Lesson 5 – Test Pile Program Transcript

Welcome to the Pile Driving Inspector Course. This is Lesson 5, Test Pile Program. To begin, select the start button or press Shift+N on your keyboard.

The learning outcomes you will achieve during this lesson:

- Describe the Test Pile Program Process
- Describe the various pile testing methods
- Identify key elements of the Driving Criteria Letter

Let's read the specification 455-5.12.1 Purpose of Test Piles: Drive piles of the same cross-section and type as the permanent piles shown in the plans, in order to determine any or all of the following:

a) the installation criteria for the piles.
b) the nature of the soil.
c) the lengths of permanent piles required for the work.
d) the driving resistance characteristics of the various soil strata.
e) the amount of work necessary to obtain minimum required pile penetration.
f) the ability of the driving system to do the work.
g) the need for point protection

During the Test Pile program the Department typically engages a Geotechnical Engineer to monitor the test pile and dynamic load tests performed on production piles. This engineer is known sometimes as the dynamic test engineer. This engineer will make all decisions regarding the driving of the test pile.

However, the Inspector's duties in this phase are very similar to that of the Production piling. You will need to record all the activities and events related to the installation of the piles. Again the only difference here and your duties during regular production piles is that the geotechnical engineer will direct the contractor to change strokes and make decision of when to stop the piles. Coordination between Inspector and Geotechnical Engineer regarding comments and records is critical. The PA or you will schedule the Geotechnical Engineer.

You will be required to inspect activities such as:

- Piles, Delivery, Handling, Marking
- Verify the Equipment on site and inspect the hammer cushion prior to any driving in the job
- Ensure the Contractor Establishes Template and /or Reference Point Elevation
- Record the Driving of the pile, including notes and remarks of relevant incidents that happened during the driving of the test pile.

In the appendix of the manual you will find a full size version of the Pile Inspector checklist. This will assist you in all the steps of pile driving. Indicated in this slide are the items you are required to inspect in the early stages of the pile installation and the items you need to check prior to and during the test pile program.

Let's keep reading the specification regarding test pile focusing on the highlighted portion. Because test piles are exploratory in nature, drive them harder (within the limits of practical refusal), deeper, and to a greater bearing resistance than required for the permanent piling.

Test piles will be driven and longer than production piles. The Dynamic testing engineer will try to collect as much information as possible during the test to facilitate his analysis during the estimation of pile lengths and driving criteria later on.

As a minimum, unless otherwise directed by the Engineer, do not cease driving of test piles until obtaining the required bearing capacity continuously, where the blow count is increasing, for 10 feet unless reaching practical refusal first. As said before, test piles will require longer driving. They require 10 ft. of capacity as opposed to production piles that require 2 feet.

When test piles attain practical refusal prior to attaining minimum penetration, perform all work necessary to attain minimum penetration and the required bearing. The minimum penetration requirements and minimum tip elevations still need to be met for test piles.

When driving test piles other than low displacement steel test piles, have preforming equipment available at the site and water jets as specified in 455-5.7 when jetting is allowed, ready for use, before the test pile driving begins. Note: Article 455-5.7 is the article of the specifications that deals with water jets. We reviewed this specification in lesson 2 when we were covering the Pile driving system.

The Engineer may elect to interrupt pile driving up to four times on each test pile, two times for up to two hours and two additional times during the next working day of initial driving to determine time effects during the driving of test piles. The Dynamic testing engineer may decide to do several set-checks as this spec mentions. In certain types of soils it may be even required to interrupt the driving longer, say for several days and perform re-drives.

Specification 455-5.12.2 Location of Test Piles: Drive all test piles in the position of permanent piles at the designated locations. Ensure that all test piles designated to be statically load tested are plumb. In the event that all the piles are battered at a static load test site, the Engineer will designate an out-of-position location for driving a plumb pile for the static load test.

