down a cage that floated up during casing removal. As indicated in the specifications, <u>the Contractor is to have a method in place to prevent this.</u> This is not an acceptable method to correct the issue.

This video shows a cage rising during the concrete placement.

Pulling Casing

Mistakes made while removing casing can put the shaft at risk. In this photo, the Contractor tried to pull the casing from one side only, rather than both sides at once. This caused it to come up at an angle, rather than straight, and therefore got lodged under the platform.

The tremie had been left in, should additional concrete need to be added to the hole upon removal of the casing. What a dilemma. They can’t pull the casing because it is lodged; they can’t get a tool back over the casing because of the tremie, and all this time, the concrete is setting up. They finally cutoff the part of the platform that the casing was stuck under and were able to complete the shaft.

The video shows casing being removed. If you look close enough, you can see the casing and hammer vibrating.

Interruption in Concreting

If concrete delivery is interrupted (in this case for about 1.5 hours), sediment can settle out of the slurry and deposit itself on top of the standing concrete in the hole. Once the pour resumes, the new, more fluid concrete flows over the old concrete and traps the sediment against the side of the borehole. This is a very common cause of defective drilled shafts when the wet method is used.

Problems in Concreting

Poor cleaning: A dirty hole will create loss of section in the bottom, soft bottom, and exposed reinforcement. Etc.

Here we have examples of significant loss of section. It is possible that some cavings occurred during or just prior to the pouring of these shafts.

Here is an example of a consequence of not over pouring until seeing good concrete. This is a shaft for an end bent. When they were going to construct the end bent they noticed the concrete was contaminated and soft at the upper part. The Contractor proposed a remedial action which included removal of the bad concrete and replacing it. The worker in the picture is indicating where the top of the shaft elevation is. You can see how much bad concrete they have removed.

Problem Indicators and Cause

Problems and causes:

- Voids outside of cage - This may occur due to low concrete slump (below 5 inches), reinforcing bars too close together, or dirty hole.
- Honeycombing – This may occur when concrete placed directly in the water; excessive groundwater head, or too much stuff in top of shaft (bars, spacers, bolt pattern, conduit, etc)

Elevations & Volumes

Now we are going to do some math to compute elevations and volumes. To perform your responsibilities and complete the Concrete Placement and Volume Form, you need to know how to:

- Calculate the theoretical volume of the shaft.
- Determine the depth to top of concrete in the shaft.
- Plot the actual concrete volume versus the theoretical volume.
- Recognize problems based upon the concrete volume plots.

Next, we will cover these items and how to fill the concrete form.

Top of Concrete Elevations

This illustrates a situation that happens during pouring. After the contractor has poured the contents of a concrete truck into the shaft, the level of the concrete rises and the inspector is required to measure it and compute the elevation of the top of the concrete after the truck is poured.

s poured, the inspector has measured a depth of 17.7 feet below the top of the casing which is used as the reference. The answer is plus 5.4 minus 17.7 equals to minus 12.3. The top elevation of the concrete is minus 12.3 feet.

Area of a Shaft

This slide shows the calculation for determining the Area of a shaft. Remember that D square is also D times D.

Let's estimate the area of this circle in square feet. The Area is equal to pi times D squared divided by 4. This Equals pi times 36 to the square divided by 4 which equals to 1,018 square inches. We divide this into 144 to get the answer in square feet. This gives us 7.07 square feet.

Volume of Shaft

Now let's compute the theoretical volume of a shaft. For this we will use the formula to compute the volume of a cylinder. First calculate the area- then multiply area by Length - Diameter and Length must be in the same units.

Let's compute the area. Area is equal to pi times D squared divided by 4. Equals to pi times 48 to the square divided by 4. This gives us 1809 square inches. To convert into square feet we divide 1809.8 by 144. This is equal to 12.57 square feet. The Length is 80 feet.

The Volume is equals to Area times length. Therefore Volume is equal to 12.57 square feet times 80 feet equals to 1005.6 cubic feet. Now, to convert this volume into cubic yards, we need to divide the result in cubic feet by 27. Therefore the answer is 37.24 cubic yards.

Concrete Placement Form

Now, we are going to cover the concrete placement form and chart.

We will go over the Concrete Placement Form, number 7000-010-89. This can be obtained from the FDOT forms webpage. In this form, the inspector will record the concrete truck information, rejections, times, depth measurements, elevations, theoretical volumes, actual volumes, volumes used but not placed into the shaft and any event related to the concrete process.

