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| REVIEW OF NEW SPECIFICATION OR SPECIFICATION CHANGE  | **Log No.: 502-1** |
| **Specification Section No.:** 502 | **Item:** Piling |
| **Originating Office:** Project Support | **By:** Ilyess Ksouri |
| **Date Sent For Review:** September 21, 2018 | **Date Comments Due:** October 19, 2018 |
| Submit response to: Shawn Yu, Standards and Specifications Unit Manager, 3rd floor, CDOT HQ |
| **Vote****Y/N** | **Concurrent Reviews – Others Commenting** | The attached Draft Specification is submitted for your review and comments. If not returned by Date Comments Due, the draft specification will be considered to be approved unless the Standards and Specifications Unit of the Project Development Branch [(303) 757-9474, (303) 757-9402] is advised otherwise.**REMARKS:** If these proposed changes are approved, our unit will issue these in a new standard special provision. |
|  | **Spec Committee Members:** | **✓** |
|  | Co-Chairman: Neil Lacey | ✓ |
|  | Region 1: Telecia McCline | **✓** |
|  | Region 1: Jason Lucerna | **✓** |
|  | Region 2: Jody Pieper | **✓** |
|  | Region 3: Jarrett Spegele | **✓** |
|  | Region 4: Chris Boespflug | **✓** |
|  | Region 5: David Valentinelli | **✓** |
|  | Project Development: Neil Lacey | **✓** |
|  | Standards and Specifications: Shawn Yu | **✓** |
|  | Area Engineers: Straub, Zamora, & Ryburn | **✓** |
|  | Bridge: Hoang Bui | **✓** |
|  | Contracts & Market Analysis: Markos Atamo | **✓** |
|  | Materials: Mike Stanford | **✓** |
|  | Materials: Craig Wieden | **✓** |
|  | Traffic Engineering: Thomas Dinardo | **✓** | REVIEWER COMMENTS:( ) Approved ( ) Disapproved ( ) ModifiedIf disapproved or modified, give reason why and show any modifications on the attached draft copy: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ Name/Signature Date |
|  | Maintenance: Tyler Weldon | **✓** |
|  | FHWA: Kelly Galardi | **✓** |
|  | Attorney General: Leo Milan | **✓** |
|  | **Others:** |  |
|  | Colorado Contractors Assoc.: Jim Moody | **✓** |
|  | **Technical Committees:** |  |
|  | Bridge |  |
|  | PDAC | **✓** |
|  | Drainage Advisory Committee (DAC) |  |
|  | Water Quality Advisory Committee (WQAC) |  |
|  | Joint Co-op, CDOT/CCA |  |

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| **COLORADO DEPARTMENT OF TRANSPORTATION****SUBMITTAL OF NEW SPECIFICATION OR SPECIFICATION CHANGE** | Log No. (Assigned by Standards and Specifications Unit)502-1 |
| TO: Standards & Specifications Unit Project Development Branch | FROM:Ilyess Ksouri(Region, Branch or Technical Committee) |
| SPECIFICATION SECTION NO.502 | ITEMAll Items | PriorityRoutine x Fast |
| Reason for this new or changed specification:Rewrite the piling specifications to meet current design and construction standards that are in line with AASHTO and FHWA guidance.The Material Advisory Committee approved the revised 502 Specification at the July 10, 2018 meeting. |
| New or Revised Specification:See attached. |
| NOTE: See Procedural Directive 513.1 for a description of appropriate specification development procedures. |

XXXXXX XX, 2018

REVISION OF SECTION 502
PILING

**NOTICE**

This is a standard special provision that revises or modifies CDOT’s *Standard Specifications for Road and Bridge Construction.* It has gone through a formal review and approval process and has been issued by CDOT’s Project Development Branch with formal instructions for its use on CDOT construction projects. It is to be used as written without change. Do not use modified versions of this special provision on CDOT construction projects, and do not use this special provision on CDOT projects in a manner other than that specified in the instructions unless such use is first approved by CDOT’s Standards and Specifications Unit. The instructions for use on CDOT construction projects appear below.

Other agencies which use the *Standard Specifications for Road and Bridge Construction* to administer construction projects may use this special provision as appropriate and at their own risk.

**Instructions for use on CDOT construction projects:**

Use on projects having steel piling.