Specification 455-5.12.3 Equipment for Driving: Use the same hammer and equipment for driving test piles as for driving the permanent piles. Also use the same equipment to redrive Piles. Any change on the driving system, including hammer and hammer cushion types will require a review of the driving criteria by the Geotechnical Engineer. Furthermore, a change of hammer or a hammer repaired on site or removed from the site and returned, is considered to have its performance altered. This is considered a change in the driving system and is subject to a Dynamic Load Test to verify or recalibrate the blow count driving criterion.

We will now talk about the methods of testing piles. Typically, driven piles are tested dynamically. Dynamic testing may consist of a Pile Driving Analyzer (PDA) or Embedded Data Collectors (EDC). Projects may also include static load tests. These are typically not common due to their cost.

When using an open-ended Diesel hammer, the specifications require that the Contractor provides a device to measure the stroke at every blow. Stroke is the height of impact of the hammer ram. The most common device used is the saximeter. Instructions for operating the Saximeter are located at the end of this lesson.

Inspectors need to become familiar with the saximeter use. Remember that in Florida the hammer that is used the most is the open ended Diesel Hammer. We suggest you read the instructions of the saximeter to be used, play with it and ask questions to the District Geotechnical Office or the Geotechnical Consultant Engineer in charge of the dynamic testing activities if you have any doubts regarding the use of the saximeter.

No drive must occur without a saximeter. Remember that as per specification 455-5.2.2 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.

You will see in the video how the saximeter works. The saximeter measures the time between two consecutive blows and calculates the blows per minute or BPM. This is indicated under the heading BPM in the picture shown here. Based on the blows per minute value, it computes the stroke and it is displayed under the H heading. In addition the saximeter keeps count of the number of blows happening between foot marks in the pile.

In the current picture what you see is the following: The upper row, under the heading called LAST the saximeter indicates the average values of the stroke during the last foot increment. In the picture shown, the average stroke of the last increment was 6.6 ft. The average BPM was 52 blows per minute. The total number of blows measured in the last foot increment was 46 blows. The total blows since the beginning of the driving is 130, which is indicated next to TOTAL. These values get updated every time the inspector hits the AVG key after he sees a foot increment being completed. These values should be input in the pile record as the pile advances.

The second row displays the instantaneous reading at every blow. For example for the particular blow that just happened in the picture, the stroke was 4.9 ft., the blows per minute measured for the particular blow is 53. The number of blows accumulated in the current foot increment is 65. After you hit the average key the next blow BN in the NOW row will be shown as 1. In the LAST row it will show the total number of blows accumulated for the foot increment you just passed.

Pile Driving Analyzer (PDA). The PDA is a portable computer built rugged for the field environment. The PDA uses specially designed strain transducers and accelerometers as the basis for its data acquisition. The Dynamic pile test involves attaching these gauges near the pile top (generally two pile diameters down from the top) with bolts or anchors to concrete, steel or timber piles.

The PDA has also been used for auger piles and drilled shaft caissons. During driving, the PDA processes signals from the gauges and calculates values in real time for each hammer blow. Required PDA user inputs include pile length, cross-sectional area, elastic modules, pile materials wave speed, weight of hammer ram, weight of hammer bonnet, and an assumed soil damping coefficient.

The PDA computes over 30 quantities. The most typically reported are the ultimate static bearing capacity as calculated by the case method, maximum compressive and tensile stresses, pile integrity, maximum hammer transferred energy, hammer operating rate and ram stroke height for diesel hammers.

In the field, engineers view the force and velocity stress waves on the computer monitor to evaluate data quality, pile integrity and aspects of soil resistance. The PDA is capable of storing all the blows on its hard disk which is replayed in the office during a more detailed analysis.

One of the important parameters that are measured during the dynamic testing is the stresses. This slide illustrates the difference between tension stress and compression stress. This is important to monitor because stresses may damage piles. Concrete piles may get damaged by both tension and compression stresses, while typically steel piles get damaged by compression stresses, especially at the tip. This slide illustrates how high tension stresses and high compression stresses may develop during pile driving.

