Supplemental Specification
901-S-803-1
LFRD Driven Pile
Specifications.

OFFICE OF STATE AID ROAD CONSTRUCTION
MISSISSIPPI DEPARTMENT OF TRANSPORTATION

DATE: May 24, 2010

SUBJECT: LRFD Driven Pile Specifications

Delete subsections S-803.01 to S-803.03.1.11 on pages 8-8 to 8-20, and replace with the following:

S-803.01--General.

S-803.01.1--Description. This work consists of furnishing and installing deep foundations in accordance with these specifications and in reasonable conformance with the lines, elevations, and spacing's shown on the plans. It shall also consist of furnishing all required labor, tools, and equipment to determine the bearing value of the deep foundation according to Load and Resistance Factor Design (LRFD) by static load testing, by dynamic load testing, and/or by driving of the specified test piles.

S-803.01.2--Order Lists for Deep Foundations. Lengths found in the plans are estimated lengths for bid purposes. Unless otherwise specified or authorized in writing by the Engineer, with the concurrence of the State Aid Bridge Engineer, all permanent deep foundations shall be installed within the prescribed tolerances specified herein and to the depths and/or lengths indicated on the itemized Order List furnished by the Engineer. The Order List shall be furnished after bearing has been verified either through static load testing, dynamic load testing, and/or driving of the specified test piles.

In general the penetration for any pile shall be: not less than five feet in hard material, not less than one-third the length of the pile, or less than twenty (20) feet in soft material. For foundation work, no piling shall be used to penetrate a very soft upper stratum overlying a hard stratum unless the piles penetrate the hard material a sufficient distance to rigidly fix the ends. If scour is predicted then the Engineer shall account for the potential loss of skin friction over the area of the pile in the scour zone.

The Contractor shall furnish or install driven piles and/or drilled shafts in accordance with an itemized list furnished by the Engineer. The Order List will show the required length of the piles or drilled shafts for each bridge bent or footing.

S-803.02--Materials. All materials shall conform to the applicable requirements set forth in S-710, S-711, S-719, S-804, and S-814.

Driven piles shall conform to all applicable requirements set forth in S-719 and the plans. Paint for steel piles or steel shells shall conform to the applicable requirements of S-710 and S-814.

Drilled shaft concrete shall conform to the requirements of S-804 for Class "DS" concrete. All reinforcing steel shall conform to the requirements of S-711 of the Specifications.

S-803.03--Construction Requirement. This work shall consist of furnishing all labor, materials, equipment and services necessary to install driven piles of the prescribed type in accordance with these specifications and in conformance with the lines, elevations, and spacing's shown on the plans.

This work shall also consist of furnishing all labor, materials, equipment and services necessary to perform all operations to complete the drilled shaft installations in accordance with these specifications and with the details and dimensions shown on the plans. Drilled shafts shall consist of reinforced or nonreinforced concrete with or without concrete bell footings.

S-803.03.1--Driven Piles.

S-803.03.1.1--General. Unless otherwise specified or authorized by the Engineer, all permanent production piles shall be driven in a continuous operation, to the full lengths indicated on the itemized order list furnished by the Engineer, with the concurrence of the State Aid Bridge Engineer.

S-803.03.1.2--Accuracy of Installation. Driven piles in trestle bents shall be driven to within a tolerance of 1/4 inch per foot from the vertical or from the batter shown on the plans. Piles to be incorporated into a cap or footing shall not be out of the position shown on the plans by more than six inches. In all cases, piles shall be driven so that they will not be excessively stressed to place them in the proper location in the cap or footing. Excessive manipulation of the piles will not be permitted, and the Contractor shall redrive or use other satisfactory methods to avoid such manipulations. No shimming on tops of piles will be permitted.

S-803.03.1.3--Extensions, Build-ups and Splices. If determined by the Engineer to be necessary, production piles that are extended below cut-off shall be extended, built-up, or spliced in accordance with the plans to the extent established by the Engineer, with the concurrence of the State Aid Bridge Engineer. Extensions or build-ups will not be measured for payment as such, but will be included in the total length of piling in the finished structure.

