Driven Piling
Section 7

View ODOT Video, Part 7/12
Pile Foundations
What is a Driven Pile?

A Driven Pile is a deep foundation that is constructed by driving a concrete, steel or timber pile to support the anticipated loads in competent subsurface material.
End Bearing and Friction Piles

**End Bearing Load**
- Sands
- Soft Clays
- Rock

**Friction Load**
- Sands
- Clays
- Sand

\[ \Delta z_1 \]
\[ R_{S1} \]

\[ \Delta z_2 \]
\[ R_{S2} \]

\[ \Delta z_3 \]
\[ R_{S3} \]

\[ \Delta z_4 \]
\[ R_{S4} \]

**Layer 1**

**Layer 2**

**Layer 3**

**Layer 4**

\[ Q_u = R_{SN} + R_T \]
Displacement piles are piles that actually displace the material they are driven into.

Low (Non) Displacement piles are piles that displace very little of the material they are driven into.

“Rebound”

• The upward movement of a pile during driving
• High displacement piles increase potential for rebound
• Highly plastic and expansive clayey soils present increased potential for rebound
Pile Strength Vs. Time

Strength Gain (pile setup or “freeze”)

Piles can gain strength over time after they are driven in certain cohesive soils like stiff clays and clayey silts. This is due to the slow dissipation of excess pore water pressure that is created during pile driving.

Strength Lose

Piles can lose strength after driving in certain soils like very dense sands and gravels due to “relaxation” of the soil. Relaxation has to do with a change in soil structure after driving. The Geotechnical Engineer will determine if this effect applies at a given site.

Pile Driving Equipment

• Crane
• Hammer
• Cushions
• Leads
• Template
• Special Tools
Crane

Hammers

Drop (Gravity Hammers)

Vibratory

Air/Steam

Diesel

Hydraulic

Single Acting

Double Acting

Differential Acting

Single Acting

Double Acting

Single Acting

Double Acting
Open End Diesel Hammers
Single-Acting

• Advantages
  – Very simple
  – No additional support equipment required
  – Lightest net weight per ft.-lb. of energy
  – Readily available (common)

• Disadvantages
  – Delivered energy variable
  – Less efficient energy transfer
  – Produces higher pile stresses
  – Dirty exhaust spray and smoke
  – Difficult to spot operation problems

Vibratory Hammer

Generally used for driving and extracting sheet piles, low-displacement H-piles, and pipe piles.

Not impact hammers.
Hammer Cushions

- Used on all impact hammers except gravity (drop) hammers
- Must be made of durable manufactured (man-made) materials
- Wood, wire rope and asbestos not allowed
- Striker plate must be used

Hammer Cushions (Cont’d)

- Inspected when beginning driving
- Inspected every 100 hours of driving
- Replaced when there is a reduction of thickness exceeding 25% of original thickness
Hammer Cushions (Cont’d)

Guided by leads, not free-swinging
Must maintain proper alignment of hammer and pile
Minimum 1 inch larger than pile
Helmet (Cont’d)

Hammer Cushion (Cap Block) Helmet Pile Cushion Concrete Pile Striker Plate Ram & Anvil

- Used with concrete piles
- Minimum original thickness not less than 4 inches
- Replaced if compressed to more than one-half original thickness
- Replaced if starts to burn
Pile Cushion (Cont’d)

Pile Driving System Components – Leads

- Crane
- Hammer
- Cushions
- Leads
- Template
- Special Tools
Fixed Lead System

- Fixed at both top & bottom
- Maximum control of pile alignment
- Higher Cost

Semi-fixed Lead System

- Low Cost
- Simple, mobile
- Some control of pile alignment

Fixed either at top or bottom but allowing vertical movement
Driven Piles

Section 7.1

Swinging Lead System

- Low Cost
- Simple, mobile
- Less control of pile alignment
- Must be approved by The Engineer

Templates

Required for offshore leads.
Maintains the pile and hammer in the correct location and position.
Driven Piles Section 7.1

Templates (Cont’d)

- Pile in incorrect position
- Pile in correct position

Special Tools

- Jets
- Drills (Preboring)
- Punches
- Followers
Jets

- Permitted when in the plans or approved by the Engineer in writing.
- Jetting plant must provide pressure equal to 100 psi at two ¾ inch jet nozzles.
- Jets must be removed for the final 5 feet of pile penetration.

