# ILLINOIS DEPARTMENT OF TRANSPORTATION

## SPECIFIC TASK TRAINING PROGRAM

# PILE FOUNDATION CONSTRUCTION INSPECTION

## S 19

## CLASS REFERENCE GUIDE

Reference Guide Available online at:
http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Bridges/Geotechnical/Pile%20Foundation%20Construction%20Inspection.pdf

## BY: Central Bureau of Construction


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# 1 Introduction

## 1.1 Summary

This course is a summary of the requirements for installation and inspection of foundation piling based upon the requirements found in:

- Standard and Supplemental Specifications
- Plans
- Construction Manual

The Construction Manual is not part of the construction documents but rather is a manual prepared by the Department containing policies to support approval and acceptance of pile constructed foundations. An electronic copy of the Construction Manual may be accessed at: http://www.idot.illinois.gov/doing-business/procurements/construction-services/contractors-resources/index.

Piles are structural elements that are typically driven into the ground to transfer structure loads to soil or rock usually because shallow layers of soil are too weak to support the required loads using a spread or mat type footing. Piles typically develop their load carrying capacity from the frictional resistance of the soil acting along the sides of the piles and the end bearing resistance of soil or rock acting at the tip of the pile.

The role of field personnel, hereafter referred to as "Inspector, is to observe and report on the construction activities at the site and ensure that the work is completed in accordance with the construction documents. The responsibilities of the Inspector include:

- Having a thorough knowledge of the plans and specifications.
- Inspecting and recording activity relative to the plans and specifications.
- Correcting or stopping work that is not being performed in compliance with the plans and specifications.
- Seeking assistance as needed to interpret the plans and specifications.

A Construction Inspector's Checklist for Piling has been prepared to provide the Inspector with a step-by-step list of requirements for the installation and inspection of the foundation piling. A copy of the checklist is included in the Appendix or may be accessed at: http://www.idot.illinois.gov/doing-business/procurements/construction-services/contractors-resources/index.

## 1.2 Course Objectives

Following completion of this course, students should be able to do the following:

- Inspect piling for overall conformance with the plans and specifications.
- Inspect test piling installations.
- Inspect pile driving operations to ensure attainment of Nominal Required Bearing.
- Inspect pile splicing operations.
- Properly record field data for documentation of the following pay items:
    - Furnishing Piling
    - Driving Piling
    - Test Piles
    - Pile Shoes
- Properly record field data for documentation of extra work (unplanned pile splices, etc.).

# 2 Pile Types & Uses

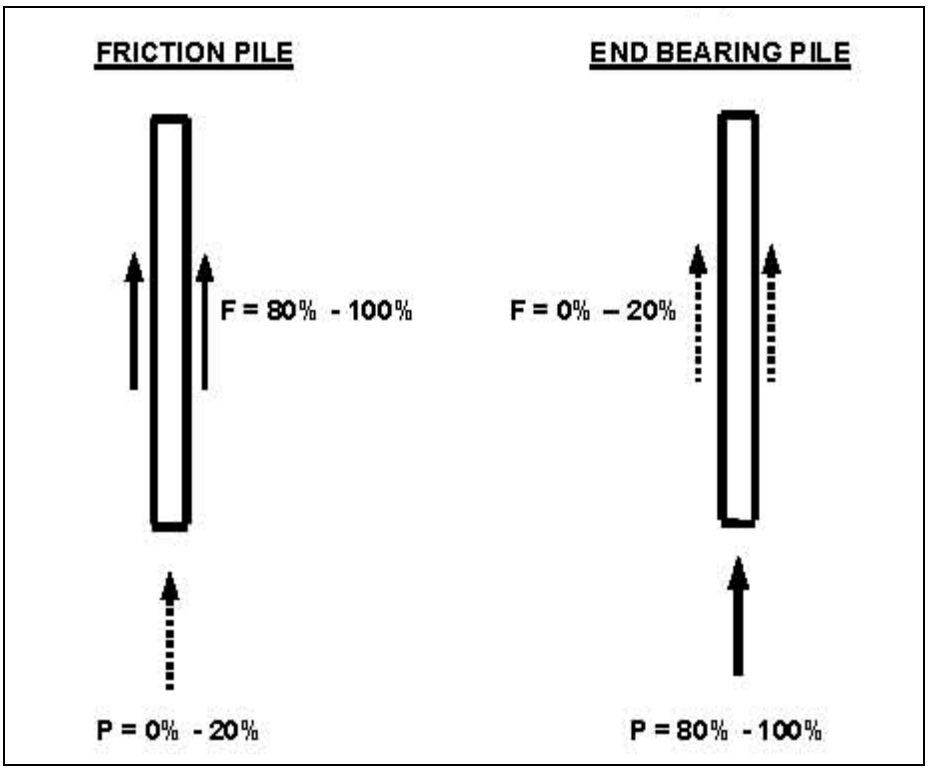
Design engineers classify piles according to their Structural Pile Type to reference the structural element to be used for the piles and according to their Geotechnical Pile Type to define a pile's primary mechanism for developing the required bearing. IDOT uses piles to provide foundation support for a wide range of structure types.

## 2.1 Geotechnical Pile Types

Geotechnical pile types consist of friction piles and end bearing piles.

Friction piles derive their bearing capacity primarily from skin friction between the sides of the pile and the adjacent soil. Such piles are often referred to as displacement piles as they tend to displace soil to the sides of the pile during driving thereby consolidating the soil around the pile and increasing the skin friction.

End bearing piles derive their bearing primarily from soil or rock below the tip of the pile.




**Geotechnical Pile Type Illustration**

## 2.2 Structural Pile Types

H-Piles: Friction or End Bearing Piles

Metal Shell Piles: Friction Piles

Concrete Piles: Friction Piles

Timber Piles: Friction Piles

Concrete piles may be conventional precast or precast, prestressed members.

Occasionally plans may require that the tip of piles be fitted with pile shoes prior to driving. Pile shoes are considered reinforcement for the pile tip and are intended to try and prevent damage to the pile during driving. The need for pile shoes is assessed during design and indicated on the plans when dense soil layers or “hard driving” conditions are anticipated or when H-piles are being driven to hard rock such as dolomite or sandstone. If required, pile shoe details for H-piles and metal shell piles will be indicated in the plans.

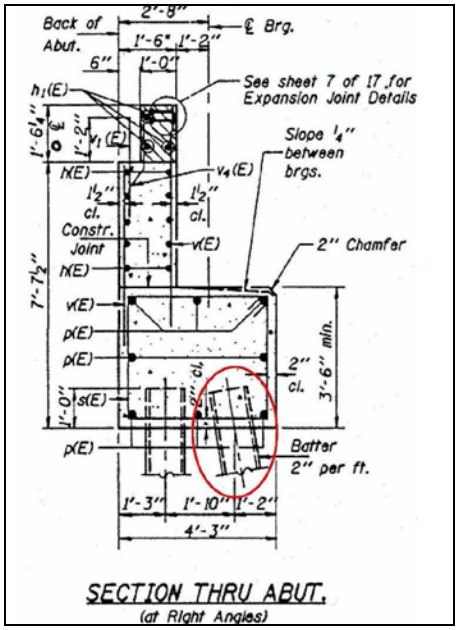
## 2.3 Pile Uses

As previously mentioned, piles are typically specified for a project when the soil conditions are not sufficient to support a spread footing within a reasonably shallow depth. Common uses for piles in Illinois are for stub (pile bent), closed, and integral abutments as well as pile bent piers and pile supported footing piers. In addition, piles are also used for soldier pile retaining walls and to support the footings of T-type retaining walls.

Battered piles (piles driven into the ground at an incline) may be utilized with some foundations to resist lateral forces applied to the structure. Substructure units that may utilize battered piles are discussed below.

