Lesson 2 – The Pile Driving System Transcript

Welcome to the Pile Driving Inspector Course. This is Lesson 2 – The Pile Driving System. To begin, select the start button or press Shift+N on your keyboard.

In this lesson, we will cover the following topics:

- Identify Pile Installation Equipment and Tools.
- Identify various pile types.
- Use Pile Driving Equipment terminology.
- Interpret 455 specifications related to the pile driving system.

The fundamental pile driving system consists of: the pile; the pile driving hammer system; the crane, crane boom and leads; the template; and the soil. Each of these components are briefly discussed in this course. These discussions and drawings are intended to be very basic and are mainly provided for your information.

We will review the driving system starting with Pile Types that are commonly used in Florida, then what types are used, for the most part, on FDOT projects and ending with the various features and applications for the different pile types.

The following is a list of pile types that have been used in Florida over the years. Some still used, others not. Concrete piles, pipe piles, steel h-piles, composite piles, hollow core cylinder piles, steel sheet piles and timber piles.

The most common types of piles used on FDOT projects are: Pre-stressed square concrete piles, steel piles (both pipe and "H" pile), and timber.

The Pile types that will be addressed in this lesson are: treated timber piling, pre-stressed concrete piling, steel piling, and test piling. We will also take the opportunity to point out that the specifications are written in active voice and are addressed to the Contractor. At the beginning of this article 455-3, who is supposed to "furnish and install the piling" etc.? The answer is the Contractor. Here when the specs says "furnish and install" etc., the specs are addressed to the Contractor.

The specifications require the Contractor to provide prestressed concrete piles that are manufactured, cured, and driven in accordance with the requirements of the Contract Documents. Provide piles full length without splices when transported by barge or the pile length is less than or equal to 120 feet. When piles are transported by truck and the pile length exceeds 120 feet but is less than the maximum length for a three point pick-up according to Index 20600, and splicing is desired, provide minimal splices. Include the cost of the splices in the cost of the pile.

Splice is the joint or connection of two pieces of pile. You notice that we want to avoid pile splices as much as possible. Splices will not have the same structural strength as the material. Piles will have weak spots for driving at the splices and reduce the structural strength of the piles for bending. In concrete piles splices will have a reduced tension strength and may limit the drivability of the pile as the pile becomes more fragile.

The specs require no splices in concrete piles up to 120 ft where they are transported by barge. For transportation by truck the required length without splices may be more, depending of the pile size, in accordance with Standard Index 20600. This index and the concept of number of pick-up points versus pile length will be covered later on in lesson 6. For example, for 18" piles, the maximum length for a three pick-up point is 121 ft. Therefore, we expect the contractor to deliver by truck, 18" piles, up to 121 ft long concrete piles.

Let's read the following specs: Time of Driving Piles: Drive prestressed concrete piles at any time after the concrete has been cured in accordance with Section 450, and the concrete compressive strength is equal to or greater than the specified 28 day compressive strength.

Shipping: Do not ship precast prestressed concrete products to the project site prior to the completion of the 72 hour curing period and attainment of the required 28-day strength. This is an excerpt of section 450 of the specifications that applies to prestressed concrete products. Since concrete piles are prestressed concrete products, this 450 section applies to piles.

Square Prestressed Concrete piles are displacement piles & the most common type of piles in Florida. Displacement means that these piles displace soil volume when they are being driven. The concrete volume will occupy the volume taken by the soil.   In sands, when the pile displaces soil around the pile the soil becomes denser. That is why when we have a group of closely spaced piles, the piles become progressively harder to drive. A non-displacement pile would be a pile with a relatively thin section such as H piles and open ended pipe piles.

Prestressed concrete piles are used in:

- Typically where limestone or dense stratum is <125'. Concrete piles longer than this become typically difficult to handle and drive, and present a greater risk for damage.
- Used in corrosive environments
- Used as friction piles, end bearing piles, and combination of both.

This chart illustrates the uses of prestressed concrete piles for both solid and hollow (voided) sections. Precast concrete piles are suitable for use as friction or end bearing piles when driven in sand, gravel, or clays. Concrete piles may also be cast with a hollow core. Precast concrete piles are usually of constant cross section but can also include a tapered section near the pile toe.

In FDOT projects, 30" piles may include an 18" void in the main portion of the pile to reduce pile weight. The voided piles have solid ends, 11 ft. long, for protection during driving. Since they have a big cross sectional area, driven as a group can sometimes densify soils in the immediate area.

This slide shows the major phases involved in producing prestressed concrete piles: pre-stressing, casting, identification, cutting off the strands, inspection and delivery. Several piles are typically cast in on bed.

Generally cylinder piles are used for marine structures or land trestles and have high resistance to corrosion.

For FDOT projects they can be 54" or 60" diameter. They are used in projects that require special structural needs, such as large lateral loads. They can be used in corrosive environments. These piles are heavy and require the use of larger than usual barges, cranes and driving equipment. It is also required that the project is accessible by large barge and cranes.