Section 502 of the Standard Specifications is hereby deleted for this project and replaced with the following:

**DESCRIPTION**

**502.01** This work consists of furnishing and driving foundation piles of the type and dimensions shown in the Contract, other than sheet piling, in accordance with these specifications and at the locations shown on the plans or established.

**MATERIALS**

**502.02 Rolled Structural Steel Piles.**Steel used in rolled structural steel piles shall conform to the requirements of ASTM A572/A572M or ASTM A992/A992M. Sections of such piles shall be of “H” or “W” shape. The flange projection shall not exceed 14 times the minimum thickness of metal in either the flange or the web, and flange widths shall not be less than 80 percent of the depth of the section. The nominal depth in the direction of the web shall not be less than 8 inches. Flanges and web shall have a minimum nominal thickness of 0.375 inches or greater.

**502.03 Steel Pipe Piles.**Steel pipe piles shall conform to the requirements of ASTM A252, Grade 2 or higher. Pipe piles shall have an outside diameter and a minimum nominal wall thickness as shown on the plans. Ends of closed-end pipe piles shall be closed with a flat plate, forged or cast steel conical point, or other end closure design approved by the Engineer. End plates used on closed-end pipe piles shall be made of ASTM A36/A36M steel or better. End plates shall have a minimum thickness of 0.75 inches. The diameter and thickness of the end plates shall be as shown on the plans. The end plate shall be cut flush with the outer pile wall. The end of the pipe shall be beveled before welding to the end plate using a partial penetration groove weld. Steel pipe piles shall be filled with Class B concrete conforming to subsection 601.02, as shown on the plans.

**502.04 Protective Coatings.**If there is a required protection, the Contractor shall be responsible for restoring or repairing any damage to the coating.

**CONSTRUCTION REQUIREMENTS**

**502.05 Pile Driving Equipment.**Piles shall be driven with an impact hammer conforming to these Specifications. Pile driving hammers shall be of the size needed to develop the energy required to drive the piles at a blow count that does not exceed 10 blows per inch at the required nominal driving resistance.

1. *Pile Hammers.* Steam, air, diesel, or hydraulic impact hammers may be usedto drive all types of piles.
2. Single or Double Acting Steam and Air Hammers.

The plant and equipment furnished for steam and air hammers shall have sufficient capacity to maintain, under working conditions, the volume and pressure specified by the manufacturer of the hammer. The hose connecting the air compressor to the hammer shall be at least the minimum size recommended by the manufacturer. The plant and equipment shall be equipped with accurate chamber pressure gauges which are easily accessible to the Engineer. Proximity switches and an electronic readout device shall be provided prior to driving piling. Hammer performance shall be evaluated at the end of driving by measuring blows per minute and comparing these blows with the manufacturer’s recommendations.

1. Diesel Hammers

If open-end (single-acting) diesel hammers are not equipped with a device to measure impact velocity at all times during pile driving operations, the stroke shall be obtained by measuring the speed of operation either manually or with a device that takes the measurement automatically.

Closed-end double acting diesel hammers shall be equipped with an accurate bounce chamber pressure gauge, easily accessible to the Engineer. The Contractor shall provide the Engineer a calibrated chart equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used. Calibration of actual hammer performance shall be performed within 90 days prior to the beginning of the work.

1. Hydraulic Hammers

The power plant furnished for hydraulic hammers shall have sufficient capacity to maintain at the hammer, under working conditions, the volume and pressure specified by the manufacturer of the hammer. Hydraulic hammers shall also be equipped with a controlled variable stroke system and a readout device to measure ram energy. The plant and equipment shall be equipped with accurate pressure and velocity gauges and an energy readout device which are easily accessible to the Engineer.

1. Vibratory Hammers

Vibratory or other pile driving methods may be used only when specified in the Contract or in writing by the Engineer. Except when pile lengths have been evaluated from static load test piles, the nominal driving resistance of piles driven with vibratory hammers shall be verified by additional driving of the first pile driven in each group of 10 piles with an impact hammer of suitable energy to measure the nominal resistance before driving the remaining piles in the group. In case of variable soils, additional piles shall be verified by an impact hammer as directed by the Engineer. All piles that rely primarily on point bearing capacity shall be re-driven with an impact hammer.

