Section 520—Piling

520.1 General Description

This work consists of placing completed piling in structures. The work includes incidentals and additional work except for the following:

- Prestressed concrete cylinder piling (see Project Special Provisions)
- Piling for ground-mounted roadside signs (see Section 636)

Although square, prestressed-concrete piles are a Pay Item under Section 520, have them manufactured, finished, cured, marked, handled, stored at the plant, and shipped from the plant according to Section 865.

The requirements in this Specification are minimal. Comply with the requirements and assume the responsibility for taking additional precautions to complete the work successfully.

520.1.01 Definitions

Plan Driving Objective (PDO): Statement on the Plans specifying the minimum requirements during pile driving. The PDO may require a driving resistance (tonnage [kilonewtons] by formula), a minimum tip elevation, or a combination of these.

Minimum Tip Elevation: Elevation the pile tip cannot stop above. When composite prestressed concrete piling is used, this term will refer to the protruded tip of the Steel H-Pile Section.

Long Pile: A pile more than 50 ft (15 m) in length.

520.1.02 Related References

A. Standard Specifications

Section 101—Definitions and Terms

Section 104—Scope of Work

Section 109—Measurement and Payment

Section 500—Concrete Structures

Section 501—Steel Structures

Section 547—Pile Encasement

Section 636—Highway Signs

Section 855—Steel Pile

Section 865—Manufacture of Prestressed Concrete Bridge Members

B. Referenced Documents

ASTM D 1143

QPL 37

520.1.03 Submittals

A. Template Plan for Positioning Piling

Before driving piling, submit a plan for ensuring piling stability and position, including templates, to the Engineer. Do not drive piling until the plan is approved.

B. Plans for Loading Test Methods

Submit the plans for loading test methods to the Engineer for approval before beginning the work.

Ensure that the test method is logical and can be rationally analyzed by a commonly accepted structural design theory.

C. Loading Test Equipment

Submit the list of equipment for conducting loading tests to the Engineer for approval before beginning the work.

If the testing apparatus is a hydraulic jack, furnish 5 copies of the calibration certification to the Engineer for the equipment, prepared by the manufacturer, an authorized representative, or an approved testing laboratory. Consult the Engineer to find out which laboratories are approved.

520.2 Materials

Ensure that materials meet the requirements of the following Specifications:

Material	Section
Preservative Treatment of Timber Products	863
Timber Piles	861.2.01
Prestressed Concrete Piles Bridge Members	865
Welded and Seamless Steel Piles	855.2.01
Fluted Steel Shell Piles	855.2.02
Steel H-Piles	855.2.03
Steel Bolts, Nuts, and Washers	852.2.01
Aluminum Alloy Sheet and Plate	850.2.01
Metal Caps	862.2.01.A.5

Refer to Subsection 855, "Steel Pile" for Specifications on cast steel-H pile points. For a list of sources, see QPL 37.

Use the following piling types where shown on the Plans:

- Timber piling
- Prestressed concrete piling
- Metal shell piling
- Steel H-piling

Use other piling types when the Plans and Special Provisions require it.

520.2.01 Delivery, Storage, and Handling

A. Timber Piling

Handle timber piling carefully using only non-metallic slings. Do not drop or damage the piling.

Store timber piles on skids above the supporting surface. Keep hardware covered.

B. Prestressed Concrete Piling

Handle prestressed concrete piling carefully to prevent fracture by impact or by excessive bending stress either in storage, during transportation, or when being transferred to the leads. Do not place other materials on the piling during storage or transport.

1. Transporting Prestressed Concrete Piling

Transport prestressed concrete piling using the approved limits of support spacing for the various sizes and lengths of piling. These limits are shown on Standard Plans or on other drawings and are available to the Engineer from the Department.

2. Loading and Unloading Prestressed Concrete Piling

   Load and unload piles using the embedded pick-up points placed during manufacture.

3. Storing Prestressed Concrete Piling

   Store piles as follows:

   - Store piling in single layers directly on the ground only when there is uniform, level bearing for the full pile length.
   - To store piles in tiers, support the piling using blocks of uniform thicknesses placed immediately adjacent to the embedded pick-up points and in line vertically.
   - Store piling in groups of the same lengths.

4. Placing Piles in the Leads or in Position

   When picking up piles from storage and placing them in the leads or in position, use only the single pick-up point, marked with "SP" or a line painted on the pile at the plant, unless noted on the Plans or otherwise directed by the Engineer.

5. Driving Piles

   Do not subject prestressed concrete piling to excessive tensile stresses from combining a particular hammer with the soil conditions. Excessive stress may occur, for example, in these situations:

   - When driving a long pile) through soft material that offers little or no soil resistance at the point of the pile
   - When encountering hard driving resistance at the point of a long pile

   When such situations damage pile, make changes to provide undamaged piling in place. If piles are damaged, the Engineer may require the following:

   a. Reduce the energy delivered to the piling by reducing the stroke, changing the cushioning, or using a lighter ram.
   b. Maintain equivalent energy but use a heavier or lighter ram with a different stroke.
   c. Use a smaller hammer for the easier, initial driving.
   d. Drill pilot holes, jet, or spud. When these driving aids are required or permitted, see Subsection 520.3.05.B, "Drill Pilot Holes" and Subsection 520.3.05.G, "Jet and Spud."

C. Metal Shell Piling

Do not deform or dent metal shell piling during handling and storage. Place shells to be stored for a prolonged period on enough skids to prevent ground contact and deflection. Keep the shells fully drained.

D. Steel H-Piling

Do not deform or bend flanges on steel H-piling during handling and storage. Place steel H-piling to be stored for a prolonged period on enough skids to prevent ground contact and deflection. Keep the piling fully drained.

520.3 Construction Requirements

520.3.01 Personnel

Furnish enough labor and work to install the complete loading test, including a temporary shelter over the area if the Engineer requires it.

520.3.02 Equipment

A. Hydraulic Jack for Loading Tests

If the hydraulic jack used to apply the loading test changes behavior during use, return the jack to the manufacturer, an authorized representative, or a testing laboratory approved by the Engineer for recalibration.

B. Driving Head

Use a structural steel driving head recommended by the manufacturer as suitable for the type and size of pile being driven. The driving head shall:

- Hold the pile in the proper driving position
- Be constructed to prevent pile damage
- Be constructed to transmit the hammer energy along the pile axis
- Fit loosely enough around the pile head so that the pile can rotate slightly without binding

C. Cushion or Shock Blocks

Replace cushion blocks as necessary to prevent pile damage. Inspect cushions periodically to ensure that they prevent pile damage.

1. Hammer Cushions

   Use cushions or shock blocks above the driving head to avoid damaging the pile. Replace used hammer cushions reduced to half their original thickness with new cushions.

   Use hammer cushions of a man-made material only such as micarta or aluminum. Do not use materials such as plywood, hardwood, wire rope, and asbestos.

2. Pile Cushions

   For prestressed concrete piling up to 24 in (600 mm), provide a suitable pile cushion block for the top of the pile. Use a cushion made of material that does not compress so far that the cushioning effect is lost.

