SECTION 711

DRIVEN PILE FOUNDATIONS

711.01 Description. This section shall consist of furnishing and installing prestressed concrete piling, steel H piling, steel pipe piling, and treated timber piling of the kind(s), dimension(s), at the location(s) and to the bearing value(s), line(s) and elevation(s) shown in the plans or as directed by the Engineer and in conformance with the plans and the special provisions.

This section shall supplement Section **704** for the manufacture and handling of prestressed concrete piling. Prestressed pilings are those made using high ultimate strength reinforcement and subjected to a prestressing force to place the concrete in compression.

Pile points for prestressed concrete piling shall be considered the same as steel piling except in payment and shall meet all requirements of this section relative to the type of pile point used.

MATERIALS

711.02 Material Requirements for Prestressed Concrete Piling. Unless otherwise specified, prestressed concrete piling shall be made from Class 5000 concrete. All materials, equipment, construction methods, etc shall conform to the requirements of Sections **701**, **702**, **703** and **704** unless otherwise specified in this Section.

711.03 Material Requirements for Steel Piling.

A. Structural Steel. Structural steel H-piling shall conform to the requirements of AASHTO M 160, (ASTM A 6) and M 270, (ASTM A 709), Grade 36 unless noted otherwise in the plans. Steel pipe shall be ASTM A 252, Grade 2 and may be seamless or spiral welded. Chemical properties shall conform to

ASTM A 53, Grade B.

B. Concrete for Pipe Pile Anchors. Unless otherwise specified in the plans or special provisions, concrete for pile anchors for steel pipe piling shall be Class 5000.

C. Reinforcing Steel for Pipe Pile Anchors. Reinforcing for pipe pile anchors shall conform to Section **703**.

711.04 Material Requirements for Timber Piling.

A. General. Unless specified otherwise on the plans or in the special provisions, all piling are to be treated and no untreated timber piling will be allowed.

B. Kind of Wood. Treated piling shall be of Southern Yellow Pine, unless otherwise specified and shall conform to Section **706**.

C. Preservative Treatment. Timber piling shall be treated for preservation in accordance with Section **707**. Dual treatment of marine piling will not be required unless specified on the plans or in the special provisions.

CONSTRUCTION REQUIREMENTS

711.05 Index Piling. When index piling is required, the Contractor shall drive index piling of the type specified and of the length(s) stipulated at the location(s) designated in the plans, subject to the approval of the Engineer. Index piling shall be driven to practical refusal as defined in Subsection **711.14** and shall be incorporated into the final structure unless otherwise directed by the Engineer. Unless otherwise approved in writing by the Engineer, index piling shall be driven with the same equipment used in driving the production piling and are for the purpose of assisting the Engineer in determining the proper length(s) of production piling. A follower will not be allowed for driving index piles unless approved in writing by the Engineer. This work shall be done as soon, as is practical to minimize delay in determining

length(s) of production piling. The estimated production pile length(s) shown on the plans are for bid estimation purposes only. Unless approved in writing by the Engineer, no production piling will be ordered until all index piling have been driven, the data evaluated, and the piling length(s) approved by the Engineer. The Contractor will be notified by the Bridge Construction Engineer of the approved pile lengths within seven (7) working days after receipt of the Index Pile and/or Load Test data. Any claim by the Contractor for delay based on the Engineer's failure to comply with the seven (7) working day requirement shall be limited to an extension of contract time as the only possible compensation.

The Department reserves the right to add, delete, or shift index piling. Any additional index piling will be paid for at the unit price bid for the specified index piling. The Department also reserves the right to revise length(s) of any additional index piling after evaluating driving records from earlier index piling.

711.06 General Requirements for Prestressed Concrete Piling.

A. Form Work. Forms for concrete piling shall conform to the general requirements for concrete formwork as provided in Sections **702** and **704**. Forms shall be such that consolidation and finishing can be accomplished with the least amount of inconvenience.

B. Reinforcement. Unless otherwise shown on the plans, reinforcement shall consist of longitudinal bars or strands in combination with spiral reinforcement in the form. All reinforcement shall meet the requirements of Section **703** or Section **704** whichever is applicable. The reinforcing system shall be rigidly wired or fastened and held to true position in the forms by means of approved devices. Splices in reinforcing steel shall be installed as detailed on the plans or approved in writing by the Engineer.

C. Casting. Piling shall be cast in a horizontal position.

Care shall be exercised to vibrate and tamp the concrete around the reinforcement, especially at the pile head, to avoid the formation of stone pockets, honeycomb or other such defects. The formation of stone pockets, honeycomb or porous places, may be cause for rejection. During the placing of the concrete, the forms may be vibrated with a hammer or wooden maul. Concrete shall be placed continuously in each pile and shall be carefully spaded, vibrated with an approved type of internal vibrator and tamped, special care being exercised to avoid horizontal or diagonal cleavage planes and to see that the reinforcement is properly embedded in the concrete. The form shall be overfilled, the surplus concrete screeded off after a suitable period of time and the top surface finished to a uniform, even texture similar to that produced by the forms.

D. Curing and Pointing. Prestressed concrete piling shall be cured in accordance with the provisions of Section **704**. When concrete has cured sufficiently, the side forms shall be removed as stated above, the piling carefully inspected and all cavities and irregularities pointed with 1:2 mortar. In removing the side forms and pointing, the burlap or other covering may be turned back for a short time at the point of immediate work, but the work shall be so conducted as to keep this interference with the curing to a minimum. Prestressed piling may be transported and driven after the concrete is at least three (3) days old and has attained the minimum design compressive strength.

E. Surface Finish. All prestressed piling shall be finished in accordance with the provisions of Section **702** governing the surface finish of concrete.

711.07 Prestressed Concrete Piling in Tidal Water. Piling to be used in tidal water shall be constructed and driven as provided for in this specification, except as otherwise specified in Subsection **702.17**.