The hammer efficiencies shown in Table 502-1 shall be used in the wave equation analysis of vertical piles unless hammer efficiency information is available from pile driving analyses. Hammer efficiencies shall be adjusted for batter driving.

**Table 502-1**

| **Hammer Type** | **Hammer Efficiency (%)** |
| --- | --- |
| Single-acting steam/air | 67 |
| Double-acting steam/air | 50 |
| Diesel | 80 |
| Hydraulic or diesel with built-in energy measurement | 90 |

For steam, air, and diesel hammers, a minimum manufacturer’s rated energy for specific HP Piles sizes as shown in Table 502-2 shall be used.

**Table 502-2**

| **Pile Size** | **Area (Square Inches)** | **Minimum Energy (Foot-Pounds)** |
| --- | --- | --- |
| HP 10x42 | 12.4 | 26,000 |
| HP 10x57 | 16.8 | 26,000 |
| HP 12x53 | 15.5 | 26,000 |
| HP 12x74 | 21.8 | 42,000 |
| HP 14x89 | 26.1 | 52,000 |
| HP 14x117 | 34.4 | 68,000 |

The rated energy of the hammer shall not be greater than 2,500 foot-pounds per square inch of unit area. Exceptions to these limits are permissible if it is demonstrated by wave equation analysis that the piles can be safely and efficiently installed with hammers having ratings outside of these energy limits.

1. *Hammer Cushion.* All impact pile driving equipment shall be equipped with a suitable hammer cushion to prevent damage to the hammer or piles and to ensure uniform driving behavior. Wood, wire rope, and asbestos cushion material shall not be used. A striker plate as recommended by the hammer manufacturer shall be used. The hammer cushion may be inspected by the Engineer at any time during progress of the work. Any hammer cushion whose thickness is reduced by 10 percent or more of the original thickness shall be replaced at the Contractor’s expense before driving is permitted to continue.
2. *Leads.* Pile driving leads shall be constructed in a manner that affords the pile hammer freedom of movement while maintaining alignment of the pile hammer and the pile to ensure concentric impact for each blow. Leads may be either fixed or swinging. Swinging leads shall be fitted with a pile gate at the bottom of the leads and shall be long enough to be securely fixed at the ground at all times.
3. *Followers.* Followers shall be used only when specified on the plans or approved in writing by the Engineer. The follower and pile shall be maintained in proper alignment during driving. The follower shall be of such material and dimensions to permit the piles to be driven to the blow count determined to be necessary.
4. *Jetting.* Jetting will be permitted only if specified in the Contract or approved in writing by the Engineer. The Contractor shall determine the number of jets and the volume and pressure of water at the jet nozzles necessary to freely erode the material adjacent to the pile.

The Contractor shall control and dispose of all jet water in a manner satisfactory to the Engineer, or as specified in the Contract. If jetting is specified or approved by the Engineer and is performed according to the specifications or as approved by the Engineer, the Contractor shall not be held responsible for any damage to the site caused by jetting operations. If jetting is used for the Contractor’s convenience, the Contractor shall be responsible for all damages to the site caused by jetting operations.

Unless otherwise specified by the Engineer or the Contract, jet pipes shall be removed before or when the pile tip is 5 feet above the minimum or final tip elevation, and the pile shall be driven with an impact hammer, without jetting, to the final tip elevation or to the required nominal resistance. If the required nominal resistance is not reached at the final tip elevation, the pile may be allowed to be set up and then the required nominal resistance will be determined by re-striking the pile.

* 1. **Approval of Pile Driving Equipment.**

 Pile driving equipment shall be sized such that the piles can be driven to the length required without damage. All pile driving equipment proposed in conformance with subsection 502.05 shall be submitted to the Engineer for acceptance prior to delivery to the site. Acceptance of pile driving equipment does not relieve the Contractor of the responsibility to drive piles, free of damage, to the required nominal driving resistance and, if specified, the minimum tip elevation shown on the plans. Continued use of pile driving equipment shall be subject to satisfactory performance during production.

To be accepted, the proposed driving system shall obtain the nominal driving resistance between the specified blow count range of 30 and 120 blows per foot, and shall maintain driving stresses below the specified 90 percent of the yield stress of the steel for the piles being driven. If wave equation analysis predicted driving stresses are greater than specification limits or the wave equation blow count for the nominal driving resistance is outside the specified blow count range, the Contractor shall modify or replace the proposed equipment until subsequent wave equation analyses indicate the piles can be driven to the nominal driving resistance within the allowable blow count range and within driving stress limits. If the driving system requires revision, the Contractor will be notified of the acceptance of the revised driving system within seven calendar days of receipt of a revised pile and driving equipment data form.

