

**S T A T E**

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**T E N N E S S E E**

(Rev.12-20-19)  
(Rev.4-11-22)

January 1, 2021

**SPECIAL PROVISION**

**REGARDING**

**DYNAMIC PILE TESTING**

**General**

**A. Scope of Work**

This work consists of assisting the Consultant Testing Engineer (CTE) with the dynamic testing of driven piles as specified.

The Department will select a qualified CTE that will be utilized to perform the testing.

**B. Performance and Design Requirements**

Performance and design conditions for dynamic testing of driven piles shall be in accordance with subsection High-Strain Dynamic Pile Testing Specification.

**C. Approved Manufacturers**

The following hardware and software components are recognized to provide the level of quality required. Substitutes may be accepted at the discretion of the Department Engineer.

<b>Component</b>	<b>Product</b>	<b>Manufacturer</b>
Pile Driving Modeling - Wave Equation Software	<u>GRLWEAP</u>	Pile Dynamics, Inc.
Pile Driving Monitoring - Hardware & Software	Pile Driving Analyzer - Model PAX or PDA 8	Pile Dynamics, Inc.
Pile Driving Analysis – Signal Matching Software	<u>CAPWAP</u>	Pile Dynamics, Inc.

**D. Test Requirements**

Dynamic pile testing shall be conducted in accordance with the standard test method indicated below.

<b>Standard Test Method</b>	<b>Designation</b>	<b>Conducted By</b>
High-Strain Dynamic Testing of Piles	ASTM D 4945	CTE

**E. Qualifications Of Department’s CTE**

The CTE that performs the pile driving dynamic monitoring shall have a minimum of 3 years dynamic pile testing and analysis experience and shall have achieved a basic or better rank on the Dynamic Measurement and Analysis Proficiency Test offered by the Pile Driving Contractors Association. The CTE who performs the driving modeling and signal matching shall have a minimum of 5 years dynamic pile testing and analysis experience or who has and shall have achieved an advanced or better rank on the Dynamic Measurement and Analysis Proficiency Test offered by the Pile Driving Contractors Association.

**Execution**

**A. Pile Driving Modeling**

Submit to the Engineer the hammer specifications that will be used in driving the piles. The CTE shall perform preconstruction wave equation analyses and prepare a summary report of the results. The wave equation analyses shall be used to assess the ability of all proposed pile driving systems to install piles to the required nominal axial resistance and the desired penetration depth within allowable driving stresses. The report shall include a drivability graph relating pile capacity, blow count and driving stresses to depth. The report shall include a bearing graph relating the nominal axial resistance to the pile driving resistance. The bearing graph shall indicate blow count versus capacity and stroke. The report shall also contain a constant capacity analysis or inspector’s chart to assist the engineer in determining the required driving resistance at other field observed strokes. The CTE shall perform wave equation analyses in accordance with subsection High-Strain Dynamic Pile Testing Specification. Acceptability of the wave equation report and the adequacy of analyses will be determined by the Engineer.

1. Approval by the Engineer of the proposed pile driving system will be based upon the wave equation analyses indicating that the proposed system can develop the required nominal axial resistance at a pile driving rate of 2 to 10 blows per inch at the end of driving, and within allowable driving stresses per *the current addition of the AASHTO LRFD Bridge Design Specifications*, subsection 10.7.8 using a resistance factor of 1.0. The CTE shall provide preliminary pile driving criteria based on wave equation analyses and any anticipated capacity changes after driving, set-up or relaxation, subject to revision based upon dynamic pile testing field measurements
2. If any changes or modifications are made to the approved pile driving system, additional wave equation analyses in accordance with subsection A shall be required.

**B. High-Strain Dynamic Pile Testing**

1. Assist the Department's selected CTE with dynamic pile testing at the locations and frequency required in accordance with subsection High-Strain Dynamic Pile Testing.
2. Dynamic pile testing involves monitoring the response of a pile subjected to heavy impact applied by the pile hammer at the pile head. The testing shall provide information on the driving stresses, nominal axial resistance, structural integrity, and hammer efficiency.
3. All field testing and measurements shall be made in the presence of the Engineer.

**C. Field Testing**

1. **Equipment.** Dynamic pile testing field measurements shall be carried out using approved equipment, software and recording equipment. The data collected at the end of initial driving and the beginning of re-strike shall be analyzed using approved signal matching techniques and software.
2. **Monitoring during driving.** During pile driving, piles shall be instrumented and monitored with testing equipment satisfying the requirements of the subsection C. Approved Manufacturers.
  - a. At the direction of the Engineer, assist with installing two sets of strain transducers and accelerometers near the top of each pile to be tested, and shall use a compatible measuring and recording system to record the blow count data during driving.
  - b. The equipment required to be attached to the pile shall be appropriately positioned and fixed to the approval of the Engineer.
  - c. The hammer and all site equipment used shall be capable of delivering an impact force sufficient to mobilize the specified nominal axial resistance indicated in subsection High-Strain Dynamic Pile Testing Specification without damaging the pile.
  - d. The testing equipment shall monitor pile stresses during driving to prevent pile damage and ensure pile integrity and capacity. If the testing equipment indicates overstressing or damage to the pile, immediately discontinue driving.
  - e. If the testing equipment determines that pile stresses during driving exceed acceptable levels, a new pile driving system, modifications to existing system or new pile installation procedures shall be proposed by the Contractor. Approval by the Engineer of any proposed changes to the pile driving system or pile installation procedures will be based upon the results of additional wave equation analyses in accordance with subsection A.2, Pile Driving Modeling.