This is page 1 of the form, which will cover up to 10 truckloads. For the majority of the projects, one page should be enough to cover the concrete operation. In any case, the form contains up to 3 pages, so we can cover pretty extreme lengths of shafts in FDOT projects. There is a 4th page to record the concrete volume curve. The form is available in excel and pdf format. All the concrete volumes to be entered in this form will be in cubic yards.

There are several calculations that you must be able to perform in the field. For example:

- Elevations based on a reference elevation (casing) and a measured depth. You will measure the depth to the top of the concrete from the casing elevation used as a reference. Then you will need to compute the elevation of the top of the concrete
- Theoretical volumes for a cylindrical shape based on a diameter and length. For example, you will need to compute the theoretical volume in the shaft and the volume in the pump lines. These are computed using the formula to compute the volume for a cylinder.
- Volumes placed in the shaft based on the volume delivered in a truck, volumes left in the pump hopper, observations of the volume not entered and wasted, and volume in the lines.
- Inspector must be able to compute units. Inches to feet, square inches to square feet, and cubic feet to cubic yards. Remember that to convert from cubic feet to cubic yards; you divide the volume in cubic feet by 27.

Let's divide page 1 of the form in 4 sections as illustrated in the slide. Section 1 contains the Project Name, Project number, Contractor's name, etc. It is recommended to have this form ready before concrete placement, or even before drilling starts. However, make sure to input the correct date of concreting. The Page 1 log is the primary location for header information input. This data is then linked to the other sheets to minimize inspector input effort on the other sheets.

Section 2: Basic Concrete Information: This area of the log contains the Placement Methods, Volume in Lines (VL), REF Elev., etc. Fill in as much information as possible prior to the concrete placement. For the Excel form, most of the header information is input on the Page 1 log sheet, and is then either directly applied to, or accessible via the cell drop-down list, on the other 4 tab sheets: Page 2, Page 3, Field Concrete Curve & Excel Concrete Curve.

Indicate the correct concrete Method of Placement (Tremie or Pump). For Excel form, Page 1 log sheet, input an “X” or use drop-down to select and apply the “X”). If concrete is pumped, it’s important to apply the “X” as it interacts with some sheet calculations.

When a Tremie is used indicate the inside diameter ID in inches and Length in feet of the Tremie pipe used.

In this length do not include the length of the hopper. Enter only the tremie length below the hopper. The Tremie must be long enough to be able to be seated firmly on the shaft bottom.

Section 2: Continuation: When concrete is pumped, fill in the Pump Lines: diameters (ID) in inches and Lengths in feet, for the pipe(s) used. Compute the Volume in Lines (VL) in the spaces provided. The Excel form’s Page 1 log sheet provides input cells for up to 2 Pump Line configurations. The Volume in Lines (VL) deduction is calculated by input of pump line ID in inches and the Length in feet.

Indicate the correct concrete Method of Placement (Tremie or Pump). For Excel form, Page 1 log sheet, input an “X” or use drop-down to select and apply the “X”). If concrete is pumped, it’s important to apply the “X” as it interacts with some sheet calculations.

When a Tremie is used, indicate the inside diameter ID in inches and Length in feet of the Tremie pipe used.

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When concrete is pumped, fill in the Pump Lines: diameters (ID) in inches and Lengths in feet, for the pipes used. Compute the Volume in Lines VL in the spaces provided. The Excel form’s Page 1 log sheet provides input cells for up to 2 Pump Line configurations. The Volume in Lines VL deduction is calculated by input of pump line ID in inches and Length in feet.

The calculation of the volume in the lines is done by using VL equals to pi times D Squared divided by 4 times L, where d is the pipe diameter and L is the pipe length. These calculations must be done using the same units. Since we will be dealing with cubic yards this volume is converted to cubic yards. Indicate the top Elev. (ft) of the top of the rebar cage at the beginning (@ Start), and at the end (@ Finish), of the concrete placement.

If a Surface Form or "beauty ring" is used, record the diameter ID in inches and the Length in feet in the spaces provided.

The surface form or "beauty ring" ID and Length are currently not used in the Excel form sheet calculations. Typically, the beauty ring ID will be equal to the Shaft Diameter and therefore, when needed, the sheet calculations default to use the Shaft Diameter for the shaft top profile.