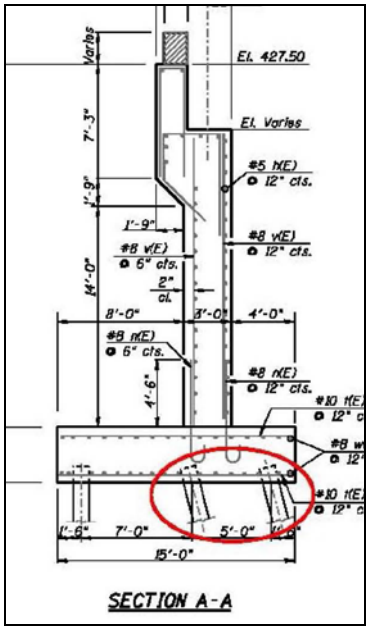
Stub Abutments (Pile Bent Abutments):

- Rather short in height
- Front row of piles are battered
- Allows superstructure movement



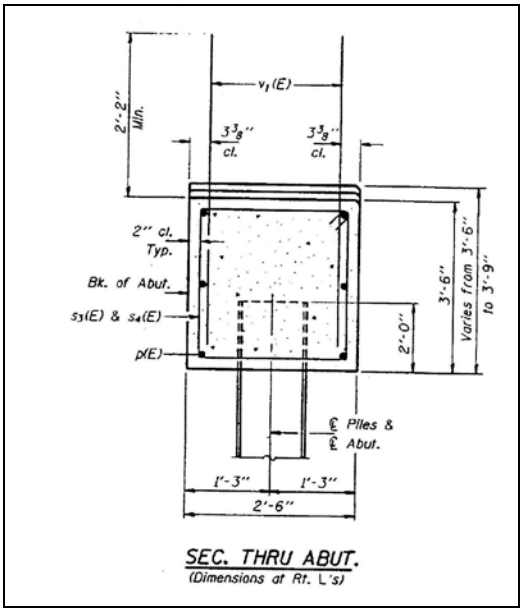

Closed Abutments:

- Rather tall in height
- Combination retaining wall/abutment
- Concrete stem on pile supported footing
- Front row of piles battered at a minimum
- Allows superstructure movement



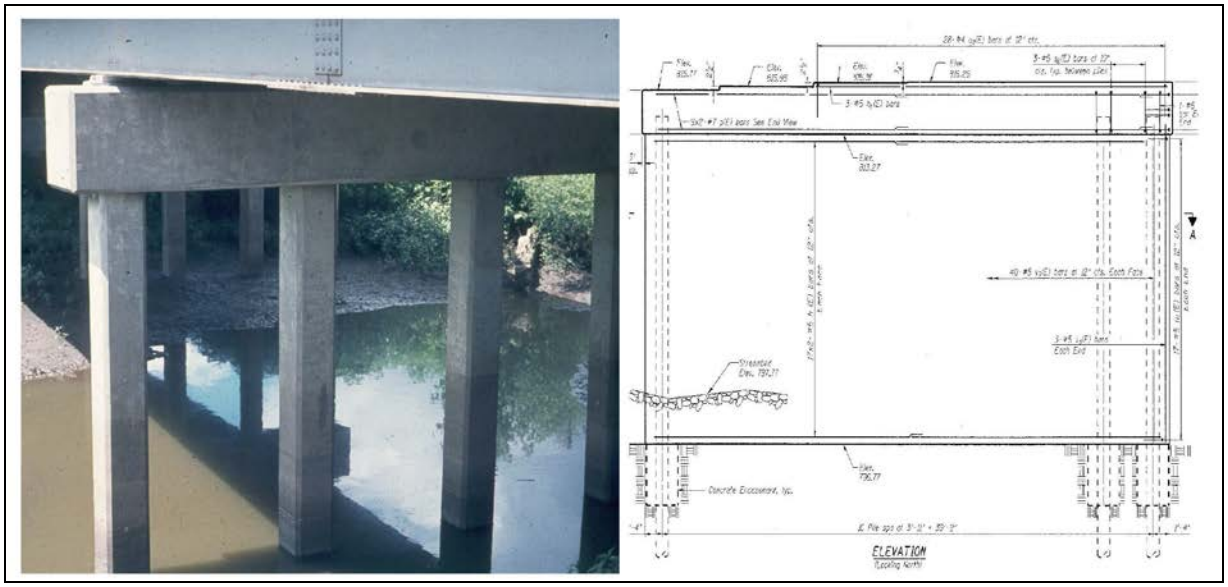

Integral Abutments:

- Also short in height
- Single row of vertical piles
- Has a rigid connection with superstructure
- Piles flex with superstructure movement



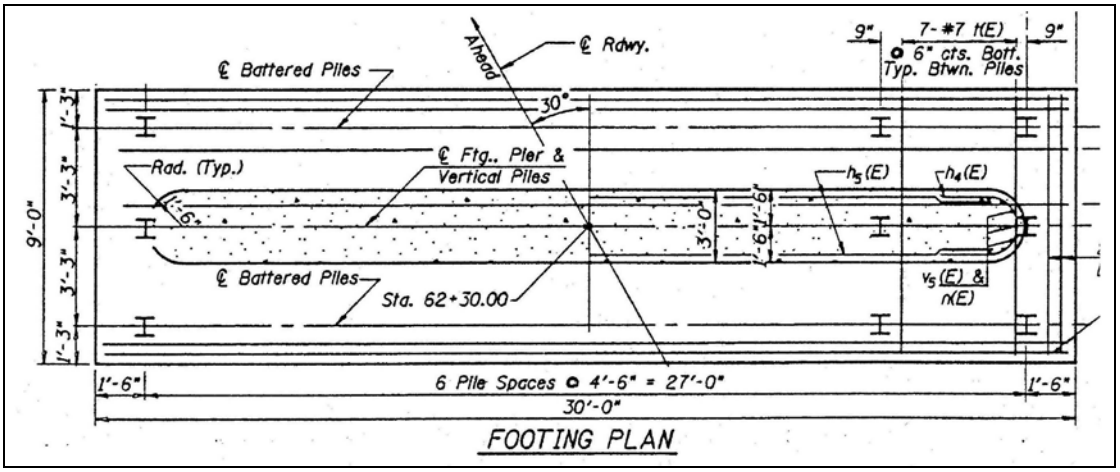
Pile Bent Piers:

- Single row of vertical piles
- Individual piles connected to a pier cap (below L), or
- Individual piles within a solid wall encasement (Below R)



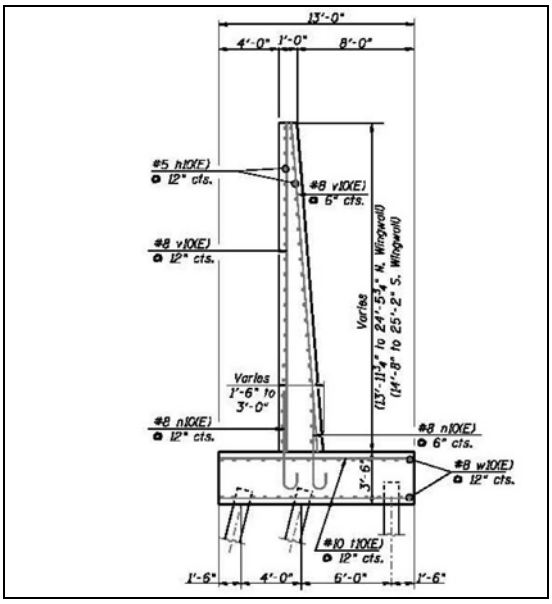

Pile Supported Footing Piers:

- Footing at base of pier stem with multiple rows of piles
- Battered and vertical rows of piles may be present



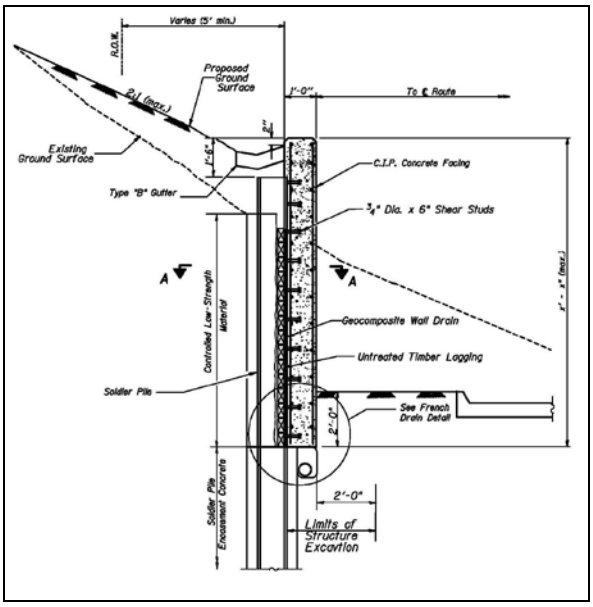
T-type Retaining Walls:

- Concrete stems on pile supported footings
- Front row of piles battered at a minimum
- Similar to a closed abutment




Soldier Pile Retaining Walls:

- Single row of vertical piles driven to a predetermined elevation.