711.08 Transporting, Storage, and Handling of Prestressed Concrete Piling. The method of transporting, storing, and handling shall be such as to eliminate the danger of cracking. Concrete piling shall be lifted by suitable devices attached to the pile at sufficient points to prevent cracking. Special care shall be exercised to avoid damage to the surface of the pile. All piling that are cracked or broken will be rejected unless a repair procedure has been approved in writing by the Department and the procedure has been completed to the satisfaction of the Engineer.

711.09 Transporting, Storage, and Handling of Steel Piling. The method of transporting, storage and handling shall be such as to avoid injury to the piling. Material to be stored shall be placed on skids above the ground. It shall be kept clean and properly drained and long members shall be supported on skids near enough together to prevent injury from deflection.

For steel H-piling, one handling hole 11/2 inches in diameter may be placed in the web of the pile at either or both ends. For steel pipe piling, two handling holes 1 1/2 inches in diameter may be placed in the wall at one end.

711.10 Transporting, Storage, and Handling of Timber Piling. The method of transporting, storage, and handling shall be such as to avoid injury to the piling. Special care shall be taken to avoid breaking the surface of treated piling; and cant-dogs, hooks or pike-poles shall not be used. Cuts or breaks unavoidably made in the surface of treated piling shall be field treated in accordance with AWPA M 4, which requires that the repair material be the same as the original treatment or may be copper naphtenate regardless of original treatment.

Piling to be air-seasoned shall be stored by segregating according to size and length, and each layer separated by 2 inch strips so that there will be an air space of 2 inches or more underneath and between each layer. The ends of piling in alternate layers shall be reversed in order to keep the stack

level. Alleys at least 3 feet wide shall be left between rows of stacks and the space under and between the stacks shall be kept free at all times of rotting wood, weeds or rubbish. The yard shall be drained so that no water will stand under the stacks or in their immediate vicinity.

711.11 Length of Prestressed Concrete Piling. Concrete piling shall be cast to the length(s) specified on the plans or in the special provisions except in cases where index piling or load test piling is required. In such cases, piling length(s) shall be determined after evaluating the data from the index piles and any required load tests. Any piling ordered before the piling length(s) are determined shall be the sole responsibility of the Contractor. For piling with pile points, the Contractor shall ensure that the correct length of the concrete portion and steel portion of the piling has been ordered. The right is reserved to vary the casting length(s) if, in the opinion of the Engineer, the driving conditions warrant such change.

711.12 Length of Steel Piling. The length(s) of steel piling shown on the plans are to be considered as approximate and are to be used solely for comparison of bids. Unless index piling is specified, the Contractor will be required, at his own expense, to determine the length(s) of piling required by driving test piling. When index piling is specified, piling length(s) shall be determined after evaluating the data from the index piles and any required load tests. Any piling ordered before the piling length(s) are determined shall be the sole responsibility of the Contractor.

Length(s) of steel piling utilized as prestressed pile points shall be shown on the plans or as directed by the Engineer.

711.13 Length of Timber Piling. The length(s) of timber piling given on the plans are to be considered as approximate and are to be used solely for the comparison of bids. The Contractor shall determine the length(s) of piling necessary to comply with these requirements by driving test piling or other means. For treated piling, the length(s) thus determined, together with any other data used in determining such

length(s), shall be submitted to the Engineer for review before such piling are ordered.

Such review shall not to be construed in any way as relieving the Contractor of the responsibility for obtaining piling of proper length(s).

Pile cut-offs shall become the property of the Contractor and shall be disposed of by the Contractor away from the site.

Full length piling shall always be used. Splicing of timber piling will not be permitted.

711.14 Penetration. All piling shall be driven to a minimum penetration equal to 10 feet excluding any prestressed pile point, the minimum tip elevation shown in the plans or the depth at which the required ultimate bearing has been achieved, whichever is greater unless directed otherwise by the Engineer. Penetration through fill material is not to be considered as penetration.

If the required ultimate bearing value, the minimum tip elevation, and the minimum penetration are obtained before the top of pile is to grade, the driving of prestressed concrete piles and steel piles shall continue for 2 feet or until the pile reaches grade, whichever is less.

To avoid cutting off a prestressed pile, the Contractor may elect, at his/her risk, to continue driving the pile until it reaches the required elevation.

After the minimum penetration and minimum bearing value requirements have been obtained, the driving of timber piling may continue to 125% of the minimum bearing specified where a gravity hammer is used and to 150% where a mechanical hammer is used, if the Engineer so directs and if the length of pile in the leads will permit.

Any extended driving beyond the required ultimate bearing

value and minimum penetration as specified above must be stopped immediately if damage to the pile occurs or if the Engineer determines that further driving would damage the pile. Such extended driving shall also be stopped if the recommendations on the driving criteria are exceeded or if the pile reaches practical refusal. Practical refusal is defined as 5 blows in 1/4 inch or equivalent multiples thereof.

If practical refusal or pile damage is encountered before reaching the minimum penetration or the minimum tip elevation, pile driving shall be stopped immediately and the Engineer shall be notified.

711.15 Driving Equipment.

A. Pile Installation Plan. Within thirty (30) calendar days after award of contract or no later than thirty (30) days before driving the first pile, the Contractor shall submit a *Pile Installation Plan* to the Bridge Geotechnical Engineer, with a copy to the Bridge Construction Engineer, and the Engineer. This plan shall provide detailed information including the following:

1. List and size of proposed equipment including cranes, driving equipment, jetting equipment, compressors and predrilling equipment, including manufacturer's data sheets on hammers.

2. Pile and Driving Equipment Data Form.

3. Methods to determine hammer energy or stroke in the field for determination of pile capacity. The submittal shall include necessary charts and recent calibrations for any pressure measuring equipment. In addition, the method for monitoring pile advancement.