On the left side is the case of easy driving, when there is little or no resistance in the soil at the tip of the pile. In this case, the downward force from the impact wave pulls the pile particles downward and the force waves are reflected upward as a tension wave that pulls the particles downward. This typically affects the bottom one third of the pile. In cases of easy driving and when driving concrete piles, you may see the dynamic testing engineer reducing the strokes to reduce the tension stresses or in some cases stop the driving to add cushion material. Also in the driving criteria letter, you may see special provisions and limitations of the stroke to avoid high tension stresses. The longer the concrete piles the more susceptible they are to generate high tension stresses.

On the right side of the slide is the case of a hard layer at the tip of pile. In this case, the downward reflected force is canceled by the soil resistance preventing elongation of the pile. In this case the reflected upward wave is in compression pushing the particles upward. The internal tension forces are very low in this case.

PDA uses externally mounted sensors locate at the top of the pile. In this picture you see the dynamic testing engineer drilling holes to attach the sensors.

In this slide you see the inspector next to the dynamic testing engineer. This is a good opportunity for the Inspector to ask questions of the Geotechnical Engineer and perhaps gain a little additional insight in to how the piles are going to drive on the Project.

This is also a great time to check the Saximeter. It should be recording stroke heights fairly equal to the PDA. If it is not, have it repaired or replaced. The PDA is more accurate than the Saximeter. Though the Geotechnical Engineer is in responsible charge of the Test Pile driving, you, as the Inspector are responsible to record all data, just like a production pile.

This image shows a PDA display of the data collected during one blow of driving. Next, we will show an enlarged detail in the next slide to see better what kind of information the PDA shows.

This image shows an enlarged detail of the right side of the previous slide. The PDA operator can monitor some important parameters on the display such as the Ultimate Bearing Capacity, Driving Stresses, Hammer Performance, Pile Integrity and Stroke. Let's discuss these.

Ultimate Bearing Capacity - The piles' ultimate capacity is usually the main interest in most pile driving projects. The PDA provides Case method computations for ultimate bearing capacity with nine different methods. In the slide, RX5 and RX8 are ultimate bearing capacities that are estimated for specific soil damping values.

Driving Stresses - During driving, piles are subjected to compressive tensile, flexural and torsional forces. Overstressing the pile material usually results in damage. The PDA computes both the tension and compression stresses in the pile for each hammer blow. In the image, CSX, CSI are compression stresses. TSX is the maximum tension stress estimated in the pile.

Hammer Performance - The PDA can evaluate a variety of quantities which can be used to evaluate the performance of a pile driving hammer. The most useful is the maximum transferred energy (EMX) from the hammer to the pile at the gauge locations.

Pile Integrity - The integrity factor, Beta, is a measure of the piles remaining cross-sectional area or reduced modulus. The location of the damage is determined based on the force and velocity wave reflecting prior to the actual pile toe. Stroke: That is STK in the image.

The Embedded Data Collector system is an alternate method to the PDA to instrument prestressed concrete piles during dynamic testing. This new technology uses two levels of instrumentation, embedded in the body of precast prestressed concrete piles near the head and tip. Strain and acceleration measurements obtained at these instrumentation levels during driving are sent wirelessly to a receiver in the field, and analyzed in real time to provide the operator with estimates of static capacity, stresses in the pile, transfer energy, damping factor, stroke height, and other relevant parameters used to evaluate the pile driving process and the driving system.

This image shows how the EDC system works. There are gauges at the top and at the bottom of the pile. Strain and acceleration measurements obtained at these instrumentation levels during driving are sent wirelessly to a receiver in the field, and analyzed in real time to provide the operator with estimates of static capacity, stresses in the pile, transfer energy, damping factor, stroke height, and other relevant parameters used to evaluate the pile driving process and the driving system.

This image shows a pile being poured with the embedded gauges.

Here is a screen display of EDC data during the instrumentation of one particular blow. The EDC system measure accelerations and strains at the top and bottom and can determine stroke, driving stresses, bearing capacity, energy transferred and pile integrity.

