2008 Geotechnical Consultant Workshop
Design & Construction of Piling

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www.dot.state.oh.us/construction/OCA
Pile driving in Ohio - 1924
Specifications - 1924
Ohio Department of Highways and Public Works

PILING.
Item S-9.

This item shall include furnishing the necessary piles and driving to such depth as may be required to secure adequate bearing power.

Material. The piles shall be in accordance with Section 8.3 of the “Material Details”.

Driving Piles. Piles shall be of sufficient length to allow being driven until the penetration under a 1500-pound hammer, falling freely 20 feet, is not more than one-half inch, or its equivalent, or as much as may be required to support the load which it must bear. The piles in no case shall be driven less than ten (10) feet. The heads of the piles, while driving, shall be protected by iron rings to prevent brooming.

Bearing Power of Piles. The total load which a pile will safely bear shall be determined from the formula \[ P = \frac{2 \times w}{S + 1} \]
in which “P” is the safe load in pounds, “w” is the weight of hammer in pounds, “h” is the height of fall in feet, and “S” is the average depth in inches that the pile sinks under the last six blows.

Cut-off. After being driven, the piles shall be cut off square at the elevation shown on the plans.

Basis of Payment. When the contract provides for payment per lineal foot of pile, the amount to be paid for is understood to be the actual number of lineal feet of piling left in place.
Today

Dynamic load testing on every project.

Static pile capacity analysis during design to determine a practical capacity and estimate the length.
Driven
A Program for Determining Ultimate Vertical Static Pile Capacity
Driven User’s Manual

www.fhwa.dot.gov/engineering/geotech/software/softwaradetail.cfm#driven

Driven 1.2 corrects a metric conversion error found only in Driven 1.1 when evaluating metric H-Piles.

Driven 1.1 corrects an SPT 'N' value problem with Driven 1.0. In Driven 1.0, SPT 'N' values at depths 100 ft and greater were not read back into the program when the file was reopened. When the user reopened the input file these N-values were shown as zeros. Driven 1.1 correctly reads the N values.

Driven 1.0 is an upgrade the existing FHWA computer program, "SPILE version 2.0", from a basic analysis tool to an efficient and easy to use design tool. The upgrade will be a design tool that will increase engineering productivity while enhancing design quality. The upgrade, Driven, will be a Microsoft Windows environment PC program that will take full advantage of the multi-tasking and utility features of the Microsoft Windows environment. The new program will also have the ability to create an input file for the GRLWEAP driveability analysis.

Download Driven User's Manual (pdf - 1.5 mb)

Driven 1.2 installation (32 bit) software (2.2 Mb): I agree to the downloading conditions above.
Friction Angle Limit

Limit on Friction Angle ($\phi$) applies only to skin friction in gravel deposits.

See Design and Construction of Driven Pile Foundations, Section 9.5
FHWA NHI-05-042 or FHWA HI-97-013
Designing for scour

Project Definition

Client Information
- Client: 
- Project Name: HOC-CR33A-0110 Pier 1
- Project Manager: 
- Date: 02/26/2007
- Computed By: P Narsavage

Soil Layers
- # Soil Layers: 3

Water Tables
- Depth at top of boring: 0.0
- Depth at Time of Drilling: 10.000 ft
- Depth for Restrike/Driving: 10.000 ft
- Depth for Ultimate: 0.000 ft

Optional Design Considerations
- Soft Compressible Soils Overlying the Bearing Strata
- Scourable Soil Overlying the Bearing Strata

Scourable Soils
- Specify depth options to begin considering Scour effects
- When computing Ultimate Static Pile Capacity

- Local Scour - Pier, Abutment: 10.000 ft
  (no reduction in vertical effective stress)
- Channel Degradation Scour and Contraction Scour: 0.000 ft
  (reduction in vertical effective stress)

OK Cancel Help
Designing for scour

Resistance due to scour is difference between driving bearing capacity and ultimate bearing capacity.
Scour

Allowable Stress Design

UBV = 220 kips, 47 ft

After scour, capacity is 183 kips for L=47 ft. (Use 50 ft on plans)

Design capacity = 183/2.0 = 91.5 kips

Do not add the loss of capacity due to scour to the max. UBV.

