ITEM 404

DRIVING PILING

404.1. Description. Drive piling.

404.2. Equipment.

A. Driving Equipment. Use power hammers for driving piling with specified bearing resistance. Use power hammers that comply with Table 1. Gravity hammers may be used for driving sheet piling and timber piling if no required design load is shown on the plans.

For initial rating of diesel hammers to determine compliance with the requirements of Table 1, the height of fall of the ram of the single-acting (open-end) hammer must be 7 ft. For a double-acting (enclosed ram) hammer, the energy rating must be 85% of the rated output by the manufacturer.

A hammer that produces less energy than required by Table 1 may be approved if a wave equation analysis indicates that the hammer can drive the specified pile against a bearing resistance of 3 times the required design load before reaching 0.1 in. of penetration per blow. The bearing resistance of the piling driven with this particular equipment will be determined in accordance with the Wave Equation Method.

Use an air compressor that supplies the volume and pressure specified by the manufacturer of the hammer. Provide an accurate pressure gauge.

Maintain the valve mechanism and other parts of power hammers so that the hammer will operate at the speed and stroke length specified by the manufacturer.

Equip enclosed ram diesel hammers with a gauge and provide charts to evaluate the equivalent energy being produced. Calibrate the gauge before work begins, whenever gauge accuracy is in question, and at least once each 6 months.

<table>
<thead>
<tr>
<th>Piling Type</th>
<th>Hammer Type</th>
<th>Ram Weight (lb.)</th>
<th>Maximum Ram Stroke (ft.)</th>
<th>Minimum Hammer Energy (ft.-lb.)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber</td>
<td>Air, Hydraulic</td>
<td>2,000 min.</td>
<td>5</td>
<td>330R</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>2,000 min.</td>
<td>10</td>
<td>330R</td>
</tr>
<tr>
<td>Steel</td>
<td>Air, Hydraulic</td>
<td>3,000 min.</td>
<td>5</td>
<td>Larger of 250R or 2-1/2 Wp</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>2,000 min.</td>
<td>10</td>
<td>Larger of 250R or 2-1/2 Wp</td>
</tr>
<tr>
<td>Concrete</td>
<td>Air, Hydraulic</td>
<td>3,000 min., but not less than 1/4 Wp</td>
<td>5</td>
<td>250R, but not less than 1 ft.-lb. per lb. of pile weight</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>2,700 min., but not less than 1/4 Wp</td>
<td>8²</td>
<td>250R, but not less than 1 ft.-lb. per lb. of pile weight</td>
</tr>
</tbody>
</table>

1. R = Design load in tons. Wp = Weight of pile in pounds based on plan length.
2. Diesel hammers with less ram weight or greater ram stroke are permitted if a wave equation analysis indicates that the combination of ram weight, stroke, and cushioning will not overstress the piling.
Cap block cushioning material, when used between the ram and anvil or follow block, must consist of layers of micarta plastic and aluminum or other material specifically produced and approved for this application.

When using gravity hammers, regulate the height of fall to avoid damage to the piling. Drive all test piling in a structure or in any approved segment of it with the same hammer, and use the same type and size hammer to drive the remainder of the piling in the structure or segment. Equip pile drivers with leads constructed to allow freedom of movement of the hammer and to provide adequate support to the pile during driving. The longitudinal axis of the leads, hammer, and pile should coincide.

Except where piling is driven through water, ensure that leads are long enough that a follower will not be necessary. Where a follower is required when driving piling underwater, use 1 pile in each 10 that is long enough to permit driving without a follower. Drive it as a test pile for proper correlation of the follower-driven piling. Payment will be made as regular piling.

Hammers designed to operate underwater may be used for underwater driving without a follower and without the correlation required for other hammers.

B. Protection of Pile Heads. Use a steel driving head (helmet) suitable for the type and size of piling. Drive steel H-piling and sheet piling with a helmet compatible with the specific pile shape driven. For concrete piling, provide a cushion block between the driving head and the top of the pile. Unless otherwise directed, use a cushion block that is a minimum of 4 in. thick for short piling (50 ft. or less) and at least 6 in. thick for longer piling. Use multiple layers of one of the following:

- 3/4-in. or 1-in. structural grade southern pine or fir plywood;
- green oak or gum, with the grain of the wood horizontal; or
- other approved material specifically produced for this application.

Pay special attention to the condition of the cushioning material. Do not drive more than 3 piles with one cushion block. Change cushioning more frequently if necessary to prevent damage. Immediately replace any cushion block that has ignited. Do not use a tight-fitting driving helmet for concrete piling. Allow room for slight movement, but ensure that the driving helmet is not large enough for the pile head to rotate freely. Center concrete piling and cushion within the helmet throughout the driving operation.