S-803.03.1.4--Cut-Offs. If it is determined by the Engineer, with the concurrence of the State Aid Bridge Engineer, that the pile has reached practical refusal above pile cut-off elevation but

below the prescribed minimum tip elevation shown in the plans then the Contractor will be allowed to cut off the pile at the cut-off elevation.

S-803.03.1.5--Driven Pile Types. Driven piles shall be of the type listed below unless otherwise specified in the plans.

S-803.03.1.5.1--Concrete Piles. Concrete piles shall be the size and shape specified. Reinforcement, unless otherwise designated, shall have a clear distance of at least two inches from the face of the pile. When the piles are for use in salt water or alkali soils this clear distance shall be at least three inches.

S-803.03.1.5.2--Steel Piles. Full-length piles shall be used unless splicing is approved in writing by the Engineer, with the concurrence of the State Aid Bridge Engineer. When permitted, splicing shall be in accordance with the notes and details shown on the plans. When authorized, splices will be paid for in accordance with S-803.05.8.

S-803.03.1.5.3--Timber Piles. Timber piles shall only be used for temporary construction and shall meet the requirements set forth in S-820.

S-803.03.1.5.4--Special Piles. Piles not of the type specified above, but called for in the plans or additional specifications shall meet the general requirements contained therein.

S-803.03.1.6--Preparation for Driving.

S-803.03.1.6.1--Excavation. When a pile cap is located below the ground line, piles shall not be driven until the required excavation is completed. All material forced up between the piles shall be removed to the correct elevation at the Contractor's expense before concrete for the foundation is placed.

S-803.03.1.6.2--Pile Cushions. Suitable cushioning material shall be used between the driving helmet and the top of the pile. This is especially critical for concrete piles. The Contractor should submit the type material, cross-sectional area and total thickness of the pile cushion. This information shall be submitted to the Engineer for approval prior to driving piling. The pile cushion shall be approved with the pile driving system and is subject to satisfactory field performance.

S-803.03.1.7--Method of Installation and Driving System.

S-803.03.1.7.1--General. The pile driving system shall be defined as all equipment necessary to install the specified piles to the required minimum tip elevations specified in the plans. The pile driving system shall include the pile hammer, hammer leads, followers, water jets, drilling equipment for pre-formed pile holes, and templates, if necessary.

S-803.03.1.7.2--Submittal of Pile Driving System Data. The Contractor shall submit to the Engineer all technical specifications and operating instructions relating to the pile driving system that is to be used to drive the piling. The Contractor shall submit this data to the Engineer at the pre-construction conference or no later than 14 days prior to the anticipated driving date. The Engineer shall use the data to assess the ability of the proposed driving system to install the piles to the desired penetration without unwarranted damage to the pile in accordance with LRFD. If a drivability analysis is not conducted, design stress shall be limited as prescribed in LRFD. The Contractor will not be allowed to install any piling until the driving system has been approved by the Engineer.

The Engineer will notify the Contractor of any additional information required and/or changes that may be necessary to meet the project requirements. Any parts of the driving system that are unacceptable will be rejected and the Contractor will submit changes. Review of these changes will be completed within seven (7) days and the Contractor notified of their acceptance or rejection.

All production piles shall be driven with the hammer bearing the same Serial Number originally submitted to the Engineer and used to drive the test piles. In the event multiple hammers of differing type are used on the same bridge, the Contractor shall submit to the Engineer for approval, data for each hammer and specify the bridge bents in which each hammer will be used. This will allow the Engineer the opportunity to develop appropriate driving and acceptance criteria specific to each hammer.

A different pile driving system, modifications to the existing system, or different pile installation procedures shall be proposed by the Contractor if the Engineer determines the system does not conform to LRFD or if problems in driving the piling are encountered. All approvals are conditional and subject to trial and satisfactory performance in the field. Unless otherwise permitted by the Engineer in writing, test piles and permanent piles shall be driven with the approved driving system.

S-803.03.1.7.3--Pile Hammers. Piles may be driven with an approved single-acting or double-acting pile hammer in combination with water jets or pre-formed pile holes. The pile driving system shall be constructed so as to afford freedom of movement of the pile hammer and to drive the piles to the required depth within the tolerances specified without undue injury to the piles.