# 3 Safety

Pile driving can be a dangerous operation and Inspectors are urged to use caution at all times to remain safe and avoid injuries. Following are a few items to be considered while piling is being driven on a project:

- Watch for falling objects and take the necessary precautions to ensure that items are secured against wind and accidental displacement.
- Prior to being driven into the ground, piles can be long, slender, flexible members that are difficult to handle and subject to buckling.
- Ensure that all rigging used for handling and driving piling is of sufficient capacity and suitable condition for the intended use. Do not use rigging that is worn & frayed.
- Use caution around the leads and hammer. Do not climb on or lean though leads that are not properly secured, without proper fall protection, and unless hammer is secured in the leads.

# 4 Plans & Specifications Review

Per Article 101.09 of the Standard Specifications, the contract between the Contractor and the Department sets forth the obligations for the performance of the work, the furnishing of labor and materials, and the basis of payment. The contract includes the Standard Specifications, Supplemental Specifications, Special Provisions, and the plans among other items. As such, it is essential that the Inspector is thoroughly familiar with and understands the material contained in these documents.

As indicated in the hierarchy of the contract documents from Article 105.05 of the Standard Specifications and as shown below, the Special Provisions and plans override information contained in the Standard Specifications and Recurring Special Provisions. The Special Provisions and plans should therefore be prudently reviewed prior to starting work on an item to see if any changes have been made to the Standard Specifications and Recurring Special Provisions.

| Hierarchy of the Contract Documents | | |
|---|---|---|
| Special Provisions | Hold over: | Plans, Recurring Special Provisions, Supplemental Specifications, and Standard Specifications |
| Plans [1/, 2/, 3/] | Hold over: | Recurring Special Provisions, Supplemental Specifications, and Standard Specifications |
| Recurring Special Provisions | Hold over: | Supplemental Specifications, and Standard Specifications |
| Supplemental Specifications | Hold over: | Standard Specifications |

1/ Detail plans hold over Highway Standards.

2/ Calculated dimensions hold over scaled dimensions.

3/ The Highway Standards indicated by the revision number listed in the Index of Highway Standards on the plans shall hold over Highway Standards listed anywhere else.

**Hierarchy of Contract Documents**

The 2016 StandardSpecifications for Road and Bridge Construction contains several revisions from the 2012 Standard Specifications and 2015 Supplemental Specifications.

Special Provisions may be written that are unique and applicable to only a specific project. However, if piling specification changes are made the changes are typically made via a Guide Bridge Special Provision (GBSP). GBSP's are standard special provisions developed by the Bureau of Bridges and Structures for items of work commonly associated with the design and construction of structures. GBSP's may be downloaded at: http://www.idot.illinois.gov/doing-business/procurements/engineering-architectural-professional-services/Consultants-Resources/guide-bridge-special-provisions. (Note a GBSP is only applicable to a contract, if it is actually included in the contract.) Current GBSP's pertaining to pile foundation issues include GBSP 56 – Piles Set in Rock, and GBSP – 85 Micropiles.

Prior to the start of construction, it is recommended that Inspectors check the plan elevations of the bottom of footings, intermediate substructure components, and bearing seat elevations of abutments and piers to ensure they correspond to the appropriate top of deck elevations and dimensions shown

on the superstructure plans. This simple check is intended to identify any potential problems prior to starting work on an item.

Inspectors should also review the General Notes and substructure sheets included with the structure plans for pertinent pile information. The General Notes section is a list of notes typically provided within the first few sheets of the structure plans that supplement the Standard Specifications. These notes and the notes on the substructure sheets may contain requirements regarding such items as wave equation analysis, precoring, hammer energy restrictions, or a required waiting period before piles can be driven. Provided below is a list of general notes commonly provided in the structure plans:

- Piles shall be driven through _____ diameter precored holes extending to elevation _____ according to Article 512.09(c) of the Standard Specifications. Cost included in driving piles.
- Pile shall not be driven at ___ until ___ days after the embankment construction is completed.

The general note that effects a waiting period between when the embankment is constructed and when the piling may be driven is to allow anticipated settlement to occur. (The note will typically be accompanied by a Special Provision.) In lieu of the waiting period, the pre-coring note mentioned above may be provided on the plans to alleviate settlement effects on the piles. Only one of these two notes should typically be shown on the plans.

In addition, the substructure sheets should contain a Pile Data table that reflects the type and size of the pile, nominal required bearing, estimated pile length, and number of production piles along with any test pile requirements.

The Department also has standard base sheets developed for H-piles, metal shells, and concrete piles. These base sheets should be included in the structure plans as applicable as they contain pertinent information relative to the pile type. A copy of these base sheets is provided in the Appendix for reference.

Inspectors should also review the appropriate sections of the Construction Manual, Documentation Guide, and Project Procedures Guide and Forms for pertinent information regarding the construction of pile foundations.

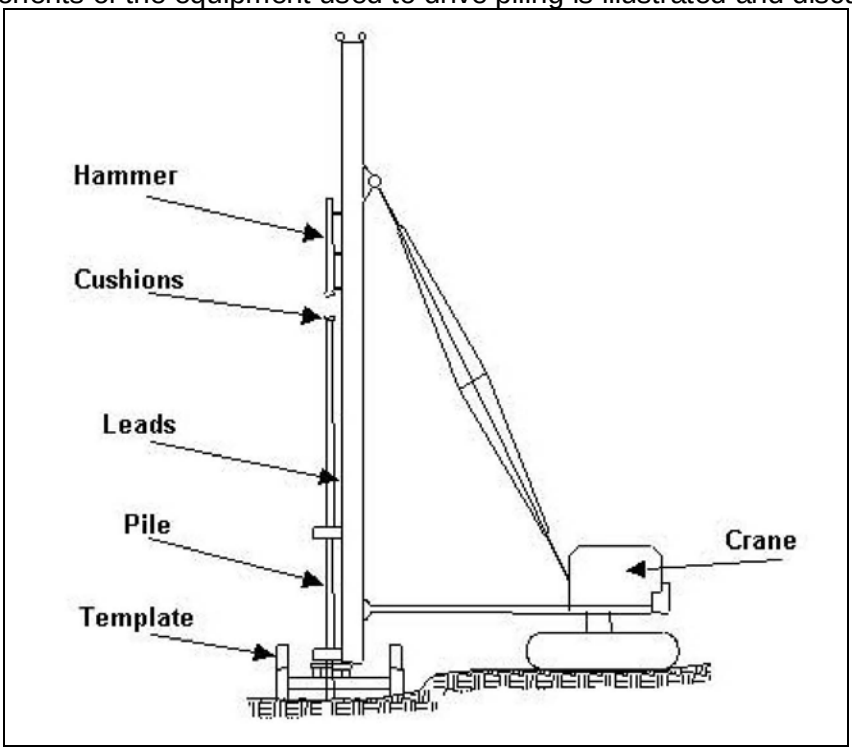
Inspectors are also encouraged to obtain and review a copy of the Structure Geotechnical Report (SGR) from the District. The SGR is prepared during the planning phase of a project with the purpose of identifying and communicating geotechnical considerations and foundation design recommendations, such as pile types and estimated lengths, to the structural engineer who in turn incorporates these items into the design and construction documents. While the SGR is not part of the contract documents, it may provide Inspectors with useful information to assist in their role in observing and documenting the piling installation.

# 5 Construction / Piling Layout

On bridge construction and reconstruction projects, check the proposed or existing span lengths and the existing or proposed vertical and horizontal clearances prior to starting to work. Recurring special provisions may make the construction layout the responsibility of the Contractor. When surveying the various control points for a structure (baselines, bearing lines, back of abutments, etc.) have someone perform an independent check of your calculations and layout prior to the Contractor starting work.

