When provided for in the contract, payment will be made under:

Pay Item	Pay Unit
Painting of Structural Steel	Lump Sum
Pollution Control	Lump Sum

SECTION 450
PILES

450-1 DESCRIPTION

Furnish and install piles in accordance with the contract and accepted submittals. Provide steel and prestressed concrete piles and composite piles with both concrete and steel sections shown in the plans. Drive and drill in piles and use pile tips and accessories as shown in the plans. Galvanize, restrike, redrive, splice, cut off and build up piles and perform predrilling, spudding and pile driving analyzer testing as necessary or required.

Define "pile embedment" as the required pile embedment in the cap or footing and "pile penetration" as the minimum required pile tip elevation or penetration into natural ground, whichever is deeper. Define "natural ground" as below the ground or mud line before constructing any embankments.

The estimated pile lengths shown in the plans are for bid purposes only. Provide piles of sufficient lengths for the required driving resistance, pile embedment and pile penetration. Determine required pile lengths by performing subsurface investigations, as needed.

450-2 MATERIALS

Refer to Division 10.

Item	Section
Flowable Fill, Non-Excavatable	1000-6
Neat Cement Grout, Type 1	1003
Portland Cement Concrete, Class A	1000
Reinforcing Steel	1070
Steel and Prestressed Concrete Piles	1084-1
Steel Pipe Pile Plates	1072

For drilled-in piles, Class A concrete shall meet Article 1000-4 except as modified herein. Provide concrete with a slump of 6 inches to 8 inches. Use an approved high-range water reducer to achieve this slump.

For composite piles with both prestressed concrete and steel H-pile sections, use prestressed concrete piles and steel H-piles that meet Section 1084. Use steel pile points and splicers that are on the NCDOT APL.

450-3 CONSTRUCTION METHODS

(A) Handling and Storing Piles

Handle, transport and store piles so piles are kept clean and undamaged. Do not use chains, cables or hooks that can damage or scar piles. Do not damage coatings on steel piles. When handling prestressed concrete piles, support piles at pick-up points shown in the plans.

Protect steel piles from corrosion. Store piles above ground upon platform skids, or other supports, and keep free from dirt, grease, vegetation and other foreign material.

(B) Pile Installation

If applicable, completely excavate for caps or footings before installing piles. If applicable and unless noted otherwise in the plans, construct embankments to bottom of cap or footing

elevations for a horizontal distance of 50 feet from any pile except where fill slopes are within 50 feet of a pile.

Install piles with the following tolerances:

(1) Axial alignment within 1/4 in/ft of vertical or batter shown in the plans,

(2) Horizontal alignment within 3 inches of plan location, and

(3) Pile embedment within 3 inches more and 2 inches less of the embedment shown in the plans.

If necessary, build up prestressed concrete piles or splice steel piles as shown in the plans. Do not use more than 3 sections (2 splices) of steel piling per pile. Cut off piles at required elevations along a plane normal to the axis of the pile as necessary. Do not damage or spall piles when cutting off prestressed concrete piles.

(C) Pile Accessories

When required, use pile accessories including pipe pile plates and steel pile points and splicers shown in the plans. Weld pipe pile plates to steel pipe piles as shown in the plans.

Attach steel pile points to steel piles in accordance with the manufacturer's instructions. Weld a minimum length of twice the flange width for steel H-piles.

Use steel pile tips with prestressed concrete piles as shown in the plans. Use steel pile splicers for splicing steel H-pile tips and composite piles. Attach steel pile splicers in accordance with the manufacturer's instructions.

(D) Driven Piles

Do not drive piles within 50 feet of CIP concrete until the concrete cures for at least 3 days. Do not use vibratory hammers to install prestressed concrete piles.

When predrilling, spudding and installing the initial portions of steel piles with vibratory hammers, submit these pile installation methods with the proposed pile driving methods and equipment for acceptance. Define "spudding" as driving or dropping a steel H-pile and then removing it. The Engineer will approve the spudding depth and H-pile size, predrilling depth and diameter and depth of pile installation with a vibratory hammer.

Limit driving stresses in accordance with the *AASHTO LRFD Bridge Design Specifications*. Use AASHTO driving stress limits for severe corrosive environments when calcium nitrite corrosion inhibitor is required for prestressed concrete piles. If a tip elevation is noted in the plans, drive steel and prestressed concrete piles to the minimum required driving resistance and tip elevation. Otherwise, drive steel and prestressed concrete piles to the minimum required driving resistance and at least 10 feet into natural ground. Drive composite piles to the minimum required driving resistance and the prestressed concrete and steel H-pile sections to their respective minimum required tip elevations noted in the plans.