The pile hammer shall be in good working condition and produce the energy required to install piles to the depth or penetration required in the plans. Single or double-acting Steam/Air, Diesel/Internal Combustion, or Hydraulic hammers may be submitted for review and approval.

In no case shall a gravity or drop hammer be used to drive concrete piles. A drop hammer may be used to install steel or temporary timber piles when approved by the Engineer.

S-803.03.1.7.4--Driving Appurtenances.

S-803.03.1.7.4.1--Pile Hammer Leads. Either fixed leads or swinging leads may be used. Swinging leads shall be used in combination with rigid templates approved by the Engineer. Battered piles shall be driven in inclined leads or multiple rigid templates capable of holding the pile in the proper position during driving.

S-803.03.1.7.4.2--Pile Cushions. Suitable cushioning material shall be used between the driving cap and the top of the pile. The cushion material shall protect the pile top during driving and shall be constructed such that the hammer energy is uniformly distributed to the pile top. If the cushion material becomes highly compressed, or chars or burns during the driving operations or damage occurs at the pile top, it shall be replaced.

S-803.03.1.7.4.3--Water Jets. When required by the Engineer, water jets will be used in conjunction with the pile hammer to install piles to the required depth or penetration called for in the plans. The use of water jets, where the stability of embankments or other improvements would be endangered, will not be permitted. When water jets are used, the number of jets and the volume and pressure of water shall be sufficient to adequately facilitate driving without undue damage to the pile or the soil adjacent to or below the pile. Unless otherwise specified, water jets shall not be used within five feet of the final tip elevation of the pile. In addition, it shall be the Contractor's responsibility to withdraw the water jets sufficiently above the five foot requirement to obtain the specified bearing at the required cut off elevation.

In the event a jetted pile fails to obtain the specified bearing at the required penetration and a determination is made by the Engineer that the Contractor has failed to properly control the jetting operation, the Contractor should submit detailed corrective measures for founding the pile to the Engineer for approval. Any required corrective measures to the pile due to the Contractor's operation shall be performed at no additional cost to the Project.

S-803.03.1.7.4.4--Followers. Followers are considered to be part of the driving system and should be included for approval with the pile driving system data.

S-803.03.1.7.4.5--Pre-formed Pile Holes. The Engineer, with the concurrence of the State Aid Bridge Engineer will make all determinations as to the necessity for pre-formed pile holes and the size and maximum depth of each hole required or permitted.

If it is determined from the Geotechnical Investigation or from the site survey that pre-formed pile holes are necessary, a pay item and estimated quantities will be included on the plans, and the Engineer will furnish the Contractor with an itemized list showing the location, size and bottom elevation of each hole.

If the plans do not specify pre-formed pile holes and the Engineer, with the concurrence of the State Aid Bridge Engineer, determines during construction that subsurface conditions are encountered that necessitate pre-formed pile holes, at certain locations, an adjustment in the contract unit price for furnishing and driving piling at these locations may be made under the provisions of S-104.02.

If in the judgment of the Engineer pre-formed pile holes are not required and the Contractor desires to use them, the Contractor may be permitted to do so under conditions prescribed by the Engineer, with the concurrence of the State Aid Bridge Engineer, and at no additional cost to the Project.

S-803.03.1.7.4.6--Additional Equipment. When a minimum penetration is indicated on the plans and is not obtained by the use of an approved hammer, the Contractor shall provide, with the approval of the Engineer, a heavier hammer or resort to jetting at no additional cost to the Project.

S-803.03.1.8--Defective Piles. Prior to driving, piles shall not be subjected to handling that causes damage either through bending, crushing or spalling of concrete, or deformation of the steel. All piles damaged because of internal defects or by improper driving, driven out of the proper location or driven below the specified elevation shall be corrected at the Contractor's expense by one of the following methods approved by the Engineer, with the concurrence of the State Aid Bridge Engineer for the pile in question:

(1) The pile shall be withdrawn and replaced by a new and, if necessary, a longer pile.

(2) A second pile shall be driven adjacent to the defective or low pile.

(3) The pile shall be spliced or built up or a sufficient portion of the footing shall be extended to properly embed the pile. All piles pushed up by the driving of adjacent piles or by any other cause shall be driven down to grade.