The Contractor shall use the accepted pile driving system. No changes shall be made without prior written acceptance from the Engineer. A change in the pile driving system will be considered only after the Contractor has submitted a new pile and driving equipment data form. The Contractor will be notified of the acceptance of a proposed change in driving equipment within three work days of receipt of the pile and driving equipment data form.

If the Engineer determines the Contractor’s hammer is not functioning properly and is unable to drive the piles to the required penetration depth or nominal driving resistance, the hammer shall be removed from service.

The Contractor is responsible for piles damaged due to misalignment of the leads, failure of hammer cushion or cushion material, failure of splices, malfunctioning of the pile hammer, or improper construction methods. Piles damaged for such reasons will be rejected and shall be replaced if the Engineer determines that the damage impairs the strength of the pile.

* 1. **Driving Piles.**

 Foundation piles shall not be driven until the excavationis complete, unless authorized by the Engineer. After driving is complete, all loose and displaced material shall be removed from around the piling before pouring any concrete.

Piles shall be driven within a variation of ¼ inch or less per foot from the vertical or from the batter shown in the Contract. The tendency of steel piles to twist or rotate shall be prevented and corrected. Foundation piles shall be within 6 inches of the position shown in the Contract after driving. No pile shall be closer than 4 inches from an edge of the pile cap. Pulling or pushing laterally on installed piles to correct misalignment, or splicing a properly aligned section on a misaligned section will not be allowed. The pile head at cutoff elevation shall be within 2 inches of plan elevation for bent caps supported by piles.

Piles driven at integral end bents shall be installed so that the axial alignment of the top 10 feet of the pile is within 2 percent of the specified alignment.

Battered piles shall be installed so that the alignment of the top 10 feet of the pile does not vary by more than 3 percent from the batter rate shown on the plans.

The order of placing individual piles within a pile group shall begin from the center of the group and proceed outward in both directions unless an alternate installation sequence is approved by the Engineer in writing. For a bent with a single row of piles, pile driving shall begin at one end of the bent and proceed toward the opposite end.

If the location or alignment tolerances are exceeded, the extent of overloading shall be investigated. If the Engineer determines that corrective measures are necessary, such corrective measures shall be designed and constructed by the Contractor. Proposed corrective measures will be subject to approval by the Engineer.

* 1. **Drilling Holes to Facilitate Pile Driving.**

 Holes to facilitate pile driving shall be drilled at all locations shown on the plans and to elevations shown.

When test piles are shown on the plans they shall be used to determine if drilling holes to facilitate pile driving is required.

If the test pile or piles do not reach the minimum tip elevation shown on the plans and do not develop the required nominal resistance as specified in subsection 502.10, holes shall be drilled or jetted to facilitate pile driving.

If the test pile or piles reach the minimum tip elevation shown on the plans and develop the required nominal resistance as determined in subsection 502.10, drilling holes will not be required and the remainder of the piles shall be driven in the normal manner.

The drilling of holes shall be done in such a manner that the piling will stand accurately positioned as shown on the plans.

The diameter of the drilled holes and the material used to fill oversize holes shall be as specified herein unless otherwise designated on the plans.

Drilled holes shall be 2 inches smaller than the diameter or diagonal of the pile cross section that is sufficient to allow penetration of the pile to the specified penetration depth. If subsurface obstructions, such as boulders or rock layers, are encountered, the hole diameter may be increased to the least dimension which is adequate for pile installation. Except for end bearing piles, drilling shall be stopped at least 5 feet above the pile tip elevation shown on the plans. The pile shall be driven with an impact hammer to the specified penetration resistance. Where piles are to be end-bearing on rock or very dense cobbles and gravels (hardpan), drilling may be carried to the surface of the rock or the hardpan. The piles shall then be driven with an impact hammer to ensure proper seating. Any void space remaining around the pile after completion of driving shall be filled with sand or other material approved by the Engineer.

If the maximum diameter of the drilled hole is exceeded due to sloughing, drifting, over-drilling, or other causes, the void area between the driven pile and the edge of the hole shall be filled with sand or pea gravel at the Contractor’s expense.