   For prestressed concrete piling, 30 in (750 mm) and 36 in (900 mm) square, use an approved solid hardwood pile cushion block at least 6 in (150 mm) thick or an equivalent in the base of the hammer to cushion the hammer ram blow on the pile or follower.

3. Follower Cushions

   When a follower is permitted or required, use an approved, square-shaped laminated cushion block between the follower and the top of the pile.

   Use a cushion block for a follower that is:

   - At least 6 in (150 mm) thick
   - Made of 1 in (25 mm) hardwood boards (preferably green) of uniform thicknesses
   - Cut to fit the pile head

   Subsection 520.3.02.F, "Followers," defines a follower within the scope of these Specifications.

D. Hammers

Regardless of the requirements for hammers in these Specifications, the PDO governs in selecting the hammer. The exception for this is the tabulations for prestressed concrete piling shown in the Energy Rating Table in Subsection 520.3.02.D.1.b. Except for timber piling, drive piling with power hammers of an approved make and model (steam or diesel) that are single-acting (open end diesel) or double-acting (enclosed ram diesel).

When desired, use gravity (drop) hammers to drive timber piling and, within the conditions in Subsection 520.3.02.D.2, "Gravity Hammers," steel H-piling and metal shell piling.

Hammer types and restrictions are as follows:

1. Power Hammers

   Maintain power hammers to obtain their potential stroke length and number of blows per minute. Driving resistance values are invalid when these requirements are not met.

   If driving resistance values are invalid, stop the driving operations and correct the problem. Do not begin driving until the problem is resolved.

   a. Power Hammer Types

      Power hammer types include:

      - **Steam Hammers.** Use steam or compressed air from boilers or air compressors to power steam hammers.

        Use boilers and air compressors with an accurate pressure gauge and capacities and hose sizes at least equal to those specified by the hammer manufacturers.
      - **Open-End Diesel Hammers.** Use open-end diesel hammers that allow measurement of the ram stroke length above the top of the hammer.
      - **Enclosed-Ram Diesel Hammers.** Use enclosed-ram diesel hammers with a bounce chamber gauge and charts that will evaluate the equivalent energy being produced under any driving condition.

   b. Power Hammer Restrictions

      Follow these power hammer restrictions:

      - **Timber Piling.** Drive timber piling using a power hammer with a maximum energy rating of 22,400 ft·lb (30 400 N·m).
      - **Steel Piling.** Drive steel H-piling and metal shell piling using a power hammer with an energy per blow of at least 1 ft·lb (1.4 N·m) but not less than 9,000 ft·lb (12 200 N·m) for each pound (kilogram) of driven weight.
      - **Prestressed Concrete Piling.** Except as specified in the following Energy Rating Table, drive prestressed concrete piling using a power hammer with an energy per blow of at least 1 ft·lb (1.4 N·m) for each pound (kilogram) of pile weight, but not less than 15,000 ft·lb (20 300 N·m).

      Driving conditions may require hammers with more energy than the minimum required on the Energy Rating Table. However, the Department will not require hammers that have more than the minimum energy rating, regardless of pile length, unless the Plans or Special Provisions specify otherwise.

Energy Rating Table (English)			
Manufacturer's Energy Ratings on Hammers for Prestressed Concrete Piling			
Pile Size (in)	**Weight Lb/Ft**	**Minimum Energy Rating Ft·Lbs , Ft·Tons**	
		Ft ▪ Lbs	**Ft ▪ Tons**
14 solid	204	22 400	11.2
16 solid	267	22 400	11.2
18 solid	338	32 000	16.0
20 solid	417	32 000	16.0
24 voided	482	32 000	16.0

30 voided	709	39 800	19.9
36 voided	923	50 000	25.0

Energy Rating Table (metric)		
Manufacturer's Energy Ratings on Hammers for Prestressed Concrete Piling		
Pile Size (mm)	**Weight kg/m**	**Minimum Energy Rating N·m**
350	304	30 400
400	397	30 400
450	503	30 400
500	621	30 400
600	717	30 400
750	1055	54 000
900	1374	67 800

2. Gravity Hammers

   When using a gravity hammer, regulate the drop height to avoid damaging the pile. Do not allow the drop height to exceed 10 ft (3 m) for timber piling and 12 ft (3.7 m) for steel piling.

   Ensure that the hammer is marked with its weight to the nearest 50 lbs (25 kg). Upon the Engineer's request, furnish a certified scale weight of the hammer.

   Follow these gravity hammer restrictions:

   a. **Timber Piling.** Drive timber piling using a gravity hammer that weighs at least 2,000 lbs (900 kg) but no more than 3,500 lbs (1500 kg).

      However, ensure that the hammer has enough weight to obtain the PDO with a maximum fall of 10 ft (3 m).

   b. **Steel Piling.** If desired, substitute a gravity hammer for a power hammer when the quantity of a steel piling type shown on the Bridge Plans Summary of Quantities does not exceed 800 linear ft (245 linear meters), including test pile lengths if any, for that pile type for an individual bridge.

      When using a gravity hammer within the scope of the linear foot (meter) condition, ensure that it has enough weight to obtain the PDO with a maximum fall of 12 ft (3.7 m). The maximum allowable hammer weight is 5,000 lbs (2300 kg).

   c. **Prestressed Concrete Piling.** Do not use gravity hammers to drive prestressed concrete piling.

E. Leads

Equip pile driving rigs with leads that allow the hammer to move freely and support piling during driving. Use leads that meet the following requirements:

- The vertical axis of the leads and hammer coincide with the vertical axis of the pile.
- The leads are long and rigid enough to hold the pile in accurate alignment while it is being driven.

However, ensure that the driving rig can slightly adjust the lead position to compensate for minor changes in direction while driving.

When the pile is supported by the material being penetrated or by approved templates, use hammer leads only.

Driving in deep water may require special platform-type templates to ensure piling stability and position (see Subsection 520.1.03.A, "Template Plan for Positioning Piling"). Use templates with enough area to accommodate all persons necessary to perform and inspect the work.

The Engineer may require templates in other necessary locations to ensure piling stability and position.

F. Followers

Do not use inserts of similar type piling placed between the hammer and a pile to keep the hammer above water level or other levels.

Within the scope of these Specifications, a follower is part of the driving mechanism used to drive larger-sized prestressed concrete piling.

Position the follower between the pile head and the hammer driving base to evenly distribute the driving energy across the concrete area of voided-type piling.

Always use followers when driving 36 in (900 mm) prestressed concrete piling. The Department allows followers when driving 30 in (750 mm) prestressed concrete piling.

G. Spuds

Use spuds heavy enough to penetrate through strata or a stratum of firm or hard material to reach the necessary depth.

Control the alignment for battered spudding using templates that maintain the batter. Unless otherwise permitted, use templates to control vertical spudding.

Mark the distance from the top of the spud clearly at 2 ft (600 mm) intervals along the length of the stem.

