Drilled Shaft Inspector CBT

Lesson 2 – Equipment and Tools

Welcome to the Drilled Shaft Inspector Course. This is Lesson 2, Equipment and Tools.

In this lesson we will discuss the typical equipment and tools used in the construction of drilled shafts.

Learning Objectives

The objectives of this lesson is to cover the following:

- Identify drilled shaft rig components
- Identify drilling tools and explain their uses
- Identify & interpret applicable 455 specifications

455-15.10 General Specification

Let's review this general specification that pertains to equipment. Use excavation and drilling equipment having adequate capacity, including power, torque, and crowd (downthrust), and excavation and overreaming tools of adequate design, size, and strength to perform the work shown in the plans or described herein

When the material encountered cannot be drilled using conventional earth augers and/or underreaming tools, provide special drilling equipment, including but not limited to rock augers, core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to continue the shaft excavation to the size and depth required.

The main concept of these highlighted parts is that the contractor is responsible to use equipment having adequate capacity and to supply the required proper tools and equipment to perform the work indicated in the plans.

Crane-mount Terms

Let us use this slide to illustrate the components of a drilled shaft rig. The particular rig shown in the picture is called a crane-mounted rig. However the main components can be found in the other types of rig that we will be covering.

The main components are the carrier vehicle that holds or carries the rig. In this particular case is the crane. The second component is the power unit which generates the mechanical power. The drill table is a mechanical device that converts the power into a rotary torque. This rotary torque is applied to the Kelly Bar.

Kelly bars are hollowed bars that transfer the rotary torque and crowd into the drilling tool. The drilling tool may be an auger, a bucket or a core barrel. These components are mounted on a vehicle that can be a crane, a truck or a track mounted vehicle. In this particular slide we see the rig mounted on a crane.

Truck-mount Terms

This illustrates another type or rig, a truck mounted rig. We see in the slide the same main components mounted on a truck.

Terminology

In this lesson we will discuss the following drilling tools:

- **Augers** - for Soil or soft rock and rock
- **Barrels** - generally for coring hard rock
- **Buckets** - generally two types;
    - Digging - for excavating soils or soft rock
    - Cleanout or Bailing - for cleaning of the shaft

There are special tools such as roller rock bits, hammer drills and retrieval tools. Auger Teeth can be flat, carbide or not, and bullet shaped.

Drilled Shaft Rigs

There are predominately two types of manufacturers of rigs, American & European. The variety of drilled shaft rigs available to contractors is considerable, particularly when you include both U.S. and European technology. Catalogs from the early 1900's show that bucket type drilled shaft drills were available even then, if you owned a horse to power it. Mechanical units were developed in the 1920's with production models in the late 1930's. This early history appears to have had its roots in Texas.

Reportedly the famous Hughes LL Series of diggers were being manufactured at the rate of 70 to 80 units per year in the late 1970's and early 1980's. Beginning in the early 1980's, it was clear that most equipment manufacturers in the U.S. were moving away from mechanical designs, opting instead for torque converters to deliver power to the rotary table/kelly bar drills. Out of Germany are units built by Delmag and Bauer. SoilMec is one of the leading Italian manufacturers are Casagrande and IMT.

This is a list some of the major American manufacturers of drilled shaft rigs.

- Atlantic Equipment Company
- American Equipment & Fabricating Corp.
- Caldweld
- Stephen M. Hain Co.
- Reedrill/Texoma
- Watson

Here is a list of the main European manufacturers of drilled shaft rigs:

- Bauer
- CasaGrande
- IMT
- SoilMec

Types of Rigs

Based on the type of vehicle the rigs can be:

- Truck-Mounted Rigs
- Carrier-Mounted Rigs
- Crane-Mounted Rigs
- Crawler-Mounted Rigs

Light Truck Mounted

This slide illustrates a light truck mounted rig. This type of rig generally handles the smaller sized holes and mast arms and signs. Medium size units such as this can be carried by a dual tandem truck. This size rig is generally capable of sizes up to 5 feet in diameter, 30 feet in depth. These units are characterized by their “wet” kelly bar design. The digging depth is dictated by a long slender hydraulic cylinder which uses the ram as a kelly bar.

Carrier Mounted

Larger drills require two front axles to accommodate highway weight limits and to achieve the off-road maneuverability needed. A carrier-mounted rig which has greater hole diameter and depth capabilities. Characteristic of these drills are three part telescoping kellys capable of drilling 120 inch diameter holes to depths of 85 feet to 200 feet.

This is another carrier-mounted rig. Notice that there is a big difference between these and the truck-mounted type. As you can see, the more heavy duty the carrier, the bigger the rig.