Preboring

Used only when specified or with approval of the Engineer
Punches

Aids for advancing pre-drilled holes through hard materials

Combination Jet/Punch

Followers

• Generally used for water projects.
• Only when authorized in writing by Engineer or in contract documents.
• The first pile in each bent and every tenth pile thereafter must be driven without a follower.
Pile Types

- Steel Pipe Piles
- Steel H-Piles
- Concrete Piles
- Timber Piles
- Cylinder Concrete Piles
- Composite Piles
- Steel Sheet Piles

Steel Pipe Piles

- Most commonly used in ODOT
- Driven either open or closed end
- Can be filled with concrete
Steel H-Piles
- End Bearing Piles
- Low-Displacement
- High Bearing

Timber Piles
- Low Bearing Piles
- High-Displacement
- Used typically for temporary structures
Sheet Piles

• Utilized mostly for temporary retaining systems, such as shoring, cofferdams and bulkheads

• Driven using either impact or vibratory hammers

Pile Tip Attachments – Steel H-Pile

See Section 02520.10 (e)
Reinforced Pile Tips
Pile Tip Attachments
– Steel Pipe Pile
See Section 02520.10 (e) Reinforced Pile Tips

Typical Pipe Pile End Plate

Fillet Weld

Flat End Plate
Subsurface Information

Subsurface Information Available to the Contractor:

- Foundation Reports
- Foundation Data Sheets
- Drill Logs
- Groundwater Conditions
- Soil & Rock Unit Descriptions
- Material Engineering Properties

General Materials Classification

- “Course Grained” Materials
  - Granular Soils
    - (sand, gravel, cobbles and boulders)

- “Fine Grained” Materials
  - Clay (plastic or nonplastic)
  - Silt; may be plastic (clayey silt)
    or non-plastic (sandy silt)

- Intermediate Geomaterials:
  - weathered rock
  - glacial till
  - cemented soils

- Rock
Pile and Driving Equipment Data Form

Pile Hammer Acceptance Process

Contractor prepares Pile Driving and Equipment Data Form and submits to Engineer for Approval, no later than 2 weeks prior to driving first pile. (00520.20 (d))

Changes to Contractor

Contractor resubmits to Engineer

Review

Changes

Engineer accepts Pile Driving & Equip. Data Sheet and issues Hammer Approval Letter with final pile driving criteria.

Acceptance

Changes

No changes may be made without the Engineers approval
Hammer Approval Letter

After reviewing the Contractors hammer submittal, the Geotechnical Engineer will provide a letter to the Project Manager summarizing the following:

- Hammer Approval (or reasons why the hammer is not approved)
- Driving Criteria (stroke vs. required blow count and Inspectors Graph)
- Any pile driving issues such as:
  - Pile Freeze (set-up criteria)
  - Hard driving conditions (high pile stress conditions)
  - Details on Preboring requirements

November 18, 2004

TO:  Bill Edmundson
    Project Manager

FROM:  Jim Xu, P.E.
        Geotechnical Engineer

SUBJECT:  Sylvan O’Ring Subsett Hwy. Bridge No. 18674

The Pile and Driving Equipment Data Sheet submitted for use on this bridge has been reviewed and is conditionally approved for use in driving the permanent piles. The hammer is fully suitable and approved for use in driving the PP3x4.0 (160) piles for the bridge. However, the hammer is somewhat oversized for use in driving the smaller PP2.75x3.75 piles for the wingwall, and is conditionally approved pending field hammer performance. For the wingwall piles the hammer strike must be manually controlled in the leverage to provide the maximum acceptable blow count of 3.0, allowed in the Special Provision and to minimize overvibrating the piles.

The data sheet submitted is for a Besmihammer B10.015; fixed hammer. The serial number was “to be determined.” Please obtain the serial number off the hammer for our records. All piles should be Grade 3 steel (108 Mpa).