Drive piles continuously to the required pile penetration unless stopped due to exceeding the maximum blow count or driving stresses, insufficient pile length or other approved reasons. Redrive piles raised or moved laterally due to driving adjacent piles.

Protect coatings in an approved manner when driving coated steel piles through templates. Repair damaged galvanizing in accordance with Article 1076-7.

(1) Predrilling and Spudding

If necessary or required, perform predrilling and spudding as noted in the plans and in accordance with the accepted submittals. Predrill pile locations to elevations noted in the plans or approved by the Engineer. When noted in the plans and at the Contractor's option, spudding may be used instead of predrilling. Do not perform spudding below predrilling elevations noted in the plans or approved by the Engineer.

When noted in the plans or predrilling in water or wetlands, use temporary steel casings that meet Subarticle 450-3(E)(1), except use steel casings with inside diameters no more than 2 inches larger than predrilling diameters. Use temporary casings from at least 2 feet above the static water elevation or ground line, whichever is higher, to at least 5 feet below the ground or mud line. More than 5 feet embedment may be necessary if temporary casings are not stable or predrilling or spudding disturbs material outside casings.

Perform predrilling and spudding so spoils are minimized, large ground movements and voids below ground do not occur and piles can be driven to the required resistance and pile penetration. Do not deposit spoils in water or wetlands. Remove all temporary casings before driving piles.

(2) Driving Equipment

Submit the proposed pile driving methods and equipment (pile driving equipment data form) including the pile driving hammer, hammer cushion, pile helmet and cushion for all piles for acceptance in accordance with Article 105-2. Do not submit more than 2 pile driving hammers per pile type per submittal. Provide 2 copies of each data form at least 30 days before driving piles. All equipment is subject to satisfactory field performance.

Drive piles with accepted driving equipment and operate pile driving hammers in accordance with the manufacturer's recommendations. Use hammers that will not overstress piles and attain the required driving resistance between 30 and 180 blows per foot. Use variable energy hammers to drive prestressed concrete piles.

Operate air and steam hammers within 10% of the manufacturer's rated speed or a rate approved by the Engineer. Use a plant and equipment for air or steam hammers with sufficient capacity to maintain, under working conditions, the manufacturer's recommended volume and pressure. Equip the plant and equipment with accurate pressure gauges that are easily accessible. Provide striking parts of air and steam hammers weighing at least 2,750 lbs. and one-third the pile helmet and pile weight.

Equip open-end (single acting) diesel hammers with a graduated scale (jump stick) extending above the ram cylinder, graduated rings or grooves on the ram or an electric sound activated remote measuring instrument to determine the hammer stroke during driving. Equip closed-end (double acting) diesel hammers with a calibrated bounce chamber pressure gauge mounted near the ground and provide a current calibrated chart or graph equating bounce chamber pressure and gauge hose length to equivalent energy. Submit this chart or graph with the proposed pile driving methods and equipment for closed-end diesel hammers.

The Engineer may inspect the hammer cushion before beginning and occasionally during driving. Expose the hammer cushion for inspection as directed. Replace or repair any hammer cushion that is less than 25% of its original thickness.

Hold pile heads in position with pile helmets that closely fit over pile heads and extend down the sides of piles a sufficient distance. Protect pile heads of prestressed concrete piles from direct impact with accepted pile cushions. Use pile cushions made of pine plywood with a thickness of at least 4 inches. Provide a new pile cushion for each

prestressed concrete pile. Replace pile cushions during driving when a cushion is compressed more than 50% of its original thickness or begins to burn.

(3) Required Driving Resistance

The Engineer will determine if the proposed pile driving methods and equipment are acceptable and provide the blows per foot and equivalent set for the required driving resistance noted in the plans, i.e., "pile driving criteria" except for structures with pile driving analyzer (PDA) testing. For structures with PDA testing, provide pile driving criteria for any bents and end bents with piles in accordance with Subarticle 450-3(F)(4).

Stop driving piles when refusal is reached. Define "refusal" as 240 blows per foot or any equivalent set.

(4) Restriking and Redriving Piles

After reaching the required pile penetration, the Contractor may choose to or the Engineer may require the Contractor to stop driving, wait and restrike or redrive piles to attain the required driving resistance. When the Engineer requires restrikes or redrives, the Engineer will determine the number of restrikes or redrives and the time to wait after stopping driving and between restrikes and redrives. The time to wait will range from 4 to 24 hours.