404.3. Construction. This Item uses the following terms:

- Foundation piling – Piling placed under interior bent footings or retaining wall abutment footings.
- Trestle piling – Piling embedded directly into the abutment cap or interior bent cap.
- Sheet piling – Retaining piling not considered either foundation or trestle piling.
- Test piling – Specific piling driven to investigate site conditions and determine regular piling lengths.
- Test-loaded piling – Specific piling driven and test-loaded to investigate site conditions and determine regular piling lengths. Do not fabricate regular piling until test loading and analysis is completed.
- Regular piling – All piling other than test piling and test-loaded piling.

Do not fabricate regular piling until test pile driving and analysis or test loading and analysis is completed. Complete the embankment at bridge ends before driving abutment piling. Refer to Item 423, “Retaining Walls,” for provisions on piling that passes through the structural volume of retaining walls.

Do not drive foundation piling until the footing excavation is approximately complete. Do not drive concrete piling until the piling concrete, including build-ups, has aged at least 14 days. Do not drive piling in a saltwater environment until the piling concrete, including build-ups, has aged at least 21 days after concrete placement.

Re-drive any piling that is raised when driving adjacent piling. Withdraw and replace any broken, split, or displaced piling, or correct it as directed after a design analysis.

To control excessive stresses resulting in damage to the piling during driving, the following, alone or in combination, may be required:

- increase in cushion thickness,
- reduction of ram stroke,
• heavier ram with a shorter stroke,
• use of pilot holes or jetting when driving through hard or alternating hard and soft strata.

A. Tolerance for Driving. Drive piling to the required vertical or batter alignment, within the tolerances of this Section. Drive piling in pilot holes or with templates when necessary to comply with tolerances. Cut off piling reasonably square at the elevation shown on the plans, with a tolerance of not more than 2 in. above or below established cutoff grade. When tolerances are exceeded and the Engineer requires corrective action, submit for approval a structural analysis and proposed corrective action, signed and sealed by a licensed professional engineer.

1. Trestle Piling.
   • Transverse to the centerline of the bent, the top of the piling may be at most 2 in. from the position shown on the plans.
   • Parallel to the centerline of the bent, the top of the piling may be at most 4 in. from the position shown on the plans.

2. Foundation Piling.
   • The top of each pile may be at most 4 in. in any direction from the position shown on the plans.
   • The center of gravity of the piling group may be at most 3 in. from the center of gravity determined from plan location.
   • The minimum edge distance for piling in a footing is 5 in. Additional concrete required to obtain this edge distance and specified reinforcing steel cover will be at the Contractor’s expense.

B. Penetration. Piling lengths shown on the plans are the lengths estimated to give required bearing and are for estimating purposes only. Drive piling to within 5 ft. of plan length and to greater depths as necessary to obtain the required bearing resistance shown on the plans, unless other penetration requirements or bearing evaluation methods govern.

When test piling or test loaded piling is used, the Engineer will establish regular pile lengths on the basis of the test data. In these cases, drive regular piling to this approximate elevation and to greater depths as required to obtain the required bearing resistance.

For unusually hard driving conditions, typically less than 0.1 in. of penetration per blow, provide either pilot holes or jetting or a combination of both if plan penetration is not obtained. Penetration may be reduced upon approval if stability requirements are met.

C. Pilot Holes. Except as specified, do not extend pilot holes more than 5 ft. below the bottom of footings for foundation piling or 10 ft. below finished ground line for trestle piling, unless the specified penetration cannot be obtained by using the depth of holes indicated. When deeper pilot holes are required, determine their size and depth from the results of trial operations on the first piling driven or from available test pile data. Obtain approval for any excess depth or size of pilot holes. The maximum hole diameter permitted will be approximately 4 in. less than the diagonal of square piling or steel H-piling and 1 in. less than the diameter of round piling. The Engineer may vary hole size and depth to obtain penetration and bearing resistance.

Extend pilot holes through all embankments to natural ground when driving concrete piling.

Where a pilot hole is required in granular material that cannot be sealed off by ordinary drilling methods, a casing may be required around the boring device deep enough to prevent loose material from falling into the pilot hole.

Drive the piling below the depth of the pilot hole a minimum of 1 ft. or 100 blows but not less than the required bearing resistance shown on the plans. Unless directed otherwise, do not drive piling beyond the point where the penetration per blow is less than 0.1 in. as determined by an average of 10 blows. If damage to the pile is apparent, stop driving.