4. Detailed drawings of any proposed followers.

5. Detailed drawings of templates.

6. Details of proposed load test equipment and procedures including recent calibrations of jacks and required load cells. See Pile Load Test specifications for additional requirements.

7. Sequence of driving footing piles for each different configuration of pile layout.

8. Proposed schedule for index pile program and production pile driving.

9. Details of proposed items and procedures used to protect the integrity of existing structures.

10. Required shop drawings for piles, cofferdams, etc.

11. Methods and equipment proposed to prevent displacement of piles during placement and compaction of fill within 15 feet of the piles.

12. Other information shown in the plans or required by the Engineer.

The Engineer will evaluate the *Pile Installation Plan* for conformance with the plans and special provisions. Within twenty-one (21) days after receipt of the plan, the Engineer will notify the Contractor of plan acceptance or any additional information required and/or changes that may be necessary to meet the plans and specifications requirements. Any parts of the plan that are unacceptable will be rejected and the Contractor shall resubmit changes agreed upon for re-evaluation. The Engineer will notify the Contractor within seven (7) days after receipt of proposed changes of their acceptance or rejection. All plans accepted by the Engineer shall be subject to trial and satisfactory performance in the field. The Contractor shall

make any required changes that may result from unsatisfactory field performance. No changes in the driving system shall be made after the final acceptance without the written consent of the Engineer.

No extension of contract time shall be granted for delays due to failure of the Contractor to observe these time requirements. Any claim by the Contractor for the delay based on the Engineer's failure to comply with the twenty-one (21) day or seven (7) day requirements shall be limited to an extension of contract time as the only possible compensation. The Engineer will evaluate only one pile driving system at a time for each pile type. The Contractor is strongly advised to submit only the pile driving system he intends to use for each pile type. If more than one system is submitted per pile type, delays in acceptance of the plan shall be expected and no additional compensation or extension of contract time will be given.

The criteria, which the Engineer will use to evaluate the driving equipment from the wave equation results, will consist of both the required number of blows per foot and the pile stresses throughout the entire driving time. The required number of hammer blows indicated by the wave equation or dynamic pile analyzer (PDA) at the ultimate pile resistance shall be between 36 and 180 per foot for the driving equipment to be acceptable. In addition, for the driving equipment to be acceptable, the compressive stress in the pile due to driving as indicated by the wave equation or dynamic pile analyzer (PDA) shall not exceed the allowable installation stresses as indicated in Subsection **711.20**.

Acceptance of the pile driving equipment does not relieve the Contractor of the responsibility to properly install the piling. The hammer acceptance and driving criteria will be based on commonly accepted hammer efficiencies, component properties, and soil parameters. Local soil conditions and the actual driving system will affect the driving. If in the opinion of the Engineer, the accepted

driving system fails to perform satisfactorily during actual driving, the Department reserves the right to revise the driving criteria.

B. Pile Hammers for Prestressed Concrete and Steel Piling. Piling shall be driven by means of a single acting air, steam or diesel, or double acting diesel hammer. Hydraulic hammers may be used if authorized in writing by the Engineer. Hammers shall be maintained in good operating condition and shall be operated at the manufacturer's rated number of blows per minute when driving piling. The hammer shall be fitted with an anvil base or bonnet that is built especially for holding the pile under the center of the hammer during the entire driving operation.

C. Pile Hammers for Timber Piling. Timber Piling shall be driven by means of a gravity, single-acting air, steam, diesel, or double-acting diesel hammer.

Gravity hammers shall weigh not less than 2000 pounds or more than 2800 pounds. The fall shall be so regulated as to avoid injury to the pile and shall not exceed 14 feet for 2000-pound hammers or 10 feet for 2800-pound hammers. For hammer weights between 2000 and 2800 pounds, the maximum permissible fall shall be proportionately adjusted.

Steam, air or diesel hammers shall develop an energy per blow at each full stroke of the piston of not less than 7200 foot-pounds nor more than 16,000 foot-pounds or sized as determined in Subsection **711.15E**. The right is reserved to reduce the maximum size of hammer where hard material is encountered which will likely cause injury of the pile as determined by the Engineer. Hammers shall be maintained in good operating condition and shall be operated at the manufacturer's rated number of blows per minute when driving piling. The hammer shall be fitted

with an anvil base or bonnet that is built especially for

holding the pile under the center of the hammer during the entire driving operation.

D. Hammer Cushions. All pile driving equipment shall be equipped with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile and to insure uniform driving behavior. Hammer cushions shall be made of durable manufactured materials, provided in accordance with the hammer manufacturer's guidelines except that all wood, wire rope, and asbestos hammer cushions are specifically disallowed and shall not be used. A striker plate as recommended by the hammer manufacturer shall be placed on the hammer cushion to insure uniform compression of the cushion material. The hammer cushion shall be inspected in the presence of the Engineer when beginning pile driving and after each 100 hours of pile driving. When the reduction in thickness of hammer cushion exceeds 25% of the original thickness, the hammer cushion shall be replaced by the Contractor before driving is permitted to continue.

E. Pile Cushions for Prestressed Concrete Piling. The heads of concrete piling shall be protected by a pile cushion made of plywood. The minimum plywood thickness placed on the pile heads prior to driving shall not be less than 4 inches. A new pile cushion shall be provided for each pile. The pile cushion shall be replaced if, during the driving of any pile, the cushion either is compressed more than one half of the original thickness or begins to burn. The pile cushion dimensions shall match the cross-sectional area of the pile head.

F. Caps and Collars for Timber Piling. Timber piling shall be driven with the aid of a metal casting that is so designed that it will securely hold the pile in position during driving and will distribute the load on the head of the pile to prevent splitting or brooming.