If required by the Contract, piles to be driven through compacted fill or embankment of a depth greater than 5 feet shall be driven in holes drilled to natural ground. The drilled hole should have a diameter not more than the greatest dimension of the pile cross-section plus 4 inches. After driving the pile, the space around the pile shall be filled to the ground surface with sand or other material approved by the Engineer.

When specified in the Contract, holes shall be cored into rock to accommodate pile placement. Holes of the diameter shown on the plans shall then be drilled through the embankment into solid rock to the elevations shown on the plans or as otherwise directed by the Engineer. The piles shall be driven to practical refusal at the bottom of the cored holes. The holes in cored rock shall then be filled with concrete.

The Engineer will determine if shooting holes with explosives or redesign is necessary when piles cannot be driven or holes drilled.

* 1. **Capping Piles.**

 Steel pipe piles will be inspected after all adjacentpiles within a 5 foot radius have been driven. Before concrete is placed in the pile, the pile shall be inspected by an acceptable method to confirm the full pile length and dry bottom condition. If accumulations of water in pipes are present, the water shall be removed before the concrete is placed. The concrete for concrete-filled pipe piles shall be Class BZ and shall conform to the requirements of section 601. Concrete shall be placed in each pile in a continuous operation. No concrete shall be placed until all driving within a radius of 15 feet of the pile has been completed, or all driving within the above limits shall be discontinued until the concrete in the last pile cast has set for at least two days.

The tops of all steel piles shall be cut off square and embedded in the concrete as shown on the plans.

* 1. **Determination of Nominal Driving Resistance.**

 The Engineer will use one of the following methods as specified to determine the nominal driving resistance of a driven pile.

* + - * 1. *Wave Equation Analysis*. When specified in the Contract, the Engineer will use a wave equation analysis to determine the driving criterion necessary to reach the required nominal driving resistance of the pile. Soil and pile properties to be used in this analysis shall be as shown in the Contract or as determined by the Engineer. The Contractor shall supply the Engineer the necessary information on the proposed driving equipment to perform the wave equation analysis.
				2. *Dynamic Testing*. Dynamic monitoring shall be performed for the purpose of obtaining the nominal driving resistance, pile driving stresses, pile integrity, and pile driving system performance. Dynamic monitoring shall be conducted by PDA in accordance with ASTM D 4945. PDA shall be performed on the first pile driven to the plan requirements. The length of the pile used in the dynamic test shall be a minimum of 10 feet greater than the estimated length of production piles in order to provide for variation in soil conditions.

A minimum of one pile per bent structure (abutment or pier foundation) shall be monitored as a test pile.

Dynamic monitoring shall be conducted by the Contractor's Engineer. The Contractor’s Engineer conducting the PDA shall be a licensed Professional Engineer who has achieved one of the following certification levels: intermediate, advanced, master, or expert through the Dynamic Measurement and Analyses Proficiency Test conducted by Pile Dynamics, Inc., and the Pile Driving Contractors Association.

An Engineer with a lower certification level can provide services so long as this individual is under the direct supervision of an Engineer with intermediate certification level or higher.

The Contractor shall notify the Project Engineer at least seven calendar days before the scheduled date of driving piles to be monitored by PDA. The Contractor shall confirm the driving date three calendar days prior to the scheduled driving date. The Contractor shall indicate at which foundation production pile driving is to begin. The Engineer conducting the PDA will provide final driving criteria for the indicated foundation.

The Contractor shall make the steel piles available so that the Contractor’s Engineer can predrill the required instrument attachment holes prior to the Contractor placing the pile in the leads. Each pile to be tested shall be instrumented with force and acceleration transducers. The transducers shall be installed before striking the pile. The pile driving may have to be temporarily interrupted for the transducers to be adjusted or replaced, or for the monitoring results to be assessed.

The Contractor shall drive the test pile to the minimum tip elevation and to the penetration depth at which the dynamic test equipment indicates that the nominal driving resistance shown on the plans has been achieved. The Contractor may reduce the driving energy transmitted to the pile by using additional cushions or reducing the energy output of the hammer in order to maintain stresses below the value shown in subsection 502.06. If non-axial driving is indicated by the dynamic test equipment measurements, the Contractor shall immediately realign the hammer system.