- 3. Preparation of the Pile Head.** The preparation of the pile head for the application of dynamic test load shall involve, where appropriate, trimming the head, cleaning, and building up the pile using materials that shall, at the time of testing, safely withstand the impact stresses. The impact surface shall be flat and at perpendicular to the pile axis.
- 4. Dynamic Measurement and Analysis.** Monitoring of pile driving shall begin when pile driving begins, unless otherwise approved by the Engineer. The data shall be recorded and processed immediately in the field by the pile driving monitoring equipment and software. Unless monitoring indicates that additional driving will damage the pile, pile driving, and monitoring shall continue until both the specified pile tip elevation and the required nominal axial resistance are reached. For each pile tested, pile driving analysis using signal matching techniques shall be performed for a selected blow at the end of driving to determine the relative resistance from end bearing and skin friction along the pile.
  - a.** Re-strike tests shall be performed at the frequency indicated in subsection High-Strain Dynamic Pile Testing Specification. The time interval between end of initial driving and beginning of re-strike shall be in accordance with subsection High-Strain Dynamic Pile Testing Specification. During re-strike, the pile shall be instrumented and monitored similar to during initial driving. For each re-strike test, pile driving analysis using signal matching techniques shall be performed for a selected blow from the beginning of re-strike to determine the relative resistance from end bearing and skin friction along the pile.
  - b.** The re-strike test shall be performed with a warmed-up hammer and shall consist of striking the pile for 20 blows or until the pile penetrates an additional 3 inches whichever occurs first unless testing equipment indicates overstressing or damage to the pile. If such overstressing or damage to the pile is indicated, immediately discontinue driving. In the event initial re-strike testing indicates a nominal axial resistance below the required nominal axial resistance additional driving may be required as directed by the Engineer.
  - c.** The Engineer may request use of pile driving monitoring equipment and software on additional piles if inconclusive results are obtained or unusual driving conditions are encountered.
  - d.** Pile nominal axial resistance and integrity shall be evaluated based on the standard procedure used in practice.

**5. Results**

**Reports.** The CTE shall prepare a report for each pile tested. Each report shall contain tabular and detailed graphical results for the dynamic test versus depth, blow analyzed using signal matching techniques and software, and indicate the pile driving criteria for the additional piles to be installed at the substructure unit of the pile tested. Each report shall include the information required by ASTM D4945 Section 7 and the following:

- 1) The maximum force applied to the pile head.
- 2) The maximum pile head velocity.
- 3) The maximum energy imparted to the pile.
- 4) The assumed soil damping factor and wave speed.
- 5) Nominal axial resistance estimate.
- 6) The maximum compressive and tensile forces in the pile.
- 7) Pile integrity.
- 8) Blows per inch.
- 9) Stroke.
- 10) Blow selected for signal matching analysis.
- 11) Temporary compression.
- 12) Force/velocity versus time trace.
- 13) Force/velocity match curve.
- 14) Resistance distribution along the pile.

**Schedule of Contract Submittals**

<b>Item Number</b>	<b>Submittal Item</b>	<b>Type</b>	<b>Calendar Days</b>	<b>Event/Date</b>	<b>Liquidated Damages Apply</b>
1	Details of the components, method of testing, pile driving equipment and materials to be used.	DOCS	15 Before	Start of Pile Driving Monitoring	No
2	Report as defined in subsection C.5.a	DOCS	3 After	Completion of Each Field Test	No

**High-Strain Dynamic Pile Testing Specification**

<b>Item</b>	<b>Requirement</b>
Wave Equation Analysis	Minimum of 1 and sufficient additional analyses as needed to define performance for all combinations of piles, driving systems and subsurface conditions anticipated.
Dynamic Testing Pile Capacity	Nominal Axial Pile Compressive Resistance
End of Initial Driving Test Frequency	Minimum of 1 production pile for substructure or as required by the Engineer.
Re-strike Test Frequency	The greater number of piles: 1 production pile for substructure, or 2% of production piles at each substructure, or Quantity required by the Engineer.
Time Interval between End of Initial Driving and Re-strike	Minimum of 3 days or as required by the Engineer.
Pile Driving Analysis using Signal Matching Techniques	For each End of Initial Driving Test and each Re-strike Test

**Method of Measurement**

The Department will measure Dynamic Pile Testing (PDA) and Dynamic Pile Re-strike Testing, performed, and accepted per each.

**Basis of Payment**

The Department will pay for accepted quantities, complete in place, at the contract prices as follows:

Item	Description	Pay Unit
930-01.01	PDA TESTING	EACH
930-01.02	PDA RE-STRIKE	EACH

Such payment is full compensation for all described work, including all material, equipment, tools, labor, and any other incidentals necessary to complete the work