Driven Pile Types

PDCA 2015 Professor Driven Pile Institute

Patrick Hannigan
GRL Engineers, Inc.
Common Driven Pile Types

- Steel Pipe
- Timber
- Steel H
- Precast Concrete
- Composite
## Timber Pile Overview

| **TYPICAL LENGTHS:** | 15 to 75 feet – Southern Pile  
15 to 120 feet – Douglas Fir |
|----------------------|-------------------------------|
| **MATERIAL SPECIFICATIONS:** | ASTM D-25  
AWPA-UC4A, 4B, 4C, 5B, and 5C |
| **ASD:** | Typical Design Stress: 0.8 to 1.2 ksi (based on pile toe area)  
Design Load: 20 to 100 kips (10 to 50 tons)  
Driving Stress: 3 x Design Stress (3 ksi +/-) |
| **LRFD:** | Factored Load: 50 to 120 kips (25 to 60 tons)  
Driving Stress: $1.15 \times F_{co}$ (1.4 ksi +/-) |
| **ADVANTAGES:** | Comparatively low initial cost.  
Easy to handle.  
Permanently submerged piles resistant to decay. |
| **DISADVANTAGES:** | Difficult to splice.  
Vulnerable to damage in hard driving at pile head and pile toe.  
Vulnerable to decay if untreated and intermittently submerged. |
| **REMARKS:** | Best suited for friction pile in granular soil. |
Timber Piles
Timber Piles
Timber Pile - Toe Protection
Timber Pile - Banding
# H-Pile Overview

<table>
<thead>
<tr>
<th><strong>TYPICAL LENGTHS:</strong></th>
<th>15 to 200 feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MATERIAL SPECIFICATIONS:</strong></td>
<td>ASTM A-572, A-588, or A-690 (F&lt;sub&gt;y&lt;/sub&gt; = 50, 60 ksi) (A-572 Grade 50 is standard)</td>
</tr>
<tr>
<td><strong>ASD:</strong></td>
<td>Typical Design Stress: ( \sigma_a ): 0.25 to 0.33 ( F_Y ) (12.5 to 16.5 ksi) Design Load: ( \sigma_a A_s ): 132 to 993 kips (HP 8x36 to HP 18x204) Driving Stress: 0.90 ( F_Y ) (45.0 ksi)</td>
</tr>
<tr>
<td><strong>LRFD:</strong></td>
<td>Factored Load: 310 to 1800 kips Driving Stress: ( \phi_{da} F_Y = 0.90 F_Y ) (45.0 ksi)</td>
</tr>
<tr>
<td><strong>ADVANTAGES:</strong></td>
<td>Available in various sizes, sections and lengths. Easy to splice. High capacities possible. Low soil displacements. Pile toe protection may assist in penetrating harder layers or some small obstructions.</td>
</tr>
<tr>
<td><strong>DISADVANTAGES:</strong></td>
<td>Vulnerable to corrosion where exposed. HP sections can be damaged or deflected by major obstructions.</td>
</tr>
<tr>
<td><strong>REMARKS:</strong></td>
<td>Best suited for toe bearing on rock. HP sections tend to “run” in granular deposits.</td>
</tr>
</tbody>
</table>
H-Piles
New Larger H-Pile Sections

HP 18 x 204, $A_s = 60.0 \text{ in}^2$
H-Pile - Toe Protection
H-Pile - Splices

Full Penetration Groove Weld

H-pile Splicer
H-Pile - Splices

1. Cut notch ¼” x 2½”
   Scarf flanges

2. Slip Splicer on, weld 2½ in. each edge.

Stand on driven pile. Weld opposite edges. Weld across flanges.
# Pipe Pile Overview