The Contractor shall wait at least one hour prior to the restriking of the dynamic test pile. The hammer shall be warmed up before restriking begins by applying at least 20 blows to another pile or other fixed object. The maximum amount of penetration required during restrike shall be 3 inches, or the total number of hammer blows shall be 20, whichever occurs first. If the pile does not achieve the required nominal driving resistance during restrike, the Engineer conducting the PDA shall specify additional pile penetration and testing.

If the required nominal driving resistance has been reached in natural ground and piles have not been driven to the estimated tip elevation but have been driven below minimum tip elevation, the Engineer conducting the PDA may order the driving to be continued for 40 additional blows.

Once the restrike test for the test pile is complete, the Contractor’s Engineer conducting the PDA shall run CAPWAP analyses and shall provide the final driving criteria the same day of the restrike test. Production piles driven prior to receipt of the final driving criteria shall be done at the Contractor’s risk. Final driving criteria for additional structures shall be provided within two business days of the restrike test or, when multiple test piles are restruck the same day, at a rate of one substructure location per business day in the order requested by the Contractor.

A detailed stamped report including the pile driving criteria with the PDA and CAPWAP results shall be submitted to the Project Engineer for acceptance within two business days after the restrike test.

If the Project Engineer requests additional piles to be monitored, pile monitoring will be paid for in accordance with subsection 502.18.

If changes are made to the pile driving system (hammer, fuel setting, piling, cushioning, etc.) after the PDA monitoring has been completed and driving criteria established, new driving criteria shall be determined using the PDA. New criteria shall be determined at the Contractor’s expense.

* + - * 1. *Static Load Test.* If a static load test is used to determine the pile axial resistance, the test shall not be performed less than five days after the test pile was driven unless approved by the Engineer or otherwise specified in the Contract. The static load test shall follow the procedures specified in ASTM D1143/D1143M, and the loading procedure shall follow the Quick Load Test Method, unless detailed longer-term load-settlement data are needed, in which case the standard loading procedure shall be used. Testing equipment and measuring systems shall conform to ASTM D1143/D1143M. The equipment to conduct the static load test shall be supplied by the entity specified in the Contract. The Engineer or the testing laboratory will perform the test.

The Contractor shall submit detailed documents for the proposed loading apparatus, prepared by a Licensed Professional Engineer, to the Project Engineer for review. The submittal shall include calibrations for the hydraulic jack, load cell, and pressure gauge conducted within 30 days before mobilization to the job site. When the approved method requires the use of tension (anchor) piles that will later be used as permanent piles in the work, such tension piles shall be of the same type and size as the production piles and shall be driven in the location of permanent piles where feasible.

While performing the static load test, the Contractor shall provide safety equipment and employ adequate safety procedures. Adequate support for the static load test plates, jack, and ancillary devices shall be provided to prevent them from falling in the event of a release of load due to hydraulic failure, test pile failure, or other cause.

The method of defining failure of the static load test shall be as defined in the Contract or by the Engineer. Based on the static load and dynamic test results, the Engineer will provide the driving criteria for production pile acceptance.

When specified, tension static load tests shall be conducted in accordance with ASTM D3689. When specified, lateral load tests shall be conducted in accordance with ASTM D3966.

* 1. **Nominal Driving Resistance of Production Piles.** Production piles shall be driven to the depth necessary to obtain the required nominal driving resistance as determined by subsection 502.10. If a minimum pile tip elevation is shown on the plans, in addition to obtaining the required nominal driving resistance, production piles shall also be driven to the minimum pile tip elevation.

When the nominal driving resistance is determined in accordance with subsection 502.10(a) or subsection 502.10(b), for acceptance, the Engineer will record the blow count per inch or foot of pile movement and the associated hammer stroke for the last two consecutive feet of driving, and the final pile tip elevation as per the pile driving criteria established through the wave equation analysis or dynamic test.

Practical refusal will be defined as 10 blows per inch of penetration for a maximum of 3 consecutive inches of pile penetration and with the hammer operated at its maximum fuel or energy setting, or at a reduced fuel or energy setting recommended by the Engineer based on pile installation stress control and less than ¼ inch rebound per blow. The Contractor shall stop driving as soon as the Engineer determines that the pile has reached practical refusal.