Use the same pile driving methods, equipment and compressed pile cushion from the previous driving to restrike or redrive piles unless the cushion is unacceptable due to deterioration. Do not use cold diesel hammers for restrikes or redrives, unless it is impractical to do otherwise as determined by the Engineer. In general, warm up hammers by applying at least 20 blows to a previously driven pile or timber mats on the ground.

(E) Drilled-in Piles

Perform pile excavation to elevations shown in the plans or approved by the Engineer. Excavate holes at pile locations with diameters that will result in at least 3 inches of clearance all around piles. Before filling holes, support and center piles in excavations and when noted in the plans, drive piles to the required driving resistance. Remove any fluids from excavations and, at the Contractor's option, fill holes with concrete, grout or flowable fill unless required otherwise in the contract.

(1) Pile Excavation

Use equipment with sufficient capacity to drill through soil, rock, boulders, timbers, man-made objects and any other materials encountered. Do not use blasting to advance pile excavations. Blasting for core removal is only permitted when approved by the Engineer. Contain and dispose of drilling spoils as directed and in accordance with Section 802. Drilling spoils consist of all materials and fluids removed from pile excavations.

If unstable, caving or sloughing soils are anticipated or encountered, use slurry or temporary steel casings to stabilize holes. When using slurry, submit slurry details including product information and additives, manufacturer's recommendations for use, slurry equipment details and documentation that mixing water is suitable for slurry before beginning drilling. When using temporary casings, use smooth non-corrugated clean watertight steel casings of ample strength to withstand handling and installation stresses and pressures imposed by concrete, earth, backfill and fluids. Use steel casings with an outside diameter equal to the hole size and a wall thickness of at least 1/4 inch.

(2) Filling Holes

Check the water inflow rate at the bottom of holes after all pumps have been removed. If the water inflow rate is greater than 6 inches per half hour or holes are stabilized with slurry, use an approved method for placing concrete, grout or flowable fill. Otherwise, remove any fluids and free fall concrete, grout or flowable fill into holes. Ensure that concrete, grout or flowable fill flows completely around piles. Place concrete, grout or flowable fill continuously and remove all temporary casings.

(F) Pile Driving Analyzer

When required, test piles in accordance with ASTM D4945 using a pile driving analyzer (PDA) manufactured by Pile Dynamics, Inc. Analyze PDA data with the CAse Pile Wave Analysis Program (CAPWAP) manufactured by Pile Dynamics, Inc. Use a prequalified PDA Consultant to perform PDA testing and CAPWAP analyses and provide PDA reports. Use a PDA Operator approved as a Field Engineer (key person) for the PDA Consultant. Provide PDA reports sealed by an engineer approved as a Project Engineer (key person) for the same PDA Consultant.

The Engineer will determine how many and which piles require PDA testing. Provide piles for PDA testing that are at least 5 feet longer than the estimated pile lengths shown in the plans. Do not drive piles until the proposed pile driving methods and equipment have been preliminarily accepted. Notify the Engineer of the pile driving schedule at least 7 days in advance.

The Engineer will complete the review of the proposed pile driving methods and equipment within 7 days of receiving PDA reports and pile driving criteria. Do not place concrete for caps or footings on piles until PDA reports and pile driving criteria have been accepted.

(1) PDA Testing

If necessary, provide a shelter to protect the PDA Operator and equipment from conditions of sun, water, wind and temperature. The shelter should have a floor size of at least 6 feet x 6 feet and a roof height of at least 8 feet. If necessary, heat or cool the shelter to maintain a temperature between 50°F and 85°F. Place the shelter within reach of the PDA cables and clear view of piles being driven.

Drill holes for PDA instruments as directed. Place piles in leads and templates before attaching PDA instruments. Use only preliminarily accepted pile driving methods and equipment to drive piles. Drive piles as directed and in accordance with Subarticle 450-3(D). The PDA Operator or Engineer may require modified pile installation procedures during driving. Dynamic measurements will be recorded and used to evaluate the hammer performance, driving resistance and stresses, energy transfer, pile integrity and various soil parameters such as quake and damping.

If required, reattach PDA instruments and restrike or redrive piles in accordance with Subarticle 450-3(D)(4). Obtain the required stroke and at least 6 inches of pile movement as directed. Dynamic measurements will be recorded during restriking and redriving. The Engineer will determine when PDA testing has been satisfactorily completed.

(2) CAPWAP Analysis

CAPWAP analysis is required for at least a hammer blow near the end of initial drive and each restrike and redrive. Additional CAPWAP analyses may be required as determined by the PDA Consultant or Engineer.