# 6 Pile Driving Equipment

The various components of the equipment used to drive piling is illustrated and discussed below.




**Example Pile Driving Equipment**

## 6.1 Leads

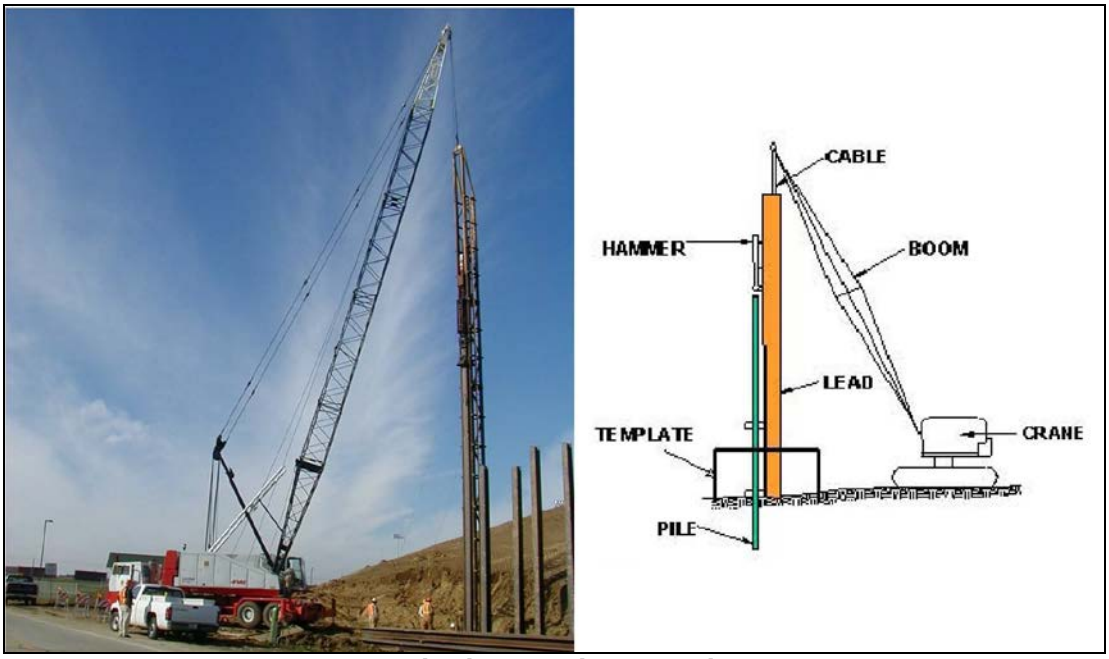
Leads are generally a box shaped frame used to align the pile and hammer during driving and must be long enough to accommodate the length of the pile segments, the hammer, and other equipment as required for the project. Types of leads include swinging, fixed, or semi-fixed leads depending upon the connection between the leads and the crane. Swinging leads tend to be the most popular and are generally suspended from the crane boom by a cable and are required by the Standard Specifications to be toed into the ground to assist with alignment of the pile during driving. An example of swinging leads is shown on the following page.

## 6.2 Hammers

Hammers are used to advance the piling into the ground to the nominal required bearing indicated in the plans. Provided below is a description of the most common types of hammers:

- Drop Hammer:
    - Drop hammers are gravity type hammers where a weight is lifted and simply released.
    - Drop hammers are not allowed to be used with precast concrete piles or piles with nominal required bearing greater than 120 kips.
    - The ram weight must be greater than or equal to the combined weight of the pile and drive cap and weigh at least one ton.
    - The fall height of the ram shall not exceed 15 ft.

- Diesel Hammers (Single Acting):
  - Commonly referred to as an “open end” diesel hammer as the top of the hammer is open allowing observation of the ram going up and down.




**Swinging Leads Example**

  - Explosion of diesel fuel thrusts the ram upward followed by the ram falling and striking the pile.
  - Energy delivered by the hammer varies with the fall height or stroke of the ram.
  - Since the fall height varies, blow counts must be calculated for the various fall heights of the ram.

- Diesel Hammers (Double Acting):
  - Commonly referred to as a “closed end” diesel hammer as the top of the hammer is enclosed with a bounce chamber to throw the ram back down.
  - Explosion of diesel fuel thrusts the ram upwards similar to a single acting diesel hammer.
  - The energy delivered by the hammer is a function of the fall height of the ram and the added pressure from the bounce chamber at the top of the hammer.
  - A gauge is required to determine the bounce chamber pressure at the top of the hammer and a manufacturer’s chart to correlate the pressure reading with the energy being delivered by the hammer.

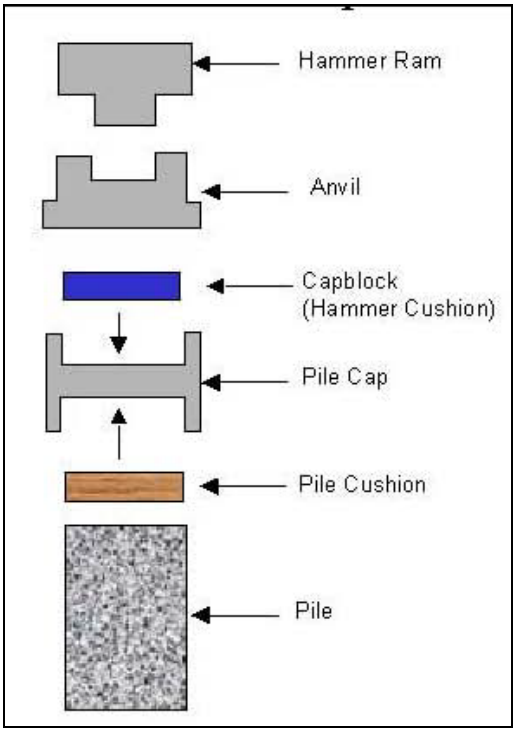
- Air/Steam Hammers:
  - These hammers may be single or double acting as previously described for diesel hammers.
  - They are fueled by compressed air or steam provided from an air compressor or steam boiler.
  - The striking parts of the hammer must have a total weight not less than 1/3 the weight of the pile and drive cap nor weigh less than 1.4 tons.

- Hydraulic Hammers:
  - Fueled by a hydraulic unit with the hammer energy correlated through pressure readings.
    - A wave equation analysis is required to aid in determining the adequacy of the hammer and to indicate the nominal driven bearing of the pile.

- Vibratory Hammers:
  - Operate by vibrating the pile into the ground and are more commonly used for sheet piling installation.
  - Piles are required to be driven with an impact type hammer when nearing the end of the installed length to verify the driven bearing.

## 6.3 Hammer Components

The figure below illustrates the various hammer components that are typically used at the top of the pile.




**Hammer Components Illustration**

A drive head, also referred to as a helmet or cap, is provided to protect the top of the pile and assist in holding the pile inline with the hammer. The Standard Specifications require that the drive cap be made from cast or structural steel and that it also serve as a pilot for metal shell piles uniformly distributing the hammer energy across the metal shell cross section.
Cushions are sometimes used above and below the drive head to protect the hammer and the pile and dampen the intensity of the hammer blow. Cushions used above the drive head are referred to as hammer cushions while cushions used below the drive head are referred to as pile cushions. Timber and concrete piles are required by the Standard Specifications to be protected with a pile cushion.

Hammer cushions may be made from a variety of materials including wire rope, polymer, Micarta, Hamortex, aluminum, or steel. Pile cushions have traditionally been made from plywood. Cushions wear and require replacement periodically throughout the pile driving process. Pile cushions should be replaced when the reduction in thickness is greater than 40% or they begin to burn. Hammer cushions should be replaced after each 50 hours of operation, when there is a reduction in thickness in excess of 25% or the manufacturer's limitations.

### 6.4 Pile Followers

Pile followers are an extension of the piles being driven to allow the piles to be driven from a higher elevation and are only allowed to be used with the Engineer's permission. Although the followers are required to bear evenly on the pile being installed into the ground, uncertainty exists regarding the amount of energy that is transferred across the joint between the follower and the production pile. As such, 1 in every 10 piles is required to be driven without a follower to determine the driven bearing of the piles. Piles being driven without a follower may be required to be longer.

