Section 2501. Piles and Pile Driving

2501.01 DESCRIPTION.

A. Furnish and place piles for foundations, trestles, and other exposed work.

B. Furnish and place piling for falsework according to Article 2403.03, L.

2501.02 MATERIALS.

Use piles that comply with the following requirements for the class of pile specified:

A. Untreated Timber Piles: apply Article 4165.03.

B. Treated Timber Foundation Piles: apply Article 4165.04.

C. Treated Timber Trestle Piles: apply Article 4165.05.

D. Concrete Piles: apply Section 4166.

E. Steel Pipe Piles: apply Section 4167.

F. Steel H-Piles: apply Section 4167.

G. Concrete Sheet Piles: apply Section 4166.

H. Steel Sheet Piles: apply Section 4167.

2501.03 CONSTRUCTION.

A. Pile Driving Equipment.
The hammer used for driving piles may be of gravity, steam, air, or diesel type. Use pile driving equipment that complies with the following provisions:

1. Gravity Hammers.
- **a.** When gravity hammers are permitted, use a ram that weighs (has a mass) between 3000 pounds (1350 kg) and 6000 pounds (2750 kg) with a height of drop not exceeding 10 feet (3 m).
- **b.** Equip gravity hammers with hammer guides to ensure concentric impact on the pile cap. Use hammer guides that have some method for visually determining the drop height during driving.
- **c.** For all gravity hammers, apply Article 2501.03, A, 10, of this article.

2. Single or Double Acting Air and Steam Hammers.
- **a.** Use equipment with sufficient capacity to maintain the hammer operation under working conditions as recommended by the manufacturer.
- **b.** Use equipment with accurate pressure gages which are easily accessible to the Engineer.
- **c.** Steam hammers may be air operated if the capacity and pressure of the compressor comply with recommendations of the hammer manufacturer.
- **d.** Ensure the weight (mass) of the striking parts of air and steam hammers is no less than 33% of the combined weight (mass) of the pile cap and pile being driven. In no case allow the striking parts to have a weight (mass) less than 2750 pounds (1250 kg).

3. Diesel Hammers.
For all diesel hammers, apply Article 2501.03, A, 10, of this article.
- **a. Open End (Single Acting) Diesel Hammers.**
  - **1)** Equip with a method to visually determine drop height during driving. Examples of measurement devices are as follows:
    - A graduated scale (jump stick) extending above the ram cylinder.
    - Graduated rings or grooves on the ram.
    - An electronic, sound activated, remote measuring instrument.
  - **2)** Provide the Engineer with the manufacturer's chart equating stroke to blows per minute for the open end diesel hammer used.

b. Closed End (Double Acting) Diesel Hammers.

1) Equip with an accurate bounce chamber pressure gage mounted in a manner to enable easy access for the Engineer.

2) Provide the Engineer with a current, calibrated chart equating bounce chamber pressure and gage hose length to either equivalent energy or stroke for the hammer being used.

4. Driving Aids.

a. Do not use vibratory hammers, hydraulic hammers, or driving aids such as jets, followers, and prebored holes unless stated in the contract documents or authorized in writing by the Engineer. When permitted, vibratory hammers and hydraulic hammers may be used for installing production piles only after the pile tip elevation is established by load test or by test piles driven with an approved hammer. As condition for approval, perform (at no additional cost to the Contracting Authority) load tests and extra work required to drive test piles as determined by the Engineer.

b. Control production pile installation with vibratory hammers according to power consumption, rate of penetration, specified tip elevation, or other means acceptable to the Engineer. Assure the pile capacity equals or exceeds the design bearing. Use an approved hammer to retap piles driven to full penetration with a vibratory hammer. Bearing will be determined by an applicable wave equation analysis.

5. Hammer Cushion.

a. Equip all impact pile driving equipment with suitable thickness hammer cushion material to prevent damage to the hammer or pile. In the Engineer's presence, inspect the hammer cushion for condition, composition, and thickness before beginning pile driving at each structure, and regularly during driving.

b. For hammers with internal cushions, check the cushion regularly at 100 hour intervals during driving. Use the hammer manufacturer's recommended beginning cushion thickness and composition. Report this information to the Engineer prior to driving. Replace the hammer cushion when it has less than 70% of the recommended thickness, has burned, or has been broomed.

6. Pile Cushion.

a. Protect the head of all concrete piling with a suitable pile cushion. When requested, provide the pile cushion composition and thickness to the Engineer. Determine the minimum thickness by the wave equation.

b. If alternate pile driving control methods are used, use a minimum thickness of 6 inches (150 mm) of suitable wood.

c. In the Engineer's presence, inspect the pile cushion for condition, composition, and thickness before beginning pile driving at each structure, and regularly during driving. Replace any pile cushion when it has less than 70% of the original reported thickness, has burned, or has been broomed.