Use either round or square spud tips for pile driving that meet the following requirements:

- At least as large as the pile to be driven at the spudding location
- If round, no more than approximately 2 in (50 mm) larger than the diameter or diagonal dimension of the pile
- If square, no more than approximately 2 in (50 mm) larger than the lateral dimension or diameter of the pile

H. Jetting Equipment

Provide enough pumping capacity, using at least two jets, to produce a volume and pressure that will freely erode the material next to the pile and the material 6 in (150 mm) below the pile tip.

I. Loading Test Equipment

Furnish the necessary material, tools, equipment (including a constant tension wire with a weight and sheave or a weight and round pin), and incidentals to properly install the complete loading test and a temporary shelter over the area if the Engineer requires it.

520.3.03 Preparation

A. Remove Obstacles

Unless otherwise permitted, remove or cut out portions of obstacles that interfere with attaining the PDO. This will be measured and paid for as described in Subsection 520.4.01.A, "Removing Obstacles."

B. Form the Embankment at Bridge Ends

Before driving piling at bridge ends and unless otherwise shown on the Plans, form the embankment as follows:

1. Make the embankment at bridge ends full depth to the subgrade template except for the stage construction providing a bench for the end bent.
2. Thoroughly compact the embankment as provided in the Specifications.
3. When the Plans or Special Provisions require a waiting period, delay the construction of all or portions of the bridge as required.

The minimum acceptable length of completed full-depth embankment is specified in Subsection 101.11, "Bridges".

520.3.04 Fabrication

General Provisions 101 through 150.

520.3.05 Construction

A. Determine the Pile Length

Use full-length piling when possible, but always use full-length timber piling. Use piling long enough to reach the PDO.

Except for test piles shown on the Plans, pile lengths are based on the lengths assumed to remain in the completed structure.

The Engineer's "Length List" will be available only after the test piles that logically cover the listed bents have been driven and evaluated and required load tests have been performed. The written "Length List" itemizes the number, type, size, and length of pile required per bent.

1. Steel H-Piling or Metal Shell Piling Lengths

   Determine and furnish the required lengths of piling in place to reach the PDO, regardless of whether the Plans require test piles or show estimated lengths.

   To determine these lengths of piling in place, either drive test piles, make borings, or make other investigations at no additional expense to the Department.

2. Timber Piling Lengths

   Have the Department determine the lengths of this piling. Furnish the piling either according to the Plan listing or according to the Engineer's "Length List," as directed.

   Lengths for timber piling up to 40 ft (12 m) will be given in 1 ft (300 mm) increments.

   Lengths for timber piling over 40 ft (12 m) will be given in 2 ft (600 mm) increments.

3. Prestressed Concrete Piling Lengths

   Have the Department determine the lengths of this piling. Furnish the piling according to the Plan listing or the Engineer's "Length List," as directed.

   Lengths for prestressed concrete piling 18 in (450 mm) square or smaller will be given in 2-1/ 2 ft (750 mm) increments.

   a. **Additional Lengths for Prestressed Concrete Piling.** If a prestressed concrete pile, including test pile, is driven below cutoff elevation before reaching the PDO, the Engineer will determine the net additional length required and add this extension length to the written "Length List."

   b. **Composite Prestressed Concrete Piling Lengths.** The composite pile length of composite prestressed concrete piling (with steel H-section tips partially embedded in and partially protruding from the concrete), is the end-to-end length of the concrete.

      The total length of the steel H-section and its embedded and protruding tips is as shown on the Plans. The steel sections are incidental to the work.

B. Drill Pilot Holes

When pilot holes are required, drill them to the diameter and approximate depth specified on the Plans.

Backfill voids and holes with sand or other suitable granular material, or other material as indicated on the Plans. This backfill is an incidental part of the work.

The following are not considered pilot holes:

- Holes created by spudding (punching)
- Holes dug to drive piling that is too long to fit leads
- Holes dug to replace a template (if permitted)

Where pilot holes are required in granular material and the material cannot be sealed off using "mudding" drilling methods, drill the pilot hole as follows:

1. Place a casing pipe with a large enough diameter around the boring device.
2. Hold the casing in position until the pilot hole is completed and the pile driving progresses deep enough into the hard material to keep loose material out of the pilot hole.

Drilling pilot holes using casing is incidental to the work.

C. Test Piling

The Plans will normally require test piles only with timber and prestressed concrete piling, including composite piling. However, the Department may require steel H or metal shell test piles.

When the Plans show the design load of a pile as well as a PDO, the design load is shown only for information purposes if a loading test is required.

Ensure that the piling to be loaded is of the size and type and at the locations specified on the Plans or designated by the Engineer.

The Engineer may revise the quantity or location of the Department's test piles.

The Department may designate locations on the Plans where the Engineer will record pile driving data during driving operations. Such piles are designated as "Driving Data Piles."

Follow these requirements when driving:

- Ensure that the cross-sectional dimensions of test piles are the same as the piles that will be part of the completed structure.
- Test piles are generally longer than piles that remain in the completed structure. Regardless of the PDO, drive test piles to their full length, where possible, for exploratory purposes.
- Drive test piles of the length, type, and size designated on the Plans in the locations the Engineer specifies.
- When using timber test piles, peel the piles and drive them next to the piles that will be part of the completed structure. If desired, machine-peel timber test piles and leave them untreated.
- Drive other types of test piles so that they become part of the completed structure.
- Ensure that test piles furnished and driven in permanent locations meet the requirements in Subsection 520.3.05.D.1, "Determine Driving Resistance," and Subsection 520.3.05.A.1, "Steel H-Piling or Metal Shell Piling Lengths."
- Drive test piles to determine required lengths in the Engineer's presence.
- Cooperate with the Engineer to obtain the required data on "Driving Data Piles" as an incidental part of the work. "Driving Data Piles" do not need to be driven before other piling.

D. Evaluate Bearing Capacity

Determine the bearing capacity of piling by determining driving resistance, performing loading tests, or doing a combination of these.

Determine driving resistance for all piling driven regardless of PDO requirements.

1. Determine Driving Resistance

   Drive a pile in one continuous operation and determine the driving resistance without delays. However, in soft material the Contractor may, at the Engineer's discretion, determine the driving resistance after delaying driving operations.

   Determine the driving resistance of the piling using the appropriate formula for the hammer type. These resistance formulas apply only when:

   - The hammer has a free fall.
   - The head of the pile is not broomed, crushed, spalled, or excessively crimped.
   - The penetration rate is reasonably uniform.

   Determining driving resistance by formula is not a Pay Item. Provide the facilities for determining driving resistance by formula as an incidental part of the work.

Driving Resistance Formulas		
Hammer Type	**Formula Number**	**Formula (DR =)**
Gravity hammer	1	$\frac{2WH}{S + 0.7}$
Single-acting steam (or air) hammer; open-end diesel hammer	2	$\frac{2WH}{S + 0.2}$
Double-acting, enclosed-ram diesel hammer	3	$\frac{2E}{S + 0.2}$
Double-acting steam (or air) hammer	4	$\frac{2(W + Ap)H}{S + 0.2}$
NOTE: Do not use the manufacturer's bearing chart unless it agrees with the applicable formula above.		