### 6.5 Jets

Jets refer to nozzles placed near the base of the pile that use pressurized fluid (air or water) to erode or temporarily loosen the bond between the pile and soil as it is being advanced. The Engineer's permission is required to use jets and the piles are required to be driven with an impact type hammer when nearing the end of the installed length to verify the driven bearing.

# 7 Hammer Energy Requirements

The hammer selected for use on a project shall be capable of operating within the energy requirements set forth in the specifications. A minimum hammer energy is specified to ensure that the pile installation progresses at a reasonably quick, uniform rate. A maximum hammer energy is also specified to potentially prevent overstressing or damage to the pile during driving. These permissible energy ranges also reflect the calibration used in development of the dynamic formulas used to determine the nominal driven bearing.

The Contractor shall provide the Engineer with specifications for their selected hammer. This information is needed by the Engineer for determination of the energy developed by the hammer during pile driving.

### 7.1 Determining Allowable Hammer Energy Range

The first step in determining the allowable hammer energy range is to determine the type of hammer that will be used by the Contractor (drop, single acting diesel, etc.). The properties of the hammer, such as ram weight and stroke range for single acting hammers or bounce chamber pressure diagram for double acting hammers, must be identified by the Contractor and provided to the Engineer.

Inspectors shall calculate the permissible energy range for the hammer type chosen by the Contractor and the nominal required bearing of the pile indicated in the plans using the formulas provided in Standard Specification Article 512.10. (Hammers are required by the specifications to be operated at an energy that facilitates a pile penetration rate ($N_b$) between 1 and 10 blows per inch as nominal driven bearing ($R_{NDB)}$ approaches the nominal required bearing ($R_{N)}$ for the Washington State Department of Transportation (WSDOT) formula. The permissible energy range for the hammer is based upon this $N_b$ range.)

The WSDOT formula, as shown in Standard Specification Article 512.14, is the dynamic pile driving formula currently utilized by IDOT to determine the nominal driven bearing ($R_{NDB}$), based upon the energy of the hammer and driving data recorded in the field. Selection of the WSDOT formula for implementation in Illinois was based upon studies conducted by the U of I with considerations given to the soils, piles, and driving equipment that are common to Illinois.

Following are the variables used to investigate the permissible energy range:

$R_N$ = Nominal Required Bearing, kips (kN)
E = Hammer Energy, ft-lbs (Joules)
H = Height of Stroke, ft (mm)
W = Ram Weight, lbs (kN)
$N_b$ = Number of Hammer Blows for Penetration, blows/inch (blows/25mm)
$F_{eff}$ = Hammer Efficiency Factor (WSDOT formula only)

The hammer's ability to drive the pile is based upon it's energy (E), where:

E = Hammer Energy as mentioned above, or
= Ram Weight (W) x Height of Stroke (H), for drop and single acting hammers
= Manufacturer's listed value, for double acting hammers

Per Standard Specification Article 512.10

- Minimum Energy, $N_b = 10$

  $E \geq 32.90 \times R_N \div F_{eff}$ (English)
  $E \geq 10.00 \times R_N \div F_{eff}$ (Metric)

- Maximum Energy, $N_b = 1$

  $E \leq 65.80 \times R_N \div F_{eff}$ (English)
  $E \leq 20.00 \times R_N \div F_{eff}$ (Metric)

Where:

$F_{eff}$ = 0.55 for air/steam hammers
= 0.47 for open-ended diesel hammers and steel piles or metal shells
= 0.37 for open-ended diesel hammers and for concrete or timber piles
= 0.35 for closed-ended diesel hammers
= 0.28 for drop hammers

## 7.2 Determining Required Number of Hammer Blows

As previously mentioned, the WSDOT formula, as shown in Standard Specification Article 512.14, is the dynamic pile driving formula currently utilized by IDOT to determine the nominal driven bearing ($R_{NDB}$). The number of required hammer blows, $N_b$, for $R_{NDB}$ to be equal to or greater than $R_N$ can be determined by rearranging the terms in the WSDOT formula.

The $R_{NDB}$ formulas are given in the Standard Specification Article 512.14 as:

$R_{NDB} = 6.6\ F_{eff}\ E\ Ln\ (10\ N_b) \div 1000$ (English)
$R_{NDB} = 21.7\ F_{eff}\ E\ Ln\ (10\ N_b) \div 1000$ (metric)

By setting $R_{NDB}$ equal to $R_N$ and rearranging the terms in the above equations, $N_b$ can be calculated as follows.

WSDOT

$$N_b = \frac{e^{\left[\frac{1000\,R_N}{6.6\,F_{eff}\,E}\right]}}{10} \text{ (English)}$$

$$N_b = \frac{e^{\left[\frac{1000\,R_N}{21.7\,F_{eff}\,E}\right]}}{10} \text{ (metric)}$$

The following examples demonstrate calculation of permissible energy ranges and blow counts needed to achieve nominal required bearings based on various given parameters.

## 7.3 Hammer Calculations: Example A

A Contractor proposes to use a Delmag single acting D22 diesel hammer to install the following piling:

PILE DATA
Type: Steel HP 10x42
Nominal Required Bearing: 330 kips
Factored Resistance Available: 165 kips
Estimated Length: 43 ft

A Delmag D22 hammer has a ram weight of 4,850 lbs with a minimum fall height of 3 ft and a maximum fall height of 8 ft. The manufacturer lists the maximum rated energy for the hammer at 39,700 lbs.

*Q1) Is the hammer acceptable for use?*

*Q2) What is the blow count (blows/inch) that needs to be achieved to ensure the nominal driven bearing ($R_{NDB}$) is equal to or greater than the nominal required bearing ($R_N$) if the hammer is operating with a ram fall height equal to 6.5 ft?*

Solution 1:
For single acting diesel hammers, minimum and maximum energies are the only requirements that need to be checked to determine hammer acceptability.

For single acting diesel hammers the maximum developed energy is taken as the ram weight times the fall height.

Max. developed hammer energy = W x H = 4,850 lbs x 8.0 ft ≈ 38,800 ft-lbs

The minimum required hammer energy for the pile is:

$E \geq 32.90 \times R_N \div F_{eff}$
$\geq 32.90 \times 330 \div 0.47 = 23{,}100$ ft-lbs

38,800 > 23,100 O.K.

The maximum allowable hammer energy for the pile is:

$E \leq 65.80 \times R_N \div F_{eff}$
$\leq 65.8 \times 330 \div 0.47 = 46{,}200$ ft-lbs

38,800 < 46,200 O.K.

Solution 1: (cont.)
The hammer satisfies energy requirements per the WS DOT formula.

Calculate the minimum and maximum permissible ram fall heights which ensure the hammer is operated within the allowable energy range.

$E_{min}$ = 23,100 ft-lbs
= W x H = 4,850 x H; H = 4.8 ft

$E_{max}$ = 46,200 ft-lbs
= W x H = 4,850 x H; H = 9.5 ft > $H_{max}$ = 8.0 ft

The hammer is capable of driving the piles within specifications as $R_{NDB}$ approaches $R_N$ if the ram for the hammer is operating between 4.8 ft and 8.0 ft of fall.

Solution 2:

E = 4,850 x 6.5 = 31,525 ft-lbs

$F_{eff}$ = 0.47

$$N_b = \frac{e^{\left[\frac{1000 \times 330}{6.6 \times 0.47 \times 31{,}525}\right]}}{10} = \frac{2.9 \text{ blows}}{\text{in.}}$$

Note that the IDOT Bureau of Bridges and Structures Foundations and Geotechnical Unit has developed an Excel spreadsheet that will perform these calculations for Inspectors. Spreadsheets for the WSDOT formula may be downloaded at: http://www.idot.illinois.gov/doing-business/procurements/engineering-architectural-professional-services/Consultants-Resources/index.

The spreadsheets calculate $R_{NDB}$ for various combinations of hammer energy and $N_b$ and highlight the acceptable operating energy for the chosen hammer. The spreadsheet also calculates this data for production and test piles as well as battered piles. The results of the spreadsheet for Example A and the WSDOT formulas are provided in the Appendix for comparison with the above calculations.