Crawler Mounted

Crawler mounted rigs are becoming very popular due to the increase in rehabilitation versus new bridge construction. These rigs require less overhead clearance and are very mobile, making them the weapon of choice for restricted work areas.

This is another crawler-mounted rig. As you can see in the photograph, this type of rig has the capability to twist in casing as it is drilling the hole, all in one operation. This speeds up production.

Crane Mounted

If there is a need for a larger drill, with greater torque and depth capability, contractors frequently use, what is termed in the industry as “crane attachment” drills. The power of some of these rigs can be truly impressive. Crane attachments come as a unit, including a diesel engine, transmission and torque converter driving a heavy duty rotary table through which a kelly is installed.

The entire drill unit is attached to a crane using a “bridge” which allows the rotary table to be rigidly held and sufficiently elevated to accommodate the drilling tools anticipated for the job. Given the power advantages offered by large crane attachments, it is the ability to vary the working room (clearance) under the rotary table which makes this type of drill so attractive for many jobs.

Kelly designs can be single, double, triple, or even quadruple configurations. Double power units such as this one are capable of drilling depths up to 285 feet. The maximum hole diameter is dependent on the bridge design, but commonly these drills are used for hole sizes varying up to 140 inches in diameter.

The Hain Model 754 shown here can accommodate a maximum outer kelly size of 18 inches square. This unit can reportedly deliver a maximum rotary torque (stall) of 374,631 ft.-lbs.

Bits and Tools

It has often been said that a drilled shaft rig, no matter how large or powerful, is no better than the tool at the end of the kelly. If you have ever tried to use a small hand drill with a worn bit, you can relate to how it can affect production.

For that reason, tools have been fabricated for virtually every below ground condition imaginable. The most common augers can be classified as either dirt (soil) or rock types, with variations of each as to the number of flights, teeth, and lead bit. Many contractors build their own designs, but there are a number of manufacturers who specialize in drilling tools as well.

Auger Bits

Auger bits are generally classified as Earth bits or rock. Earth auger bits could be single flight or double flight. The double flight has superior removal capacity. Rock auger bits can be double or triple flight, single core barrels and double wall core barrels also known as "air barrels".

Why is this important?

The Inspector must have the knowledge to identify the various drilling tools being used by the Contractor. Remember; it is not the Inspector's responsibility to direct the Contractor's work or technique (Means & Methods). However, the Inspector must make accurate notes as to the tools and equipment on-site and being used.

If the Contractor only has earth augers on site and rock needs to be penetrated, it is important to have this information noted, as the Contractor may say the material cannot be penetrated and was misrepresented or harder than indicated. The Inspector's accurate, unbiased observations and documentation can help alleviate problems or questions that might arise.

Earth Augers

Earth augers are usually made with single or double flights. Earth augers are distinguished from rock augers by the use of lighter weight material and flat edge blades as cutting teeth. Because of their superior removal capacity, double flight designs are usually best for the fine sandy soils. This slide shows a single flight auger designed so as to cut on both sides of the stem.

That is called SF Dc for Single Flight Double Cut. When inspecting earth augers, the Inspector should examine them for diameter, condition of the flights, and if on, condition of the teeth. Check teeth for missing from the pockets, and worn down or broken teeth edges. It is not the Inspector's responsibility or authority to reject the augers but their condition should be noted.

This slide shows another single flight, double cut earth auger which works better in sandy soils than the single flight augers.

This is a double flight, double cut earth auger which works better in sandy soils than the single flight augers. Double cut augers make it easier to keep the hole straight since they are less likely to "walk" to one side. The same type of inspection we discussed on the previous slide holds true here too.

This is a single flight single cut auger design for excavating relatively weak soils that have some cohesion and in some instances, soft rock. Note the tooth design for gouging out large volumes of soil and the several turns on the auger, which allows for transport of considerable soil to the surface at one pass.

This type of bit has a tendency to walk off, meaning getting out of axial alignment. The stinger is needed because there is an unbalanced torque on the cutting face when the auger is excavating. The stinger is needed to ensure that the tool remains aligned. The advantage of this bit is that it can remove large volumes of material. The disadvantage is in its tendency to walk off. If a stinger bit is being used, the Inspector should examine it for missing or broken teeth and type.

These are typical of the cutting teeth used on earth augers. The Pocket, which holds the cutting teeth, is welded onto the auger. This allows for changing out broken or worn teeth. The stinger bit aids in keeping the axial alignment and minimizing "walking off".