S-803.03.1.9--Determination of Bearing Value of Piling.

S-803.03.1.9.1--General. The ability of the pile to transfer load to the ground will be determined to the satisfaction of the Engineer. Such determination will be made using a Geotechnical investigation, load tests and/or test piles and LRFD methodologies.

S-803.03.1.9.2--Determination of Bearing Value by Pile Hammer Formulas. The safe bearing values will be determined using one of the LRFD approaches outlined herein. If an alternative approach to determine safe bearing values is used, it must comply with LRFD and be approved by the Engineer, with the concurrence of the State Aid Bridge Engineer.

The determination of bearing values shall be documented by the Engineer. Documentation shall include but not be limited to: drivability information, location of test piles or load tests, results of test piles or load tests, supporting calculations, the itemized Order List furnished by the Engineer and any other items determined necessary by the Engineer.

S-803.03.1.9.2.1--Dynamic Formulas. Dynamic formulas shall not be used when the required nominal resistance exceeds 600,000 lbs. The required nominal resistance shall be taken as the LRFD factored load divided by the LRFD resistance factor as determined by the Engineer. If scour or liquefaction is predicted at the bridge location, the Engineer shall account for potential loss of skin friction over the area of pile.

The formulas described herein are applicable for the following conditions only:

(a) The hammer has a free fall.
(b) The pile head is not crushed.
(c) The penetration is reasonably quick and uniform.
(d) There is no appreciable bounce after the blow.
(e) A follower is not used.

When using single-acting steam/air hammers and open cylinder diesel hammers where ram velocity on the hammer is not measured, developed hammer energy shall be calculated as follows:

$E_d = WH$

Where W = weight, in lbs, of striking parts of hammer
H = height of fall in feet.

Where there is appreciable bounce of the hammer, twice the height of the bounce shall be deducted from "H" to determine its value in the formula.

For all other hammer types, the developed hammer energy shall be determined by the Engineer and based on information provided by the Contractor and any further information provided by the manufacturer.

When water jets and dynamic formulas are used in combination, the bearing value shall be determined from the results of driving after the jets have been withdrawn, or a static or dynamic load test has been conducted.

Formulas for pile hammers not covered herein must be approved by the State Aid Bridge Engineer before the hammer is used.

S-803.03.1.9.2.2--FHWA Gates Formula. The FHWA Gates Formula shall be used in LRFD applications. The nominal pile resistance as measured during driving using this method shall be taken as:

$$R = 1.75 \sqrt{E_d} \log_{10}(10N_b)-100$$

Where R = nominal pile resistance measured during pile driving in kips
E_d = developed hammer energy in foot-lbs

N_b = Number of hammer blows for 1.0 inch of pile penetration.

S-803.03.1.9.2.3--Resistance Factor. The Engineer shall use a resistance factor of 0.40 with the FHWA Gates Formula. This resistance factor shall be applied to the nominal pile resistance determined by the Engineer using the results of the pile driving formula.

803.03.1.9.3--Determination of Bearing Value by PDA Monitoring (Dynamic Load Testing).

803.03.1.9.3.1--Description. This work consists of furnishing all labor, materials, equipment and services necessary to perform all operations to complete the determination of the bearing value of piling using a Pile Driving Analyzer (PDA) and associated equipment. The dynamic load testing measurements will be performed in accordance with the plans, Engineers direction and the requirements herein.

803.03.1.9.3.2--Resistance Factors and Number of Dynamic Test Piles. The Engineer shall use a resistance factor of 0.65 when the driving criteria are established by a dynamic test with signal matching. This resistance factor shall be applied to the nominal pile resistance determined by the Engineer using the results of PDA and the wave equation.

If scour is predicted during design flood and/or liquefaction is predicted during the design seismic event, the Engineer shall account for the potential loss of skin friction over the area of pile when determining bearing resistance.

The location and number of test piles shall be indicated on the plans or directed by the Engineer. Depending upon the conditions encountered in the field, the Engineer may increase the number of test piles required.