Concrete cylinder piles are post-tensioned, hollow concrete piles which are cast in sections, bonded with a plastic joint compound, and then post tensioned in lengths containing several segments. Special concrete is cast by a process unique to cylinder piles which achieves high density and low porosity. The pile is virtually impervious to moisture.

Cylinder piles are sometimes difficult to drive. However, they usually extend directly to the superstructure support level avoiding the need for a pile cap, which can result in substantial cost savings. Because the segments are post tensioned in the manufacturing yard, this pile type is not conducive to splicing for additional driving which can be a problem if the required capacity is not attained.

Let's review the specification 455-8.1 Steel Piling Description: Furnish, splice, drive, and cut off structural steel shapes to form bearing piles. Include in this work the installation of bracing members of structural steel by bolting or welding, construction of splices and the filling of pipe piles with the specified materials.

Steel pipe piles can be used in friction, end bearing, or a combination of both. They are commonly used where variable pile lengths are required since splicing is relatively easy. They are useful for projects with space limitations, as shorter lengths are easily handled and spliced to accommodate the required depths.

Additionally, steel piles are lighter per foot than concrete piles. Pipe piles may be driven either open or closed end. Pipe pile shafts may be left open or filled with concrete. In driving through dense materials, open end piles may form a soil plug. The plug makes the pile act like a closed end pile and can significantly increase the pile toe resistance. Select the "More info" button to learn more about the types of steel piping. When you are ready to move to the next slide, select the continue button or press Shift+N on your keyboard.
(Refer to PPT for the info for the "more info" advanced action)

Steel pipe piles can be used in friction, end bearing, or a combination of both. Steel piles in Florida are typically either pipe piles or H-piles.

Pipe piles can be closed ended pipe piles or open ended piles. Closed ended pipe piles include a plate welded at the bottom that provides end bearing capacity. These close ended pipe piles are considered displacement piles since they will displace a significant amount of soil during driving. Open pipe piles are considered non displacement piles.

They are commonly used where the pile lengths are over 125 ft or where variable pile lengths are required since splicing is relatively easy. They are useful for projects with space limitations, as shorter lengths are easily handled and spliced to accommodate the required depths.

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Steel H-piles consist of rolled wide flange sections that have flange widths approximately equal the section depth. In most H-pile sections, the flange and web thickness are the same. In some cases, W-sections are also used for piles.

They are considered non-displacement piles and not as common as concrete. They are typically used where pile lengths are over 125 ft in length or there are extremely variable subsurface conditions.

H-piles are suitable for use as end bearing piles, and as combination friction and end bearing piles. Since H-piles generally displace a minimum amount of soil, they can be driven more easily through dense granular layers and very stiff clays than displacement piles.

However, sometimes H-piles will "plug". That is, the soil being penetrated will adhere to the web and the inside flange surfaces creating a closed-end, solid section. The pile will then drive as if it were a displacement pile below the depth of plug formation. Plugging can have a substantial effect on both driving resistance and static capacity.

One advantage of H-piles is the ease of extension or reduction in pile length. This makes them suitable for nonhomogeneous soils with layers of hard strata or natural obstructions. Splices are commonly made by full penetration groove welds so that the splice is as strong as the pile in both compression and bending. The welding should always be done by properly qualified welders. The disadvantages of H-piles include a tendency to deviate when natural obstructions are encountered.

This image shows a highly variable site where concrete piles were used. See how the lengths ranged from 85 to 185 ft. Some piles needed splicing. In cases like this, a steel pile foundation would have been more effective in handling the variability of the soil because splicing and cutting off piles are much easier to perform on steel piles.

In general, a composite pile is made up of two or more sections of different materials or different pile types. Depending upon the soil conditions, various composite sections may be used. The upper pile section is often precast concrete, steel pipe, or corrugated shell. The lower pile section may consist of steel H, steel pipe, or timber pile.

One of the composite piles that may be used in non FDOT projects consists of a lower section of steel H, or pipe pile embedded in an upper pile section of precast concrete. In some cases, the stinger actually is driven back into the pile, which besides damaging the pile is mistaken for penetration. Note that this type of pile is not used in Florida DOT projects anymore.

When shown in the plans or as directed by the Engineer, the Contractor has to drive timber piles constructed of round timber of the kind and dimensions specified in the plans at the locations and to the elevations shown in the plans.

Note: Engineer in the Specs is the Director of the State Construction Office, or his duly authorized representatives. These representatives could be the District Construction Engineers who in turn may delegate some authority to the Resident Engineers and other personnel representing the Department.

Timber piles are typically 8” tip and 12” butt diameters. Common lengths may between 15 ft and 50 ft. They are best suited for modest loads when used as friction piles in sands, silts and clays. The taper of timber piles is effective in increasing the shaft resistance, particularly in loose sands. Overdriving of timber piles can result in the crushing of fibers or brooming at the pile head.