For treated timber piling, a flexible and adjustable

metal collar, approved by the Engineer, shall be tightly strapped around the head of the pile below the cap casting to further prevent splitting of the pile during driving.

G. Leads. Pile driver leads for driving piling shall be constructed to afford freedom of movement of the hammer. Leads shall be supported at sufficient points to maintain position and to insure support of the pile during driving. The vertical axis of the leads and hammer shall coincide with the vertical axis of the pile.

Except where piling are driven through water, the leads shall be of sufficient length so that the use of a follower will not be necessary.

H. Templates. The Contractor shall provide an adequate fixed template to maintain the pile in proper position and alignment during driving with swinging leads or with semi-fixed leads. For piles on land, the template shall be b-cated within 5 feet of cut-off or within 5 feet of ground line whichever is lower. For piles in water, the template shall be located within five feet of cut-off or within 5 feet of the waterline whichever is lower. Floating templates attached to a barge will not be allowed. Where practical, the template shall be placed so that the pile can be driven to cut-off elevation before the template is removed.

When driving piles with a follower using floating equipment, a double template, or other approved equipment shall be provided to maintain alignment of the hammer, follower, and pile. A double template shall consist of a pile template within five feet of cut-off elevation and a second upper support above the water surface for the leads. Where practical, the template shall be placed so that the pile can be driven to cut-off elevation before the template is removed. The individual pile positions of the second upper template shall be adjustable in size to serve as a guide for both the pile and follower. Templates shall not restrict the vertical movement of the pile.

I. Followers. Unless specifically allowed in the plans, special provisions, or approved in writing by the Engineer, the driving of piling by use of followers shall not be permitted. In no case will followers be allowed except when pile placement is required through water. Followers will not be permitted during driving of index or test piling unless approved in writing by the Engineer. If the use of a follower is desired, the Contractor must make the hammer selection with consideration that a follower can greatly reduce the energy transferred to the pile. Any hammer and follower combination must be capable of driving the piling to the required tip elevation(s) and ultimate bearing value(s), without damaging the pile(s).

Details of any proposed follower shall be included in the information provided to the Engineer so that the proposed follower can be modeled into the pile analysis.

J. Water Jets. Water jets will not be permitted unless approved by the Engineer or specified in the special provisions or on the plans. The number of jets and the volume and pressure of water at the jet nozzles shall be sufficient to freely erode the material adjacent to the pile. The pump shall have sufficient capacity to deliver at all times at least 100 psi pressure at two jet nozzles of 3/4-inch diameter. Before the desired penetration is reached, the jets shall be withdrawn and the piling shall be driven with a hammer to secure the final penetration and bearing. When directed by the Engineer, two separate jets shall be used.

711.16 Allowable Installation Stresses

A. Prestressed Concrete Piling. The tensile stresses in the concrete pile shall not exceed 3 multiplied by the square root of the concrete compressive strength (f'_c in psi) plus the effective prestress value:

$$\text{Tensile Stresses} < 3 \times \text{SQRT}(f'_c) + \text{prestress}$$

The compressive stress shall not exceed 85% of the compressive strength of the concrete minus the effective prestress:

$$\text{Compressive Stress} < 0.85f'_c - \text{prestress}$$

Stresses shall be determined by Wave Equation Analysis or Dynamic Pile Analyzer, whichever is appropriate.

B. Steel Piling. The Compressive stresses in the steel pile due to driving shall not exceed 90% of the yield stress. Stresses shall be determined by Wave Equation Analysis or Dynamic Pile Analyzer, whichever is appropriate.

C. Timber Piling. The compressive stress in the timber pile due to driving as indicated by the Wave Equation Analysis or Dynamic Pile Analyzer shall not exceed three times the Allowable Unit Working Stress Compression Parallel to Grain for Normal Duration of Loading - σ_a. For Southern Pine, σ_a is 1200 psi, which then computes to a maximum driving stress of 3600 psi.

711.17 Preparation for Driving. Piling shall not be driven until after the excavation is complete. Any material forced up between the piling shall be removed to correct elevation before concrete for the foundation is placed.

711.18 Methods of Driving. Piling shall be driven in accordance with an accepted pile installation plan as specified in Subsection **711.15**.

Predrilling for piling shall not be permitted except where specifically noted in the plans or approved in writing by the Engineer. When predrilled holes are allowed the pile shall be driven by the hammer to its final position and to the required ultimate bearing. If predrilled holes are larger than the pile, the space between the pile and the predrilled hole shall be

backfilled with sand, pea-gravel, or an approved material and tamped in an approved manner.

Spudding or other methods shall not be used to facilitate pile installation unless specifically approved in writing by the Engineer.

Prestressed concrete piling driven below grade shall be built up where necessary as shown in the plans or directed by the Engineer and in accordance with Subsection **711.22**.

Steel piling driven below grade shall be spliced in accordance with Subsection **711.23**.

711.19 Allowable Variation in Driving. Piling shall be driven with a variation of not more than 1/4 inch per foot from the vertical or from the batter indicated, with a maximum variation of the head of the pile from the position shown on the plans, or indicated, of not more than 3 inches. Piling shall be driven so that the heads may be placed in proper position without inducing excessive stresses in the piling.

Piling not within the maximum tolerances stated above shall, with the approval of the Engineer, be withdrawn and re-driven within such tolerances, or replaced by an additional pile without compensation. If impracticable to replace, piling not within the above tolerances shall be subject to an appropriate reduction in payment for unsatisfactory workmanship. Piling shall be driven so that the cap may be placed in its proper location without inducing excessive stresses in the piling. Manipulation of piling considered by the Engineer to be excessive will not be permitted and the Contractor will be required to re-drive the pile(s) or use other satisfactory corrective methods to avoid such manipulation. Applying lateral pressure to a pile while that pile is being driven will not be permitted.