Shown here are the earth cutting teeth, the pockets they fit into and the stinger bit that helps minimize the “walking off “ or getting out of axial alignment.

The pockets are welded on to the auger and the teeth can be mounted into the pockets. When the teeth are broken or worn out they can be removed from the pockets and replaced. This slide shows a pocket and an earth tooth. The right part of the slide shows two type of stingers: spade and fish tail. They are bit aids that helps maintain the axial alignment and minimize the walking off of the auger.

The Contractor may have trouble maintaining hole alignment or jamming the auger in the hole if the hole diameter becomes larger than 5 to 8 feet, depending upon the hardness and regularity of the soil. In such a case, he or she should change to a double flight auger such as this. Note that the opposing rows of teeth will give a balanced torque reaction on the cutting face. This slide shows a double flight double cut earth auger for use in large diameter holes.

Rock Augers

When use of soil augers and buckets does not excavate the shaft, contractors frequently use rock augers. A typical rock auger is shown here. The rock is broken into small pieces by the ripping (tungsten carbide) teeth and either lifted out on the auger or removed with a bucket or other tool. Some rock is hard enough, however, that rock augers will not be effective.

The Inspector should examine the auger bit for broken or worn teeth, much like earth augers. Note that the tapered geometry does not cut a “flat” bottom which is required by the specs. Therefore for final cuts and to provide the flat bottom a different toll will need to be used.

Pockets are welded on to the auger and the teeth can be mounted in the pockets. This is the feature that makes these “replaceable” teeth. Broken or worn out teeth can be easily replaced into the pockets. The teeth come in various size carbide tips. On the left is a ¾” carbide tip, and ¼” on the right.

Here is a picture showing the rock auger pockets, bullet teeth and the pilot bit.

This is a typical pilot bit used on rock augers. As with earth auger pilots, these assist in starting the hole and keeping the auger aligned.

This is a rock auger designed for use in soft to medium rock. Notice the different type of cutting teeth on the bit versus the earth augers. Also, generally the material used to make the rock auger gets a little more heavy duty than the one used for earth augers.

This is another rock auger designed for use in soft to medium rock. Note the conical or bullet shape teeth. Also, generally the material used to make the rock auger gets a little more heavy duty than the one used for earth augers.

This is another type of rock auger for soft to medium rock. Note that it is not flat on the bottom.

This slide shows an auger designed for cutting hard rock. These work in the same way as the other rock augers in that they chew up the rock.

Here is another auger for hard rock similar to the previous one, but with different type of teeth.

Rock Bits

When rock augers are not sufficient to excavate rock because it is too hard, these (and other) tools might be considered.

This slide shows the business end of a circulating rock bit with replaceable roller bits (often called “roller bit”.)

Digging Buckets

An auger will not work well in a truly cohesion-less soil, like a sand or gravel, especially below the groundwater table where boreholes are often filled with drilling fluid. In such soil, contractors often use digging buckets, like this one.

It is a good idea that these tools be vented to allow drilling fluids to bypass them during insertion and extraction of the tool when drilling under a fluid. This circumvents creating a piston effect during insertion or suction during extraction, which may cause the borehole to collapse. A simple pipe passing through the tool can often be used for this purpose.

Sand or gravel is scooped up by the teeth and fed through flaps into the bucket. The sand or gravel cannot fall back through the flaps and so will be lifted when the bucket is lifted. This bucket has opposing cutting faces. One face has ripping teeth, which allows the tool to cut through thin seams of cemented sand or gravel. Note that the tool also has a side cutter. To minimize disturbed soil on the borehole face the tool is turned as it is withdrawn.

Here is another picture of a drilling or digging bucket. Note the absence of the side cutter teeth.

Core Barrels

Harder rock may require the use of core barrels to speed advancement of the hole. The concept of a core barrel is to minimize the amount of rock that has to be “cut” in order to deepen the hole, thereby accelerating the process. By using a single tube design, shown in the left side picture, the cutting force (down pressure and torque) can be concentrated along the perimeter of the barrel. This barrel uses replaceable carbide tipped “bullet” teeth.

Larger drill units with sufficient down pressure and torque can utilize “air barrels” effectively as the barrel shown in the right side of the slide. This system uses large volumes of compressed air in conjunction with a double-wall core barrel which can be equipped with a variety of cutting devices. These cutters can be replaced when worn, or exchanged for button-type bits for harder rock formations.

Here is a single core barrel extracting a rock core out of the shaft excavation.

This slide shows a 10-foot-diameter, double-walled core barrel. The small roller bits cut a core in the rock. Cuttings are flushed to the surface with drilling fluid that is pumped through orifices in the roller bits and exits between the outer barrel and the inner barrel.