(3) PDA Reports

Submit 2 copies of each PDA report within 7 days of completing PDA testing. Include the following in PDA reports:

(a) Title Sheet

(i) Department's TIP number and WBS element number
(ii) Project description
(iii) County
(iv) Bridge station number
(v) Pile location
(vi) Personnel
(vii) Report date

(b) Introduction

(c) Site and Subsurface Conditions (including water table elevation)

(d) Pile Details (including driving dates and times)

(i) Pile type and length
(ii) Required driving resistance and resistance factor
(iii) Concrete compressive strength or steel yield strength
(iv) Pile splice type and locations
(v) Pile batter
(vi) Installation methods including use of predrilling, spudding, vibratory hammer, template, barge, etc.

(e) Driving Details

(i) Hammer make, model and type
(ii) Hammer and pile cushion type and thickness
(iii) Pile helmet weight
(iv) Hammer efficiency and operation data including fuel settings, bounce chamber pressure, blows per minute, equipment volume and pressure
(v) Driving data (ram stroke, blows/ft and set for last 10 hammer blows)
(vi) Ground or mud line, template reference and final pile tip elevations
(vii) Restrike and redrive information

(f) PDA Field Work Details

(g) CAPWAP Analysis Results

(i) Table showing percent skin and tip, skin and toe damping, skin and toe quake and match quality

(h) Summary/Conclusions

(i) Attachments

(i) Boring log(s)
(ii) Pile driving equipment data form (from Contractor)
(iii) Field pile driving inspection data (from Engineer)
(iv) Accelerometer and strain gauge serial numbers, calibration and locations
(v) PDA hardware model and CAPWAP software version information
(vi) PDF copy of all PDA data and executable CAPWAP input and output files

(4) Pile Driving Criteria

Analyze pile driving with the GRL Wave Equation Analysis Program (GRLWEAP) manufactured by Pile Dynamics, Inc. Use the same PDA Consultant that provides PDA reports to perform GRLWEAP analyses and develop pile driving criteria. Provide driving criteria sealed by an engineer approved as a Project Engineer (key person) for the same PDA Consultant.

Analyze pile driving so driving stresses, energy transfer, ram stroke and blows per foot from PDA testing and resistances from CAPWAP analyses correlate to GRLWEAP

models. Provide pile driving criteria for each combination of required driving resistance and pile length installed for all pile types and sizes. Submit 2 copies of pile driving criteria with PDA reports. Include the following for driving criteria.

(a) Project information in accordance with Subarticle 450-3(F)(3)(a)

(b) Table showing blows per foot and equivalent set vs. either stroke for multiple strokes in increments of 6 inches or bounce chamber pressure for multiple pressures in increments of 1 psi

(c) Maximum stroke or blows per foot or pile cushion requirements to prevent overstressing piles as needed

(d) GRLWEAP software version information

(e) PDF copy of all pile driving criteria and executable GRLWEAP input and output files

450-4 MEASUREMENT AND PAYMENT

No additional payment will be made for subsurface investigations to determine required pile lengths or larger caps or footings due to piles out of position.

Pile Driving Equipment Setup for ____ Prestressed Concrete Piles, *Pile Driving Equipment Setup for ____ Steel Piles* and *Pile Driving Equipment Setup for ____ Galvanized Steel Piles* will be measured and paid in units of each. Setting up equipment to drive piles will be measured as one per pile. No payment will be made for pile driving equipment setup for installed piles that are not driven. The contract unit price for *Pile Driving Equipment Setup for ____ Prestressed Concrete Piles*, *Pile Driving Equipment Setup for ____ Steel Piles* and *Pile Driving Equipment Setup for ____ Galvanized Steel Piles* will be full compensation for mobilizing and demobilizing pile driving equipment, personnel, supplies and incidentals, setting up and breaking down pile driving equipment, e.g., pile hammer, crane, template, etc. and submitting the proposed pile driving methods and equipment.

____ *Prestressed Concrete Piles,* ____ *Steel Piles* and ____ *Galvanized Steel Piles* will be measured and paid in linear feet. Steel and prestressed concrete piles will be measured as the pile length before installation minus any pile cut-offs. No payment will be made for pile cut-offs or cutting off piles. No payment will be made for damaged, defective or rejected piles or any piles for false work, bracing, templates or temporary work bridges. The contract unit prices for ____ *Prestressed Concrete Piles,* ____ *Steel Piles* and ____ *Galvanized Steel Piles* will be full compensation for furnishing and installing piles except for the items paid for separately in this article.