Driving Resistance Formulas (metric)		
Hammer Type	**Formula Number**	**Formula (DR =)**
Gravity hammer	1	$\frac{0.167WH}{S + 17.8}$
Single-acting steam (or air) hammer; open-end diesel hammer	2	$\frac{0.167WH}{S + 5.08}$
Double-acting, enclosed-ram diesel hammer	3	$\frac{0.15E}{S + 5.08}$
Double-acting steam (or air) hammer	4	$\frac{0.166(W + A)Hp}{S + 5.08}$
NOTE: Do not use the manufacturer's bearing chart unless it agrees with the applicable above formula.		

The abbreviations in the driving resistance formulas are defined as follows:

Driving Resistance Formula Abbreviations	
Abbreviation	**Meaning**
DR	Driving resistance in tons (kilonewtons).
W	Weight of the striking part of the hammer in tons (newtons).
H	Height of fall in feet (meters) for gravity, steam, and air hammers. When using Formula 1, the maximum height is 10 ft (3 m) for timber piling and 12 ft (3.7 m) for steel H or metal shell piling.
	Observed average height of fall in feet (meters) for open-end diesel hammers. Record "H" as the average penetration in inches (millimeters) per blow being determined. When rating open-end diesel hammers to comply with energy requirements, use the height of fall as 8 ft (2.4 m).
E	Average equivalent energy in foot-tons (newton-meters) for enclosed-ram diesel hammers. Measure "E" as the average penetration in inches (millimeters) per blow being determined using a gauge attached to the hammer.
A	Area of piston in square inches (meters) for double-acting steam or air hammers.
p	Pressure at the hammer in tons per in² (pascals) for double-acting steam or air hammers.
S	Average penetration in inches (millimeters) per blow for the last 5 to 10 blows for a gravity hammer and the last 10 to 20 blows for a power hammer.

2. Perform Loading Test

Unless otherwise specified on the Plans, use a test method that conforms to ASTM D 1143, modified for quick load tests.

Use loading apparatus capable of the lesser value of the following:

- For concrete piles, 400 percent of the design load or 500 tons (4450 kilonewtons)
- For steel piles, 400 percent of the design load or 90 percent of the yield strength

The Engineer may increase or decrease the number of loading tests.

The Department will furnish and read the instrumentation necessary to determine the pile settlement under load.>

A loaded pile is unsatisfactory when the total settlement under 200 percent of the design load exceeds 1 in (25 mm) or the permanent settlement exceeds 1/4 in (6 mm) using the standard loading procedure in ASTM D 1143 Section 5.

The laboratory will determine the maximum safe design load or the failure load of original loading materials based on the results of the loading test.

The Engineer may require the following piles to be driven further:

- Unsatisfactory piles as defined in the paragraphs above
- Piles without enough maximum safety design or failure loads as determined by the Office of Materials and Research

Perform the loading test as follows:

a. Test load piling as required on the Plans, or as directed by the Engineer.

b. Furnish and drive the piling to be test loaded.

c. Furnish and drive necessary anchor piling.

When the Engineer permits, use piling that will remain in the completed structure after load testing as anchor piles when desired.

d. Apply the test loads in equal increments of 10 to 15 percent of the design load.

e. Apply the loads at constant 2-1/2-minute time intervals throughout the test.

f. After the test is complete, remove the temporary materials. These temporary materials remain the Contractor's property.

g. Remove or cut off the piling that will not remain in the completed structure.

Cut off the piling at least 1 ft (300 mm) below the bottom of the footing or the ground line, whichever applies.

h. In deep water, have the Engineer direct how much pile to remove.

E. Drive Piling

Drive piling to the PDO shown on the Plans. When the PDO involves only a driving resistance requirement, the Engineer will determine the depth to drive piling. If there is no Plan PDO, drive the piling as directed by the Engineer.

If the Engineer determines that driving results and loading test results require modification, drive the piling to a PDO modified by the Department.

Drive piling as follows:

1. When using pilot holes, drive the piling enough to fix the point firmly and reach the PDO.
2. Drive piling so that it conforms closely with the position and line shown on the Plans.
3. Drive piling of a given type, including test piles, with the same type and size of hammer.
4. Use vibratory or other pile driving methods only when permitted by Special Provisions Plan Notes or directed by the Engineer.
5. Do not damage piling during driving. Pile damage includes:
    - Crushed, spalled, or cracked concrete
    - Split, splintered, or broomed wood
    - Broken piling
    - Shell collapse
    - Steel deformation
6. Do not force piling into the proper position.
7. When driving a prestressed concrete pile, ensure that the pile point is well-seated with reasonable soil resistance before using full driving energy.
8. Determine the driving resistance when driving the pile using the appropriate Driving Resistance Formula.

F. Excavate and Redrive

Do not drive foundation and end bent piling until excavation is nearly complete.

If driving a test pile to the side (one that will not become part of the structure) have it begin penetration at approximately the same ground elevation as if it were driven within the structure.

Redrive piles that are raised or moved while driving adjacent piling.

G. Jet and Spud

Jetting and, unless otherwise noted in the Contract, spudding are considered incidental to the Work.

Unless otherwise permitted by the Engineer, do not jetting or spudding operations lower than 3 ft (900 mm) above the estimated final elevation of the pile tip, or lower than 3 ft (900 mm) above the specified Minimum Tip Elevation to obtain minimum penetration.

When jetting or spudding to drive a prestressed concrete pile, ensure that the pile point is well seated with reasonable soil resistance at the point before using full driving energy.

1. Jetting

   When the Engineer permits, use jetting to properly position a pile. Additional driving may be required to determine the final driving resistance when piles are positioned by jetting.

   Should additional driving require additional length, the additional expense involved is considered incidental to the Work.

   Jetting may be required with any hammer or piling type (including test piling) and at any site. However, jet only when directed or permitted by the Engineer and as follows:

   a. Do not use jets where the Engineer determines that the jets may endanger the stability of embankments or other improvements.
   b. Perform trial jetting to determine whether to jet using one or two jets. Have the Engineer approve the trial run.
   c. Suspend the pile driving that requires jetting until the jetting is accomplished as directed by the Engineer.
   d. Jet either ahead of the actual pile driving or simultaneously with it as the Engineer determines from the results of trials.

      Control and dispose of water and solids that run off from the jetting.
   e. Maintain parallel drainage to railroad tracks.
   f. Do not simultaneously drive and jet a prestressed concrete pile unless there is reasonable soil resistance at the pile point.
   g. If using jets and hammers simultaneously as required or permitted by the Engineer, withdraw the jets before reaching the PDO and continue driving to fix the point of the pile firmly and reach the PDO.
   h. After jetting an area completely, recheck the driving resistance of questionable piles.

2. Spudding

   If the Plans or Engineer require spudding, do it to facilitate driving.