7. Pile Driving Cap.

a. Piles driven with impact hammers require an adequate cap to distribute the hammer blow evenly to the top of the pile. Align the cap axially with the hammer and the pile. Guide with leads. Use an appropriate cap for the type and size of pile. Ensure it fits around the top of the pile so that the driving unit is centered during driving.

b. For special types of piles, provide appropriate driving caps, mandrels, or other devices according to the manufacturer's recommendations so that the piles may be driven without damage.

c. Cut all pile tops squarely to ensure proper fit of the driving cap.

8. Followers.

Use followers only with the Engineer's authorization.

9. Water Jets.

Use water jets only with the Engineer's authorization. When jets are used, ensure the size, number, and location of jets, as well as the volume and pressure of water at the jet nozzles, is sufficient to freely erode material from under and adjacent to the pile.

10. **Approval of Pile Driving Equipment.**
    a. On each project, the Engineer's approval is required for all pile driving equipment. Size all pile driving equipment so that the piles can be driven with reasonable effort to the required lengths without damage.
    b. Pile driving equipment approval on Interstate and Primary projects will be based on the wave equation analysis. For other projects, the alternate approval method will be used unless specified otherwise.
        1) **Wave Equation Analysis.**
            a) For wave equation approval, submit to the Engineer the required data forms detailing equipment to be used on the project. Submit this information to the Engineer at least 20 calendar days prior to driving piles.
            b) The Contractor will be notified of the acceptance or rejection of the driving system within 12 calendar days of the Engineer's receipt of the data forms. Modify or replace the proposed methods or equipment (at no additional cost to the Contracting Authority) if the wave equation analysis:
                - Indicates pile damage could occur, or
                - The pile could not be driven to the required bearing.
            c) Ensure the subsequent driving system results in wave equation analysis indicating the piles can be reasonably driven to the desired capacity without damage. The Engineer will notify the Contractor of the acceptance or rejection of the revised driving system within 9 calendar days of receipt of a revised data form or method plan.
            d) Equipment meeting the values in Tables 2501.03-1 and 2501.03-2 in the Appendix will be acceptable for wave equation analysis.
        2) **Alternate Approval Method.**
        Use the tabulated energy values in Tables 2501.03-1 and 2501.03-2, in the Appendix, as a basis for approval of pile driving equipment for the alternate approval method. Approval will be based on meeting all requirements of this article. This approval does not relieve the Contractor of the basic obligation to provide equipment suitable for driving the specified pile to the required bearing without damage.

11. **Pile Driving Equipment.**
    a. Use an approved system or placement method. Variations in the driving system will not be permitted without the Engineer's approval. If the hammer performance deviates from the manufacturer's recommended specifications, take immediate corrective action. The Engineer will not allow driving to continue until the system is performing to the manufacturer's specifications.
    b. Changes in the driving system will be considered after the Contractor has submitted the required data for review. The Contractor will be notified of the acceptance or rejection of the driving system changes within 9 calendar days of the Engineer's receipt of the requested change. Time required for submission, review, and approval of a revised driving system does not constitute the basis for a contract time extension.

B. Determination of Pile Lengths.

1. When pile length is not specified, the Engineer will determine the length from the results obtained under the procedure specified in the contract documents. Wood pile lengths will be in multiples of:
    - 2 feet (0.5 m) for lengths of 20 feet (6 m) and less, and
    - 5 feet (1.5 m) for lengths over 20 feet (6 m).

2. Steel H-piles and steel pipe piles will be in multiples of 5 feet (1.5 m). Precast concrete piles may be specified in any length of whole feet (to the nearest 0.5 m).

C. Test Piles.

1. When the contract documents specify that the lengths of piles are to be determined from results of driving test piles, furnish and drive piles:
    - Of lengths designated in the contract documents or by the Engineer, and
    - In locations designated in the contract documents or by the Engineer.

2. Determine the load carrying capacity of test piles as provided in Article 2501.03, M. Drive these test piles with the same or comparable type of equipment as that which is to be used for driving other piles for the structure. The Contractor may be required to excavate the test pile area to the proposed footing elevation before driving the test pile. Within 10 calendar days, the Engineer will determine the length of piles to be furnished by considering the results of the test pile.

D. Concrete Piles.

1. Use concrete bearing piles of the form and dimensions specified in the contract documents. Place as indicated in the contract documents.