Timber piles may be used in the construction of temporary bridges, bridge fender systems and small jetties due to the good energy absorption properties of wood.

Sheet piling could be made out of concrete or steel. Sheet piles are utilized for retaining systems, such as sheet pile walls, cofferdams & bulkheads. Steel sheet piles are driven in the ground using either impact or vibratory hammers. In case of hard driving or obstructions, pre-drilling may be required. Concrete sheet piles are installed with the aid of jetting and pre-excavating. Sections 455-9 cover the FDOT requirements for sheet piling.

True or False: Square prestressed concrete piles are considered non-displacement piles. False

Multiple Choice: Timber piles are used for which of the following on which type of projects?

A. Temporary structures

B. Docking & fender systems

C. Light commercial

D. All of the above

Multiple Choice: Steel H piles are typically used when piles lengths are expected to be over ___ feet.

A. 50

B. 75

C. 100

D. 125

Multiple Choice: Concrete piles must be cured ___ days prior to ____ and the concrete has achieved the 28-day compressive strength.

A. 3 driving

B. 7 driving

C. 7 shipping

D. 3 shipping

The next component in the Pile Driving System that we will discuss is the hammer and cushion.

This graphic presents the basic components of a pile driving hammer. The ram will impact the anvil and striker plate at a certain kinetic energy. This impact energy is transferred through the hammer cushion (also called capblock), then onto the helmet (also called pile cap), pile cushion and pile. Some of the energy is absorbed by the pile cushion to protect the concrete piles. Timber piles and steel piles do not use pile cushions.

The common hammer types that we will be covering in this class are: Air or Steam hammers, Diesel hammers: (These could be Open end Diesel hammers or Closed end Diesel Hammers.), Hydraulic hammers, and Vibratory hammers

The first three types of hammers are impact hammers, meaning they drive the piles into the ground by impacts or blows. The most popular type of hammer is the open end Diesel hammer. The fourth, one, the vibratory hammers, use continuous vibratory forces to push the pile into the ground. This hammer is commonly used on steel piles or steel sheet piles. Vibratory hammers are also used to extract steel piles.

Let’s review the specification for 455-5.2 Pile Hammers: All equipment is subject to satisfactory field performance. The contractor submits in their pile installation plan what hammer he intends to use. The hammer is typically evaluated during the test pile program. However, the evaluation period goes into the production piles phase. This means that equipment may be rejected at any time the equipment is not performing satisfactorily.

The hammer proposed must have be able to provide variable energy. This means to have a hammer that can provide variable or strokes that can be adjusted to achieve a satisfactory driving operation. The driving equipment must be able to drive the piles at reasonable blow counts without overstressing or damaging the pile.

The specs require that the driving equipment supplied by the Contractor must provide the required resistance at a blow count ranging from 3 blows per inch (36 blows per foot) to 10 blows per inch (120 blows per foot) at the end of initial drive, unless approved otherwise by the Engineer after satisfactory field trial.

This range of blows per foot allows the hammer to be properly sized. If the hammer mobilizes the capacity with very few blows the hammer is too big and may damage the pile. If, on the other hand, a hammer needs too many blows, the hammer is too small and we may risk the capacity of not being properly mobilized.

Let's read this spec requirement: When the Engineer determines the stroke height or bounce chamber pressure readings do not adequately determine the energy of the hammer, the Contractor must provide and maintain a device to measure the velocity of the ram at impact.

Here, the term "stroke" refers to the height of the hammer ram that falls to hit the pile, "bounce chamber pressure" refers to a device typically used in double acting Diesel hammers discussed later. In certain cases, such as hydraulic hammers, in order to determine correctly the impact energy, it is necessary to install a device to measure the velocity of the ram just before impact.

This image shows an air/steam single acting hammer. The advantages of this hammer are:

- Same stroke each impact
- Consistent operation rate
- Low impact velocity
- More efficient than diesel
- Cleaner exhaust than diesel

The disadvantages of this hammer are:

- Additional support equipment required
- Heaviest hammer
- Not as dependable as diesel
- Thick hammer cushion stack required

Single acting air/steam hammers are essentially gravity, or drop hammers, for which the hoist line has been replaced by a pressurized medium, being either steam or air. While originally developed for steam power, most of these hammers today operate on compressed air.

To lift the ram weight with motive pressure, a simple one-cylinder steam engine principle is used. During the upstroke cycle, the ram is raised by externally produced air or steam pressure acting against a piston housed in the hammer cylinder.

The piston, in turn, is connected to the ram by a rod. During the downstroke cycle, the ram falls by gravity (less friction) to impact the striker plate and hammer cushion. Just before impact, the pressure valve is activated and pressure again enters the cylinder. These hammers must be equipped with at least two strokes, one full stroke and another of lesser height called short stroke.

The stroke is controlled by the use of a device called slide bar shown in this picture. The slide bar has cams that trip the valves at fixed locations. The maximum stroke of single acting air/steam hammers generally ranges from 2 to 5 feet. Single acting air/steam hammers have the advantages of moderate cost and relatively simple operation and maintenance. They are versatile for many pile types, particularly large concrete and steel pipe piles.

