



## SECTION 702

### LOAD-BEARING PILES

**702.1 Description.** This work shall consist of furnishing and driving concrete and steel load-bearing piles to the bearing and penetration required, at the location shown on the plans.

**702.2 Material.** All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section/ Specification
Reinforcing Steel for Concrete	1036
Cast-In-Place Pile Shells (Thick Shell Type) Welded or Seamless Steel Pipe	ASTM A 252
Closure Plates	AASHTO M 270, Grade 36
Structural Steel Pile	AASHTO M 270, Grade 36
Fluted Pipe	SAE-1010 or SAE-1015
Forged Steel Tips or Noses	SAE-1020
Pile Point Reinforcement	ASTM A 27, Grade 65-35 (450-240) or ASTM A 148, Grade 90-60 (620-415)

**702.2.1 Cast-In-Place Concrete Piles.** Cast-in-place concrete piles shall consist of Class B-1 concrete cast in pre-driven metal shells. The metal shells shall be in accordance with the shape, size and minimum shell thickness shown on the plans, or to an approved equivalent section. All material, proportioning, air-entraining, mixing, slump and transporting of concrete shall be in accordance with [Sec 501](#). Metal shells shall hold the original form without distortion after being driven, and shall be free from water, soil and other deleterious matter when concrete is cast in the shells.

**702.2.2 Structural Steel Piles.** Structural steel piles shall be of the size, weight and structural shape shown on the plans. Piles shall not have a camber or sweep in excess of 1/8 inch (10 mm) multiplied by the length of pile in feet (m) divided by five. Steel piles shall be stored such that damage to the piling does not occur.

**702.2.3 Pile Point Reinforcement.** Pile point reinforcement shall be furnished and installed on load-bearing piles at locations shown on the plans. Manufactured pile point reinforcement to be furnished and installed on cast-in-place concrete piles shall be attached to the pile in accordance with the manufacturer's recommendations. Pile point reinforcement for steel piles shall be furnished and installed in accordance with [Sec 1080](#), except as modified herein.

**702.2.4 Pile Length.** The contractor shall be fully responsible for the lengths the contractor furnishes for driving to obtain the specified bearing and penetration. The pile lengths shown on the plans shall be considered approximate lengths.

**702.2.5 Test Piles.** Test piles shall be of the same material and size as the permanent piles. Test piles shall be of such length as to permit driving the tips to an elevation 10 feet (3 m) below that indicated by plan lengths.

**702.2.6 Certification.** For structural steel piles and thick shells for cast-in-place piles, the contractor shall furnish two copies of a certification from the pile manufacturer or fabricator setting out the designated specification with which the material furnished complies.

### **702.3 Equipment.**

**702.3.1 Driving Equipment.** Piles shall be driven with power-driven hammers, or by a combination of power-driven hammer and water jets. Power-driven hammers will be defined as hammers operated by steam, air or diesel power. For determining the energy per blow of diesel power hammers without a fully enclosed ram, 75 percent of the manufacturer's energy rating for the hammer will apply. If the contractor desires to check a diesel power hammer against an approved steam hammer on a specified type of pile at a particular site, the contractor may do so at the contractor's expense, and the checked rating of the diesel powered hammer will be used in determination of pile bearing values at that site. Diesel hammers that have a fully enclosed ram shall be equipped with a gauge and accompanying charts which evaluate the equivalent manufacturer's rated energy being produced under any driving condition.

**702.3.2 Leads.** Pile driver leads shall be constructed in such a manner as to afford freedom of movement of the hammer, and leads shall be held in position by guys or stiffener braces to ensure support to the pile during driving. Inclined leads shall be used for the driving of battered piles.

**702.3.3 Followers.** Followers may be used in driving piles only if approved in writing by the engineer. If a follower is used, one pile of every group of ten shall be driven without a follower to determine the available bearing value of the group.

**702.3.4 Water Jets.** Water jets used to aid in driving piles shall be sufficient in number to deliver a volume and pressure of water at the jet nozzles that will freely erode the material adjacent to the pile. The use of water jets shall be discontinued before the final penetration is reached, and piles shall be driven to secure a final penetration of no less than 2 feet (600 mm) if the nature of the soil permits.