In reviewing the spreadsheet data included in the Appendix, students should recognize that the $N_b$ calculated above corresponds with the $N_b$ shown in the Production Pile table for a ram fall height of 6.5 ft.

## 7.4 Hammer Calculations: Example B

A Contractor proposes to use a Vulcan #1 single acting air/steam hammer with a drive head that weighs 895 lbs to install the following piling:

PILE DATA
Type: Metal Shell – 12 in. dia. w/ 0.179 in. walls
Nominal Required Bearing: 189 kips
Factored Resistance Available: 95 kips
Estimated Length: 24 ft

The ram for a Vulcan #1 hammer ram weighs 5,000 lbs and has a maximum fall height of 3 ft.

*Q1) Is the hammer acceptable for use?*

*Q2) What is the blow count (blows/inch) that needs to be achieved to ensure the nominal driven bearing (RNDB) is equal to or greater than the nominal required bearing (RN) if the hammer is operating at the maximum fall height?*

Solution 1:
For air/steam hammers, inspectors need to verify that the striking parts of the hammer weigh more the 1.4 tons and more than 1/3 of the combined weight of the pile and drive head. (Std. Spec. Art. 512.10)

The ram for a Vulcan #1 hammer ram weighs 5,000 lbs, which is greater than 1.4 tons. O.K.

Calculate the combined weight of the pile and drive head using a unit weight of 22.6 lbs/ft for the pile. (See metal shell pile plan sheet in the Appendix)

Drive Head Wt. + Pile Wt. = 895 lbs + (22.6 lbs/ft)(24 ft) = 1437 lbs

$$\frac{1{,}437\,\text{lbs}}{3} = 479\,\text{lbs} < 5{,}000\,\text{lbs}$$ O.K.

Therefore, the hammer satisfies both weight requirements.

For determining $R_{NDB}$, the maximum developed energy is taken as the ram weight times the fall height:

Hammer $E_{max}$ = W x H = 5,000 lbs x 3.0 ft = 15,000 ft-lbs

The minimum required and maximum allowed hammer energy for the pile using the WSDOT formula is:

Minimum Required Energy

$E \geq 32.90 \times R_N \div F_{eff}$
$\geq 32.90 \times 189 \div 0.55 = 11{,}305$ ft-lbs

Hammer $E_{max}$ = 15,000 > 11,305 O.K.

Maximum Allowable Energy

$E \leq 65.80 \times R_N \div F_{eff}$
$\leq 65.8 \times 189 \div 0.55 = 22{,}611$ ft-lbs

Hammer $E_{max}$ = 15,000 < 22,611 O.K.

Solution 1: (cont.)
The hammer is capable of driving the pile to the $R_{NDB}$ with a rate of penetration between 1 and 10 blows per inch if operated at its anticipated energy.

Solution 2:
Determine the required $N_b$ to achieve $R_{NDB}$ at a ram fall height of 3 ft (i.e. the max fall height).

$$N_b = \frac{e^{\left[\frac{1000 \times 189}{6.6 \times 0.55 \times 15{,}000}\right]}}{10} = \frac{3.2\,\text{blows}}{\text{in.}}$$

In reviewing the spreadsheet data included in the Appendix, students should recognize that the $N_b$ calculated above corresponds with the $N_b$ shown in the Production Pile table for a ram fall height of 3.0 ft. This penetration rate is also highlighted on the bearing graph included in the Appendix along with the hammer energy and fall height of the ram.

## 7.5 Hammer Calculations: Class Problem #1

A Contractor proposes to use a Vulcan #010 single acting air/steam hammer with a drive head that weighs 895 lbs to install the following piling:

PILE DATA
Type: Metal Shell – 14 in. dia. w/ 0.25 in. walls
Nominal Required Bearing: 383 kips
Factored Resistance Available: 210 kips
Estimated Length: 65 ft

Determine:

1. *Is the hammer acceptable?*
2. *What is the blow count for the maximum hammer energy?*

Given: The unit weight of the piles is 36.7 lbs/ft.
The ram weight is 10,000 lbs and has a maximum fall height of 39 in.

Solution:

## 7.6 Hammer Calculations: Class Problem #2

A Contractor proposes to use a Delmag D-36 single acting diesel hammer to install the following piling with an anticipated ram fall height of 5 ft:

PILE DATA
Type: HP 12 X 53
Nominal Required Bearing: 418 kips
Factored Resistance Available: 230 kips
Estimated Length: 60 ft

Determine:

1. *Is the hammer acceptable?*
2. *What is the blow count for the anticipated fall height of 5 ft?*

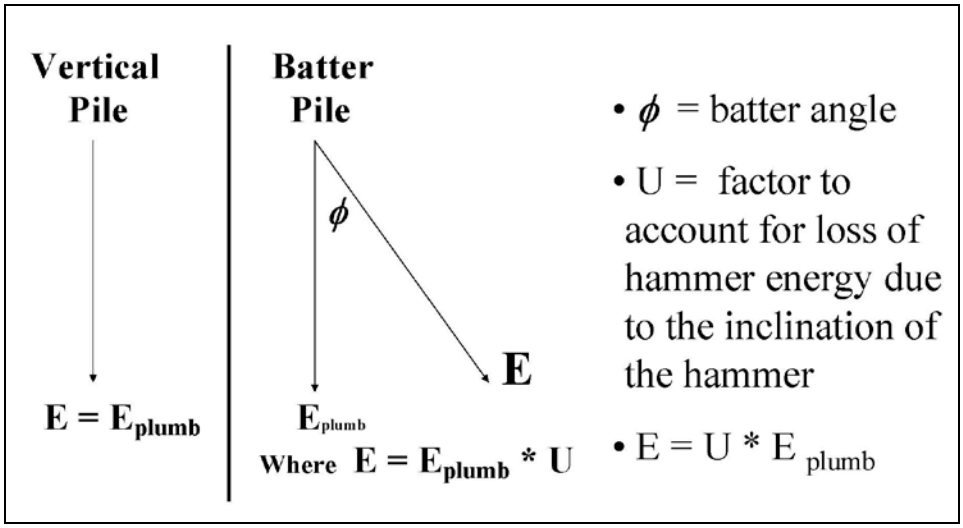
Given: The ram weight is 7,940 lbs and has a fall height range of 4.5 to 9 ft.

Solution:

## 7.7 Batter Piles:

Batter piles are piles driven into the ground at the angle defined in the plans. Batter piles are typically specified by designers to provide increased horizontal resistance at a substructure unit.

When driving batter piles, the hammer energy typically needs to be reduced to account for losses due to the inclination of the hammer as illustrated below. When hammers are equipped with ram velocity measuring devices that are being used to determine energy, use of a reduction coefficient is not necessary as any losses will already be reflected in the measured ram velocity.




**Vertical vs Batter Pile Comparison**

The following equations are provided in the Standard Specifications for determining the energy reduction coefficient, "U".

For drop hammers:

$$U = \frac{0.25(4-m)}{\sqrt{1+m^2}}$$

For all other hammers:

$$U = \frac{0.10(10-m)}{\sqrt{1+m^2}}$$

Where m = tangent of the batter angle (i.e., m = 0.25 = 3/12 for a 3H:12V batter).

## 7.8 Batter Piles: Example C

A Contractor proposes to drive HP12X53 piles to a nominal required bearing, $R_N$, of 330 kips on a 2:12 (H:V) batter using a Delmag #50C single acting diesel hammer.

What is the hammer energy reduction coefficient (U) for this batter?

m = H / V = 2 /12 = 0.167

$$U = \frac{0.10(10-m)}{\sqrt{1+m^2}} = \frac{0.10(10-0.167)}{\sqrt{1+0.167^2}} = 0.97$$

Therefore, the calculated hammer energy must be reduced by 3% to 97% of the hammer's standard value for all $R_{NDB}$ calculated for this batter.