711.20 Determination of Bearing Values. Pile bearing will be determined by the Engineer based on the wave equation

analysis or Dynamic Pile Analyzer Test. If a bid item for Dynamic Pile Analyzer Test Set-up is provided, then the Dynamic Pile Analyzer will be utilized. If conditions warrant, the Department reserves the right to require Dynamic Pile Analyzer Tests, even if not provided for in the plans. Unless otherwise specified in the plans or special provisions, allowable pile bearing for timber piles shall be determined by the Dynamic Formula in Subsection **711.20.C**.

A. Wave Equation Analysis Piling shall be driven to the required ultimate bearing shown in the plans. The actual ultimate pile bearing obtained during driving shall be determined by the Engineer based on a Wave Equation Analysis.

B. Dynamic Pile Analyzer. Piling shall be driven to the required ultimate bearing shown in the plans as determined by the Engineer using the Dynamic Pile Analyzer.

If a bid item for Dynamic Pile Analyzer Test Set-up is provided, then the Engineer will be utilizing a Dynamic Pile Analyzer to monitor the driving of the index piling and a selected number of production piling as determined by the Engineer for the purpose of determining actual ultimate bearing. Before placement in the leads, the Contractor shall make each designated pile available for wave speed measurements and for pre-drilling the required instrument attachment holes. The Engineer will furnish the equipment, materials, and labor necessary for the attachment of the instruments. The Contractor shall provide a responsible person to attach the instruments to the pile after the pile is in the leads. A platform with a minimum size of 4 feet x 4 feet designed to be raised to the top of the pile while the pile is located in the leads shall be provided by the Contractor. The Contractor should anticipate short delays to allow for the attachment of the dynamic test instruments. The Contractor shall furnish electrical power for the dynamic test equipment. The power supply at the outlet shall be 10 amp, 115 volt, 55-60 cycle, AC only. Field generators used as a power source shall be

equipped with functioning meters for monitoring voltage and frequency levels.

C. Dynamic Formula. Timber pile(s) shall have the minimum bearing value required by the plans or special provisions. In the absence of requirements in the plans or special provisions, the minimum bearing value shall be 35 tons. The bearing value shall be determined by the following formulas:

The following Dynamic Bearing Formula is based on English units of measure:

For gravity hammers,

$$P = \frac{2\,WH}{S + 1.0}$$

For single acting steam, air, diesel hammers,

$$P = \frac{2\,WH}{S + 0.1}$$

For double acting steam hammers,

$$P = \frac{2\,H(W + A \times p)}{S + 0.1}$$

Where

P = Bearing value in pounds.

S = The average penetration in inches per blow for the last 3 to 10 blows for gravity hammers, and the last ten or more blows for steam, air or diesel hammers.

W = Weight, in pounds, of falling parts of hammer.

H = Height of fall in feet. The fall shall be 14 feet in testing the capacity of pile using a gravity hammer

A = Area of piston in square inches.

p = Mean effective steam pressure in pounds per square inch at the hammer.

The above formulas are applicable only when:

1. The hammer has a free fall.

2. The head of the pile is free from broomed or crushed wood fiber.

3. The penetration is at a reasonably quick and uniform rate.

4. There is no sensible bounce after the blow.

In case water jets are used in connection with the driving, the bearing value shall be determined by the above formulas from the results after driving the pile without the aid of jets.

Penetration secured by water jets, predrilling, etc., considered by the Engineer to be unnecessary, will not be permitted.

Piling that are driven and do not meet all of the requirements of these specifications shall be replaced by piling that comply with the requirements of the specifications at no additional compensation.

711.21 Restriking Piling. The Contractor may be required to restrike a number of index piling or selected production piling after initial driving. If a Dynamic Pile Analyzer is being utilized, a restrike may be required after the dynamic test instruments are attached. The length of time required between initial driving and restriking will be determined by the Engineer, but, the required time will not be greater than fourteen (14) days, unless specified otherwise in the plans or special provisions. The hammer shall be warmed up before re-driving begins by applying at least 20 blows to another pile. The maximum amount of re-driving required to determine bearing shall be 6 inches or the total number of blows required will be 50, whichever occurs first. If the bearing has not reached the required ultimate bearing, the Contractor may

be required to continue driving until the required ultimate bearing is obtained.

Payment for restriking of piling will be as specified in Subsection **711.32J**.

711.22 Build-Ups for Prestressed Concrete Piling. When build-ups are necessary, concrete in build-ups shall be of the same quality and strength as required in the original pile. Just before placing the concrete, the pile tops shall coated with a Department approved moisture insensitive bonding epoxy. Forms shall remain in place for at least six (6) days. This period may be reduced to three (3) days if high-early-strength cement is used or if an approved admixture is used to obtain high-early strength. No payment will be made for build-ups where made necessary by damage to the pile during driving. Where build-ups are necessary, the reinforcement shall be as shown on the plans.

711.23 Splices for Steel Piling.

A. Steel H-Piling. If splices are necessary for steel H-piling, they shall be made as follows:

1. If bent during the driving process, the top portion of the lower pile shall be straightened or, if it cannot be satisfactorily straightened, cut off below the bent portion.

2. The bottom surface of the upper pile shall be beveled on the outside edge of the flanges and along one edge of the web. The bevel shall be made at an angle of approximately 45 degrees with the horizontal. A surface of 1/8 inch may be left unbeveled. Guide plates may be temporarily attached to the web or flanges to properly align the pile sections before welding.

3. The upper pile shall then be set on the lower pile and temporarily clamped thereto. The beveled

edges of the upper pile shall be separated about 1/8 inch from the unbeveled edges of the lower pile and the axes of the two piling shall then be made to coincide by adjusting the clamps.