The end-of-driving (EOD) pile criteria are listed in the chart below. This column is based on a wire equation analysis for the PP3x4.0 (160) pile and on the USSG Code Equation for the PP2.75x3.75 piles. Inspector’s graphs are also attached showing the required driving resistance (tension) versus hammer strike.

For the PP2.75x3.75 wingwall piles, the maximum allowable hammer is only 7.0 ft-lbs for the minimum allowable blow count of 3.5. Strike higher than 7 feet will result in blows counts below the minimum acceptable value. The last setting for the Besmihammer must be reduced such that the strike does not exceed 7 feet.

For Item 1, the hammer should be operating near its maximum fuel setting and stroke at the end of driving in order to satisfy the required criteria. Pile stresses should not be a problem during driving the PP3x4.0 (160) piles.
Driven O’Xing Sunset Hwy.
Bents 1 & 2
PP 24 x 0.500, driven open end
Ultimate Capacity, Rult, = 1075 kips

<table>
<thead>
<tr>
<th>STROKE (ft)</th>
<th>BLOWS/INCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>10.5</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>11.5</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: Strokes are rounded to the nearest 0.50ft. for convenience in field recording. If more precise strokes can be determined in the field then use linear interpolation between the corresponding blow counts required.

Wingwall Locations
PP 12.75 x 0.375, driven open end
Ultimate Capacity, Rult, = 490 kips

<table>
<thead>
<tr>
<th>STROKE (ft)</th>
<th>BLOWS/INCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 (max)</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>5.5</td>
<td>5</td>
</tr>
</tbody>
</table>

All the piles at both bents may come up to bearing very quickly in the basalt bedrock or rubble. This could quickly lead to a high driving stress condition for the wingwall piles. The inspector should be aware of this condition and immediately stop driving at any signs of pile damage.

A saximeter is available for measuring the field hammer stroke and will be sent to your office on request. Please contact me at 986-3377 if you have any questions.

Attachments:
Inspector’s Graphs (PP24x0.500 & PP12.75x0.375)

Construction Documents
General Notes

Steel piling conforming to ASTM 252, grade 3.

All piling shall be PP12½ x 0.25 driven closed ended to an ultimate capacity of 270 kips per pile.

Pile tip elevation for minimum pile penetration for each bent shall be elevation 210.

All piling shall be driven to the ultimate capacity using driving criteria developed from a wave equation analysis.
Foundation Data Sheet

• Pile Record Book
• General Daily Progress Report
• Personal Field Diary
### Pile Record Book

shows pile layout and numbering system used.
Driven Piles Section 7.1

Pile Record Book (Record Pile)

- A continuous record for every foot of penetration
- One Record Pile should be recorded for each bent and at least one in every 10 piles.
Piling Set Check

- Within 2 ft of estimated pile length.
- Wait for 24 hours to see if freeze will occur and bearing can be reached.
- Conserves piling and maximizes the friction ability of the soil.
Pre-Production Program (test piles)

- Determine Pile Lengths Required for Production
  - concrete and timber pile order lengths
- Check Drivability of Proposed Hammer System
- Check Performance of Contractor’s proposed Driving System
- Determine Required Driving Resistance
Driven Piles

Section 7.1

Check the Driving System

- Manufacturer
- Model
- Type
- Serial Number
- Energy Rating
- Ram Weight
- Ram Stroke

Check the Driving System

Are the leads the proper type and configuration for the job?
Does the helmet and hammer cushion meet the requirements of the Driving Criteria Letter?

Pile Drive Head (Helmet):
• Axially aligned with the hammer and pile
• Guided by the leads
• Not free-swinging
• Cut squarely for steel and timber
• Plane and perpendicular to longitudinal axis for concrete piles

Hammer Cushion:
• Required for all impact hammers except gravity (drop)
• Made of manufactured materials
• Wood, wire rope and asbestos not allowed

Steel Piles
Check the Pile Certifications. Do the heat numbers on the piles match the Certificate of Analysis for the piles?
Steel Pipe Piles

Compare diameter, length and wall thickness to plan details.

Steel Pipe Piles

Verify Open End or Closed End.

Closed End
Verify the bottom plate is the correct diameter and thickness and welded per the plans.
Measure the Pile Depth and Flange Width for comparison to plan details.