Absolute refusal is defined as 20 blows for 1 inch or less of pile penetration. Driving shall terminate immediately if this criterion is achieved. In the case of hard rock, an absolute refusal criterion of 5 blows per ¼ inch or 10 blows per ½ inch should be adopted to reduce the risk of pile toe or driving equipment damage.

The nominal driving resistance of jetted piles shall be based on impact driving penetration resistance after the jet pipes have been removed. Jetted piles not attaining the nominal driving resistance at the ordered length shall be spliced and driven with an impact hammer until the nominal driving resistance is achieved in accordance with the driving criteria in subsection 502.10.

* 1. **Piling Length.**

 The lengths of piles shown on the plans and in the Schedule of Pay Items are estimated lengths and are for bidding purposes only. Piles may be ordered in plan lengths or standard production lengths. The Contractor shall provide the actual length of piles necessary to obtain the nominal driving resistance and penetration depth required as determined from results obtained from driving representative test piles or other pertinent data. There will be expected variations in final tip elevations due to differences in nominal pile driving resistance. The final tip elevation of each pile shall be determined during the driving operation.

A minimum pile penetration of 10 feet below the bottom of the footing elevation in natural ground is required for all piles. This requirement may be waived by the Engineer if the subsurface material at the pile tip location is bedrock or other acceptable bearing material provided that the bearing elevation is below scour depth.

If minimum tip elevations are specified, the Contractor shall drive piles to a penetration depth that satisfies this requirement in addition to the nominal driving resistance. If the pile cannot be driven to the minimum tip elevation, the Engineer will determine if pre-drilling is required. Any pre-drilling not required by the Contract and ordered by the Engineer will be paid for in accordance with subsection 502.18. The depth of the pre-drilling will be determined by the Engineer.

Water jets may be used in conjunction with the hammer to obtain the specified penetration only with approval by the Engineer. The last 3 feet of penetration shall be obtained by driving without the use of water jets. Test blows to determine average penetration shall be applied after the jets have been removed. The use of water jets will not modify any of the requirements of this specification.

* 1. **Extensions and Splices.**

 When the American Welding Society (AWS) D1.1 Structural Welding Code is cited in this section, it shall be the current edition.

Full length piles shall be used where practicable. The number of splices shall be kept to a minimum. Commercially available splices may be used if approved by the Engineer of Record.

It shall be stated on the plans which splices shall be partial joint penetration (PJP) or complete joint penetration (CJP). Depth of penetration for PJP splices shall also be stated on the plans. All welded splices shall be made by using a prequalified joint design in accordance with AWS D1.1. The CJP design shall include beam copes (weld access holes) through the web of the pile at the junctures with the flanges. Copes shall be made in accordance with AWS D1.1, section 5.17. If backing is used it shall be in accordance with AWS D1.1. Removal of the backing after welding is not required.

Personnel performing owner acceptance (OA) and process control (PC) welding inspection shall be qualified as a certified welding inspector (CWI) in accordance with AWS D1.1, Chapter 6. All welded pile splices shall be made in accordance with a written Welding Procedure Specification (WPS) that shall be reviewed, and approved by the Contractor’s CWI, prior to welding any piling splices on the project. The WPS shall list all essential variables of the process in accordance with AWS D1.1. The WPS shall be available to those authorized to use or examine them.

All welded splices shall be made with low hydrogen electrodes. The Contractor shall adhere to the low hydrogen practice for electrodes in accordance with AWS D1.1.

All cuts at splices shall be made normal to the longitudinal axis of the pile. The cut-off portion may be driven to start the next pile or it may be welded to previously driven piles to provide the necessary extension length.

All welders shall be currently qualified in accordance with AWS D1.1. Welder qualifications shall be approved by the Contractor’s CWI prior to the start of welding. The welder shall be requalified if any essential variables listed in AWS D1.1 are not met.

The Contractor shall provide an AWS Certified Welding Inspector (CWI) on the project site for quality control. The CWI shall inspect all production stages of the welded splice, including assembly of the splice joint, during welding, and after welding to ensure that workmanship and materials meet the requirements of the Contract. The CWI shall be responsible for acceptance or rejection of the material and the workmanship. The CWI shall keep a record of all findings, which shall be available to the Engineer upon request.