Let us review the first type of hammers, the air/steam hammers. The specs require that variable energy air/steam hammers shall be capable of providing at least two ram stroke lengths. The short ram stroke length shall be approximately half of the full stroke for hammers with strokes up to 4 feet and no more than 2 feet for hammers with maximum strokes lengths over 4 feet. Operate and maintain air/steam hammers within the manufacturer's specified ranges.

The air /steam hammer must operate within 10% of the manufacturer's rated speed, given in blows/minute.

Let's talk now about the open-end Diesel Hammers. These are the most popular hammers used by contractors in Florida and as an inspector you will encounter them quite often.

The open ended Diesel hammers have the following advantages:

- Very Simple; dependable
- No additional support equipment required
- Lightest net weight per ft.-lb. of energy
- Readily available

These hammers also have the following disadvantages:

- Variable stroke and delivered energy
- Less efficient energy transfer
- Produces higher pile stresses
- Dirty exhaust spray
- Difficult to spot operation Problems

The basic distinction between all diesel hammers and all air/steam hammers or hydraulic is that, whereas air/steam hammers are one-cylinder engines requiring motive power from an external source, diesel hammers carry their own fuel from which they generate power internally.

The initial power to lift the ram must be furnished by a hoist line or other source to lift the ram upward on a trip block. After the trip mechanism is released, the ram guided by the outer hammer cylinder falls under gravity. As the ram falls, diesel fuel is injected into the cylinder below the air/exhaust ports. Once the ram passes the air/exhaust ports the diesel fuel is compressed and heats the entrapped air. As the ram impacts the anvil, the fuel explodes, increasing the gas pressure. The combination of ram impact and fuel explosion drives the pile downward, and the gas pressure and pile rebound propels the ram upward in the cylinder. On the upstroke, the ram passes the air ports and the spent gases are exhausted. Since the ram has a velocity at that time, the ram continues upward against gravity, and fresh air is pulled into the cylinder. The cycle then repeats until the fuel input is interrupted.

For Diesel hammers the specifications require that variable energy diesel hammers shall have at least three fuel settings that will produce reduced strokes. The hammer must be operated and maintained within the manufacturer's specified ranges.

The specifications require the contractor to provide the Engineer with a chart from the hammer manufacturer equating stroke and blows per minute for the open-end diesel hammer to be used. Also the contractor must provide and maintain in working order for the Engineer's use an approved device to automatically determine and display ram stroke for open-end diesel hammers.

A very common device is the saximeter ™. As an inspector you should become very familiar with the use of this device. Once you get the device from the contractor check it out, go over the instructions, test it and play with it until you feel comfortable before going into the job. If needed, ask assistance from the District Geotechnical Office.

Let's talk now about the Close-End or Double acting Diesel Hammers: The double acting diesel hammer works very much in principle like the single acting diesel hammer. The main change consists of a closed cylinder top. When the ram moves upward, air is being compressed at the top of the ram in the so called "bounce chamber" which causes a shorter stroke and therefore a higher blow rate.

Operationally, as the ram passes the bounce chamber port and moves toward the cylinder top, it creates a pressure which effectively reduces the stroke and stores energy, which in turn will be used on the downstroke. Like the single acting hammer, the actual stroke depends on fuel charge, pile length and stiffness, soil resistance, and condition of piston rings. As the stroke increases, the chamber pressure also increases until the total upward force is in balance with the weight of the cylinder itself.

This type of hammer has the following advantages: No additional support equipment required, Drives piles faster, and it's Lightweight. This hammer also has the following disadvantages: Lowest efficiency and the Most difficult to spot operation problems.

The specifications require the contractor to provide closed-end (double acting) diesel hammers with a bounce chamber pressure gauge, in good working order, mounted near ground level so the Engineer can easily read. Also, the contractor must provide the Engineer with a chart, calibrated to actual hammer performance within 30 days prior to initial use, equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used. The next slide will show a chamber pressure gauge and a typical chart.

This is a chamber pressure gauge and a chart that equates bounce chamber pressure with equivalent energy. These must be provided by the Contractor.

Hydraulic hammers have the following advantages: Controllable variable stroke, High efficiency blow, Low impact velocity (Short strokes), Wide range of sizes available, Clean running/quiet. Hydraulic hammers have the following disadvantages: Need hydraulic power pack and hoses, Need dedicated person for hydraulic controls, Reparability / highly qualified tech required, and Expertise in hammer operation needed.

Hydraulic hammers are not very common in FDOT projects. The Contractor is required to provide variable energy hydraulic hammers with least three hydraulic control settings that provide for predictable energy or equivalent ram stroke. The shortest stroke shall be a maximum of 2 feet for the driving of concrete piles. The remaining strokes shall include full stroke and approximately halfway between minimum and maximum stroke.