Steel H Piles

10 in.

Pile Depth

Flange Width

10 in.
Pile Splices

The Project Plans and Specifications detail the splicing requirements for piles. For Steel Pipe Pile a full penetration butt weld is required with a backing ring.

Pile Splice Measurement

00520.80 (f)(1)

- None if within length listed in Special Provision
- One splice if splice is 5 ft or more when estimated pile length is 60 ft or less
- One splice if splice is 10 ft or more when estimated pile length is over 60 ft
- Only one splice per pile
Marking Piles

Ground Surface Elevation = +0.00'
Reference Elevation = +2.00'
Cutoff Elevation = +5.00'

Length Driven is the length of pile below the cutoff elevation!

Tip Elev. = -27.00'

Monitoring Driven Pile Lengths

Cutoff Elevation = +5.00'
Reference Elevation = +2.00'
Ground Surface Elevation = +0.00'
Pile Marker @ 29' penetration

Length Driven is the length of pile below the cutoff elevation!
Method to determine hammer stroke in the field

Calculating Stroke Heights

(Air-Steam Hammer) 
Blows per minute

\[ \text{height} = \left[ \frac{14,400}{[\text{bpm}^2]} \right] - 0.3 \]

Example: bpm = 36

\[ 14,400/1296 = 11.11 \]

\[ 11.11 - 0.3 = 10.81 \text{ ft} \]

(Open-End Diesel Hammers) 
Seconds per blow

\[ h = 0.0402 \times (T^2) - 0.3 \]

h = Stroke Height in Feet

T = Time in Seconds for 10 blows

EXAMPLE

Took 16 seconds for 10 blows, therefore:

\[ h = 0.0402 \times 256 - 0.3 \]

\[ h = 9.99 \text{ or } 10 \text{ ft.} \]
Marking Pile To Check For Bearing

Pile Bearing

00520.42 (a)

• Maintain required blows/inch (bpi) for 3 consecutive inches unless refusal is first obtained.

• Refusal is defined as 20 bpi
PDA Testing

• Tends to result in shorter pile lengths.

Horizontal Tolerance for Driving 00520.41 (f)

Within 6" of plan location

At least 4" from edge of cap
Common Problems – Open End Diesel

<table>
<thead>
<tr>
<th>Common Problems</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water in fuel</td>
<td>Hollow sound, white smoke</td>
</tr>
<tr>
<td>Fuel lines clogged</td>
<td>No smoke or little gray smoke</td>
</tr>
<tr>
<td>Fuel pump malfunctioning</td>
<td>Inconsistent ram strokes, little gray smoke or black smoke</td>
</tr>
<tr>
<td>Fuel injectors malfunctioning</td>
<td>Inconsistent ram strokes, little gray smoke or black smoke</td>
</tr>
<tr>
<td>Oil low</td>
<td>Blows per minute rate is lower than specified</td>
</tr>
<tr>
<td>Oil pump malfunctioning</td>
<td>Blows per minute rate is lower than specified</td>
</tr>
<tr>
<td>Water in combustion chamber</td>
<td>Hollow sound, white smoke</td>
</tr>
<tr>
<td>Piston rings worn</td>
<td>Low strokes</td>
</tr>
<tr>
<td>Tripping device broken</td>
<td>Pawl does not engage piston</td>
</tr>
<tr>
<td></td>
<td>Pawl engages but doesn’t lift piston</td>
</tr>
<tr>
<td>Over heating</td>
<td>Paint and oil on cooling fins start to burn/sound changes</td>
</tr>
</tbody>
</table>

Steel Piles
### Steel Piles

<table>
<thead>
<tr>
<th>Typical causes of damage</th>
<th>Possible indicators during driving</th>
<th>Types of damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Transporting and Lifting</td>
<td>• Pile moving out of position during driving</td>
<td>• Bending</td>
</tr>
<tr>
<td>• Low Steel Strength</td>
<td>• Abrupt blow count change</td>
<td>• Buckling</td>
</tr>
<tr>
<td>• Hard Driving (Compression)</td>
<td>• Observed pile damage near the pile head</td>
<td>• Accordion</td>
</tr>
<tr>
<td>• Welding</td>
<td></td>
<td>• Splitting</td>
</tr>
<tr>
<td>• Splices</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Timber Piles