**702.3.5 Hammer Energy.** The minimum energy developed by hammer per blow shall be no less than the following:

<b>Hammer Energy</b>	
<b>ENGLISH</b>	
Type of Pile	Minimum Hammer Energy Required per Blow, foot-pound (ft-lb)
Steel Shells for Cast-In-Place	3.0 ft-lb/lb times the total pile weight in pounds, including mandrel if used, but no less than 8000 ft-lb.
Structural Steel	The largest of the following: (a) 3.0 ft-lb/lb times the total pile weight in pounds. (b) 225 ft-lb/ton times the design bearing value in tons, divided by the pile batter factor, B, if applicable. (c) 7000 ft-lb.
<b>METRIC</b>	
Type of Pile	Minimum Hammer Energy Required per Blow, Newton-meter (N-m)
Steel Shells for Cast-In-Place	9.0 N-m/kg (mass) times the total pile mass in kilograms, including mandrel if used, but no less than 11,000 N-m.
Structural Steel	The largest of the following: (a) 9.0 N-m/kg (mass) times the total pile mass in kg. (b) 35.0 N-m/kN times the design bearing value in kN, divided by the pile batter factor, B, if applicable. (c) 9500 N-m.

**702.4 Construction Requirements.**

**702.4.1 Test Piles.** The contractor shall furnish and drive test piles at locations specified. Where required, test piles shall be driven to refusal or to a capacity 50 percent greater than that shown on the plans. In all cases, test piles shall be driven to at least the minimum tip elevation shown on the plans for permanent piles. If no minimum tip elevation is shown on the plans, piles shall have a tip elevation at least 10 feet (3 m) below the bottom of the supported footing or 10 feet (3 m) below the natural ground line, whichever is lower, unless specifically authorized otherwise by the engineer. Test piles shall be driven with the same type of equipment as will be used for driving the permanent piles. Before driving test piles, the excavation shall be completed to an elevation no more than 2 feet (600 mm) above the proposed grade at the point where a test pile is to be driven. Test piles not driven in a permanent location shall be cut off, or pulled and backfilled as approved by the engineer.

**702.4.2 Load-Bearing Piles.** Load-bearing piles shall not be driven until after the excavation for the footing has been substantially completed. The heads of piles shall be protected against damage during driving. The procedure incident to the driving of piles shall not subject piles to excessive and undue abuse. Any pile broken or damaged by reason of internal defects, by improper driving, or driven outside of the pile's proper location, shall be removed and replaced, or a second adjacent pile may be driven if this can be done without detriment to the structure, as determined by the engineer.

**702.4.3 Preboring.** Where piles are to be driven through more than 5 feet (1.5 m) of compacted embankment that has been in place for less than five years, holes shall be prebored entirely through the embankment to the lowest elevation of the natural ground line adjacent to the embankment, or as shown on the plans. Other locations where preboring for piles will be required will be shown on the plans. At such locations, holes shall be prebored to the elevation specified prior to pile placement. The holes shall have a diameter no less than that of the pile and shall be large enough to avoid damage to the pile being driven through the hole

in hard material. The size of the hole shall be approved by the engineer before preboring is started. Pilot holes of lesser diameter than the pile shall not extend below the pile tip. After the pile is placed in the hole and before driving begins, the space remaining around the pile shall be filled with sand or other approved material before and maintained full during the driving of the pile. The pile shall then be driven in accordance with [Sec 702.4.11](#). Any space remaining around any type of pile after the pile is driven shall be completely filled with sand or other approved material.

**702.4.4 Pile Placement Tolerances.** Final position of piles shall be no more than 1/4 inch per foot (20 mm/m) from the vertical or from the batter line shown on the plans. The maximum variation of the head of the pile from the position shown on the plans shall be no more than 2 inches (50 mm), except that piles in footings entirely below the finished ground line may not vary more than 6 inches (150 mm). All piles forced upward by the driving of adjacent piles or by any other cause shall be redriven to the required bearing and penetration.

**702.4.5 Pile Point Reinforcement.** Each point shall be manufactured in one piece of cast steel. Pile points furnished for cast-in-place concrete piles shall be attached to the pile in accordance with the manufacturer's recommendations and as specified herein. Pile points for structural steel piles shall be furnished with the minimum point web and flange thickness at the location of attachment to the pile equal to the thickness of that portion of the pile being attached thereto multiplied by the factor (t) shown below with additional requirements as described herein.

Material	(t)
ASTM A27 Grade 65-35 (450-240)	2.0
ASTM A148 Grade 90-60 (620-415)	1.6

**702.4.5.1** The point shall extend onto the pile a minimum of 1/2 inch (13 mm) for both faces of the web and for the end one-fourth of the inside face of each flange.

**702.4.5.2** The web portion of the point shall protrude a minimum of 0.2 times the flange width below the pile with the flange portion of the pile point transitioning to a protrusion depth of no less than the pile point flange thickness at the extreme ends.