With top and tip gauges, accurate assessment of side friction and tip components of pile capacities is possible. In addition, having a strain gauge near the tip of the pile allows for a more accurate direct measurement of the compression stresses at the tip, as opposed to the PDA, which estimates the tip stresses based on readings at the top of the pile. This is a very important feature to control the tip compression stresses on concrete piles that need to be driven through very dense or hard layers, before reaching the required minimum penetration, or piles that are founded on very dense or hard layers.

The new system tracks the change in strain/stress within the pile during driving and may be readily used to assess damage (i.e. and loss of prestress), which may be used to control the hammer (i.e. fuel settings) or stop the driving to prevent further damage. The tip gauges warn the EDC operator when excessive loss of prestress is occurring and the integrity of the pile may be impacted.

Let’s review what the specifications say about Dynamic Load Tests. The Engineer will take dynamic measurements during the driving of piles designated in the Plans or authorized by the Engineer. All test piles will have dynamic load tests.

The Engineer will perform Dynamic Load Tests to evaluate any or all of the following:

1. Evaluate suitability of Contractor's driving equipment, including hammer, capblock, pile cushion, and any proposed follower.
2. Determine pile capacity.
3. Determine pile stresses.
4. Determine energy transfer to pile.
5. Determine distribution of soil resistance.
6. Evaluate soil variables including quake and damping.
7. Evaluate hammer-pile-soil system for Wave Equation analyses.
8. Evaluate pile installation problems.
9. Other issues, such as the variability of capacity with time.

When directed by the Engineer, perform instrumented redrives. Do not use a cold diesel hammer for a redrive unless in the opinion of the Engineer it is impractical to do otherwise. Generally, warm up the hammer by driving another pile or applying at least 20 blows to a previously driven pile or to timber mats placed on the ground.

Let's now talk about Static Load Tests. In this type of test, the desired load is applied gradually to the test pile. The pile is tested to a load of at least the nominal bearing capacity required computed during the design phase.

Static Load tests have the following advantages: The load is applied gradually which simulates better the actual load conditions than a dynamic load test, there is Extensive instrumentation Possibilities, and it is repeatable. However static load tests have the following disadvantages: It is Time consuming and expensive, it is Extensive setup & teardown, and there are certain Manpower requirements.

These images illustrate a typical static test arrangement. The load is applied through a jack that uses a beam as reaction. The reaction beam transfers the load to reaction piles (see steel piles around the concrete pile in the picture).

These pictures illustrates a typical arrangement for a tension test. In this case, the steel bars are extended from the pile, and the jack pulls the pile through these bars. The jack pushes against the reaction beam, which in turn transfers the load to the reaction piles or footings.

Lateral load tests are not very common on piles. Pictured here is a lateral load test in a shaft. The test pile, or test shaft in this case, is pushed away from a reaction shaft. The load is applied as a shear at the top level of the pile or shaft. Both lateral deflections at the top of the shaft and the slope of the shaft at the head and along the shaft can be measured.

Multiple Choice: The Saximeter is typically used to determine____.

A. The number of blows per foot

B. The total number of blows on the pile

C. The average stroke height

D. All of the above

Multiple Choice: Which of the following is not a function of the Pile Inspector during the Test pile program?

A. Verifying equipment matches the Pile Installation Plan

B. Monitoring MOT

C. Recording the pile driving operation

D. Coordinating with the Geotechnical Engineer

Following the driving and testing of the test pile(s), the Geotechnical Engineer generates several documents written to the Contractor, which are extremely important to the Inspector. They are the Authorized Length Letter and the Driving Criteria Overview.

Upon the completion and evaluation of the test pile program, the Department issues an authorized pile length letter. This letter is usually issued as soon as practical after the end of the test pile to permit the Contractor to order piles from the prestressed concrete yard.

A driving criteria letter is issued by the Department which the inspector will use to verify that the production piles for the job will obtain the capacities specified in the plans and are not damaged during installation. The information that was obtained during the test pile program is used to develop this letter. The driving criteria letter which the inspector should have a copy of in his possession at all times during pile driving, sets out the parameters for the inspector's construction control.