This is section 3 where we fill in the truck load information. As each truck arrives and pours, the load and times must be recorded, along with the depths. For each concrete truck load delivery, record the Truck Number and the concrete Volume Delivered VD. Coordinate with the QC technician testing the concrete.

Apply the previously computed total Volume in Lines (VL) by inputting the volume into the VL block of the applicable truck load placement (usually the first accepted truck load only). Be consistent with the times. It could be military (00 to 24 hrs) or standard clock (0-12). In this case remember to enter the AM or PM after the hour.

For every truck load fill in the following:

- Volume Delivered VD.
- Batch times. Check the delivery ticket.
- Placement Start and Finish Times.(For the Excel form, Pages 1 to 3 log sheets, the "Start Time" column cells performs a dual function - they also include "REJECTED or Not Placed". *More information on this is will be provided.)
- Tremie Depth after finishing each truck placement. Make sure the tremie pipe has been marked properly to facilitate inspection monitoring of the tremie depth during placement. During the placement, it is important to check the depth of the tremie and concrete to ensure the bottom of the tremie stays submerged into the concrete.
- Depth to Concrete, after finishing each truck placement.
- Volume used for (QC) Testing (estimated).

- Volume Left on Ground (Spillage) (estimated).
- Volume Left in Truck (it is very likely that the last truck will not use the full load)
- Volume Left in Pump Hopper (LPH) (estimated). There are two columns one for left in hopper for the truck before the one we are currently recording and one for amount left in hopper after we finish pouring the current truck. These are only used in the pumping method. We will talk more about these two columns in couple of slides and how they are handled.

When utilizing the Excel Concrete Placement log (form 70001089 Pg. 1, 2, & 3 tab log sheets), if a truck load of concrete arrives on-site, or is inspected, and is then either “REJECTED” (for example it failed the slump test) or “Not Placed” (for example it was not needed), under the "Start Time or REJECTED or Not Placed" column, click on the field for that truck delivery, and click to select/apply either "REJECTED" or “Not Placed”.

When you click the cells under this column you will see a drop down list that includes only 2-items to select from:

"REJECTED" or “Not Placed”. To highlight a truck load is either rejection or not placed. "REJECTED" or “Not Placed” and the VD input volume, are conditionally formatted to appear in red font.

For each REJECTED or Not Placed truck load, record the Truck Number and input the rejected truck's Volume Delivered (VD). Leave the LPH, VW and VL cells blank. Under the Notes column enter the reasons for the truck load rejection, or for not placing the load.

Volume Placed Calculations: Volume placed is defined as the volume of concrete that goes actually into the hole. In general the Volume placed is equal to the Volume delivered (VD) in each truck minus the wastage (VW) and minus the volume in the lines (VL). In the tremie method there will be no volume in the lines.

In the pump method, VW will be the combination of several components: The trickiest part is the volumes left in the hopper and deserves an explanation. In a particular truck there will be some amount left in the pump hopper from the previous truck. This will be placed with the current truck load that we are dealing with. This adds to the Volume placed because it will go into the hole with the current truck load. We call this volume as LPH before.

Now, after we finish pouring the current truck there will be a volume left in the hopper that will be placed in the next truck. We call the amount left after we finish the current truck as LPH after. This should be subtracted from the current truck Volume as it does not go into the hole in the current truck load. In the first truck the volume left in the hopper before is zero. In the last truck, the volume left in the hopper becomes waste since it will not be placed in the hole and will be wasted.

Check before and after every truck placement and estimate and record the volume which is Left in the Pump Hopper.

Other volumes that will be subtracted from the current truck load will be the amount of concrete spent in testing, left in the truck, left in the ground, and spent during the priming of the lines. These are included as part of the Wastage volume VW.

Volume Placed Calculations: Continuation. For the tremie placement the calculations are simpler. There are no Volume in the lines and the wastage only consists of the amount spent in testing, the amount left in the truck and the amount left on the ground.

In the excel spread sheet, remember to input the “X” in the pump method, otherwise the concrete placed volumes will not be calculated properly by the spreadsheet.

This illustrates how the calculations for the volumes placed are made. Here we have a case with four trucks. For the first truck LPH before is zero. Therefore the Volume placed (VP) will be the volume delivered 9.0 plus zero minus the summation of the following wastages:

- 0.5 cubic yards for the LPH observed after
- 0.1 cubic yards used in the testing
- 0.5 cubic yards used priming the lines
- And the volume of the lines of 0.7 cubic yards
- This results in a net volume placed of 7.2 cubic yards for this first truck.