   The Engineer may require advance jetting exploration before deciding whether or not spudding is necessary to penetrate firm or hard material.

<![endif] --> ***H. Cut Off, Splice, and Extend Piling***

Cut off pilings atthe required elevation. Splice piling driven below this elevation and extend itaccording to the Pile Splice Details[Figure 1(metric)].Ensure that the minimum splice spacing is at least 10 ft. (3 m).

Lengths of cutoff of any piling,including test piles, remain the property of the Contractor. Dispose of cutofflengths outside the highway right-of-way according toSubsection 104.07, "Final Cleaning Up."Ifdesired, use undamaged pieces of steel H and metal shell cutoff for spliceplates, extensions, and reinforcement for steel H-tips.

1. Cut Off Prestressed Concrete Piling

   Cut prestressedconcrete piling using pneumatic tools, saws, or other approved methods asfollows. Do not use explosives.

   When the Engineerconsiders it necessary, use an approved collar when cutting.

   a. Cut back the required amount of concrete at the end of thepile to be extended, leaving the prestressed strand exposed.
   b. Make the final cut at right angles to the pile axis.
   c. When cutting, avoid spalling or damaging the pile belowthe cutoff elevation.
   d. If the pile is damaged, replace the pile or repair thedamage by cutting back to the extent determined by the Engineer. Replace orrepair piles at no expense to the Department.

2. *Extend Prestressed Concrete Piling*

   Driven extensionsof prestressed concrete piling shall consist of Class AAA concrete. Undrivenextensions shall consist of Class A concrete.

   Extend prestressedconcrete piling as follows:

   a. *Build, place, and brace the form work for the extensioncarefully to obtain true alignment and prevent leaks at the construction joint.*

   b. *Just before placing the new concrete, thoroughly wet thecut area and cover it with a thin coating of cement paste.*

   c. *When driving the extension, chamfer the top 1 in (25 mm)at right angles to the extension axis.*

   d. *Remove theforms and cure and finish theconcrete according toSubsection 865.2.01.B.10, "Concrete Curing"andSubsection500.3.05.Z, "Cure Concrete."*

   e. *When extending prestressed concrete piling, comply withthe required details when additional driving is or is not necessary aftermaking the extension.*

      When additionaldriving is necessary, ensure that the extension reaches its 28-day compressivestrength and has been water-cured for 5 curing days before resuming driving.The delay is considered incidental to the Work.

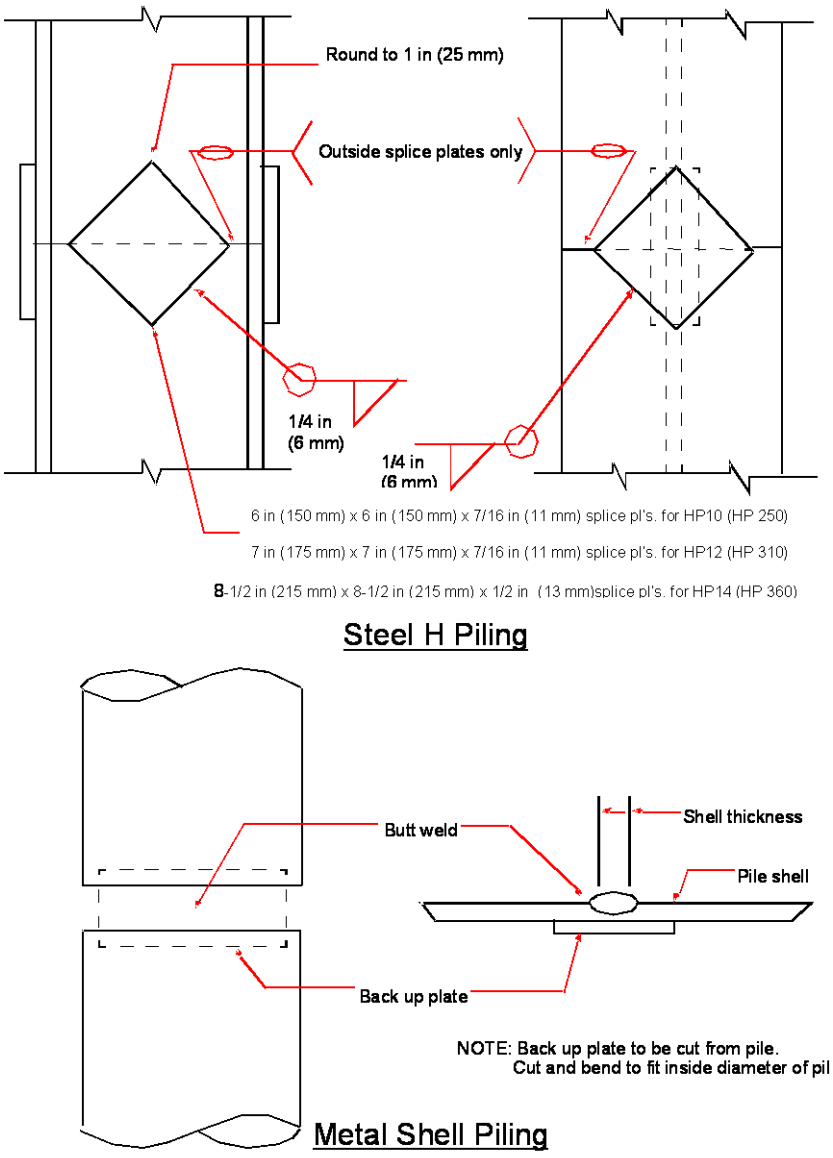

Figure 1 (metric)

3. *Splice and Extend Steel H-Piling and Metal Shell Piling*

   Splice and extendsteel H-piling or metal shell piling before, during, or after driving accordingto the Pile Splice Details [Figure1(metric)]. Ensure that the sections have identical cross sections.

   Instead of using the splice detailsfor H-piles shown in the Pile Splice Details (Figure 1(metric)], when desired,use approved H-pile splicers as follows:

   a. *Ensure that H-pilesplicers are the proper size recommended by the manufacturer for the pileto be spliced.*

   b. *With the splicer in position and before making the splice,ensure that at least 90 percent of the mating ends of the piling to be splicedtouch.*

   c. *Connect the splicer and the piling by welding according toa procedure approved by the Department.*

4. *Cut Off and Splice Timber Piling*

   Accurately cut off piling to becapped with timber or precast concrete to obtain true bearing on every pilewithout using shims.

Replace or repair piles inaccuratelycut off at no additional expense to the Department. Replace or repair to theEngineer's satisfaction.

Do not splice timber piling withoutthe Engineer's permission.

I.Weld SteelPiling Splices and Swaybracing Attachments

Weld steel pilingsplices and swaybracing attachments according toSection501.3.06.C.

Weld only in theEngineer's presence. Use a welder with current Department certification forwelds involved.