2. Piles may be driven when the concrete compressive strength has reached a minimum of 5,000 psi (35 MPa), but no less than 7 calendar days after casting.

E. Steel Pipe Piles.

Construct steel pipe piles by first driving steel pipe of the specified type and size in the locations specified in the contract documents, and then filling the pipe with concrete. Construct the piles according to the following additional requirements:

1. **Inspection.**
   - **a.** Furnish a light suitable for visual interior inspection of driven pipe piles. This inspection will be conducted before cut off and filling is allowed.
   - **b.** Remove and replace, or otherwise correct as directed by the Engineer, all piles which have been improperly driven, broken, or are otherwise defective.
   - **c.** Ensure the interior of the pile is clean and free of water at the time of inspection.

2. **Cut Off.**
   Upon completion of driving, inspection, and approval, neatly cut the pile on a horizontal plane at the elevation specified in the contract documents.

3. **Filling.**
   - **a.** After the piles have been cut off, remove water piles.
   - **b.** After reinforcement has been accurately placed, fill pile completely with Class C structural concrete meeting requirements of Section 2403. Ensure pile is free of accumulated water at the time concrete is placed.
   - **c.** In order to avoid formation of air pockets, place the concrete:
     - Using vibratory methods as specified in Article 2403.03, D or
     - In small charges of not over 2 cubic feet (0.05 m^3) each.

4. **Painting.**
   After the piles have been filled with concrete, clean the exposed sections using hand methods. Paint with three coats of paint from the cap to the low water elevation or 2 feet (0.5 m) below finished ground line according to the provisions of Section 2508. Apply all three coats of paint in the field.

F. Steel H-Piles.

1. Use steel H-piles of the cross section, size, and weight per foot (mass per meter) specified in the contract documents. The contract documents may allow an option of pipe piles in place of steel H-piles. Pipe piles are also described in Section 4167.

2. When driving is complete, cut the pile off neatly at the elevation specified. The contract documents may require encasement of steel H-piles. The Contractor may increase the diameter of encasements with no additional payment. Limit the increase to 4 inches (100 mm) or less. For a structure, use encasements all of the same diameter. Clean steel H-piles that are exposed to the atmosphere in the finished structure. Paint these piles with three coats of paint as specified in Section 2508.

3. Limit the number of permitted welds used to develop plan specified lengths of steel H-piles to those in Table 2501.03-3:

Table 2501.03-3: Number of Permitted Welds.

Plan Pile Length, feet (m)	Number of Permitted Welds (splices)
0 - 50 (0-15.0)	0
51-100 (15.1-30)	1
101-150 (30.1-45.0)	2

4. Welds (splices) in excess of the number specified above will not be permitted unless required for a pile extension. When steel H-piles are to be spliced, make the last added length the shortest pile length.

G. Steel Sheet Piles.

1. For steel sheet piles that will become a part of a finished structure, use an interlocking type with a:
- Web thickness no less than 3/8 inch (9 mm),
- Section modulus no less than that specified in the contract document.

2. Use an interlock approved by the Engineer.

3. Put used sheet piles in proper condition before redriving.

4. Where steel sheet piles will receive a concrete cap, cut them off neatly in straight lines at the required elevations after driving. Adapt the details at angles in sheet pile walls to the type of pile used. Obtain the Engineer's approval.

5. Steel sheet piles need not be painted unless specified.

H. Foundation Piles.

1. The term "foundation piles" means all piles, whether of wood, concrete, or steel, which support superimposed loads and have no part of their length exposed above ground line.

2. Except as provided otherwise in the contract documents, complete excavation before driving foundation piles. After driving is completed, remove all loose and displaced material forced up during driving from around the piles, leaving a firm surface to receive the footing concrete.

3. After piles have been driven, cut the tops to the plane indicated at the required elevation. Remove all crushed or broomed wood, broken concrete, or deformed steel. Paint the tops of treated wood piles with two coats of treatment material meeting the requirements of Section 4160. Inspect steel pipe piles for damage according to Article 2501.03, E.

I. Trestle Piles.

1. The term "trestle piles" means all piles, whether of wood, steel, or concrete, which support superimposed loads, but will be exposed above the ground level for a part of their length. Bents around which fills may later be constructed are considered trestle piles.

2. Drive wood and steel piles with an accuracy that will permit them to be capped as shown in the contract documents, with only such springing and bending that will not damage the pile. If, in the Engineer's judgment, a pile has been deformed or cracked by springing after being driven, replace it. Perform all springing prior to placing the cap.