803.03.1.9.3.3--Scope and Sequence of Construction. The dynamic measurements shall be performed on the piles as detailed below for the purpose of obtaining pile bearing capacity, pile lengths, pile driving stresses, pile integrity, and the pile driving system efficiency. Unless otherwise directed in the plans, the sequence of construction outlined below shall not be deviated from unless an alternate sequence of construction is approved in writing by the Engineer.

1) When called for in the plans or directed by the Engineer, Conventional Static Load Testing will be performed. Piles to be load tested shall be driven at location shown in the plans or directed by the Engineer, with PDA monitoring under initial drive, and have restrikes performed.

2) When called for in the plans or directed by the Engineer, PDA Test Piles will be driven with PDA monitoring under initial drive and have restrikes performed as detailed below. The test piles will be used as production piles and be incorporated into the bridge structure.

3) The Engineer can require PDA monitoring or PDA restrikes to any production pile.

4) For Quality Control purposes, PDA testing shall be performed on 10% of the production piles when PDA testing is set up by the plans.

803.03.1.9.3.4 --PDA Monitored Driving and/or Restrike of Piling.

803.03.1.9.3.4.1--General. When called for in the plans or directed by the Engineer, a PDA and instrumentation will be used to obtain dynamic measurements during pile driving and pile restrikes. The analysis of the monitoring will be the responsibility of the Engineer.

803.03.1.9.3.4.2--Contractor Requirements. The Contractor shall be responsible for the following:

1. A power supply providing at least 1800 watts of 115-volt AC power with a frequency of 60 Hz at the driving site.

2. Prepare the driving site.

3. Supply the labor necessary for attaching the dynamic monitoring instrumentation to the piles. The Contractor shall make one of their personnel available to place the transducers on the piles after the piles have been placed in the leads.
4. Notice to the Engineer at least 14 calendar days before the scheduled date of driving piles to be monitored and confirmation of the driving date 3 calendar days prior to the scheduled driving date.

5. Access to the pile prior to driving for drilling and tapping of holes that are necessary for attachment of instrumentation.

6. Reasonable care when working with piles and installed instrumentation.

7. Drive the piles as directed by the Engineer.

The Contractor shall replace any damaged piles, instruments or PDA related equipment caused by Contractor error at no additional cost to the Project.

803.03.1.9.3.4.3--Driving Requirements. Piles to be used in the determination of pile bearing by PDA monitoring shall be driven with PDA instrumentation attached to the pile and shall have a PDA monitored 1-day and 7-day restrike performed after the initial pile driving. When a static load test is to be performed, the 7-day restrike should be eliminated and a PDA monitored restrike done within 24 hours of completion of the static load test. When determined by the Engineer, waiting periods that are required before the restrikes are performed shall be adjusted.

When deemed necessary by the Engineer, permanent piles may have PDA monitored restrikes performed to confirm or supplement design requirements.

Restrikes shall be performed with a warm hammer operating at normal efficiency. A warm hammer is defined as a hammer that has applied a minimum of 20 blows to another pile or a dummy block immediately before being used in a restrike. The restrike shall consist of striking the pile for 50 blows or until the pile penetrates an additional three inches, whichever occurs first. In the event the pile movement is less than one inch after 15 blows during the restrike, the restrike may be terminated.

S-803.03.1.9.4--Determination of Bearing Value by Static Load Testing.

S-803.03.1.9.4.1--General. When called for in the plans or directed by the Engineer, static load testing will be conducted to determine the ultimate bearing capacity of piles. Depending upon the conditions encountered in the field, the Engineer with the concurrence of the State Aid Bridge Engineer may increase or decrease the number of static load tests required.

In the event the number of loading tests are increased from that indicated in the contract, consideration will be given for delays, if any, in the applicable controlling phase of work caused solely by the seven-day or other waiting period required by the Engineer. Any adjustments will be in accordance with S-108.06.

S-803.03.1.9.4.2--Static Load Test Resistance Factors. When using static load testing, the Engineer shall determine the resistance factor according to LRFD. Factors range from 0.55–0.90 and shall consider the number of static load tests performed and soil variability at the project site as defined in LRFD. If site variability cannot be determined, a "High" site variability shall be used.