J.Repair and Treat Timber Piling

-->Repair and treattimber piling as follows:

1. *-->Field treat cuts and abrasions in treated timber pilingwith either of these heated treatments:*
   - *<Two applications of a mixture of 60 percent creosote oiland 40 percent roofing pitch*
   - *-->Two thorough brush coats of creosote oil followed by acovering of roofing pitch*

   -->Allow each coat todry before applying the next.
2. *-->Before placing bolts, field treat holes made aftertreating with hot creosote oil.*
3. *-->Plug unused holes with treated plugs after the fieldtreatment.*
4. *-->When the approved use of temporary forms or braces causesnail or spike holes in treated piling, fill the holes using either of thesemethods:*
   - *-->Drive galvanized or aluminum nails or spikes flush withthe surface.*
   - *-->Plug the holes with treated plugs after the fieldtreatment.*
5. *-->Field treat treated piling heads used in permanentstructures that will not be encased in concrete footings or caps after cutoff:*
   a. *-->Treat the sawed surfaces with either of these heatedtreatments:*
      - *-->Three applications of a mixture of 60 percent creosote oiland 40 percent roofing pitch*
      - *Three thorough brush coats of creosote oil followed by acovering of roofing pitch.*

      Allow each coat todry before applying the next.
   b. *Cover each pile head with a minimum 28-gauge (0.015 in [0.38mm] thick) metal.*
      - *The metal may be aluminum or galvanized steel. However,aluminum is preferred.*
      - *Trim the metal neatly.*
      - *Bend the metal down around the pile and fasten it to theside using large-headed aluminum or galvanized roofing nails.*

K.Bolt TimberBracing

Bolt permanenttimber bracing at its intersections with piles using standard steel bolts andnuts and cast or malleable iron ogee washers. Refer toSubsection520.2 "Materials"

1. *Place an ogee washer under the bolt head and under thenut.*
2. *Ensure that the diameters of the bolt and the drilled holeare each 3/4 in (19 mm).*
3. *After adjusting the nuts, burr the bolt threads.*

L.Use PrestressedConcrete Piling

Piles cracked intransportation, handling, or storage may be rejected by the Engineer asdefective piles if the cracking indicates structural damage.

Piles with cracksthat are not structurally damaging that will not be used in sea water or alkalisoils may be accepted by the Engineer if the cracks close and are not visiblewhen the pile is in the leads.

When usingprestressed concrete piling, comply with the following:

- *Do not drive prestressed concrete piles until they reach aminimum strength of 5,000 psi (35 MPa) and a minimum age of 5 days.*
- *Form vent holes for voided-type piles in one face of eachpile at approximately 5 ft (1.5m) on the centers. Ensure that these holesremain open permanently.*
- *After completing the driving, cut back and point overcable loops used as embedded pick-up points that remain above the ground orwater line.*

M.Use Metal ShellPiling

Metal shell pilingconsists of steel shells filled with Class A concrete after they are driven inplace and cut off.

Ensure that theshell's minimum wall thickness is 1/4 in (6mm) unless otherwise shown onthe Plans. However, furnish shells thick and rigid enough that they can bedriven to the PDO without crimping, buckling, or distorting.

The Contractor mayuse either of the following:

- *Shells of constant section*
- *Shells that meet the requirements ofSubsection 855.2.02, "Fluted Steel Shell Pile"*

Use metal shellpiling as follows:

1. *Drive metal shell piling closed-ended.*
2. *Unless the Plans specify another detail, construct the endclosure according to Option1 of the Closure Plate Detail [Figure 2 (metric)]so that theclosure plate does not project beyond the outside diameter of the pile.*
3. *After driving, keep the tops of shells covered until theconcrete is placed.*
4. *Ensure that driven shells are clean and free of waterimmediately before placing concrete. Use a suitable light to inspect the entirelength of the shell in place.*
5. *Before placing concrete, examine the shells for collapseor diameter reduction.*

   Shells that are broken or arecollapsed enough that bearing capacity is materially decreased will be rejectedas defective piles.

   Fill rejected shells that cannot beremoved with Class A concrete at no expense to the Department.
6. *When reinforcement steel is required, rigidly assemble andlower it into the shell so that its position is correct during concreteplacement.*

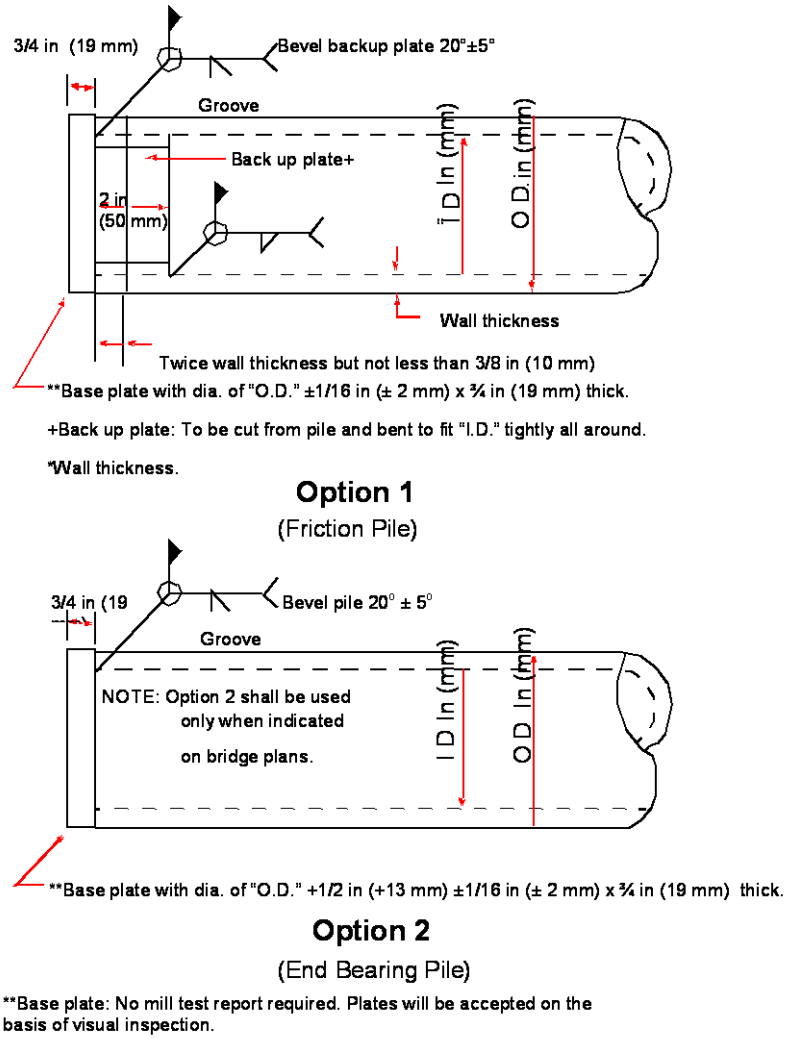

Figure 2 (metric)

7. *Ensure that there are no loose reinforcement steel bars.*
8. *Do not place concrete in the shells until completingdriving within a 30 ft (9 m) radius or until driving shells in any one bent orfooting.*

   If this is not possible, stop thedriving within the radius limit until the concrete in the last shell filledreaches a minimum strength of 2,000 psi (14MPa).