3. Drive concrete piles to stand without springing within 4 inches (100 mm) of the intended location, and in no case closer than 3 inches (75 mm), to the faces of the caps as shown in the contract documents. In case it is necessary to move a concrete pile after driving to secure the above accuracy, move it by loosening the soil surrounding the pile with jets until it can be moved and can stand without strain in the correct position. After being moved, drive the pile a sufficient amount to assure the specified minimum bearing value.

4. Cut trestle piles off to be level or at the designed slope at the elevation of cut-off shown in the contract documents. Ensure the length of pile above this elevation is sufficient to permit complete removal of all material damaged by driving.

5. In treated wood piles, apply two coats of an approved treatment material meeting requirements of Section 4160 to all bolt holes, cuts, daps, or chamfers made subsequent to treatment, as well as all abrasions of the surface and the tops of piles after cut-offs. When the tops of treated piles are not to be encased in concrete, protect them as specified in Article 2409.03, D.

J. Preparation of Wood Piles for Driving.
Prepare all wood piles for driving according to the following:

1. **Preparation of Pile Heads.**
Trim the pile head accurately to make a driving fit into the driving cap. If the head of the pile becomes broomed or crushed before driving is completed, trim off the broomed fibers to provide sound wood accurately fitting the driving cap.

2. **Preparation of Pile Points.**
Cut the lower end of a pile square. If directed by the Engineer, shape it to a point no less than 4 inches by 4 inches (100 mm by 100 mm). Form the tapered point concentric to the center line of the pile.

K. Protection of Concrete Piles during Driving.
Protect the tops of all concrete bearing and sheet piles from damage by the impact of the hammer. Design, maintain, and use this protection to cause the minimum absorption of energy consistent with adequate protection of the top of the pile.

L. Accuracy in Placing and Driving Piles.

1. In spotting the points of piles in preparation for driving, use care to locate them as shown in the contract documents or as directed by the Engineer. Limit the deviation from such designated locations to 3 inches (75 mm) or less at the time driving is begun, except as may be made necessary by the presence of unavoidable obstructions.

2. While being driven, hold piles so they deviate the minimum possible amount from the vertical or batter line shown in the contract documents. Firmly and securely hold in place in proper position the leads used in driving piles to assure driving the pile in the line required.

3. Suspend pile driving during and for 12 hours following concrete placement that is within 50 feet (15 m) of the pile driving operation.

M. Determination of Bearing Value of Piles.
When load tests are not specified in the contract documents or are not directed by the Engineer, determine the bearing value of piles determined using one of the following methods:

1. **Wave Equation Analysis.**
   a. Wave equation analysis will be used on all Interstate and Primary projects, on other projects when specified in the contract documents, or as directed by the Engineer.
   b. Drive piles to full penetration using approved driving equipment.
   c. Retaps or pile extensions may be necessary to obtain the required pile bearing capacity, including potential adjustments for scour or downdrag conditions.
   d. Do not continue driving beyond a depth at which acceptable pile stress is exceeded. With the Engineer's approval, driving may be stopped when the rate of driving exceeds 160 blows per foot (0.3 m).

2. **Bearing Determinations by Formula.**
   a. When wave equation analysis is not required, compute the bearing value of piles using the following formulas:

      For Gravity Hammers with Wood, Steel H, or Steel Pipe Piles:

English

$$P = \frac{3WH}{S+0.35} \times \frac{W}{W+M}$$

Metric

$$P = \frac{2.5WH}{S+8.9} \times \frac{W}{W+M}$$

For Gravity Hammers with Concrete Piles:

English

$$P = \frac{4.5WH}{S+0.2} \times \frac{W}{W+M}$$

Metric

$$P = \frac{3.7WH}{S+5.1} \times \frac{W}{W+M}$$

Set the height of fall to no less than 5 feet (1.5 m) or more than 8 feet (3 m), and the rate of driving to no less than 8 blows per minute.

Diesel Hammers with Wood, Steel H, or Steel Pipe Piles and (Construction) Steam Hammers for all Piles:

English

$$P = \frac{3E}{S+0.1} \times \frac{W}{W+M}$$

Metric

$$P = \frac{0.25E}{S+2.5} \times \frac{W}{W+M}$$

Diesel Hammers with Concrete Piles:

English

$$P = \frac{7E}{S+0.1} \times \frac{W}{W+M}$$

Metric

$$P = \frac{0.58E}{S+2.5} \times \frac{W}{W+M}$$

Where, for the above equations:

P = The bearing value in tons (kN),

W = The weight (mass) of the gravity hammer, or the ram of an air hammer or diesel hammer in tons (kilograms),