Note that the value entered in LPH after becomes also the LPH before for the next truck. For example, for the second truck the 0.5 cubic yards that was left in the hopper after the first truck will be placed in the second truck. Therefore it will add to the VP. In the second truck the only other waste we see is the left on the ground.

Then the volume placed for the second truck will be 9 plus 0.5 minus (0.4 plus 0.2). This results in 8.9 cubic yards of volume placed for this truck.

Now for the last truck, we have 0.5 CY left in the hopper from the third truck. We also see that 0.1 cubic yards were used in testing and 3.0 cubic yards were left in the truck. The Volume placed is now 9 plus 0.5 minus (0.3 plus 0.1 plus 3.0). This results in a volume placed for the last truck of 6.1 cubic yards. The last column before the Notes is the accumulated placed volume throughout the pouring.

For the third truck is the summation of the volumes placed from truck through 3. In this case that is 7.2 plus 8.2 plus 8.9 equals to 25 cubic yard. Note. These calculations are done automatically in the excel spreadsheet. When you use the pdf form, you will have to perform these calculations yourself.

At the end of the placement of the last truck, the following balance must be met for the total quantities: Total Volume Placed is equal to Total Volume Delivered minus Total Wastage minus Volume in Lines: VPT is equal to VDT minus VWT minus VL.

Total Wastage can be expressed as: VWT is equal to LPH after last truck plus Total Testing plus Total Left in Truck plus Total Left on Ground plus Total Prime Lines. VL = as computed earlier (Volume in Lines). Applied to the initial placed load.

This illustrates how the total volumes are calculated at the end of the pour. Individual waste volumes are summated at the bottom of each column. For example, for testing the total was 0.2 which is the result of 0.1 plus 0.1. Now the volume left in the hopper after the last truck is waste because it will not be used at all and should be added to the other waste totals.

Notice that LPH after last truck is equal to the total LPH after minus the total LPH before, which in this case it would be 1.7 – 1.4= 0.3 cubic yards. The total wastage for this example would be 0.3 plus 0.2 plus 3 plus 0.2 plus 0.5 equals to 4.2 cubic yards.

The total volume delivered is calculated at the bottom of the column. In this case this is 36 cubic yards. The total volume placed is the total volume delivered minus the total volume wasted minus the volume in the lines. This is 36 minus 4.2 minus 0.7 equals to 31.1 cubic yards. Note how this value matches the last final accumulated volume placed.

The tremie case is simpler as it does not have to deal with LPH after and LPH before and it does not have to deal with volume in lines. For the tremie method, the totals must be equal to: Total volume placed, VPT is equal to VDT minus Total VW. Total VW includes Testing + Left in Truck + Left on Ground.

Total volume delivered VDT is equal to the sum of all Volumes Delivered (VD), which is the sum of all placed truckload VD, excluding the trucks that were rejected or not placed. Total Wastage VWT can be expressed as: VWT equals to Total Testing plus Total Left in Truck plus Total Left on Ground. Volume in lines VL is as computed earlier and it is applied to the initial placed load only.

Section 4: This part of the form contains fields to record additional information in the shafts. In Page 1 totals. Enter the totals of the volumes corresponding to the first 10 trucks. This is done automatically by the excel spreadsheet. In Placement Totals sum Pages 1 to 3, enter the totals accumulated from pages 1 to three. This is done automatically by the excel spreadsheet.

To access pages 2 and 3, you can click at the bottom of the excel spreadsheet. These pages are used when more than 10 trucks are used. With three pages up to 40 tricks can be entered. The information to be entered is the same as the information we have explained for page 1.

Enter as Casing 1 & 2 information such as ID, Top Elevation, Bottom Elevation, and Installation/Removal times. Enter a check mark to indicate whether Rebar Cage was centered. Enter finishing times for anchor Bolt installation and concrete finishing time. Enter time elapsed during the concrete placement or the Concrete Placement Time. Enter the total theoretical volume VT, and the Over pour volume OP in cubic yards. The over pour quantity OP is computed as:

OP = VP - VT, where VP is the total Volume Placed and VT is the total Theoretical Volume for the shaft.