<table>
<thead>
<tr>
<th>TYPICAL LENGTHS:</th>
<th>15 to 200 feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATTERIAL SPECIFICATIONS:</td>
<td>ASTM A-252, Grade 2 or 3 ($F_Y = 35, 45$ ksi), API 5L ($F_Y = 42$ to $80$ ksi)</td>
</tr>
<tr>
<td></td>
<td>ACI 318 – for concrete (if filled)</td>
</tr>
<tr>
<td></td>
<td>ASTM A-572 – for core (if used)</td>
</tr>
<tr>
<td>ASD:</td>
<td>Design Stress: $\sigma_a = 0.25$ to $0.33 \ F_Y$ (on steel) + $0.40 \ f'_c$ (on concrete)</td>
</tr>
<tr>
<td></td>
<td>Design Load: 100 to 3,400 kips</td>
</tr>
<tr>
<td></td>
<td>Driving Stress: $0.90 \ F_Y$ (31.5 to 40.5 ksi) or (37.8 to 72.0 ksi)</td>
</tr>
<tr>
<td>LRFD:</td>
<td>Factored Load: 100 to 1250 kips (closed end) with concrete fill</td>
</tr>
<tr>
<td></td>
<td>365 to 4,000 kips (open end) without concrete fill</td>
</tr>
<tr>
<td></td>
<td>Driving Stress: $\phi_{da} \ F_Y = 0.90 \ F_Y$ (31.5 to 72.0 ksi)</td>
</tr>
<tr>
<td>ADVANTAGES:</td>
<td>Available in various lengths, diameters, wall thicknesses and strengths.</td>
</tr>
<tr>
<td></td>
<td>High capacities possible.</td>
</tr>
<tr>
<td></td>
<td>Easy to splice.</td>
</tr>
<tr>
<td></td>
<td>Closed end can be internally inspected after driving.</td>
</tr>
<tr>
<td></td>
<td>Open end pipe can be cleaned out and driven deeper.</td>
</tr>
<tr>
<td></td>
<td>Open end pipe has low soil displacements.</td>
</tr>
<tr>
<td>DISADVANTAGES:</td>
<td>Vulnerable to corrosion.</td>
</tr>
<tr>
<td></td>
<td>Soil displacement for large, closed end pipe</td>
</tr>
<tr>
<td>REMARKS:</td>
<td>High bending resistance on unsupported length.</td>
</tr>
</tbody>
</table>
Typical Pipe Pile Closure Plate

- Flat Closure Plate
- Fillet Weld
- Flat Closure Plate
Conical Pipe Pile Tip
Outside Cutting Shoe
Inside Cutting Shoe
Large Diameter Open End Pipe
Spin Fin Pile
Pipe Pile - Splicing

Full Penetration Groove Weld
Pipe Pile - Splicing

Friction Splicer
# Monotube Pile Overview

<table>
<thead>
<tr>
<th><strong>TYPICAL LENGTHS:</strong></th>
<th>15 to 100 feet</th>
</tr>
</thead>
</table>
| **MATERIAL SPECIFICATIONS:** | SAE-1010 - for steel \( ( F_Y = 50.0 \text{ ksi} ) \)  
ACI 318 - for concrete |
| **ASD:** | Typical Design Stress: \( \sigma_a = 0.25 F_Y \) (on steel) + 0.40 \( f'c \) (on concrete)  
Design Load: 100 to 300 kips  
Driving Stress: 0.90 \( F_Y \) (45.0 ksi) |
| **LRFD:** | Factored Load: 100 to 450 kips  
Driving Stress: 0.90 \( F_Y \) (45.0 ksi) |
| **ADVANTAGES:** | Can be inspected after driving.  
High capacity for relatively shorter lengths.  
Tapered pile section provides high resistance in granular soils.  
Reduced concrete fill volume in tapered pile section. |
| **DISADVANTAGES:** | Potential soil displacement effects. |
| **REMARKS:** | Best suited for friction pile of medium length. |
Monotube Piles

Pile toe: 8 or 8.5 inch diameter

Initial taper section: 10 to 75 ft long

Wall thicknesses: 0.15 to 0.24 inches (3 to 9 gage)

Uniform extensions with one crimped end
Monotube Splicing

Cut V Notches at 90°

Grind V Notches

Fillet Weld
## Tapertube Pile Overview

<table>
<thead>
<tr>
<th><strong>TYPICAL LENGTHS:</strong></th>
<th>50 to 150 feet</th>
</tr>
</thead>
</table>
| **MATERIAL SPECIFICATIONS:** | ASTM A-252, Grade 3 (F<sub>Y</sub> = 45.0 ksi)  
ACI 318 – for concrete |
| **ASD:** | Typical Design Stress: \( \sigma_a = 0.25 F_Y \) (on steel) + 0.40 \( f_c \) (on concrete)  
Design Load: 200 to 420 kips  
Driving Stress: 0.90 \( F_Y \) (40.5 ksi) |
| **LRFD:** | Factored Load: 200 to 850 kips  
Driving Stress: 0.90 \( F_Y \) (40.5 ksi) |
| **ADVANTAGES:** | Can be internally inspected after driving.  
High capacity for relatively shorter lengths.  
Tapered pile section provides high resistance in granular soils.  
Reduced concrete fill volume in tapered pile section. |
| **DISADVANTAGES:** | Potential soil displacement effects. |
| **REMARKS:** | Best suited for friction pile in granular soils. |
Tapertube Piles