The contractor must supply hammer instrumentation with electronic read out, and control unit that allows the operator to read and adjust the hammer energy or equivalent ram stroke. When pressure measuring equipment is required to determine hammer energy, the pressure measuring equipment must be calibrated before use.

These hammers are generally used for driving and extracting sheet piles and non-displacement H-piles and pipe piles. They are not impact hammers.

Vibratory hammers use paired counter-rotating eccentric weights to impart a sinusoidal vibrating axial force to the pile (the horizontal components of the paired eccentric weights cancel). Most common hammers operate at about 1000 Hz.

These hammers are rigidly connected by hydraulic clamps to the pile head and may be used for either pile installation or extraction. These hammers typically do not require leads, although templates are often required for sheet pile cells. Vibratory hammers are not rated by impact energy delivered per blow, but instead are classified by energy developed per second and/or by the driving force they deliver to the pile. The power source to operate a vibratory hammer is usually a hydraulic power pack.

Now let's review the specification 455-5.2.4 Vibratory: Vibratory hammers of sufficient capacity (force and amplitude) may be used to drive steel sheet piles and, with approval of the Engineer, to drive steel bearing piles, a sufficient distance to get the impact hammer on the pile (to stick the pile). The Engineer will determine the allowable depth of driving using the vibratory hammer based on site conditions.

However, in all cases, use a power impact hammer for the last 15 feet or more of the final driving of steel bearing piles for bearing determinations after all piles in the bent/pier have been driven with a vibratory hammer. Do not use vibrating hammers to install concrete piles, or to install support or reaction piles for a load test.

Here are a couple of observations. Currently there is not a method to establish capacity with a vibratory hammer. Therefore, to accept piles from the bearing point of view, a blow count criterion will be required and therefore driving using an impact hammer will be required at the end of the driving. In addition, in certain soils it has been observed that vibration may affect the capacity of adjacent piles. That is the reason for the rule of driving steel piles at least 15 feet after all the piles in the group have been installed.

Multiple choice: Which of the following hammers is NOT to be used to drive concrete piles?

A. **Vibratory**
B. Diesel
C. Hydraulic
D. Air/Steam

Multiple choice: A bounce chamber pressure gauge is to be provided for which of the following hammers?

A. Air/Steam

B. Open end diesel

C. Closed end diesel

D. Hydraulic

Multiple choice: A “scale” or “jumpstick” is to be provided for which hammer?

A. Closed end diesel

B. Open end diesel

C. Hydraulic

D. Not required on any hammer

Multiple choice: A diesel hammer is to have a least ___ fuel settings that produce reduced strokes.

A. 2

B. 3

C. 4

D. None required

Most hammers use a hammer cushion between the hammer and the helmet to relieve the impact shock, thus protecting the pile hammer. However, some hammer models exist that do not require a hammer cushion, or utilize a direct drive option where the hammer cushion is replaced by a steel striker plate. Ineffective hammer cushions in hammers requiring a cushion can cause damage to hammer striking parts, anvil, helmet or pile.

All cushion materials become compressed and stiffen as additional hammer impacts are applied. Therefore, hammer cushions eventually become ineffective, or may result in significant reduction in transferred energy or increased bending stress.

Cushions are used to protect both the hammer and the pile. Cushions that protect the hammer are called capblock cushions or hammer cushions. Hammer cushions are constructed of man-made materials that are heat resistant, durable and absorb a certain amount of shock.

Hammer cushions are used on all impact hammers except gravity (drop) hammers. They must be made of durable manufactured (man-made) materials. Wood, and asbestos are not allowed materials as hammer cushions. A striker plate must be used.

Common types of materials are polymer and aluminum/micarta and are in the form of disks 1/2” to 2” thick. Aluminum layers are typically added to the micarta to prevent fast deterioration of the cushion from heat. Another less common hammer cushion material is Hamortex, which is metal-coated paper tightly rolled. Hammer or capblock cushions should be periodically checked, as required by the specifications, by the inspector.

Keep in mind that a certain amount of disassembly is required of the Contractor to perform the observation, therefore, any time the Contractor has the capblock assembly open for some other reason, it is a good idea to check the hammer cushion. Hammer cushions must be inspected before the test pile begins and at intervals in accordance with the specifications.

The types of hammer cushions that are not permitted are asbestos and wood.

Let’s review the specification 455-5.3.1 Capblock: Provide a capblock (also called the hammer cushion) as recommended by the hammer manufacturer. Use commercially manufactured capblocks constructed of durable manmade materials with uniform known properties. Do not use wood chips, wood blocks, rope, or other material which permit excessive loss of hammer energy. Do not use capblocks constructed of asbestos materials.

Maintain capblocks in good condition, and change them when charred, melted, or otherwise significantly deteriorated. The Engineer will inspect the capblock before driving begins and weekly or at appropriate intervals determined by the Engineer based on field trial. Replace or repair any hammer cushion which loses more than 25% of its original thickness, in accordance with the manufacturer's instructions, before permitting further driving.