This is the concrete volume field chart. The inspector needs to plot the volume placed versus the elevation. In excel this form can be conveniently formatted at the elevation and volumes ranges desired using the X Y values at the lower part of form.

Excel Concrete Curve

This is the chart produced by excel automatically once you have completed the information for all the concrete operation in pages 1 and 3. It is automatically formatted as well.

The concrete volumes Form

This slide will illustrate how to plot the concrete volume curve. In this table, the inspector already has processed the concrete elevations and the volume placed and the accumulated placed volumes. We are intentionally not showing the intermediate columns so we can just focus in the plotting process. For this example, let's assume that the theoretical volume was 40 cubic yards, with only one diameter section being used. The top of the shaft elevation was at Elevation plus 50 and the bottom of the shaft elevation was at Elevation minus 20.

To complete the concrete volumes curve follow these steps. Determine the theoretical volume of the hole. Plot that. It should be a straight line, as illustrated by the solid line. In this example, the bottom of the shaft was at elevation –20.00 ft., with a finished elevation of +50.00 ft. and a theoretical concrete volume of 40 yd^3.

Plotting concrete volume curves

At the bottom elevation, the volume is zero then we plot our first point one: At the top elevation of the shaft and the total theoretical volume we can plot our second point of the line. These points give us the theoretical volume.

Note: if there are two shaft diameters, the theoretical line would be actually made of two straight lines. The theoretical volume must be calculated as in the special case for 2 diameters we calculated earlier.

For the actual volume curve, the first point will be volume zero at the bottom elevation of the shaft. Then, as each load is placed in the shaft, determine the accumulated placed volume and the elevation at the top of the concrete and plot that point for each load. For example, after the first truck we will plot Elevation minus 8.0 versus a volume of 8.9 cubic yards.

We continue this way until plotting all the loads used. The dashed line shows the actual volume placed into the shaft.

The concrete volumes Form

The volume curve is very important because it allows us to see if there are problems on the shaft. The Theoretical Line is used as a reference to compare with the actual volume curve. We will have a problem if either of the following conditions happen:

1. The theoretical line falls at the left side of the theoretical curve.
2. In any depth of the shaft the slope of the actual curve is steeper than the theoretical curve at the same depth range. In this case the results indicate the shaft has a necking and we have a smaller section than expected. In severe cases, it may indicate a collapse in the hole during concreting. When the slope of the actual is flatter than the theoretical at one particular depth range this will not be a problem. This means the shaft at the depth range measured has a bigger cross section than expected. When dealing with voids or if the contractor experienced cavings that he stabilized later on, we may end up with bulges in which the actual curve will end up like this.

In casing situations specially permanent casing it is expected that in the cased section the slope of the theoretical and actual volumes will be parallel.

What the shape of the curve means

We will use this slide to describe what the shape of the Actual curve versus the Theoretical curve can indicate. We have a shaft with bulges and neckings. The red straight line represents the theoretical volume line for this shaft. Let us estimate how the concrete curve would look for this shaft. At the lower segment the shaft has the same placed volume as it was expected. Therefore we expect the line to be parallel to the theoretical.

Next, this segment is a bulge. The volume placed will be more than the one expected. Therefore the line should have a slope flatter than the theoretical line. The third segment has the same concrete placed volume as the theoretical. Therefore we expect the slope of the actual curve to be parallel to the theoretical line.

In the fourth segment there was a void that was filled with additional concrete than the theoretical. The volume placed is more than the one expected. Therefore the line should have a slope flatter than the theoretical line. In the fifth segment the placed volume was as expected. Therefore we expect the slope of the actual curve to be parallel to the theoretical line.

In the sixth segment we have a necking. The volume is significantly less than expected. Therefore the slope of the placed volume is significantly steeper than the theoretical line. In the last segment the section is as expected. Therefore we expect the slope of the placed volume to be parallel to the theoretical line.

Topics Covered

We have achieved the following learning outcomes:

- Describe typical tremie and pump placement methods.
- How to Verify Contractor compliance with concrete placement.
- Utilize the Concrete Placement Log inspection form,   determine theoretical concrete volumes, and plot placed concrete volume curves.
- Identify problems based on the concrete curves.
- Identify the applicable 455 Specifications. We also covered the basic concrete requirements from section 346 that applies to drilled shafts.

End of Lesson

This is the end of lesson 8. Please continue to the next lesson.