**702.4.5.3** The point shall be attached to the pile with a full penetration weld along each flange. Weld backing shall be furnished for the total width of each flange.

The point extension onto the web of the pile may be omitted if alternating 1 1/2-inch (38 mm) x 1/4-inch (6 mm) fillet welds are placed on each side of the web.

**702.4.5.5** Welding of the point to the pile shall be by a MoDOT-certified welder. Properly dried low hydrogen electrodes of the E70XX series shall be used with adequate protection from the elements in accordance with [Sec 1080](#). The contractor shall be fully responsible for the adequacy of welds during driving.

**702.4.6 Splices.** Full length piles shall be driven wherever possible and practical. If extensions and splices are permitted or required by the engineer, splices shall be made as follows. All welding, including splicing of steel shells and structural steel piles, and support or reinforcing angles welded to steel piles, shall be in accordance with [Sec 1080](#) and performed by a MoDOT-certified field welder using properly dried low-hydrogen E7018 electrodes that have been protected from the elements to maintain the dry condition. Steel shells for cast-in-place concrete piles shall be spliced as shown on the plans. Structural steel piles shall be spliced with a butt joint as shown on the plans. The contractor may furnish lengths of cast-in-place pile shells that incorporate no more than one splice per pile or structural steel piles that incorporate no more than one splice per pile for lengths up to and

including 40 feet (12 m). No more than two splices will be permitted in each structural steel pile furnished for lengths exceeding 40 feet (12 m). In preparation of piles prior to driving, the use of individual sections less than 8 feet (2.5 m) long will not be permitted. Additional field splices necessary to extend structural steel piles or cast-in-place pile shells to reach adequate bearing material shall be limited to one per pile, unless authorized by the engineer.

**702.4.7 Cut-Offs.** The tops of all piles shall be cut off square at cut-off elevations.

**702.4.8 Protective Coatings.** Before the coatings are applied, steel shall be thoroughly cleaned. A commercially available bituminous coating, as approved by the engineer, shall be applied heavily to steel shells and structural steel piles in end bents for a length of 3 feet (1 m) below the bottom of the concrete cap. All exposed steel piles shall have a bituminous coating 3 feet (1 m) below and one foot (300 mm) above the finished ground line. Unless otherwise specified in the contract documents, all other exposed surfaces of steel shells and structural steel piles, including bracing, shall be coated with one 6-mil (0.15 mm) thickness of an approved gray epoxy mastic in accordance with the epoxy mastic manufacturer's recommendations. Protective coatings will not be required below the normal low water line.

**702.4.9 Time Restrictions.** Concrete footings shall not be placed on cast-in-place piles until at least 12 hours after the last pile in the footing has been cast. No piling shall be driven within a radius of 20 feet (6 m) of concrete that has not attained a minimum compressive strength of 1500 psi (10 MPa). Compressive strength will be determined by tests performed in accordance with approved methods.

**702.4.10 Dynamic Bearing Formulas.** The following formulas shall be used as a guide to determine the safe bearing value of piles when other methods of determination are not specified in the contract documents:

ENGLISH					
P	=	$\frac{2WH}{(S+0.1)}$	x	$\frac{2W}{(W+w)}$	<sup>a</sup> for single acting hammers.
P	=	$\frac{2E}{(S+0.1)}$	x	$\frac{2W}{(W+w)}$	<sup>a</sup> for double acting hammers and diesel powered hammers with enclosed rams and bounce pressure gauges.
P	=	$\frac{2(0.75E)}{(S+0.1)}$	x	$\frac{2W}{(W+w)}$	<sup>a</sup> for all other diesel powered hammers unless tested as specified in <a href="#">Sec 702.3.1</a> .
METRIC					
P	=	$\frac{1636WH}{(S+2.54)}$	x	$\frac{2W}{(W+w)}$	<sup>a</sup> for single acting hammers.
P	=	$\frac{167E}{(S+2.54)}$	x	$\frac{2W}{(W+w)}$	<sup>a</sup> for double acting hammers and diesel powered hammers with enclosed rams and bounce pressure gauges.
P	=	$\frac{167(0.75E)}{(S+2.54)}$	x	$\frac{2W}{(W+w)}$	<sup>a</sup> for all other diesel powered hammers unless tested as specified in <a href="#">Sec 702.3.1</a> .