4. The entire periphery of the pile joint shall then be butt welded with a shielded-arc low hydrogen electrode of proper size and with sufficient generating amperage to fuse the root of the weld. The weld shall be made with sufficient passes to completely fill the joint, removing the slag of each pass before beginning the next pass. The weld specified here is the butt weld designated as B-U4b in the ANSI/AASHTO/AWS D1.5 *Bridge Welding Code*.

At no additional cost to the Department and with written approval of the Engineer, pre-fabricated splicers may be used. Installation will be in accordance with the manufacturer's installation recommendations. Each splice shall develop the moment, shear, and axial capacity of the pile. As a minimum, each flange shall have full penetration butt welds, and the total amount of weld provided on the web will at least equal the length of weld should a splicer not be utilized. Pre-fabricated splicers shall be of equal strength and thickness as the web.

Care shall be taken to remove all paint and/or coating from the metal at the welds before welding begins, and after all welding is complete, the slag shall be removed and the welds painted as prescribed in Subsection **711.28**.

B. Steel Pipe Piling. If splices are necessary for steel pipe piling, they shall be made as follows:

1. The surface of one of the piling shall be beveled on the outside edge of the wall at an angle of approximately 45 degrees with the horizontal. A surface of 1/8 inch may be left unbeveled. Guide bars may be temporarily attached to the pipe wall to properly align the pile sections before welding.

2. The beveled pile shall then be butted to other pile and temporarily clamped thereto. The beveled edge of the pile shall be separated about 1/8 inch from the squared edge of the other pile and the axes of the two piling shall then be made to coincide by adjusting the clamps.

3. The entire periphery of the pile joint shall then be butt welded with a shielded-arc low hydrogen electrode of proper size and with sufficient generating amperage to fuse the root of the weld. The weld shall be made with sufficient passes to completely fill the joint, removing the slag of each pass before beginning the next pass. The weld specified here is the butt weld designated as B-U4b in the ANSI/AASHTO/AWS D1.5, *Bridge Welding Code*.

Care shall be taken to remove all paint and/or coating from the metal at the welds before welding begins, and after all welding is complete, the slag shall be removed and the welds painted as prescribed in Subsection **711.28**.

711.24 Splices and Cut-offs at Cap for Steel Piling. The tops of steel piling shall be placed to the elevation indicated on the plans or special provisions or as approved by the Engineer. Splices at concrete caps will not be required if the head of the pile, after removing pile material deformed during driving, is less than 6 inches below its plan position and extends not less than 12 inches, or the required minimum shown on the plans, into the concrete cap. Cut-offs shall be made at right angles to the axis of the pile.

711.25 Elevation of Cut-Off for Timber Piling. The tops of all timber piling shall be sawed off to a true plane at the elevation indicated on the plans or as approved by the Engineer. Piling which support timber caps shall be sawed to the exact plane of the superimposed structure and shall exactly fit it. Before the roofing pitch and galvanized metal or aluminum sheet are applied on such pile heads, the timber cap shall be

temporarily set and any misfits shall be corrected in an approved manner. Broken, split or misplaced piling shall be withdrawn and properly replaced. Piling driven below the cut-off grade shall be withdrawn and replaced by new, and if necessary, longer piling at the expense of the Contractor. All piling raised by heaving during the process of driving adjacent piling shall be driven down again unless this requirement is waived in writing by the Engineer.

711.26 Treatment of Pile Heads for Timber Piling. After having been cut, the head(s) of treated timber piling shall be treated as follows:

The sawn surface shall be field treated by heavy applications of preservative treatment as recommended by the latest edition of AWPA M4. The preservative shall be applied until visible evidence of further penetration has ceased. The pile head shall then be covered with a heavy application of coal-tar roofing cement meeting ASTM D-4022 specifications. Upon this shall be placed a covering of 20 gage galvanized metal or aluminum sheet, which shall be bent down neatly over the sides of the pile and firmly secured thereto with large-headed galvanized nails or a galvanized wire band. Pile heads which are to be encased in concrete shall not require the galvanized metal or aluminum cap.

711.27 Welding of Steel Piling. The welding of steel piling, including bracing, caps, splices, etc., shall be in accordance with the requirements of Section **709** of these specifications.

711.28 Painting of Steel Piling. All painting shall conform to Subsection **710.11B**.

711.29 Encasement of Steel Piling. Where piling are to be encased in concrete, the encasement shall be in accordance with the plans or special provisions.

711.30 Prestressed Pile Points and Reinforced Pile Tips.

A. Prestressed Pile Point. When indicated on the plans the prestressed concrete piling will be supplied with prestressed pile points of the size and shape as required. Pile points will conform to the requirements for steel piling as required in this section of the specifications, and as amended by the special provisions. The Department reserves the right to extend prestressed pile points by field welding additional lengths of pile points, and to shorten lengths of pile points by cutting off pile points. Therefore, any reinforced pile tips used shall not be welded onto the pile point until directed by the Engineer, normally just prior to driving. If, in the opinion of the Engineer, splices are necessary, they shall be made as indicated in Subsection **711.23**.

B. Reinforced Pile Tips. When specified in the contract, steel piling shall be reinforced with manufactured cast steel pile tips conforming to AASHTO M 103 (ASTM A 27). The steel pile tips shall be installed in accordance with the manufacturer's recommendations except that as a minimum, the welds shall extend across the full width of each flange or the full circumference of steel pipe piles. The steel pile tips shall be approved by the Engineer before installation, and the welds shall be visually inspected by the Engineer in the field.

711.31 Pile Load Test. In special cases, it will be desirable to load test certain piling of a project in order to determine the relationship between the driving resistance of the pile and the actual load bearing capacity of the driven pile as determined by actual test loading of the pile, taking into consideration the assumed safety factor of the pile. When such is the case, the plans and special provisions will outline the work to be done and the method of payment for the portion of work to be done by the Contractor.