The first two CJP welded splices shall be ultrasonically tested (UT) for acceptance in accordance with Table 6.3 of AWS D1.1. If both of the UT tested CJP splices are determined to be acceptable, no further UT testing of CJP splices will be required. If either of the first two UT tested CJP splices are not acceptable, UT testing of CJP splices shall continue until two consecutive tests are acceptable.

Personnel performing UT testing of CJP splices shall be qualified in accordance with the current edition of the American Society for Nondestructive Testing Practice No. SNT-TC-1A. Individuals who perform nondestructive testing shall be qualified for NDT Level II.

* 1. **Defective Piling.**

 Piles damaged in driving by reasons of internal defects or improper driving shall be corrected by one of the following approved methods:

1. The pile shall be withdrawn and replaced by a new, and if necessary, longer pile.
2. A second pile shall be driven adjacent to the defective pile.

Piles driven below the specified butt elevation shall be corrected by one of the following approved methods:

1. The pile is spliced or built up as otherwise provided herein.
2. A sufficient portion of the footing is extended down to properly embed the pile.

A pile driven out of its proper location, specified in the Contract or by the Engineer, shall be corrected by one of the following methods:

1. One or more replacement piles are driven next to the out-of-position piles.
2. The footing is extended laterally to incorporate the out-of-location pile.
3. Additional reinforcement is added.

All such remedial materials and work shall be approved by the Engineer and furnished at the Contractor’s expense.

All piles pushed up by the driving of adjacent piles shall be driven down again.

* 1. **Pile Tips.**

 Pile tips shall be placed on piles when shown on the plans. Pile tips and details for fastening tips to piles shall be in accordance with the plans or as approved by the Engineer. If difficult driving conditions are encountered, the Engineer may order the Contractor to furnish and attach pile tips even though tips are not required by the plans. In that event, the tips will be paid for in accordance with subsection 502.18.

* 1. **Painting Steel Piles.**

The exposed portion of steel piles not embedded inconcrete, including 2 feet below the stream bed or ground line, shall be painted as described in Section 509.

**METHOD OF MEASUREMENT**

**502.17** Piling will be measured by the linear foot in place. Measurement shall be from the tip to the cut-off elevation.

The length of pile cut-off to be measured will be those random lengths of piling which result from cutting off the tops of driven piles and which are not used in the work.

Where piling is driven to within 1 foot of the elevation of cut-off, butt ends will be included in the length measured for piling actually driven.

Measurement of splices will be limited to two per steel pile, except when extra splices are ordered.

Partial Joint Penetration (PJP) welded splices for piles, when specified on the plans, will be measured as additional length of pile. The additional length for each PJP splice will be measured as follows: steel “H” piles, 3 linear feet; steel pipe piles, 3 linear feet. CJP welded splices, when specified in the plans, will be the actual number completed and accepted per splice.

Pile tips and end closure plates for steel pipe piles will be measured by the actual number used.

Drilled holes to facilitate pile driving will be measured by the linear foot, to the nearest foot.

**BASIS OF PAYMENT**

**502.18** The accepted quantities will be paid for at the contract unit price per unit of measurement for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

 **Pay Item Pay Unit**

 Steel Piling (size) Linear Foot

 Steel Pipe Piling (size) Linear Foot

 Drilling Hole to Facilitate Pile Driving Linear Foot

 End Plate Each

 Pile Tip Each

 Pile Monitoring and Report Each

 Pile Load Testing and Report Each

 Complete Joint Penetration (CJP) Splice Each

All costs for providing Certified Welding Inspector (CWI) services for Partial Joint Penetration (PJP) welded splices shall be included in the additional measured length of pile in accordance with subsection 502.12.

Complete Joint Penetration (CJP) splices shall be paid for at the contract unit price for each completed and accepted CJP Splice. All costs for completing the CJP welded splices including, but not limited to, Ultrasonic Testing, Certified Welding Inspector (CWI) services, and required documentation shall be included in the price per each for Complete Joint Penetration (CJP) Splice.

Steel cut-offs 10 feet or less in length will be paid for at the contract unit price minus 20 percent. These cut-offs shall become the property of the Contractor.

Pile cut-offs greater than the above specified lengths will not be paid for.

Authorized jetting, blasting, or other work necessary to obtain the specified penetration of piles will be paid for in accordance with subsection 104.03.

Concrete used to fill steel pipe will not be measured and paid for separately, but shall be included in the work.