*Steel Piles may be band at the top to prevent "brooming" during driving.*
### Timber Piles

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<tr>
<td>• Transporting</td>
<td>• Pile moving out of position during driving</td>
<td>• Splintering</td>
</tr>
<tr>
<td>• Knots and natural defects</td>
<td>• Abrupt blow count change</td>
<td>• Cracking</td>
</tr>
<tr>
<td>• Handling</td>
<td>• Appearance</td>
<td>• Shearing</td>
</tr>
<tr>
<td>• Driving</td>
<td></td>
<td>• Brooming (head &amp; tip)</td>
</tr>
</tbody>
</table>

### Safety

Where is that Pile Data Table?
Pile Exercise

• Are obstructions anticipated? _____
  See SP00520.41(d)
• If so, what is the course of action? _______
• Why is stroke limited to 8.5 ft? __________
  See Approval Letter
• What is the required blows/inch for a stroke of 7.5 ft? _____
Driven Piles Section 7.1

Special Provisions

Table 7.1: Special Provisions

<table>
<thead>
<tr>
<th>Location</th>
<th>No.</th>
<th>Name</th>
<th>Length (ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Train</td>
<td>15</td>
<td>Pile Cap</td>
<td>61</td>
<td>PPI 80 x 5 (Clause 5)</td>
</tr>
</tbody>
</table>

Section 7.1: Special Provisions

Table 7.1:

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</table>

Approval Letter

March 14, 2018

TO: Project Manager

FROM: Project Manager

SUBJECT: Approval of Special Provisions for Building the Bridge

This letter contains the approval of the Special Provisions for the building of the bridge as outlined in Section 7.1. The provisions are as follows:

1. The piles shall be designed to carry the full design load for the bridge.
2. The pile caps shall be designed to carry the full load of the superstructure.
3. The piles shall be driven to a minimum depth of 40 ft below the final finished grade.
4. The pile caps shall be constructed with a minimum thickness of 18 in.

This approval is based on the thorough review of the special provisions and the confirmation that they meet the required engineering standards. The provisions are in line with the standards set by the Department of Transportation.

[Signature]

[Name]

[Title]
Approval Letter

Pile Exercise Key

• Are obstructions anticipated? Yes
  See SP00520.41(d)

• If so, what is the course of action? Preboring

• Why is stroke limited to 8.5 ft? (See Approval Letter) High Pile stresses

• What is the required blows/inch for a stroke of 7.5 ft? 13
Pile Driving Example

• BPI measured at 15 for 3” with required BPI of 13. Pile tip is at minimum tip elevation. What do you do? ___________ Stop & Accept Pile
Pile Driving Exercise 1

• BPI measured at 10 with required BPI of 13. Pile tip is at minimum tip elevation and is within 2′ of estimated pile length. What do you do? ___________
Pile Driving Exercise 1 Key

• BPI measured at 10 with required BPI of 13. Pile tip is at minimum tip elevation and is within 2′ of estimated pile length. What do you do? Stop For Set Check & Contact PM

Pile Driving Exercise 2

• BPI measured at 20 with required BPI of 13. Pile tip is 2 ft above minimum tip elevation. What do you do? ___________
Pile Driving Exercise 2 Key

• BPI measured at 20 with required BPI of 13. Pile tip is 2 ft above minimum tip elevation. What do you do? **Stop & Contact PM**
<table>
<thead>
<tr>
<th>Station</th>
<th>Boreless</th>
<th>Bored</th>
<th>Diameter</th>
<th>Depth</th>
<th>Length</th>
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<td>Section 7.1 Driven Piles</td>
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<td><strong>Drill Logs</strong></td>
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<td><strong>Soil Samples</strong></td>
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<tr>
<td><strong>Structural Details</strong></td>
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<tr>
<td><strong>Other Information</strong></td>
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<table>
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**Note:** The table contains information related to driven piles, including records, drill logs, soil samples, structural details, and other relevant notes. The specific details are not clearly legible due to the image quality.