Composite piles will be measured as the pile length of the prestressed concrete and steel H-pile sections before installation minus any pile cut-offs. The concrete and steel sections will be measured and paid at the contract unit prices for ____ *Prestressed Concrete Piles* and ____ *Steel Piles*, respectively. No payment will be made for portions of steel H-pile sections embedded in prestressed concrete sections or steel pile splicers and any associated hardware or welding.

After piles attain the required resistance and pile penetration and at the Contractor's option, drive piles to grade instead of cutting off piles provided the remaining portions of piles do not exceed 5 feet and piles can be driven without damage or reaching the maximum blow count or refusal. When this occurs, the additional pile length driven will be measured and paid at the contract unit prices for ____ *Prestressed Concrete Piles,* ____ *Steel Piles* and ____ *Galvanized Steel Piles*.

For prestressed concrete piles that are built up, the build-up will be measured and paid at the contract unit price for ____ *Prestressed Concrete Piles*. Steel pile tips are not included in the measurement of prestressed concrete piles. No separate payment will be made for steel pile

tips or splicers and any associated hardware or welding. Steel pile tips and steel pile splicers will be incidental to the contract unit price for ____ *Prestressed Concrete Piles*.

Steel Pile Points and *Pipe Pile Plates* will be measured and paid in units of each. *Steel Pile Points* and *Pipe Pile Plates* will be measured as one per pile.

Predrilling for Piles will be measured and paid in linear feet. For bents with a predrilling pay item shown in the plans, predrilling will be paid as *Predrilling for Piles* and measured per pile location as the depth from the ground or mud line to the specified predrilling elevation or revised elevation approved by the Engineer. The contract unit price for *Predrilling for Piles* will also be full compensation for using temporary casings. For bents without a predrilling pay item shown in the plans, predrilling will be incidental to the contract unit prices for ____ *Prestressed Concrete Piles,* ____ *Steel Piles* and ____ *Galvanized Steel Piles.*

No direct payment will be made for spudding. Spudding will be incidental to the contract unit prices for ____ *Prestressed Concrete Piles,* ____ *Steel Piles* and ____ *Galvanized Steel Piles.*

Pile Redrives will be measured and paid in units of each. *Pile Redrives* will be measured as the number of restrikes or redrives required by the Engineer. No payment will be made for restrikes or redrives when the Contractor chooses to restrike or redrive piles.

Pile Excavation in Soil and *Pile Excavation Not in Soil* will be measured and paid in linear feet. Pile excavation will be measured as the depth from the ground line to the specified pile excavation elevation or revised elevation approved by the Engineer. Define "not in soil" as material with a rock auger penetration rate of less than 2 inches per 5 minutes of drilling at full crowd force. When not in soil is encountered, seams, voids and weathered rock less than 3 feet thick with a rock auger penetration rate of greater than 2 inches per 5 minutes of drilling at full crowd force will be paid at the contract unit price for *Pile Excavation Not in Soil*. Seams, voids and weathered rock greater than 3 feet thick will be paid at the contract unit price for *Pile Excavation in Soil* where not in soil is no longer encountered. The contract unit prices for *Pile Excavation in Soil* and *Pile Excavation Not in Soil* will be full compensation for stabilizing and filling holes with concrete, grout or flowable fill.

PDA Testing will be measured and paid in units of each. *PDA Testing* will be measured as one per pile. The contract unit price for *PDA Testing* will be full compensation for performing PDA testing the first time a pile is tested, performing CAPWAP analysis on data collected during initial drive, restrikes and redrives, providing PDA reports, performing GRLWEAP analysis and developing and providing pile driving criteria. Subsequent PDA testing of the same piles will be incidental to the contract unit price for *Pile Redrives*. The contract unit price for *PDA Testing* will also be full compensation for the Contractor's assistance to perform PDA testing during initial drive, restrikes and redrives.

Payment will be made under:

Pay Item	**Pay Unit**
Pile Driving Equipment Setup for ___ Prestressed Concrete Piles	Each
Pile Driving Equipment Setup for ___ Steel Piles	Each
Pile Driving Equipment Setup for ___ Galvanized Steel Piles	Each
____ Prestressed Concrete Piles	Linear Foot
____ Steel Piles	Linear Foot
____ Galvanized Steel Piles	Linear Foot
Steel Pile Points	Each
Pipe Pile Plates	Each
Predrilling for Piles	Linear Foot
Pile Redrives	Each
Pile Excavation in Soil	Linear Foot
Pile Excavation Not in Soil	Linear Foot
PDA Testing	Each