<sup>a</sup>The value of  $\frac{2W}{(W+w)}$  shall be considered one if 2W exceeds W+w

- P = safe allowable bearing value in pounds (N).
- W = weight (mass) of striking part of hammer in pounds (kg).
- w = weight (mass) of pile and mandrel in pounds (kg).
- H = height of fall in feet (m).
- E = manufacturer's rated energy in foot-pounds (J) per blow at manufacturer's rated speed, or in case of a diesel hammer equipped with a bounce pressure gauge the actual energy shown by the gauge chart.
- S = average penetration in inches (mm) per blow for 10 to 20 consecutive blows, measured along the pile batter, if applicable.

**702.4.10.1** The above formulas will be applicable only if:

- (a) The hammer has an unrestricted fall.
- (b) The pile head is not broomed, crushed or splintered.
- (c) There is no appreciable bounce of the hammer after striking the pile.
- (d) The penetration is at a uniform or uniformly decreasing rate.

**702.4.10.2** For piles driven to a batter, the safe allowable bearing value, P, in the equations provided in [Sec 702.4.10](#) shall be divided by the pile batter factor, B, in order to calculate the value of S, the average penetration per blow.

$$B = \frac{0.1(10 - m)}{1 + m^2}, \text{ pile batter factor}$$

m = the tangent of the angle of batter to a vertical line

**702.4.11 Minimum and Maximum Limits of Pile Driving.** Piles shall be driven to at least the minimum tip elevation indicated on the plans. If no minimum tip elevation is shown on the plans, piles shall have a tip elevation at least 10 feet (3 m) below the bottom of the supported footing or 10 feet (3 m) below the natural ground line, whichever is lower, unless specifically authorized otherwise by the engineer. Piles other than structural steel piles shall be driven to attain a bearing value no less than that shown on the plans, determined in accordance with [Sec 702.4.10](#). Structural steel piles shall in general be driven to practical refusal, which will be defined as a pile bearing value of 1.9 times the design bearing value. Prior to driving structural steel piles, the contractor shall review the boring logs to determine the depth at which rock may be anticipated. The contractor shall be attentive to the physical conditions of practical refusal. When indication of practical refusal occurs, driving shall cease immediately to avoid damage to the pile and to reduce the risk of injury. Shells for cast-in-place concrete piles shall not be driven to a bearing value in excess of 10 tons (90 kN) over the design bearing value.

#### **702.5 Method of Measurement.**

**702.5.1 Test Piles.** Test piles will be measured to the nearest linear foot (0.5 m) of pile authorized and driven.

**702.5.2 Load-Bearing Piles.** Piles in place will be the actual length of all piles, except test piles, measured to the nearest foot (0.5 m) for that portion of each pile that remains permanently in the structure.

**702.5.3 Preboring.** Final measurement will not be made except for authorized changes during construction or where appreciable errors are found in the contract quantity. Where required, measurement of prebored holes required under the provisions of [Sec 702.4.3](#) will be made to the nearest linear foot (0.5 m) of each hole specified or directed by the engineer. The revision or correction will be computed and added to or deducted from the contract quantity.

**702.5.4 Pile Point Reinforcement.** Pile point reinforcement will be measured per each.

#### **702.6 Basis of Payment.**

**702.6.1 Test Piles.** Test piles will be paid for at the contract unit price. Test piles, if driven and used as permanent piles in place, will be paid for as test piles, and not as load-bearing piles in place.

**702.6.2 Load-Bearing Pile.** The accepted quantity of load-bearing pile in place will be paid for at the contract unit price for each of the items included in the contract. No direct payment will be made for incidental items necessary to complete the work unless specifically provided as a pay item in the contract.

**702.6.3 Pile Cut-Offs.** No direct payment will be made for pile cut-offs.

**702.6.4 Preboring.** Preboring will be paid for at the contract unit price. No direct payment will be made for backfilling.

**702.6.5 Pile Point Reinforcement.** Pile point reinforcement, where specified, will be paid for at the contract unit price per each.

**702.6.6 Splices.** If a splice is authorized to extend a structural steel or steel shell pile to reach adequate bearing material, the only splices that will be paid for are those required to extend the pile after plan length plus 10 percent has been driven. Splices, if authorized, will be paid for as an additional 8 feet (2.5 m) of pile in place at the contract unit price.

**702.6.7 Protective Coatings.** No direct payment will be made for coating exposed surfaces of steel shells, structural steel piles and bracing. Payment for coating the structural steel piles and sway bracing as described herein, and all material, excavation, labor, tools, equipment and incidentals necessary to complete the protective coating items will be considered completely covered under the contract unit price for other items.