37 + 220 = 257 kips

This will cause drivability problems.
**Scour**

**LRFD**

(Remember UBV = R_{ndr})

\[
R_{ndr} = \sum \frac{\eta \gamma Q}{\phi_{dyn}} + R_{Ssc}
\]

\[
220 = \frac{\sum \eta \gamma Q}{0.7} + 37
\]

\[
\sum \eta \gamma Q = 128 \text{kips}
\]
Driving Strength Loss
is not typically used for ODOT projects.

Using a driving strength loss for a soil will reduce the calculated capacity during driving.

It is difficult to estimate and of little value unless you plan on utilizing pile setup to provide the required capacity.
Pile Setup

If you do need to utilize pile setup to provide the required capacity (such as in loose fine sand or soft clay) then the project engineer needs to know ...

1. How far to drive the pile.
2. How long to wait before performing the restrike.
Perimeter & tip area

Pile Perimeter

H-Pile
Box

Tip Area

H-pile
Box

Caused by pile plugging

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Perimeter & tip area

4 possible combinations
1. H-pile perimeter & box tip area
2. H-pile perimeter & H-pile tip area
3. Box perimeter & box tip area
4. Box perimeter & H-pile tip area

Case 1 will result in the shortest estimated pile length; Case 4 the longest. But both of these cases are generally unrealistic.

Case 2 or 3 may be longer than the other depending on the soil properties.
H-piles & LRFD

H-piles to rock
Maximum factored structural resistance, $R_{R_{\text{max}}}$
Total factored load given in the plans
- HP 10 x 42 310 kips
- HP 12 x 53 380 kips
- HP 14 x 73 530 kips

Friction H-piles
Nominal driving resistance, $R_{\text{ndr}}$
Same as Ultimate Bearing Value given in the plans
- HP 10 x 42 350 kips
- HP 12 x 53 380 kips
- HP 14 x 73 440 kips

Why the difference?
Based on structural capacity of the pile.
Guideline based on generalized drivability analyses. Greater UBV may be used, but consult the Office of Structural Engineering.
Pile Points
Piles without points

H-piles driven to refusal in hard limestone
Piles without points

H-piles driven to refusal in soft shale
Do not use pile points when driving piles to bear on shale.
Pile Points

Some pile points are slightly larger than the H-pile cross-section. This reduces side resistance on the H-pile.

Therefore, do not use pile points on friction H-piles. It will cause the pile to “run” and result in additional project cost.
Effect of Pile Overruns

Change orders over $100,000 or 5% of the total project cost must be approved by the Director.

Consider a bridge with 136 piles. They are 16-inch pipe piles with an estimated length of 50 feet. During construction they actually drive to 60 feet to obtain the Ultimate Bearing Value.
Effect of Pile Overruns

Additional quantities for 16" CIP pile

Driven \(10' \times 136\) piles = 1360'

Furnished \(5' \times 136\) piles = 680'

Additional cost

Driven \(18 \times 1360'\) = $24,480

Furnished \(45 \times 680'\) = $30,600

Splices \(350 \times 136\) = $47,600

Total \(102,680\)
Using Pile Setup

Four 3-span bridges over a creek.

Borings encountered saturated loose to medium dense silt, sand, and gravel A-1-b, A-3b, A-4a, and some A-4b. Borings were 100 to 130 feet deep; they did not encounter 30 ft of 30 blow.
Using Pile Setup

16” pipe piles, estimated length 80 to 85 ft
UBV = 328 to 340 kips
Drove initial pier piles 120 to 130 feet.
EOID capacity was only 200 to 240 kips.

After some experimentation with restrikes, we ended up driving the piles 88 ft and waiting 6 to 21 days before performing restrike tests. Capacity was 350+ kips.
Difficult Driving

Multiple span bridge over river.
Piers 2, 3, 4, & 5 are supported by 40 piles each.
Piles are 14-inch pipe piles; UBV = 340 kips
Piles at piers 2 and 4 drove with no problem.
(Pier 5 hasn’t been built yet)
However at Pier 3, 12 of the piles were damaged while attempting to drive to the minimum pile tip elevation.
Difficult Driving

The measured length inside the pile did not agree with the length of driven pile, e.g. Pile 110 was driven 29.0 ft into the ground, but was only 25.3 ft long when measured inside the pile after driving. Pile tips were probably crushed.

Dynamic load test on each pile to verify capacity, and designer verified that slightly shorter piles would still support pier after scour.

Drove two replacement piles; one for a pile that did not have capacity and one for leaking pile.