H = The height of free fall of the hammer or ram in feet (meters),

M = The weight (mass) in tons (kilograms) of the pile plus the weight (mass) in tons (kilograms) of the cap plus (for diesel hammers) the weight (mass) of the anvil in tons (kilograms),

E = The energy per blow in foot-tons (joules) (for single acting steam hammers E = W x H (E = 9.81 x W x H)),

S = The average penetration in inches (millimeters) of the pile per blow for the last 5 blows for gravity hammers and the last 10 blows for air or diesel hammers.

b. Apply the following conditions in the use of the above formulas:

1) Unless the hammer has free fall, substitute a value for "W" that is less than the weight (mass) of the hammer by an amount sufficient to compensate for all friction and drag tending to retard its fall.

2) With approval from the Engineer, driving may be stopped when the rate of driving exceeds 160 blows per foot (0.3 m).

3) There is no excessive bounce to the hammer after the blow.

4) For the computation of the bearing value for battered piles driven with gravity hammers, multiply the value obtained from the formulas by the following factor:

(Cosine a) minus (f sine a), where "a" equals the angle the leads make with the vertical and "f" equals the coefficient of friction between the hammer or ram and the surface on which it slides. For gravity hammers sliding on greased steel surfaced leads, assume the value of "f" to be 0.1.

c. The Engineer may modify the above formulas on the basis of load tests. At the Engineer's discretion, the Wave Equation Analysis may be used to evaluate the driving system, as well as determine pile bearing.

3. Static Load Test.

a. When directed by the Engineer, bearing value of piles will be determined by actual load test in which the entire load is applied concentric with the pile.

b. Careful measurements will be made to determine the amount and rate of settlement.

c. Gages reading in thousandths of an inch (0.001 µm) will be used to determine the settlement.

d. The designated test pile(s) shall stand, after being driven, at least 40 hours before the test load may be applied.

e. This method is outlined in Section 5.6 and 6.4 of ASTM D 1143. The procedure in ASTM D 1143 will be followed except as modified below:

1) Apply the test load in increments of 10% of the proposed design load.

2) Apply the load at 2.5 minute intervals. Record readings of time, load, and settlement immediately before and after the application of each load. The test is to continue by adding load increments until continuous jacking is required to maintain the test load (i.e., failure by settlement), or the load limit of the jacking equipment is reached.

3) When the maximum load has been applied, take pile settlement readings immediately, and at 2.5 minutes and 5 minutes, after jacking has ceased. Remove the test load and immediately record pile rebound readings. Take additional rebound readings 2.5 minutes and 5 minutes later.

4) Use the data obtained to plot a load (tons (kilonewtons) versus settlement in inches (millimeters)) curve.

f. The failure load is defined as the intersection between the tangent of the linear portion of the load settlement curve and a line with a slope of 0.05 inches per ton (0.14 mm/kN) from the yield point.

g. The yield point is defined as the intersection between the load settlement curve and a line which is parallel to the linear portion of the load settlement curve at 0.25 inches (6 mm) of settlement.

h. The safe bearing value will be 50% of the load at the failure point.

4. Dynamic Pile Analyzer Tests.

a. The Engineer will take dynamic measurements during the driving of piles designated as dynamic load test piles, or as directed by the Engineer. Instruments for dynamic analysis will be:

- Attached near the top of the pile with bolts placed in approved masonry anchors, or
- Bolted through drilled holes in the web of steel piles, or
- Bolted with wood lag screws for timber piles.

b. The Engineer will furnish the instruments, material, and labor necessary for drilling the holes and mounting the instruments.

c. When specified in the contract documents, or ordered by the Engineer, furnish a shelter to protect the dynamic test equipment from the elements. Maintain the inside temperature of the shelter above 45°F (7°C). Locate the shelter within 100 feet (30 m) of the test location.

d. Pretest, Pile Calibration.

1) Predriving wave speed measurements will be required for concrete or wood piles. Make each designated pile available for this measurement prior to placement of the pile in the leads.

2) When predriving wave speed measurements are required, block the piling up off the ground in a horizontal position and locate it to not contact other piling. Predriving wave speed measurements will not be required for steel piles.

e. Prior to Driving.

1) Prior to placing the designated pile in the leads, provide access to the pile and allow the Engineer time to predrill instrument mounting holes or conduct predriving wave speed measurements, or both, if required.

2) When the designated test pile is placed in the leads and is ready to drive, provide the Engineer reasonable access to the pile for testing purposes.

3) Attach the instruments and associated test cables to the top of the pile as directed by the Engineer, unless there is an acceptable personnel platform (minimum size of 4 feet x 4 feet (1.2 m x 1.2 m) designed to be raised to the top of the pile) provided for the Engineer.