711.32 Method of Measurement.

A. Dynamic Pile Analyzer Test Set-ups. The number of Dynamic Pile Analyzer Test Setups shown in the plans is estimated for bid purposes only. The number of Dynamic Pile Analyzer test set-ups measured for payment will be the number of index or production pilings to which Dynamic Pile Analyzer test equipment has been attached for the purpose of testing.

Dynamic Pile Analyzer Test Set-ups required due to Contractor errors or inadequate pile driving procedures or equipment may not be counted for payment.

B. Prestressed Concrete Piling. The length of prestressed concrete piling of each size and shape to be measured for payment shall be the linear feet of prestressed concrete piling approved by the Engineer to be cast and driven, regardless of cut-offs (except those cut-offs made due to damage during driving), plus the linear feet of build-ups necessary (exclusive of build-ups due to driving damage or due to the Contractor unnecessarily driving past the designated top of pile elevation). The length of build-up will be the length above the original pile head; in addition to the length required to be chipped back on the original pile for proper installation of the build-up.

C. Pile Build-up Preparations. The number of Pile Build-up Preparations included in the plans is estimated for bid purposes only. The pile build-up preparation of each size and shape to be measured for payment shall be the number of prestressed concrete piles receiving a reinforced concrete build-up. Measurement will not include build-ups required because of driving damage or due to the Contractor unnecessarily driving past the designated top of pile elevation.

D. Prestressed Pile Points. The length of prestressed pile points of each size and weight or strength to be measured for payment shall be the linear feet of

prestressed pile points cast into the concrete piling plus any length spliced on at the direction of the Engineer. In addition, an allowance of 2 feet of pile point (Steel H-Pile or Pipe Pile) will be made for each splice eligible for payment.

E. Reinforced Pile Tips. The reinforced pile tips of each size and weight or strength to be measured for payment shall be the number of reinforced pile tips installed in the finished structure.

F. Index Piling. The length of index piling of each size and shape, weight or wall thickness to be measured for payment shall be the linear feet of piling measured in the same manner as the appropriate corresponding Subsection **711.32B**, **711.32G**, or **711.32I** for the type of index pile driven.

G. Steel Piling. The length steel piling of each type, size, and weight or wall thickness to be measured for payment shall be the linear feet of accepted piling in the finished structure, with allowances for splices as follows: An allowance of 2 feet of steel H-pile will be made for each steel H-pile splice eligible for payment under Subsection **711.23**. An allowance of 6 feet of steel pipe pile will be made for each pipe pile splice eligible for payment under Subsection **711.23**. These measurements will not include piling that are not in conformance with these specifications or accepted by the Engineer.

H. Encasements of Steel Piling. Reinforced concrete encasement will be measured as the cubic yards of concrete and pounds of steel reinforcement in the finished structure placed in accordance with the plans and special provisions.

I. Timber Piling. The length of timber piling to be measured for payment shall be the linear feet in the finished structure, except where payment for cut-offs in excess of 2 feet will be made as described in Subsection **711.33I**.

These measurements will not include piling that are not installed in accordance with the plans and special provisions, piling driven in falsework, or piling used in bracing.

J. Restrike. If a bid item for Dynamic Pile Analyzer Test Set-up is included in the contract and a Dynamic Pile Analyzer Test is performed on the pile, then the restrike will be considered as a Dynamic Pile Analyzer Test Set-up as specified in Subsection **711.32A**, and will be considered full compensation for the restrike.

If a bid item for Dynamic Pile Analyzer Test Set-up is not included in the contract or test equipment is not attached to the pile, an allowance of 3 linear feet of piling will be made for each restrike ordered by the Engineer and eligible for payment.

711.33 Basis of Payment.

A. Dynamic Pile Analyzer Test Set-ups. The number of Dynamic Pile Analyzer Test Set-ups, determined in Subsection **711.32A**, will be paid for at the contract unit price for Dynamic Pile Analyzer Test Set-up, which price and payment of shall be full compensation for mobilization, equipment, labor, materials, and incidentals required to assist the Engineer in the preparation, performance and monitoring of a Dynamic Pile Analyzer test.

The number of pile restrikes determined in Subsection **711.32J** to be counted as Dynamic Pile Analyzer Set-ups will also be paid for at the contract unit price for Dynamic Pile Analyzer Test Set-up.

B. Prestressed Concrete Piling. The length of Prestressed Concrete Piling determined in Subsection **711.32B** will be paid for at the contract unit price bid for Prestressed Concrete Piling for each size and shape, which price and payment shall be full compensation for furnishing all materials, equipment, jetting, removal of obstructions, drilling, tools, labor and other items necessary

for casting, curing, protecting, transporting, driving, cutting off, and finishing the piling. It shall include the furnishing and placing of any temporary bracing necessary to hold the piling in alignment and the removal of any obstructions in order to complete the work as required.

C. Pile Build-up Preparations. The number of Pile Build-up Preparations determined in Subsection **711.32C** will be paid for at the contract unit price for Pile Build-up Preparation of the designated size and shape, which price and payment shall be full compensation for all material, equipment, labor, tools and other items necessary to drill, chip, weld, grout, or otherwise prepare the pile head to receive the build-up.

D Prestressed Pile Points. The length of Prestressed Pile Points determined in Subsection **711.32D** will be paid for at the contract unit price for Prestressed Pile Points of each designated size and weight or strength, complete in place, which price and payment shall be full compensation for furnishing all materials, equipment, tools, labor and other items necessary for placing the pile points as required.

E. Reinforced Pile Tips. The number of Reinforced Pile Tips determined in Subsection **711.32E** will be paid for at the contract unit price for Reinforced Pile Tips of each size and weight or strength, complete in place, which price and payment shall be full compensation for furnishing all materials, equipment, tools, labor and other items necessary for installing and welding such tips as required.