S-803.03.1.9.4.3--Methods and Equipment. Apparatus for measuring the behavior of the pile during the test shall consist of a measuring frame and two approved dial gage type measuring devices attached to the pile. Each gage shall be actuated by its stem or by a stem attachment resting on the beam of the measuring frame. Supports for the measuring frame shall be placed the maximum practical distance from the test pile and the anchor piles. Each dial gage shall be capable of providing measurements to an accuracy of 0.001 inch throughout a movement range of four inches and shall be sensitive to a force of one pound or less. At least one approved standby gage of each type used shall be provided at all times. The Contractor shall furnish a certification of the sensitivity and accuracy of each dial gage through the required range of use. The Engineer may require recertification of a gage at any time there is an indication of inaccuracy. The Contractor shall provide adequate protection from the elements or from other damage to gages and other specified measuring devices during handling, transportation, and use so that inaccurate measurements or delays will not result because of such damage.

S-803.03.1.9.4.4--Hydraulic Method. The Contractor shall furnish a hydraulic jacking system complete with gages and charts. The system shall include one or more hydraulic jacks in good condition without leaks. The jacks shall be capable of applying the required load and shall have adequate piston travel to compensate for the yield of the reaction facilities and the vertical displacement of the pile being tested.

The pressure gages shall accurately reflect the fluid pressure in the system within plus or minus one percent throughout the system capacity. The gage shall be such that the applied load can be read directly in increments of two percent or less, or shall be such that when read to the exact graduation and referred to a certified calibration chart will provide a determination of the load being applied within plus or minus one percent. Each gage shall contain a capacity for recalibration to zero at zero pressure.

The complete hydraulic jacking system and gages shall be calibrated in accordance with AASHTO Designation: T 67, ASTM Designation: E-4, at least once, and pressure gages shall be calibrated within one year preceding the time of use and whenever there is a reason to doubt the accuracy of the results. If the laboratory performing the calibration uses a hydraulic testing machine in lieu of the methods specified in AASHTO Designation: T 67 to apply the test load, the testing machine used to apply this load shall be calibrated in accordance with ASTM Method E 74, and the report shall state that the testing machine had been calibrated by this method. Calibration shall include loading and unloading with the jacking system to determine the hysteresis losses in the system. The calibration and certificate shall be made by a qualified testing laboratory approved by State Aid, and the Engineer shall be furnished a report and certificate of each calibration.

Systems containing two or more jacking pistons shall be approved by the Engineer before use and shall be subject to periodic calibration as determined by the Engineer.

S-803.03.1.9.4.5--Preparation for Loading. The Contractor shall provide means for preventing eccentricity in the pile during loading, and shall be fully responsible for all loss or damage caused by loading an eccentric pile or one which becomes eccentric during loading.

The pile to be load tested shall be installed as indicated on the plans to the specified tip elevation, or as directed. After the pile is in place, all loading devices shall be assembled in their proper position. Before load is applied to the pile, the measuring frame shall be assembled and positioned with gages properly installed.

The head of the pile shall be normal to the longitudinal axis or shall be capped in such a manner as to produce a plane bearing surface normal to the longitudinal axis. When cut-off is necessary, the head of the pile shall be normal to the longitudinal axis or capped as above. A one-inch steel plate of the pile size or larger shall be set on top of the pile.

The jacking system shall include a reaction member of sufficient strength and support to withstand required loads. The reaction member shall be attached to anchor piles. Anchor piles

shall not be closer to the test pile than five times the greatest dimension of the largest pile driven; except for 18-inch or larger piles the Engineer with the concurrence of the State Aid Bridge Engineer may authorize in writing reaction piles at a closer interval, subject to the conditions included in the authorization. The Contractor shall provide reaction facilities capable of withstanding at least two and one-half times the design load. All reaction facilities shall be subject to the approval of the Engineer with respect to possible adverse influence upon the behavior of the test pile.

S-803.03.1.9.4.6--Application of Loads. Unless otherwise directed by the Engineer, a time period of at least seven days shall elapse from the time the test pile and anchor piles, if used, are installed before the loading test is performed. During the required time lapse period, no other driving operations shall be performed within a 30-foot radius of the test pile, or a new seven-day period shall begin at the ending of the last pile driven within the 30-foot radius.