4) Allow time to attach or reattach and check the instruments as needed before beginning to drive.

f. **Driving.**

1) Drive the designated pile to at least the depth at which the dynamic test equipment indicates that the capacity shown in the contract documents has been achieved, unless the Engineer directs otherwise. The stresses in the pile will be monitored during driving with the dynamic test equipment to ensure that damage, as determined by the Engineer, does not occur.

2) If an over-stress condition is indicated, the Engineer will suspend driving and determine if plan capacity has been achieved. If necessary, in order to maintain monitored stresses below the accepted values, reduce the driving energy transmitted to the pile by:

- Using additional cushion thickness,
- Reducing the energy output of the hammer, or
- Changing hammers.

3) If nonaxial driving is indicated by the dynamic test equipment measurements, immediately realign the driving system.

4) When the Engineer orders, wait a minimum of 24 hours and retap the dynamic load test pile after the instruments are reattached. Do not use a cold hammer for the retap. Warm up the hammer before the retap by applying at least 20 blows to another pile. The maximum amount of penetration required during a retap is 6 inches (150 mm). After retapping, the Engineer will determine if desired bearing has been achieved or if additional pile penetration is required.

5. **Retaps.**

a. When piles do not achieve the specified driving resistance during driving, the Engineer may require one retap per 10 piles or a minimum of 2 piles in each foundation at no additional cost to the Contracting Authority. Only piles with the lowest driving resistance will be considered for retap.

b. Perform the retap by allowing the pile to set up for 24 hours, or as directed by the Engineer.

c. Warm up hammers (other than gravity) by applying a minimum of 20 blows to another pile before the retap driving begins. Take the bearing for the retap within the first 6 inches (150 mm) of penetration.

d. The first two blows of a retap are for seating the cap and assuring proper operation of the hammer. Do not use the first two blows as part of bearing evaluation.

e. Measure the penetration of the next ten blows, or record the number of blows it takes to drive the pile 6 inches (150 mm). Correct to the appropriate measurement and check for bearing.

1) If bearing is achieved, driving may be halted. However, if the Engineer approves, driving may be continued to cut-off as long as acceptable pile stress is not exceeded.

2) If penetration is less than 1 inch (25 mm) for the first ten blows, discontinue driving. Record the bearing as refusal.

f. Have the Engineer evaluate piles not achieving the specified driven resistance after a retap and, if so ordered, extend as required following the procedures of Article 2501.03, P.

N. **Bearing Required.**

Unless modified by the Engineer, drive all piles to the design bearing specified in the contract documents. Ensure the specified design bearing is obtained below scour elevation for substructure subject to scour.

O. **Penetration.**

1. Unless provided otherwise in the contract documents, drive all piles until the design bearing, determined as provided in Article 2501.03, M, is at least equal to that specified in Article 2501.03, N.

2. Drive all piling for piers and abutments of stream crossings, and the piling for piers and abutments of other structures, when ordered by the Engineer, until the following requirements for penetration have been met:

a. The length of all piles specified in the contract documents, or ordered by the Engineer, for any specific structure is to be construed as indicating the desired penetration. Continue

the effort to secure this penetration as long as the pile can be driven without damage to the pile.

b. When the pile can not be driven to the required length without damage, the Engineer will determine if additional penetration is required. If full penetration is required, advance the pile by jetting, preboring to a maximum depth of 20 feet (6 m), or other approved methods which will secure the required penetration and bearing without damage to the pile.

c. The driving of wood piling in excess of 40 ton (350 kN) bearing will not be permitted.

d. If soil conditions permit auguring, perform the auguring according to Article 2501.03, Q, except drill the holes to the approximate size of the pile measured at mid length. Do not use Bentonite slurry in prebored holes to gain additional penetration.

e. Drive piles which do not carry superimposed vertical loads, such as wingwall piles, fender piles, wing dam piles, and revetment piles, to the penetration shown in the contract documents without regard to bearing values.