Standard pipe pile extensions

Taper wall thicknesses: 0.25 to 0.438 inches

Taper section: 15 to 30 ft long, flat sided polygon

Pile toe: 8, 10, 12, or 14 inch diameter
# Prestressed Concrete Overview

<table>
<thead>
<tr>
<th>TYPICAL LENGTHS:</th>
<th>30 to 150 feet</th>
</tr>
</thead>
</table>
| MATERIAL SPECIFICATIONS: | ACI 318 – for concrete  
| ASD: |  
Design Stress: 0.33 \(f'c\) – 0.27 \(f_{pe}\) (on gross concrete area)  
Design Load: 90 to 1000 kips  
Driving Stress: 0.85 \(f'c\) – \(f_{pe}\) (in compression)  
\(3 \sqrt{f'c} + f_{pe}\) (in tension, \(f'c\) in psi) |
| LRFD: |  
Factored Load: 350 to 2,200 kips on solid sections.  
1,500 to 3,000 kips on spun cast cylinder piles.  
Driving Stress: 0.85 \(f'c\) – \(f_{pe}\) (in compression)  
\(3 \sqrt{f'c} + f_{pe}\) (in tension, \(f'c\) in psi) |
| ADVANTAGES: | High load capacity.  
Corrosion resistance obtainable.  
Hard driving possible. |
| DISADVANTAGES: | Can have relatively high breakage rate.  
Potential soil displacement effects from large sections.  
Difficult to splice when insufficient length ordered. |
| REMARKS: | Cylinder piles well suited for bending resistance. |
Prestressed Concrete
Prestressed Concrete Details

Typical Sizes

- Square Solid: 10 – 20 inch
- Square Hollow: 20 – 36 inch
- Octagonal Solid or Hollow: 10 – 24 inch
- Void: 11 – 18 inch
Concrete Pile Splices
KIE-LOCK
Mechanical Splice
Epoxy-Dowel Splice
Spun Cast Concrete Cylinder Piles
Spun Cast Concrete Cylinder Piles

Pile Properties
High strength concrete, f’c = 7 ksi, fpe = 1.2 ksi
16 ft long pile segments (typical)
Segments combined and post-tensioned

Typical Sizes
36, 42, 48, 54, & 66 inch O.D.
5 & 6 inch wall

Typical Design Loads
250 to 800 tons
ICP Spun Cast Pile

**Pile Properties**

- High strength concrete
- $f'c = 10$ ksi, $f_{pe} = 1$ ksi
- 20 to 120 ft long segments
- Welded pile splice

**Typical Pile Sizes**

- 9.8 to 47.2 inch O.D.
- 2.2 to 5.9 inch wall

**Typical Design Loads**

- 80 to 1100 tons
ICP Spun Cast Pile

Welded Splice
## Composite Piles - Overview

<table>
<thead>
<tr>
<th>TYPICAL LENGTHS:</th>
<th>50 to 200 feet.</th>
</tr>
</thead>
</table>
| MATERIAL SPECIFICATIONS: | ASTM A-572 for H-pile sections  
                       ASTM A-252 for pipe pile sections  
                       ACI 318 – for concrete  
                       ASTM D25 for timber sections |
| MAXIMUM STRESSES: | Typical Design Stress: Depends on pile materials  
                     Driving Stress: Depends on pile materials |
| TYPICAL DESIGN LOADS: | 30 to 200 tons |
| ADVANTAGES: | May solve unusual design or installation problems.  
             High capacity may be possible depending on pile materials.  
             May reduce foundation costs. |
| DISADVANTAGES: | May be difficult to attain god joint between pile materials. |
| REMARKS: | Weakest pile material controls allowable stresses and capacity. |
Composite Piles

Concrete – H-pile

Pipe – H-pile
Composite Piles

Pipe - Concrete

Corrugated Shell - Timber
Other Pile Selection Considerations

• Site and access considerations.
• Subsurface considerations.
• Pile shape considerations.
• Drivability considerations.
Site Considerations on Pile Selection

Impact of vibrations on nearby structures.