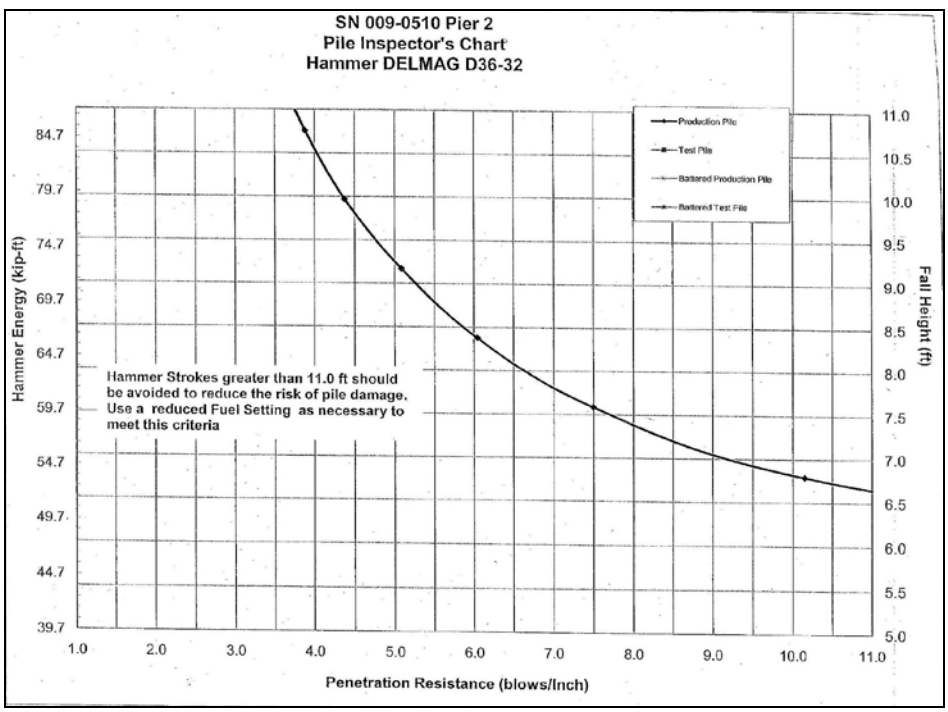
The Appendix contains a table of calculated U values for various batter angles. The WSDOT Pile Bering Verification spreadsheet (examples shown in the Appendix for Examples A and B) also calculates the U value and reduces the hammer energy for battered piles based upon the batter angle input by the user.

## 7.9 Wave Equation Analysis of Piles

As specified in Standard Specification Article 512.10, when a hydraulic hammer is used for pile driving operations the Contractor shall furnish wave equation analysis to aid in the determination of the adequacy of the hammer and indicate the nominal driven bearing of the pile. The formula provided in Standard Specification Article 512.14 may not be used.

The wave equation analysis of piles (WEAP) is a computer analysis of the dynamic pile driving process that models wave propagation through the hammer-pile-soil-system. The analysis should indicate that that expected stress levels in the piles at the maximum specified hammer energy will be less than 90% of the yield stress of the piles.

A WEAP analysis is required to be submitted to the Bureau of Bridges and Structures (BBS) for review and approval. The WEAP analysis is a function of the hammer, hammer accessories, pile, and soil properties and as such the necessary hammer data should be included with the submittal for the BBS's consideration. The WEAP submittal should also include an Inspector's chart that indicates hammer stroke or energy versus pile penetration rate near $R_N$. The BBS will typically provide a graph similar to that indicated below in the response back to the District to assist Inspectors in observing the pile driving operation.




**Example WEAP Graph Provided by BBS**

# 8 Test Piles

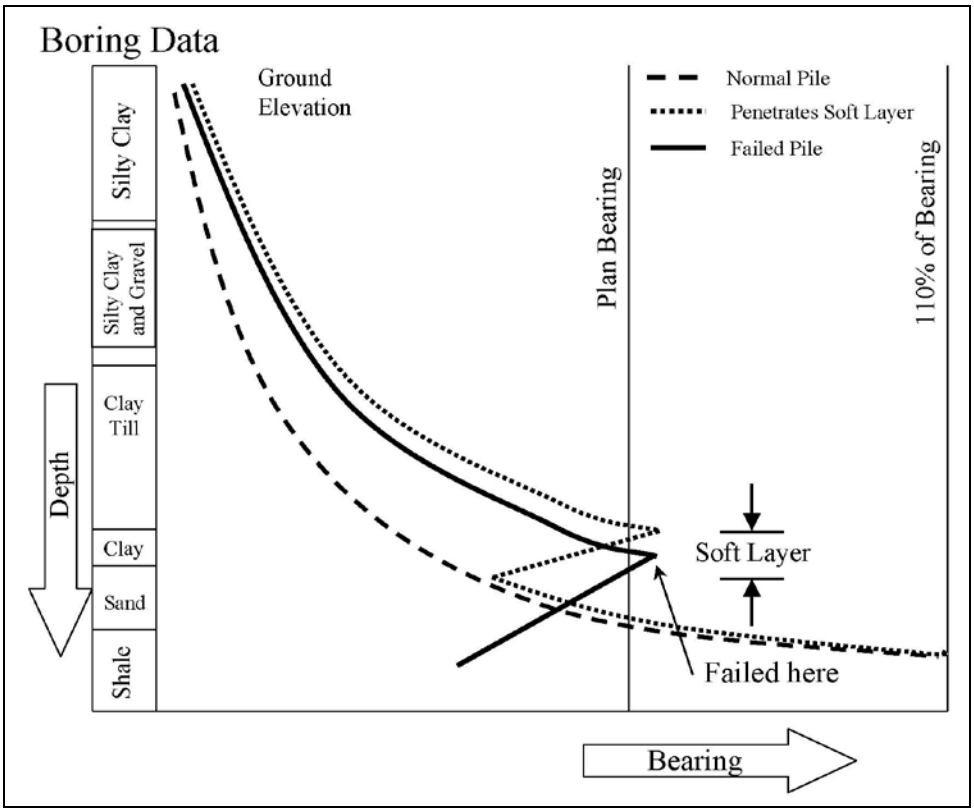
Test piles are specified to provide site specific pile bearing vs. length data, which is used by the Department during construction to verify the required length to be ordered for the production piles. As such, test piles shall be driven prior to ordering the production piles. The abutment and pier plan sheets should be reviewed to determine which substructure units require test piles.

Test piles are required by the Standard Specifications to be at least 10 ft longer than the estimated length shown on the plans for the production piles and are required to be driven to a bearing 10% greater than the $R_N$ shown in the plans. Test piles must be of the same type and satisfy the same splicing and pile shoe requirements specified for the production piles and be driven with the same hammer equipment that will be used for the production piles.

Following is a sample procedure that provides guidance for the installation of test piles:

1. Excavate or construct the embankment to within 2 ft of the bottom of footing or substructure elevation.
2. Locate test piles as far as possible from the soil boring locations. The general plan of the structure that is typically located near the beginning of the structure plans generally shows the conceptual location of the boring logs.
3. Notify the District Office prior to driving the Test Pile.
4. Establish the referenced driving elevation for monitoring the penetration of the pile into the ground.
5. Measure and mark the test pile in 1 ft increments to allow the pile driving data to be recorded in the Test Pile Driving Record (Form BBS 757). An example of Form BBS 757 is included in the Appendix and may be downloaded from: http://www.idot.illinois.gov/doing-business/procurements/construction-services/contractors-resources/index.
6. Record the average blows per inch over each foot of pile penetration until the required driven bearing for the test pile has been achieved.
7. Mark and measure the cut-off elevation for the test pile.
8. Plot the driving record versus the boring log data. This is generally only necessary when the Inspector notices a significant decrease in the pile bearing as the pile is being driven. Graphing the driving record versus the boring log can help rationalize unexpected driving behavior. An example graph is provided below.
9. Determine the lengths of the remaining production piles based upon the test pile data.
10. Provide a letter to the Contractor containing a list of the authorized lengths to be furnished for the production piles. A copy of the letter must be retained in the contract documentation file. An example letter to a Contractor authorizing the length of piles to be furnished is provided in the Appendix.

Test piles will generally be driven in a production pile location but may occasionally be driven outside production pile locations. Test piles driven in production pile locations shall be cutoff as production piles. Test piles driven elsewhere shall be cutoff or extracted as directed by the Engineer. Steel test piles driven as production piles shall be painted when also specified for the production piles.