P. Extensions and Splices.

Follow Article 2501.03, M, 5, when piles driven to the specified depth fail to develop the required design bearing. If the Engineer orders pile extensions, driving will continue as long as practical, then the piles will be extended in the manner specified below:

1. Concrete Piles.

a. When a concrete pile is to be extended and the pile does not require further driving, cut away the concrete at the end to expose 24 inches (600 mm) of the existing extension bars cast in the upper end of the pile, as well as 24 inches (600 mm) of the prestressing tendons. To the exposed steel, properly lap and securely wire reinforcing equivalent in cross sectional area to the exposed extension bars.

b. If for any reason extension bars do not exist at the splice, cut the concrete off squarely with at least 24 inches (600 mm) of the prestressing tendons exposed. Use eight No. 7 (No. 25) reinforcing bars, from full lap with the tendons to within 3 inches (75 mm) of the extension top.

c. In the concrete pile extension, use 5 gage (No. W 3.5) spiral reinforcing placed at a 3 inch (75 mm) pitch, and ending with six close turns at the top.

d. After the extension reinforcement is in place, place the necessary forms. Do not allow leakage along the face of the pile.

e. Use the same quality concrete for the extension used to cast the original pile.

f. Just prior to placing concrete for the extension, prepare the joint according to Article 2403.03, I. Coat with a creamy mixture composed of 1 part of water and 1.5 parts of dry cement. The grout may be poured in at the top of the form, depositing it as nearly as possible in the center of the pile.

g. After placement, the forms may be removed after 24 hours, and the extension cured by wrapping with two thicknesses of burlap kept wet for 4 calendar days. Finish the entire surface of the exposed pile to present a uniform color and texture. Splice piles that require further driving as specified in the contract documents or as directed by the Engineer.

2. Steel Piles.

a. For extensions of steel H-piles and steel pipe piles, neatly weld the entire cross section after removing all damaged metal. Ensure the axis of the extension coincides with the axis of the original pile. Perform welding of all steel piles according to Article 2408.03, B.

b. Allow only welders qualified according to Material I.M. 560 to make field extensions of steel piles. Ensure they use an approved welding procedure involving the use of backing plates according to Article 2408.03, B.

c. When designated in the contract documents, the Contractor has the option of extending steel piles by means of mechanical splices approved by the Engineer.

3. Wood Piles.

Splice wood piles as directed by the Engineer.

Q. Prebored Holes as per Plan.

1. When required by the contract documents, bore holes greater than the maximum cross sectional dimension of the pile. Bore holes to the elevations shown and to a minimum diameter 4 inches (100 mm) greater than the maximum cross sectional dimension of the pile 3 feet (1 m) from the butt. Drive piles through the holes to at least the specified design bearing.

2. Use natural bentonite slurry when piling is to be advanced in prebored holes. For holes drilled in noncollapsing soils, the bentonite slurry may be placed after piles are driven. In collapsing soils, place the bentonite slurry at the time the hole is drilled. Cover holes to prevent footing concrete from entering the holes.

3. Use prebored hole filling materials consisting of polymer free sodium bentonite designed for sealing wells and bored holes. Materials may consist of American Petroleum Institute Specification 13A, sodium bentonites, high solids bentonite grout mixes, or granular bentonites composed of approximately 1/4 inch (6 mm) or larger particles.

4. For collapsing soils, make a slurry by thoroughly mixing the bentonite with water according to the manufacturer's recommendation for the product used. In no case use more than 100 gallons (500 L) of water per 80 pounds (50 kg) of bentonite. Place slurry materials by pumping or other applicable methods that assure the hole is filled from the bottom up.

5. For noncollapsing dry holes, coarse 1/4 inch (6 mm) or larger bentonite particles may be poured directly into the hole and hydrated with water after placement.

6. Completely stabilize the hole and fill with bentonite prior to placing footing concrete.

2501.04 METHOD OF MEASUREMENT.

Measurement for the quantities of Wood Piles, Steel HP-Piles (either encased or not), Steel Pipe Piles, Concrete Piles, and Steel Sheet Piles, will be the plan quantity. The quantity may be modified by Article 2501.04, D, F, or G.

A. Wood Piles.

When a wood pile is broken in driving, through no fault of the Contractor, the length measured for payment will be the plan length.

B. Sheet Piles.

The area of walls of sheet piles will be determined from the plan length and the horizontal center line length measured to the nearest 0.1 foot (0.1 m) of wall.

C. Concrete Encasement.

The length of concrete encasement of steel HP-piles constructed will be measured to the nearest 0.1 foot (0.1 m).

D. Extension and Splices.

1. **Wood and Steel Piling.**
   a. For Measurement for extensions of wood, steel HP (either encased or not), or steel pipe piles ~~that are extended, the length measured for payment~~ will be the length of the extension specified by the Engineer. Portions of pile cut-offs used as extensions on the same contract will not be remeasured as additional plan quantity.
   b. Splices (welded or mechanical) are measured by count. Only splices specified by the Engineer to extend piles beyond plan length will be counted.