Remote areas may restrict equipment size.

Local availability of pile materials and capabilities of local contractors.

Waterborne operations may dictate use of shorter pile sections.

Steep terrain may make use of certain pile equipment costly or impossible.
# Subsurface Effects on Pile Selection

<table>
<thead>
<tr>
<th>Typical Problem</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulders over Bearing Stratum</td>
<td>Use Heavy Low Displacement Pile With Shoe. Include Contingent Predrilling Item in Contract.</td>
</tr>
<tr>
<td>Loose Cohesionless Soil</td>
<td>Use Tapered Pile to Develop Maximum Shaft Resistance.</td>
</tr>
<tr>
<td>Negative Shaft Resistance</td>
<td>Avoid Batter Piles. Use Smooth Steel Pile to Minimize Drag Load or Use Bitumen Coating or Plastic Wrap. Could Also Use Higher Design Stress.</td>
</tr>
<tr>
<td>Deep Soft Clay</td>
<td>Use Rough Concrete Piles to Increase Adhesion and Rate of Pore Water Dissipation.</td>
</tr>
</tbody>
</table>
## Subsurface Effects on Pile Selection

<table>
<thead>
<tr>
<th>Typical Problem</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Artesian Pressure</strong></td>
<td>Hydrostatic Pressure May Cause Collapse of Mandrel Driven Shell Piles and Thin Wall Pipe. Pile Heave Common on Closed End Pipe.</td>
</tr>
<tr>
<td><strong>Scour</strong></td>
<td>Adequate Pile Capacity Should be Developed Below Scour Depth (Design Load x SF). Tapered Pile Should Be Avoided Unless Taper Extends Below Scour Depth.</td>
</tr>
<tr>
<td><strong>Coarse Gravel Deposits</strong></td>
<td>Use Prestressed Concrete Piles Where Hard Driving is Expected.</td>
</tr>
</tbody>
</table>
# Pile Shape Effects on Pile Selection

<table>
<thead>
<tr>
<th>Shape Characteristic</th>
<th>Pile Types</th>
<th>Placement Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>Closed End Steel Pipe</td>
<td>Increase Lateral Ground Stress.</td>
</tr>
<tr>
<td></td>
<td>Prestressed Concrete</td>
<td>Densify Cohesionless Soils.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temporarily Remolds and Weakens Cohesive Soils.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Setup Time for Large Pile Groups in Sensitive Clays May Be Up To Six Months.</td>
</tr>
</tbody>
</table>
# Pile Shape Effects on Pile Selection

<table>
<thead>
<tr>
<th>Shape Characteristic</th>
<th>Pile Types</th>
<th>Placement Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Displacement</td>
<td>Steel H-pile</td>
<td>Minimal Disturbance to Soil.</td>
</tr>
<tr>
<td></td>
<td>Open End Steel Pipe</td>
<td>Not Recommended for Friction Piles in Coarse Granular Soils. Piles Often Have Low Driving Resistances in These Deposits Making Field Capacity Verification Difficult Resulting in Excessive Pile Lengths Installed.</td>
</tr>
</tbody>
</table>
## Pile Shape Effects on Pile Selection

<table>
<thead>
<tr>
<th>Shape Characteristic</th>
<th>Pile Types</th>
<th>Placement Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapered</td>
<td>Timber</td>
<td>Increased Densification of Soil.</td>
</tr>
<tr>
<td></td>
<td>Monotube</td>
<td>High Capacity for Short Penetration Depth in Granular Soils.</td>
</tr>
<tr>
<td></td>
<td>Tapertube</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thin Wall Shells</td>
<td></td>
</tr>
</tbody>
</table>
Final Pile Selection

• Each type has advantages and disadvantages.

• Several pile types or sections may meet the project design requirements.

• All candidate pile types should be carried forward in the design process.

• Final pile selection should be based on the most economical pile section meeting all the design requirements.
Questions