F. Index Piling. The length of Index Piling determined in Subsection **711.32F** will be paid for at the contract unit price for Index Piling of each size and shape, weight, or wall thickness, complete in place (or removed if specified), which price and payment shall be full compensation for furnishing all materials (exclusive of steel pile encasement), equipment, tools, jetting, drilling, labor and other items necessary for driving, casting, curing, protecting,

transporting, finishing, cutting off, splicing, welding, painting, and removing such piling as required. It shall include the furnishing and placing of any temporary bracing necessary to hold the piling in alignment and the removal of any obstructions in order to complete the work as required.

Any length of Concrete Pile Build-Ups and number of Pile Build-Up Preparations necessary in conjunction with index piling and measured in Subsections **711.32B** and **711.32C** will be paid for at the contract unit price for Prestressed Index Piling and Pile Build-up Preparation respectively.

G. Steel Bearing Piling. The length of Steel H-Bearing Piling and/or Steel Pipe Piling determined in Subsection **711.32G** will be paid for at the contract unit price for Steel H-Bearing Piling or Steel Pipe Piling for each designated size and weight or wall thickness, complete in place, which price and payment shall be full compensation for furnishing all materials (exclusive of encasement), equipment, tools, labor and other items necessary for driving, cutting off, splicing, welding and painting such piling as required. It shall include the furnishing and placing of any temporary bracing necessary to hold the piling in alignment and the removal of any obstructions in order to complete the work as required.

H. Encasement for Steel Piling. The quantity of Class 4000P Concrete and Reinforcing Steel for Structures used in pile encasement will be paid for at the contract unit prices for these items, which price and payment shall be full compensation therefore as prescribed in the basis of payment for these items in Sections **701** and **703** of these specifications.

I. Treated Timber Piling. The length of Treated Timber Piling determined in Subsection **711.32I** will be paid for at the contract unit price for Treated Timber Piling, complete in place, which price and payment shall be full compensa-

tion for furnishing all materials (exclusive of hardware), equipment, jetting, tools, labor and other items necessary for driving and cutting off such piling as are required. It shall also include the furnishing and placing of any temporary bracing necessary to hold the pile in alignment and the removal of any obstructions in order to complete the work as required.

Compensation for cut-off of treated timber piling shall be made as follows:

Cut-Off Length (in feet)	**Unit Price (per linear foot)**
3 feet and less	No compensation
Greater than 3 feet	0.4 of unit price of piling complete in place for length of cut-off in excess of 3 feet

The cost of all necessary hardware complete in place and accepted will be paid for under Section **708**.

The cost of furnishing metal shoes when directed by the Engineer will be paid for in a Supplemental Agreement, but the placing thereof will be included in the contract price for piling.

J. Pile Load Tests. When required, Pile Load Tests will be paid for at the contract unit price for Pile Load Test of the applicable pile. In the absence of a bid item for Pile Load Test, the work shall be performed under the direction of the Engineer and paid for by a supplemental agreement.

Payment for each item will include all direct and indirect costs and expenses required to complete the work.

Payment will be made under:

Item No.	Pay Item	Pay Unit
7110001	Dynamic Pile Analyzer Test Set-up	Each
7110XX0	Prestressed Concrete Piling (*(size)*" Sq.)	Linear Foot
7110XX1	Pile Build-up Preparation (*(size)*" Sq.)	Each
7110XX2	Pile Load Test - Prestressed Concrete Piling (*(size)*" Sq.)	Each
71104X0	Prestressed Concrete Octagonal Piling - *(size)*"	Linear Foot
71104X1	Prestressed Concrete Octagonal Pile Build-up Preparation (*(size)*")	Each
71104X2	Pile Load Test - Prestressed Concrete Octagonal Pile - *(size)*"	Each
71111XX	Prestressed Pile Point (*(HP size)*)	Linear Foot
71113XX	Prestressed Pile Point (*(pipe diameter and Extra Strong or Dbl. Extra Strong pipe)*)	Linear Foot
71115XX	Reinforced Pile Tips (*(size)*)	Each
71117XX	Reinforced Pile Tips (*(pipe diameter and Extra Strong or Double Extra Strong)*)	Each
7110XX5	Prestressed Index Piling (*(size)*" *(shape)*)	Linear Foot
7112XX0	Steel H Bearing Piling (HP*(size)*x*(weight)*)	Linear Foot
7112XX1	Pile Load Test - Steel H-Piling (HP*(size)*x*(weight)*)	Each
7112XX2	Steel H Bearing Index Piling (HP*(size)*x*(weight)*)	Linear Foot
7113XX0	Steel Pipe Piling (*(diameter)*" Diameter)	Linear Foot
7113XX1	Pile Load Test - Steel Pipe Piling (*(dia.)*" Diameter)	Each

Pay Items (Continued)

Item No.	Pay Item	Pay Unit
7113XX2	Steel Pipe Index Piling (*(dia.)*" Diameter)	Linear Foot
7119100	Treated Timber Piling	Linear Foot
7119101	Pile Load Test - Treated Timber Piling	Each

SECTION 712

DRILLED SHAFTS AND DRILLED PILE FOUNDATIONS

712.01 Description. This work shall consist of furnishing all labor, materials, equipment, and services necessary for construction of portland cement concrete foundations consisting of fully cast-in-place shaft foundations and pile foundations within drilled excavations. The size and locations are shown on the plans. Work shall be in strict accordance with the plans and the special provisions. Work shall comply with the applicable requirements of Sections **701**, **702**, and **703** of these specifications.

For the purposes of this specification:

Drilled Shafts are cast-in-place shafts with reinforcing steel, and

Drilled Pile Foundations consist of a drilled excavation of the proper size, with a pile section concreted or grouted in place. Reinforcing steel may or may not be required in a Drilled Pile Foundation.

712.02 Site Information. Data on subsurface conditions are not intended as representations or warranties of continuity of