2. **Concrete Piling.**
   a. ~~For~~ Measurement for extensions of concrete piles ~~that are extended, the length measured for payment~~ will be the length of the extension specified by the Engineer, plus the additional length required to be removed for splicing the reinforcement.
   b. Splices are not measured separately.

E. Prebored Holes.

1. The length of prebored holes will be calculated in linear feet (meters) from elevations as shown in the contract documents to the nearest 0.1 foot (0.1 m).

2. Preboring required by Article 2501.03, O, will be measured for payment to the nearest 0.1 foot (0.1 m).

F. Extra Pile.
Extra piles ordered, in addition to the plan quantities, will be measured for payment.

G. Unused Piles.
The quantity of unused piling delivered to the job site without having been placed in the leads or any attempt made to drive it will be subtracted from the plan quantity.

2501.05 BASIS OF PAYMENT.
Payment will be the contract unit price for the quantities of Wood Piles, Steel HP-Piles (either encased or not), Steel Sheet Piles, Steel Pipe Piles, and Concrete Piles measured as provided above. The price bid for piles is full compensation for delivering piles to the site, preparing, driving, cutting, and filling (steel pipe piles only) piles, except as modified in this article.

A. Unused Piles.

1. Return unused piling (either ordered as directed by the Engineer, or specified in the contract documents to the supplier. Unused piles are piles that have been delivered to the job site without having been placed in the leads or any attempt made to drive them. Payment will be made for freight, restocking, and handling charges.

2. The Contracting Authority may purchase unused piles for the invoice cost plus handling and transporting costs.

B. Extension of Concrete Piles.
Payment for the extension will be twice the contract unit price per linear foot (meter) of pile. The length of extension is to be as directed by the Engineer.

C. Extension and Splicing of Steel ~~H-piles or Pipe~~ Piles.

1. Payment for extension will be at the contract unit price for pile.

2. Payment for splice (welded or mechanical) will be at ten times the contract unit price per linear foot (three times the contract unit price per meter) for splices (welded or mechanical) for steel HP-piles or pipe piles required to be spliced to obtain lengths greater than specified in the contract. Payment includes all equipment, labor, and materials necessary to complete the splice.

D. Extension and Splicing of Wood Piles.

1. Payment for extension will be at the contract unit price for pile.

2. Payment for splice will be according to Article 1109.03, B.

E. Pile Cut-Offs.

1. Pile cut-offs not used as extensions on the same contract become the property of the Contractor. Steel pile cut-offs used as extensions on the same contract will not be paid for as additional plan quantity.

2. All piles, or portions thereof, which become the property of the Contractor shall be removed from the project site by the Contractor.

F. Encasement.
Payment will be the contract unit price per linear foot (meter).

G. Test Piles.
The contract may provide a lump sum item for Test Piles. If an item is not provided, Test Piles ordered by the Engineer and driven under the Engineer's supervision will be considered as extra work and will be paid for as provided in Article 1109.03, B.

H. Pile Points.
When the contract documents require that points of piles be protected with metal points, furnish these points without extra compensation. When metal points are not specified in the contract documents, furnish them only upon direction of the Engineer, in which case payment will be made as provided in Article 1109.03, B.

I. Sheet Piles.
When specified to become a part of the permanent structure, payment will be at the contract unit price per square foot (square meter) for steel sheet piles of the specified weight (mass) and cross section for the area of the wall or walls placed.

J. Pile Loading Tests.

1. When required, payment will be the contract lump sum price. Payment is full compensation for all labor, material, and equipment required to comply with the procedure shown in the contract documents, including the test and anchor piles, welding, and placing and removing the test beam.

2. For pile loading tests ordered by the Engineer, payment will be a lump sum price of $3000. When this test is performed within a cofferdam, the lump sum price will be $6000. Payment is full compensation for all labor, material, welding, and equipment, for placing and removing the test beam, and loss of time.

K. Prebored Holes.

1. When required by the contract documents, payment will be the contract unit price per linear foot (meter).

2. Payment is full compensation for all labor, equipment, and materials including bentonite slurry.

3. Prebored holes required by Article 2501.03, O, will be paid for according to Article 1109.03, B.

L. Dynamic Pile Test.

1. When required by the contract documents, or ordered as directed by the Engineer, payment will be a lump sum price of $250 per test pile.

2. Payment is full compensation for all labor, materials, equipment, and time associated with this test as outlined in Article 2501.03, M.

M. Jetting.
When required by Article 2501.03, O, payment will be according to Article 1109.03, B.

N. Payment for Driving Only.
If extensions or extra piles are furnished by the Contracting Authority, payment for driving will be paid according to Article 1109.03, B.