   The Engineer may adjust the 30 ft (9m) limit according to the prevailing vibration conditions.
9. *Place concrete in the shells continuously from tip tobutt. Where shells contain reinforcement steel, use tremies to pour theconcrete.*
10. *For shells in trestle bents, mechanically vibrate theconcrete starting approximately 10 ft (3 m) below the ground and working up.*
11. *For shells in footings, mechanically vibrate the concretefor approximately 25 ft (7.5 m) downward from the top of the shell pile.*
12. *Pour footings and trestle bent caps at least two hoursafter filling the last shell in the footing or trestle bent with concrete.*

N.Use SteelH-Piling

<Wherever the Plansrequire HP 14 in by 73 lb (360 mm by 108 kg) steel H-piling, the Contractor maysubstitute HP 13 in by 73 lb (330 mm by 109 kg) steel H-piling and, as appropriate, 13 in (330 mm) pile tip reinforcement for bearing pile infootings. Do not make this substitution for pile bents. Do not change theContract Bid Price to make the substitution.

*Do not cut or trimsteel H-piling to fit into an improperly sized steel driving head. Instead,replace the head with one that conforms to the requirements of*Subsection 520.3.02.B,"Driving Head."

*Place swaybracing members as shown on the Plans or asrequired by the Engineer and weld it according to the Swaybracing AttachmentDetail [*Figure 3(metric)*].*

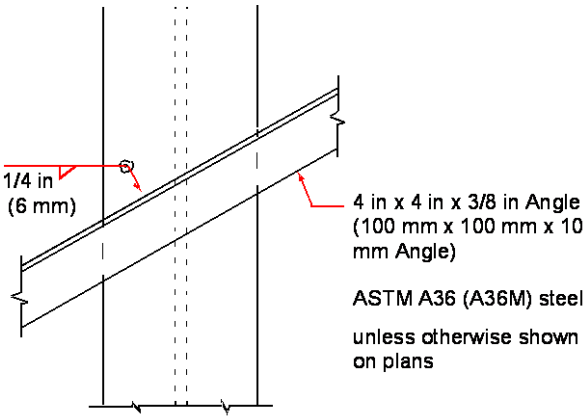

Figure 3 (metric)

If steel H-piles are not driven inthe position and to the alignment required, the Engineer may require fills andshims between the bracing and the pile flanges as an incidental part of the Work.

O. Coat and Paint Piling

Apply a special protective coating as described below to steel H-Piling, metal shell piling, steel sway bracing, and when specified, PSC piling. Clean and paint the piling according to Subsections 535.3.03.A, "Clean New Steel Structures," and Subsection 535.3.05.E, "Paint Steel H-Piling, Metal Shell Piling, and Steel Sway bracing."

1. *Coating Requirements for End-Bent Piling*

   Clean end-bent piling and coat it with a System IV paint for 2 ft (600 mm) below the bottom of the cap.

   As an alternate to coating, pour a concrete collar 2 ft (600 mm) deep with a 3 in (75 mm) cover around the pile.

2. *Coating Requirements for Structures Crossing Streams*

   Coat pilings as follows:

   a. ***Piles Not Encased.*** *For piles within the stream and within 10 ft (3 m) of the top of the stream bank, extend the coating required in Subsection 520.3.05.O.1,"Coating Requirements for End-Bent Piling" for 5 ft (1.5 m) below the stream beds.*

      Give piles a protective coating 5 ft(1.5 m) below ground line for bents more than 10 ft (3 m) outside each stream bank.

   b. ***Piles Encased.*** *For piles that will be encased according to Section 547, extend the System IV paint 12in (300mm) below the top of the encasement.*

3. *Coating Requirements for Grade Separation Structures*

   For grade separation structures, extend coatings for intermediate bent piling to 5 ft(1.5 m) below the finished ground line.

520.3.06 Quality Acceptance

A. Reaching the PDO

The Engineer is solely responsible for determining whether the PDO has been reached satisfactorily.

B. Driving Corrections

Correct driving deviations that exceed 3in (75 mm) from either the position or the line shown on the Plans as directed by the Engineer.

Do not allow the pile heave from driving nearby piling to exceed 1/4 in (6 mm) without retapping.

C. Correcting Rejected Piles

Rejected piles are:

- *Unable to meet material certification*
- *Damaged by internal defects or by improper driving*
- *Driven out of proper location as described in Subsection 520.3.06.B,"Driving Corrections".*
- *Incorrectly driven below the elevation fixed by the Plans or the Engineer*
- *Excessively crimped in driving (steel piling)*

If cracks develop in a prestressed concrete pile that do not classify the pile as defective, seal the cracks with an approved epoxy crack sealer at no expense to the Department. Place the sealer as directed by the Engineer.

If a pile is driven excessively out of position orbelow cutoff elevation through no fault of the Contractor, correct it using the method designated by the Engineer at the Department's expense.

Correct rejected piling at no expense to theDepartment using one or more of the following methods approved for the pile:

1. *Extract the pile and replace it with a new one.*
2. *Drive a second pile next to the defective pile.*
3. *Cut off the pile to obtain a fresh heading, splice it, and extend the pile according toSubsection520.3.05.H, "Cut Off, Splice, and Extend Piling."*
4. *Extend the footing or cap concrete to embed the pile properly and change the bar reinforcement steel as required.*
5. *Delay the Work pending a design analysis (performed by the Contractor with a Department review) and make the corrections specified by the Engineer. The delay is considered incidental to the Work.*

520.3.07 Contractor Warranty and Maintenance

A. Unused Piling (Prestressed Concrete or Timber)

Undriven and undamaged whole lengths of piling ordered by the Engineer will become the property of the Department.

Assemble and neatly stack the lengths as directed by the Engineer at a convenient location for loading on Department vehicles.

Guard the lengths against damage or loss for 10 days after notifying the Engineer in writing that the lengths are ready for loading. The 10-day period begins when the Engineer receives the notice.

520.4 Measurement

The items included in this work will be measured for payment as described in Subsection 520.4.01, "Limits."

520.4.01 Limits

A. Removing Obstacles

When the obstacle removed (see Subsection 520.3.03.A, "Remove Obstacles") consists of the structure being replaced, and the Department has previously paid for removing the structure, remove or cut the obstacle at no cost to the Department.

When the obstacle consists of another object below the original ground and its removal or cutting is necessary, the removal or cutting is measured as Extra Work if it is not covered by another Pay Item.

Cutting by spudding is not measured for payment.

B. Order Lengths

The Department will not recognize, accept, or pay any claim for adjusting the Contract Unit Prices because of underruns or overruns of estimated lengths or quantities of piling.

C. Test Piling

Accepted test piles required by the Plans or the Engineer are measured per each and paid for at the Contract Unit Price.

Accepted piles furnished and driven as test piles at the Contractor's option to determine order lengths are measured and paid for the same as for other piling in place of that type used in the completed structure.

Piling measured and paid for as test piles is not included in other measurement for payment.