D. Jetting. Jetting is permitted when the specified penetration cannot be obtained by driving and pilot holes or other methods are not feasible. Before jetting, submit details of the proposed methods for approval. The Engineer may authorize varying depths of jetting to achieve the desired results.
Jet as required in conjunction with driving but only to the approved depth. For jetting operations, use enough power to simultaneously operate at least two 2-1/2-in. diameter pipes equipped with 3/4-in. nozzles at a pressure of 150 psi. Perform the jetting with 1 or 2 jets as determined and approved from results of trial operations.

Drive the piling below the depth of the jetting a minimum of 1 ft. or 100 blows but not less than the required bearing resistance shown on the plans. Unless directed otherwise, do not drive piling beyond the point where the penetration per blow is less than 0.1 in. as determined by an average of 10 blows. If damage to the pile is apparent, stop driving.

E. **Hammer Formula Method of Bearing Evaluation.** Unless otherwise shown on the plans, determine the dynamic bearing resistance of piling by one of the hammer formulas in this Section. If the Engineer has determined a K factor based on test piling, test-loaded piling, or other methods, the computed resistance will be the driving resistance determined based on the appropriate formula multiplied by the K factor.

1. **Single-Acting Power Hammers.** Use the following formula:

\[ P = \frac{2WH}{S + 0.1} \]

where:
- \( P \) = dynamic resistance in pounds.
- \( W \) = weight of ram in pounds.
- \( H \) = height of fall of ram in feet.
- \( S \) = average penetration in inches per blow for the last 20 blows.

Determine \( H \) by visual observation of the ram against a calibrated rod mounted on the hammer, by an approved stroke indicator and blow count logging device, or by the following formula:

\[ H = (\frac{30}{B})^2 - 0.3 \]

where \( B \) = blows per minute.

2. **Double-Acting Power Hammers.** Use the following formula:

\[ P = \frac{2E}{S + 0.1} \]

where:
- \( P \) = dynamic resistance in pounds
- \( E \) = manufacturer’s rated energy in foot-pounds (for double-acting power hammers), or the equivalent energy in foot-pounds determined by a calibrated gauge attached to the hammer and taken when the average penetration in inches per blow is determined (for enclosed ram diesel hammer)
- \( S \) = average penetration in inches per blow for the last 20 blows.

F. **Wave Equation Method of Bearing Evaluation.** When plans specify that the bearing capacity of the piling be determined by the wave equation method, submit the following data:

- manufacturer’s specification data for the hammer proposed for use, including all modifications and
- complete description and dimensions of all cushioning material used between the pile and helmet and in the cap block, including total thickness of each, and the direction of grain if wood is used.

These data are used by the Engineer to determine the required number of blows per unit of penetration the hammer must deliver to obtain the required bearing resistance.

After evaluation by the wave equation method, any change in the driving equipment may require reevaluation. Such changes must be approved before further driving.
G. **Test Piling.** Drive test piling at locations shown on the plans or as directed. In general, make test piling part of the completed work, cut off or built up to grade as necessary. Use the required bearing evaluation method to determine bearing resistance.

Initially drive test piling to 3 ft. above plan tip elevation of the regular piling for the structure with the blow count recorded for each foot of driving (for example, drive test piling to 13 ft. above its plan tip elevation if the test piling is 10 ft. longer than regular piling). Retain the cushion if used.

At least 7 days after the original driving, re-drive the test piling the additional length required by the plans with the same hammer and cushion originally used. Record the blow count for each inch of driving for the first foot, for every 3 in. for the next 2 ft., and for each foot thereafter.

Provide the data to the Engineer for use in determining regular piling lengths and K factors. The K factor will be determined based on the following formula:

\[ K = \frac{P_R}{P} \]

where:

- \( K \) = a static correction factor applied to the evaluation method
- \( P_R \) = re-drive bearing (tons) of the test pile determined by the evaluation method
- \( P \) = original bearing (tons) of test pile determined by the evaluation method.

H. **Test-Loaded Piling.** Conduct test load in accordance with Item 405, “Foundation Test Load.”

Provide the data to the Engineer for use in determining regular piling lengths and K factors. The K factor will be determined based on the following formula:

\[ K = \frac{L}{P} \]

where:

- \( K \) = a static correction factor applied to the evaluation method
- \( L \) = maximum safe static load proven by test load
- \( P \) = bearing resistance of the test loaded pile determined by the evaluation method.

404.4. **Measurement and Payment.** The work performed, materials furnished, equipment, labor, tools, and incidentals will not be paid for directly, but will be considered subsidiary to pertinent Items.