The driving criteria letter will set the required blow counts based on hammer energy (stroke). It will also set parameters for initial driving, such as using a reduced fuel setting to control stresses in the pile during early driving. The driving criteria will also address issues such as allowing for scour resistance, jetting, set-check, redrive information and when to consider that a practical refusal condition has been achieved.

This is an example of a driving criteria letter. Let’s examine the contents of this letter. The letter will include project data such as project name, project number, bridge number and county.

The letter will include the required instruction and criteria for specific bents or piers to accept the piles. Piles will be accepted when the following two conditions are met:

- Bearing Capacity requirement has been met and
- Penetration or minimum tip elevation has been met. If the plans indicate a minimum tip elevation the piles have to reach at least this elevation or deeper. If the plans do not show a minimum tip elevation, then the required penetration requirements of the specifications must be met. We will cover the specification requirements in Lesson 7.

The letter includes a definition of practical refusal. When the hammer is adequately sized, a refusal condition will meet the capacity requirements. Regarding practical refusal, note that it is defined as 20 blows per inch, not 240 blows per foot.

Piles, especially concrete piles, should not be driven excessively to prevent damage. Piles driven more than 1 or 2 inches with over 20 blows per inch may get damaged at the tip. To assist the inspector in determining when a pile meets the bearing requirements; a blow count vs. stroke table is included. Please note that this blow count is specific for the hammer being used to drive the piles.

Here is an example of the driving criteria requirements for the interior bent 2. Note the practical refusal definition, required minimum penetration requirements and the stroke height vs. blow count requirements.

The driving criteria letter will also include specific instructions that indicates to the inspector how the hammer should be operated. A maximum stroke height allowed is included. This is typically included to prevent excessive compression stresses or tension stresses. Also, note how beginning stroke heights are indicated and also how the strokes may be increased or should be decreased. These are typically included to prevent excessive tension stresses in easy driving that may damage concrete piles.

Also, the driving criteria will indicate the required pile cushion thickness, the particular driving hammer and hammer cushion for which the criteria was developed and the augering and jetting requirements. Please note that the criteria is developed for a specific pile driving system. Changes in the hammer driving system will require revisions in the different driving criteria letter. If the contractor makes changes in the driving system additional dynamic load testing may be required to revise the driving criteria.

Here is a typical Pile Driving Letter. The letter will include the project data and an itemized list of authorized pile lengths for each bent or pier.

Please perform this exercise. Enter your answer in the text field and then select the “check answer” button to reveal the correct answer. The table indicated here is the record of the last feet, between 19 feet and 25 feet, of a pile being driven. Use the Driving Criteria blow count requirement at the bottom of the page.

Did the pile achieve 2 consecutive feet of driving criteria? YES
…at what depth? 23’-25’

Let’s review the requirements regarding test pile lengths and production pile lengths: Test Pile Length: Provide the length of test piles shown in the plans or as directed by the Engineer.

Production Pile Length: When shown in the plans, the lengths are based on information available during design and are approximate only. The Engineer will determine final pile lengths in the field which may vary significantly from the lengths or quantities shown in the plans.

The test pile lengths are given in the plans. The production pile lengths will be determined construction after the test piles are performed. There may be some projects that have no test piles. These projects require a good soil investigation during design, available PDA data and very good existing pile records.

Authorized Pile Lengths: The authorized pile lengths are the lengths determined by the Engineer based on all information available before the driving of the permanent piles.

The Contractor may elect to provide piling with lengths longer than authorized to suit his method of installation or schedule. When the Contractor elects to provide longer than authorized pile lengths, the Department will pay for the furnished length as either the originally authorized length or the length between cut-off elevation and the final accepted pile tip elevation, whichever is the longer length.

In this lesson we have covered the following topics:

- Describe the Test Pile Program Process
- Describe the various pile testing methods
- Identify key elements of the Driving Criteria Letter
- Identify key elements of the Authorized Pile Length Letter

This concludes Lesson 5, please continue to lesson 6 by selecting the next lesson button on this page.