There is no additional measurement for payment for "Driving Data Piles."

D. Steel H-Piling and Metal Shell Piling

These piling types are measured in linear feet (meters) of piling in place remaining in the completed work and will be paid for at the respective Contract Price. Measurement does not include piling measured as test piling.

Payment is full compensation for furnishing, driving, jetting, spudding, lining, filling with concrete, disposing of cutoffs, and painting, including special protective coatings.

Pile encasement will be paid for by the linear foot (meter) according to Section 547.5.

Steel sway bracing of steel H-piling will be measured and paid for under Subsection 501.4, "Measurement" and Subsection 501.5, "Payment."

E. Prestressed Concrete Piling and Timber Piling

These piling types are measured in linear feet (meters) of piling in place (plus an allowance for cutoff lengths noted in Subsection 520.4.01.F, "Cutoffs") and paid for at the Contract Price. Measurement does not include piling measured as test piling.

Pay lengths will be based on the Engineer's pile order length.

Payment is full compensation for furnishing, driving, jetting, spudding, lining, disposing of cutoffs, and placing special protective coatings on prestressed concrete piling, if required.

For timber piling, this payment is also full compensation for the costs of furnishing, placing, and removing temporary bracing necessary to hold the piles in alignment.

The pay quantity includes prestressed concrete piling extensions (see Subsection 520.4.01.G.2, "Extensions").

F. Cutoffs

No separate payment will be made for cutting off pile or for using the cutoff lengths of steel H or metal shell piling.

However, cutoff undamaged pieces of steel H or metal shell piling used to make other piles or used as extensions will be paid for as piling in place, described in Subsection520.4.01.D, "Steel H-Piling and Metal Shell Piling, "Subsection520.4.01.G, "Splices and Extensions," and Subsection520.4.01.G.2, "Extensions."

G. Splices and Extensions

All extensions and splices are measured and paid for the same way, whether or not the pile is a test pile.

Splicing and extending timber piling, if allowed, will be measured and paid for as Extra Work according to Subsection109.05, "Extra Work."

1. *Splices*

   For any pile including test piles, each splice per steel H or metal shell pile provided for in the Splice Tabulations will be included in the pay quantities and paid for as a Specification allowance of piling in place in the amounts of4 linear ft (1.2 m) for steel H-pile and 2linear ft (600 mm) for metal shell pile.

   When the original length of a Department test pile is increased by the Engineer after being driven, each splice required as ordered and accepted is measured for payment in the amount provided above. Other steel pile splices, including others made on test piles, will be performed at the Contractor's expense.

   For prestressed concrete piling, each splice ordered and accepted (except those required because of Contractor negligence) will be measured and paid for as a Specification allowance of 5 linear ft (1.5 m) of piling. This payment compensates for the costs of making the actual splice within the limits of the cut-back portion. Include uncompensated costs in the overall bid submitted.

Splice Tabulations	
Steel H or MetalShell Piling	
In Place Length	**Maximum PaySplices (If Made)**
60 ft (18 m) or less	None
Above 60 ft (18m) through 90 ft (27m)	1
Above 90 ft(27m) through 120 ft (36m)	2
Above 120 ft(36m) and up	3

   Splices will be paid for only when performed.

2. *Extensions*

   The extension of a prestressed concrete pile, including test piles, will be the net length ordered by the Engineer measured from the original pile head to the extended head. This extension is measured as piling.

   The actual splice within the cutback portion is measured separately as specified in Subsection 520.4.01.G.1, "Splices."

   Extensions required because of the Contractor's negligence are not measured for payment.

   The Engineer will determine the length of extensions for the Department's steel H or metal shell test piling. These extensions will be paid for as piling in place according toSubsection520.4.01.D, "Steel H-Piling and Metal Shell Piling."

H. Alternate to Extending Test Piling

Instead of extending a prestressed concrete test pile that requires additional driving to reach the PDO (as provided in Subsection 520.4.01.G.2,"Extensions."), the Engineer may give the Contractor the option of abandoning the pile as a test pile as far as measurement and payment are concerned.

If the Contractor chooses this option, the Engineer will allow the Contractor to drive a substituted, longer pile of the required length as the test pile at another location selected by the Engineer.

The Engineer will determine the net additional length required. This additional length will be paid for as piling with no splice allowance.

Complete the abandoned test pile, which is measured the same as non test piles.

The Engineer will not allow the option if the driving data obtained is sufficient or if a loading test is needed instead of further driving.

I. Loading Tests

The number of loading tests completed and accepted will be measured and paid for per each at the Contract Price.

Any loading testor additional stage of loading abandoned because of Contractor fault will not be measured.

J. Cast SteelH-Pile Points

Cast steel H-Pilepoints of the type and size designated on the Plans are measured per each.

K. Pilot Holes

Pilot holes drilled and accepted as a Contract Item are measured per linear foot (meter) from the natural ground (intermediate trestle bents) or from the bottom of concrete, whichever applies. Pilot holes will be paid for at the Contract Price.

Pilot holes not required by the Plans but made at the request of the Engineer will be measured and paid for as Extra Work according to Subsection 109.05, "Extra Work."

L. Composite Prestressed Concrete Piling

No separate payment will be made for furnishing and driving steel H-pile sections partially embedded in and partially protruding from prestressed concrete piling, including test piles.

M. Unused Prestressed Concrete or Timber Piling

Unused prestressed concrete or timber piling will be paid for at invoiced cost, including transportation plus 10 percent.

520.5 Payment

This work will be measured and paid for at the Contract Prices, complete in place.

Payment is full compensation for all costs of complying with these Specifications, including incidentals and additional work.

Payment will be made under:

Item No. 520	Piling in place,(type), (size)	Per linear foot(meter)
Item No. 520	Piling, (type), (size*)	Per linear foot(meter)
Item No. 520	Test pile, (type), (size*)	Per each
Item No. 520	Loading test, (type), (size*)	Per each
Item No. 520	Pilot holes	Per linear foot(meter)
Item No. 520	H-pile points (type), (size)	Per each
Item No. 520	Cast steelH-pile points (type), (size)	Per each
*For timber piling, size will be omitted.		

520.5.01 Adjustments

A. Test Piles

No deduction will be made when a required test pile under runs in length with the Engineer's consent.

When a required test pile overruns in length with the Engineer's consent, see Subsection520.4.01.G.1, "Splices."

B. Cutoff Allowances

Cutoff allowances exclude test piling.

Cutoff allowances will be made for each excess linear foot (meter) removed to achieve the cutoff elevation as follows:

- *For timber piling, the cutoff allowance is 50 percentof the Contract Price.*
- *For prestressed concrete piling, the cutoff allowance is75 percent of the Contract Price.*

C. Loading Tests

If the loaded pile does not carry the load satisfactorily after the load is placed and it is necessary to redrive and reload the pile, this reload constitutes an additional stage of loading but not an additional loading test.

Each additional stage of loading made and accepted on any single pile as specified will be measured and paid for as 50 percent of a loading test.