As inspector you to inspect the hammer cushion before starting any driving to verify the condition, type, dimensions and thickness of the cushion. In case of discrepancy with what the contractor submitted in the pile installation plan, contact the project administrator and inform him right away. In addition you will need to inspect it weekly or at appropriate intervals, depending on the amount of piles driven, to verify the condition and thickness of the hammer cushion.

Unfortunately to inspect the hammer cushion the hammer needs to be placed on the ground and the helmet needs to be disassembled to expose the cushions. You have to use common sense, if few piles or no piles are driven in a week, the contractor may not like it and it would not be necessary to inspect it after a week. Also, when the hammer cushion is due for inspection, talk with the contractor and find an appropriate moment in which the pile operation is suspended, or when the contractor is performing some maintenance or repairs on the hammer.

Let's talk about the pile cushions. They can be made of layers of plywood or oak lumber. They are used to protect concrete piles. They are placed between the top of pile and the helmet.

Pile cushions are used with concrete piles and made of pine plywood or oak lumber. The pile cushion will need to be replaced if compressed to more than one-half their original thickness, charred, starts to burn, splintered, or instructed by an Engineer.

Let’s review the specification 455-5.3.2 Pile Cushion: Provide a pile cushion that is adequate to protect the pile from being overstressed in compression and tension during driving. Use a pile cushion sized so that it will fully fill the lateral dimensions of the pile helmet minus one inch but does not cover any void or hole extending through the top of the pile.

Determine the thickness based upon the hammer-pile-soil system. For driving concrete piles, use a pile cushion made from pine plywood or oak lumber. Alternative materials may be used with the approval of the Engineer. Obtain the Engineer’s approval for all pile cushions.

Driving will generate compression stresses and tension stresses in the pile. Pile cushions are dimensioned to protect the piles against these two type of stresses. The lateral dimension of the pile cushions must be 1 inch smaller than the inside lateral dimension of the helmet.

In this picture, you can see a used pile cushion inside the helmet. The picture illustrates how the cushion compresses. The cables you see here are typically placed by the Contractor on top of the new cushion to make it easier to remove the used cushion from the helmet once the driving finishes.

Let’s continue with the specification. Do not use materials previously soaked, saturated or treated with oil. Maintain pile cushions in good condition and change when charred, splintered, excessively compressed, or otherwise deteriorated to the point it will not protect the pile against overstressing in tension and/or compression.

Protect cushions from the weather, and keep them dry. Do not soak the cushions in any liquid. Replace the pile cushion if, during the driving of any pile, the cushion is either compressed more than one-half the original thickness or begins to burn.

The message is clear from the specs: keep the cushions dry and do not add any water or liquid. We don' want the properties of the pile cushion disturbed which could affect significantly our blow count criteria.

Provide a new cushion for each pile unless approved otherwise by the Engineer after satisfactory field trial. Reuse pile cushions in good condition to perform all set-checks and redrives. Use the same cushion to perform the set-check or redrive as was used during the initial driving, unless this cushion is unacceptable due to deterioration, in which case use a similar cushion.

Let's talk about the term Re-strike: It is the action of hitting a pile after the initial driving and waiting a certain amount of time. This is done to evaluate changes in the capacity of the pile. In many cases piles tend to gain capacity with time after driving. This is called pile freeze or pile set-up. In some other less frequent cases, it has been seen that piles loses capacity. This is called relaxation.

Re-strikes require to be done with a used cushion, preferably the one that was used in the initial drive. In the specs there are two types of re-strikes defined depending on the amount of time waited. Set-checks: are when the re-strike is performed within a time not to exceed the following working day after the initial driving of the pile. Re-drives: are when the re-strike is performed after one working day following the initial driving of the pile.

We will see later on, that if a pile is not getting capacity within a foot of completing the length of pile, we will stop the pile driving and wait to perform a set-check, or a re-drive, or both, with the hope of getting the capacity through freezing.

Let’s take a look at specification 455-5.3.3 Pile Helmet: Provide a pile helmet suitable for the type and size of piling being driven. Use a pile helmet deep enough to adequately contain the required thickness of pile cushion and to assist in maintaining pile-hammer alignment.

Use a pile helmet that fits loosely over the pile head and is at least 1 inch larger than the pile dimensions. Use a pile helmet designed so that it will not restrain the pile from rotating. The main concept to retain here is that the helmet must be one inch larger than the pile dimension.

Next, in the pile driving system is Cranes and Leads.

It is not your responsibility to inspect the crane. The crane and leads should be the ones indicated on the Pile Installation Plan. The crane must be large enough to handle the leads, hammer and the pile. Cranes are usually rated based on their lifting capacity. For example, for a small pile driving job, a 50 to 100 ton crane is commonly used. Larger jobs and over-water jobs usually use heavier capacity cranes up to 250 tons or more.