During the entire period that the test load or any portion thereof is on the pile, no pile driving operations, operation of heavy equipment, or any other operations shall be carried on within a distance, as determined by the Engineer, from the load test which might affect the behavior of the loaded pile. In the event of such occurrence, or in the event of failure of the reaction facilities or other loading and measuring equipment, the load test may be considered as defective and unacceptable, and in the case of driven piles only an additional seven-day waiting period shall elapse before the loading test is resumed.

Loads shall be applied in increments of 25 percent of the LRFD factored load until the Engineer determines an adequate test load has been reach or failure of the pile has occurred. The test load shall be taken as 1 1/2 times the LRFD factored load divided by the appropriate LRFD resistance factor in accordance with S-803.03.1.9.4.2.

If scour is predicted during design flood and/or liquefaction is predicted during the design seismic event, the Engineer shall increase the test load to account for calculated loss of skin friction over the area of pile.

A guide for determining whether the pile has failed is as follows:

(A) For lengths of driven and cast-in-place concrete piles and timber piles up to 50 feet, a total top settlement of 1.0 inch and for lengths in excess of 50 feet, a total top settlement of 1.5 inches. However, for cast-in-place piles, when skin friction is broken there may be some settlement due to compression of relatively loose or bulked soil under the point of the pile, therefore the test must not be suspended until this possibility has been fully considered. Any special effort by the Contractor in the drilling and casting the test pile to prevent possible settlement from such cause shall be duplicated to the satisfaction of the Engineer for all piles represented by the load test.

(B) For steel piles and steel pile shells not filled with concrete up to 60 feet in length, a total top settlement of 1.5 inches and for lengths in excess of 60 feet, a total top settlement of 2.0 inches.

Each of the following loading conditions shall be applicable until the loading is completed or unless the Engineer has suspended the loading because of obvious failure of the pile:

a. Each loading increment, including the final increment, shall be maintained for a 15-minute period and for as many additional 15-minute periods, not to exceed two hours total time, as necessary to satisfy the conditions stated herein.

b. During the entire loading, readings are to be made at each five-minute increment of each 15-minute period and are to be made to the nearest 0.001 inch.

c. When the settlement rate for the pile in the last five-minute increment of a 15-minute period, averages less than 0.001 inch per minute, the next increment of load shall be applied.

d. When at the end of a 15-minute period, the settlement rate in the last five-minute increment averages more than 0.001 inch per minute, the load increment shall remain applied for the necessary successive 15-minute periods up to a total of two hours, after which the next increment of load shall be applied.

e. The total load shall be maintained on the pile for two hours unless directed otherwise directed by the Engineer.

f. The pile shall be unloaded in accordance with S-803.03.1.9.4.2.7.

S-803.03.1.9.4.7--Unloading and Measuring. Unless the loading has been suspended by the Engineer, the pile shall be unloaded in decrements of 50 percent of the design load. Each decrement shall be maintained for a minimum of 15 minutes with settlement readings taken immediately before and after its removal and at five-minute intervals. The final settlement reading shall be taken two hours after the removal of the last decrement of load and shall mark the conclusion of the loading test.

S-803.03.1.10--Pile Acceptance. The safe allowable load for each type and size of pile will be as shown on the plans or as determined by the Engineer with the concurrence of the State Aid Bridge Engineer. Acceptance criteria for the length of permanent production piles will be based on the recommended lengths as determined by the Engineer with the concurrence of the State Aid Bridge Engineer from the test pile reports.

S-803.03.1.11—Test Piles. The Contractor shall furnish and install test piles of the sizes and types at the locations shown on the plans. It is the Contractor's responsibility to furnish test piles of sufficient length to obtain the minimum tip elevation and required bearing. This requirement

may necessitate test pile lengths in excess of that required to reach minimum tip elevation. The number of test piles may be increased or decreased by the Engineer with the concurrence of the State Aid Bridge Engineer as field conditions warrant. If determined by the Engineer with the concurrence of the State Aid Bridge Engineer to be necessary, test piles shall be extended, built-up, or spliced and in the case of steel piles driven further. Similarly, the Contractor may be required to drive test piles below cut-off and extended as necessary.