The outer barrel provides the energy for cutting the core. The inner barrel remains stationary around the core, and the core is held in place by cuttings that jam between the core and the inner barrel. When joints or discontinuities in the rock are reached, the core breaks off and can be lifted. **Note** at the bottom some home-made barrels.

This slide shows some home-made barrels.

Belling Tool

A belling tool can be used to make enlarged bases for drilled shafts in the dry or casing drilling processes. This slide shows a 42” 60^{o} belling tool in the open position at the right side, and the closed position in the left side.

Belling is not recommended under slurry due to the potential for slurry to get trapped in the bell, not to mention collapse of the bell and cleaning problems. These are seldom seen in Florida and has not been used in FDOT projects. They have been removed from our specifications.

Punch

A punch is a tool used to break obstructions and rock by repeatedly dropping it from a crane, eventually chopping the obstruction or rock up. Requires the ability to “free fall” line or kelly.

Cleanout (Bailing) Bucket

Cleanout (bailing) buckets are used to remove the sediments and cuttings from the bottom of the shaft. The kelly is rotated in the normal drilling direction and the bottom stays open and picks up sand, muck and water. Then, while leaving the bucket on the bottom, the kelly is turned in the opposite direction, which closes the bottom of the bucket. The bucket can then be removed from the hole, dumped and the process started again.

Normally, cleanout buckets are about 10%-20% smaller than the hole diameter, enabling movement around the hole bottom while reducing the danger of putting large, suction pressures on the shaft excavation when the tool is withdrawn. This can be very important where formations contain significant amounts of sand. The tool should be removed slowly, since rapid removal can generate the “suction” effect.

Cleanout Tool

Another tool commonly used for final cleaning of the shaft is a down-hole-submersible hydraulic pump. Two type of hydraulic pumps are shown here. Slurry is pumped from the bottom of the shaft to a de-sanding unit while fresh slurry is replaced in the top of the shaft.

Pumping shafts from the bottom greatly speeds the operation of shaft cleaning and gets better end results as opposed to extended periods of using muck buckets alone. The tool needs to be moved around in a large diameter hole to ensure coverage over the bottom of the shaft. This can be difficult if the tool is suspended in the hole by a cable versus a kelly bar.

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Here is another type of hydraulic down hole pump.

Another tool commonly used for final cleaning of the shaft is an Air Lift. An air lift acts similarly to a vacuum cleaner. As indicated in the sketch in the right side, compressed air is injected through a small diameter pipe near the bottom of the shaft. The high velocity of the air injected creates the suction.

Setting Casing Tools

Vibratory hammers are used to install and remove casing. This slide is used to introduce vibratory hammers which are used for installing or extracting casing. The vibratory hammer at the left would not be suitable for installing and removing casing because it only has one jaw to grab the casing. The one at the right is appropriate as it is able to grab the casing in two opposite sides.

This photo shows a vibratory hammer attached to the casing and vibrating it in. This shows the casing installed a few minutes later. Installation with casing with vibratory hammers may produce significant vibrations and settlements and even damage adjacent structures.

Casing can be also installed and removed by non-vibratory methods. The contract documents may require non vibratory methods to install the casing and forbid vibratory methods in sensitive areas or near sensitive structures.

Here is tool used to install casing by the twisting method. The casing twister is inserted in the notches on the casing (photo lower right) attached to the rig drill table so that the rotational torque is transmitted to the casing. The casing is then twisted or screwed into the ground.

The following pictures show casing being installed by the twisting method. In this picture, the casing twister is about to be connected to a casing. This picture shows a casing installed with the twister. This picture shows a casing being provided with cutting teeth at the bottom. These are required to assist in the penetration of the casing and reduce the side friction with the soil.

Oscillators are used to set casing by an oscillation movement while pushing down the casing. The rotator are tools that rotate the casing while pushing it down; they do not oscillate.

Miscellaneous Tools

We will learn later on than when the excavation extends too long the specifications require over-reaming the walls of the shaft excavation. An over-reaming tool is required for this purpose.

This picture shows a Contractor's homemade over-reaming bucket. The Contractor, using a drilling bucket, cut holes in the sides, slipped a steel cable through the holes, forming his own tool. A drilling bucket can also be provided with side teeth to perform the over-reaming operation as shown in this picture.

In this Lesson, we have covered the following topics:

- Identify drilled shaft rig components
- Identify drilling tools and explain their uses
- Identify & interpret applicable 455 specifications

End of Lesson

This is the end of lesson 2. Please select the next lesson button on this page to continue to the next lesson.