The crane's boom should be long enough to reach about 30’ above the longest pile due to the height of the hammer and leads above the pile top. Longer booms are also required for special site conditions. The boom angle is proportional to the cranes lifting capacity. In other words, the greater the angle (from the vertical) the lower the lifting capacity.

Leads are used to align the pile and hammer during driving. There are numerous different lead designs as shown on the next slides. Box leads have been the most common on FDOT jobs in the past. Lead systems include three main types: swinging, semi-fixed, and fixed leads. Batter configurations are also shown.

There are, what seems to be an infinite number of combinations of pile driving equipment systems available. The equipment used is solely dependent on what the Contractor wants to use. The 455 Specification, however, does provide a guideline for certain equipment items.

The pile driving inspector is not responsible for equipment selection, but must compare which pieces of equipment the Contractor has on site to the Pile Installation Plan submitted by the Contractor. The intent of this section is to familiarize the inspector with basic pile driving equipment.

These types of leads are suspended from the crane line and can hang freely. There is not fixity at the bottom of the lead. In addition, there is no fixity in the top of the lead. When this type of leads is used the Contractor must use a template.

This type of lead have some restriction at the top. However it is not fixed at the bottom and the lead can swing in one direction. When this type of leads is used the Contractor must use a template.

Fixed Leads are fixed at the top and at the bottom. When this type of lead is used, the template is not required.

This slide shows a short video of a fixed lead in operation. Look how easy it is to handle and position the pile.

Let's look at the specification 455-5.4 Leads: Provide pile leads constructed in a manner which offers freedom of movement to the hammer and that have the strength and rigidity to hold the hammer and pile in the correct position and alignment during driving.

Next, in the pile driving system is an introduction to Templates.

Templates are required to ensure the piles are placed at the right location and the correct alignment. Templates are not required where fixed leads are utilized.

The template at your left does not provide neither good positioning nor the correct alignment. The one at your right offers both good alignment and positioning. Also, note the 4x4 lumber pieces to position better the piles and protect the pile surface from damage that could happen if the piles advance in direct contact with the steel from the template

When positioning templates that include batter piles, it must be remembered that the correct template position of batter piles will vary depending upon the template elevation relative to the pile cutoff elevation. For example, consider a template located 5 feet above pile cutoff elevation. If the plan pile locations at cutoff are used at the template elevation, a 1H:4V batter pile would be 15 inches out of location at the pile cutoff elevation. This problem is illustrated here. Template construction should also allow the pile to pass freely through the template without binding. Templates with rollers are preferable, particularly for batter piles.

Let's take a look at the specification 455-5.6 Templates: Provide a fixed template, adequate to maintain the pile in proper position and alignment during driving with swinging leads or with semi-fixed leads. Where practical, place the template so that the pile can be driven to cut-off elevation before removing the template. Ensure that templates do not restrict the vertical movement of the pile.

Supply a stable reference close to the pile, which is satisfactory in the opinion of the Engineer, for determination of the pile penetration. At the time of driving piles, furnish the Engineer with elevations of the original ground and template at each pile or pile group location. Note the highest and lowest elevation at each required location and the ground elevation at all piles.

Would this be an acceptable template? Does this meet the specification?

Next, in the pile driving system is an introduction to soil testing and the Standard Penetration Test. One of the plans and information you may need to deal with will be soil borings and soil information. They are taken during design by the Geotechnical Designer to determine the type of foundation and lengths.

In every bridge job, the plans will include what is called the Report of Core Borings, which is a graphic representation of the soil information obtained during the exploration phase of the project. The Report of Core Borings may be called outside FDOT Boring log drawings, soil profiles. Or a similar name.

Pictured here is a hammer utilized in the Standard Penetration Test. This particular one is an automatic hammer which is the one the Department now requires for soil investigation. This one offers the advantage of deliver a consistent energy as opposed from the ones operated manually.

This is a pictorial illustration of the SPT Test. The Standard Penetration Test is a field test performed during the advancement of a soil boring to obtain an approximate measure of the dynamic soil resistance, as well as a disturbed drive sample (split barrel type). The test is the most common In situ test worldwide, and you will see this information presented in your Report of Core Boring plans. In lesson 3 we will show you a typical Report of Core Boring plan.

The SPT is conducted at the bottom of a borehole that has been prepared using either flight augers or rotary wash drilling methods. At regular depth intervals, the drilling process is interrupted to perform the SPT. Generally, tests are taken every 2.5 feet at depths shallower than 10 feet and at intervals of 5.0 feet thereafter. However, for FDOT bridge projects is required to test every 2.5 to 3.0 ft. maximum interval.

The SPT involves the driving of a hollow thick-walled tube into the ground and measuring the number of blows to advance the split-barrel sampler a vertical distance of 1 foot. A drop weight system is used for the pounding where a 140-lb hammer repeatedly falls from 30 inches to achieve three successive increments of 6-inches each.

The first increment is recorded as a “seating”, while the number of blows to advance the second and third increments are summed to give the N-value ("blow count") or SPT-resistance (reported in blows per foot). If the sampler cannot be driven 18 inches, the number of blows per each 6 inch increment and per each partial increment is recorded on the boring log together with the penetration, reported to the nearest inch.

For partial increments, the depth of penetration is recorded in addition to the number of blows. Occasionally, a longer split-spoon is used and a fourth 6 inch increment is driven. This is to merely obtain additional soil sample and is not considered in the “N” value.

Next, in the pile driving system is an introduction to Special Installation Tools including Jets, Drills, Punches and Followers.

Jetting is the use of water or air to facilitate pile penetration by displacing the soil. In some cases, a high pressure air jet may be used in combination with water. Jets may be used to create a pilot hole prior to, or simultaneously, with pile placement. Jetting pipes may be located either inside or outside the pile. Jetting is usually most effective in loose to medium dense granular soils.

Let’s take a look at specification 455-5.7 Water Jets: Use jet pumps, supply lines, and jet pipes that provide adequate pressure and volume of water to freely erode the soil. Do not perform jetting without prior approval by the Engineer or unless allowed by the plans.

Do not perform jetting in the embankment or for end bents. Where conditions warrant, with approval by the Engineer, perform jetting on the holes first, place the pile therein, and then drive the pile to secure the last few feet of penetration. Only use one jet for pre-jetting or jetting through piles constructed with a center jet-hole.

Use two jets when using external jets. When jetting and driving, position the jets slightly behind the advancing pile tip (approximately 3 feet or as approved by the Engineer). When using water jets in the driving, determine the pile bearing only from the results of driving after withdrawing the jets, except where using jets to

continuously eliminate soil resistance through the scour zone, ensure that they remain in place as directed by the Engineer and operating during pile bearing determination.
Where practical, perform jetting on all piles in a pile group before driving begins.

Punching is used to break up obstructions such and rock material through which piles cannot be driven. They are used by dropping it repeatedly from a crane. This image shows a tool that combines the use of jet and punching.

Soil augers or drills is one of the tools frequently used to install piles. Predrilling is used to perform the following:

- Install piles by preforming holes or predrilling through soils with obstructions, such as old timbers, boulders, and riprap.
- Install piles through soil embankments.
- Drill a starter hole.
- To assist in the advancement of the piles through very dense materials that prevent the piles to reach a minimum penetration.
    - To reduce pile heave when displacement piles are driven at close spacings.
    - To predrill holes in order to minimize vibrations
    - Where jetting or punching are not allowed by the Contract documents.

Pictured above are continuous flight augers. On the left is a close-up of the drive head and on the right, the drive head and auger mounted. Soil augers or drills may sometimes be used where jetting is inappropriate.

Followers are structural members to assist in driving, when the top of the pile is below the reach of the hammer. For example when the pile is below water or when in a special situation a pile needs to be driven below the deck of an existing bridge. They are made of steel and must be designed properly and minimize the loss of energy transferred to the pile. Due to the compression of the follower and the losses in the connections.

Let's take a look at the specification 455-5.5 Followers: Use followers only for underwater driving. Obtain the Engineer's approval for the type of follower, when used, and the method of connection to the leads and pile. Use followers constructed of steel with an adequate cross-section to withstand driving stresses. When driving concrete piles, ensure that the cross-sectional area of the follower is at least 18% of the cross-sectional area of the pile. When driving steel piles, ensure that the cross-sectional area of the follower is greater than or equal to the cross-sectional area of the pile.

Provide a pile helmet at the lower end of the follower sized according to the requirements of 455-5.3.3. Use followers constructed that maintain the alignment of the pile, follower, and hammer and still allow the pile to be driven within the allowable tolerances. Use followers designed with guides adapted to the leads that maintain the hammer, follower, and the piles in alignment.

Use information from driving full length piles described in 455-5.1.2 compared to driving piles with the follower and/or dynamic load tests described in 455-5.13 to evaluate the adequacy of the follower and to establish the blow count criteria when using the follower.

Multiple Choice: Which of the following leads does not require the use of a template?

A. Swinging
B. Semi-fixed
C. Fixed
D. None require the use of a template

Multiple Choice: For piles on land, the template should be located___.

A. Within 2 feet of cutoff elev.

B. Within 5 feet of cutoff elev. or ground surface elev.

C. Within 10 feet of cutoff elev. or ground surface elev.

D. No specific requirement

Multiple Choice: When jetting & driving, the jets should be positioned approx. ___ ft. behind the pile tip.

A. 2

B. 3

C. 4

D. 5

Multiple Choice: Jetting in the embankment is permitted when ____.

A. Not permitted

B. Anytime

C. Embankment heights are less than 10 feet

D. Embankment heights less than 20 feet

In this lesson, we have covered the different pile installation equipment and tools. We studied the various pile types that you may encounter in FDOT projects. We have introduced pile driving equipment terminology. We also have covered the pertinent specifications regarding the pile driving system.

This concludes Lesson 2, please continue to lesson 3 by selecting the next lesson button on this page.