**Example Driving Data vs. Boring Data Example**

# 9 Material Inspection, Handling, and Storage

## 9.1 Material Inspection

All piling arriving at the job site should have evidence that it was inspected and approved prior to shipment. The District Materials Office should be contacted immediately if piling arrives at the jobsite without evidence of having been inspected as such piling is not acceptable for use until there is proper evidence of inspection.

Steel piling is required to be labeled with heat numbers that agree with the heat numbers printed on the certification papers or else the piles cannot be used. These heat numbers should be recorded in the field pile driving record book. Inspectors should also verify that all iron and steel products have been domestically manufactured per requirements mandated by Federal and State Laws.

Approved piles may be identified according to the acceptable evidence indicated in the 2009 Project Procedure Guide. Excerpts from the Project Procedure Guide identifying acceptable evidence of inspection and approval are provided in the Appendix and the entire guide may be accessed at: http://www.idot.illinois.gov/doing-business/procurements/construction-services/contractors-resources/index. An example of a steel pile labeled with a heat number and evidence of inspection is indicated below.

Note that if steel piles are delivered from a Contractor's yard, the Contractor must provide manufacturer's certification and heat numbers even if there is evidence of past inspection.

**Example Heat No. and Evidence of Inspection**

All piles should be inspected upon arrival to ensure that the piles were not damaged during shipping. Inspectors should also verify that pile shoes, if required, have been attached to the piles with a quality continuous groove weld.

## 9.2 Handling and Storage

Piles delivered to the job site shall be stored and handled in a manner that protects them from damage in accordance with Standard Specification Article 512.08.

Timber piles shall be stored off the ground on wooden supports in a manner that permits air space under the piles and prevents contact with standing water. Timber piles shall be protected from the weather if they are being stored for an extended period of time and shall be handled with rope slings to minimize surface damage.

Precast and precast, prestressed concrete piles shall be stored with supports placed at the locations indicated on the shop drawings. Concrete piles shall be lifted using bridles attached to lifting points that are clearly marked on the piles or by using lifting devices cast into the concrete pile. Improper lifting or handling of the piles may result in cracked or spalled concrete.

Metal shell piles shall be stored on cribbing in a manner that will prevent bending, distortion, or other damaged to the piles and prevent dirt, water, or other foreign material from entering the pile.

H-piles shall also be stored off the ground using cribbing or skids in a manner that prevents distortion of the piles or damage due to excessive deflection. The Contractor shall use sufficient lifting points when handling the piles to ensure that member stresses do not exceed 80% of the yield strength of the member.

# 10 Pile Driving

## 10.1 Preparation

Final preparation for driving the production piles includes ensuring that the footing has been excavated to the required elevation and that the pile layout has been properly staked.

Article 512.09(b) of the Standard Specifications requires that all precast concrete piles be saturated with water over their entire length for a minimum of 6 hours prior to driving.

Pre-cored holes shall be provided for the piles when indicated in the plans. The plans will also specify the required diameter and depth of the holes. Pre-cored holes are generally specified on the plans when piles are being driven through new embankments or where the presence of dense soil layers are identified in the soil boring logs during design that could cause damage to a pile. Voids around the piles shall be backfilled with dry, loose sand after the piles have been driven in accordance with Article 512.09(c) of the Standard Specifications.

Prior to being lifted into the leads, the piles should be marked in 1 ft increments to facilitate recording $N_b$ as the pile penetrates the ground and inspected to verify that the piles remain in satisfactory condition for the intended use. It is also recommended that Inspectors inquire with Contractors to determine the means and methods that will be used to lift the piles into the leads.

It is important to investigate the means and methods that the Contractor will be using to lift the piles into the leads as Contractors have a history of cutting lifting holes in the pile. Depending upon the size and location of the hole, potential effects include a weakened pile cross section, an undesirable reduced structural capacity, and additional risk of the pile buckling during driving.

The Department does not have a firm policy regarding the use of lifting holes. While it is preferred that piles be handled using a choker or with lifting holes located in the piles above the cut-off elevation, the following table has been used as a guide for many years.

| Pile Size | one hole per flange | two holes per flange | one hole per web | two holes per web |
|---|---|---|---|---|
| HP 8 x 36 | .75" | .375" | 1.000" | .5" |
| HP 10 x 42 | 1" | .5" | 1.375" | .6875" |
| HP 10 x 57 | 1" | .5" | 1.375" | .6875" |
| HP 12 x 53 | 1.25" | .625" | 1.625" | .8125" |
| HP 12 x 63 | 1.25" | .625" | 1.625" | .8125" |
| HP 12 x 74 | 1.25" | .625" | 1.625" | .8125" |
| HP 12 x 84 | 1.25" | .625" | 1.625" | .8125" |
| HP 13 x 60 | 1.25" | .625" | 1.75" | .875" |
| HP 13 x 73 | 1.375" | .6875" | 1.75" | .875" |
| HP 13 x 87 | 1.375" | .6875" | 1.75" | .875" |
| HP 13 x 100 | 1.375" | .6875" | 1.75" | .875" |
| HP 14 x 73 | 1.5" | .75" | 1.875" | .9375" |
| HP 14 x 89 | 1.5" | .75" | 1.875" | .9375" |
| HP 14 x 102 | 1.5" | .75" | 1.875" | .9375" |
| HP 14 x 117 | 1.5" | .75" | 1.875" | .9375" |

**Recommended Maximum Hole Sizes in H-pile Webs and Flanges**

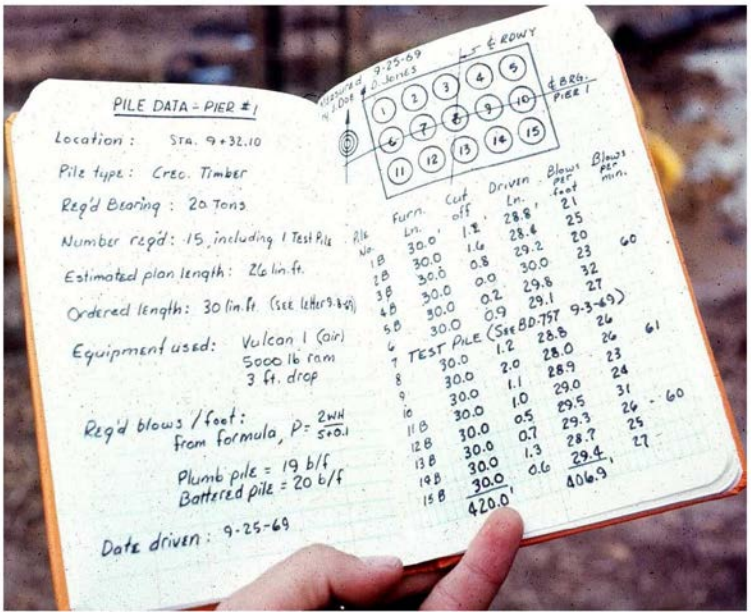
It is also recommended that the holes, drilled or burned, be circular in shape and located at least 6 in. above or 10 ft below the bottom of the foundation. The minimum distance between the edge of a hole and any edge of the pile is recommended to be not less than the larger of 1 in. or the diameter of the hole and that the minimum distance between two holes should not be less than the larger of 1 in. or

twice the diameter of the hole. Inspectors should contact the BBS if they have any concerns regarding the use of lifting holes proposed by the Contractor.

Prior to commencing pile driving, the Inspector should also prepare a hardback field book or other record that allows the pile driving data to be permanently recorded in a complete and accurate manner. The following data should be recorded at a minimum:

1. Foundation diagram showing the pile layout.
2. Location of the foundation.
3. Pile type.
4. Nominal required bearing ($R_N$).
5. Number of pile required.
6. Furnished length of piles.
7. Driving equipment used.
8. Required blows per inch of pile penetration into the ground ($N_b$) for vertical and battered piles.
9. Date driven.
10. Names of the Inspectors.
11. Tabulation of furnished lengths, cutoffs, & driven lengths.

Provided below is an example of hardback field book configured to record pile driving data.




**Example Field Book**

## 10.2 Pile Driving Operation

Prior to commencing the driving operation for production piles, Inspectors should be familiar with the make and model of the hammer that will be used by the Contractor and already have calculated the acceptable operating energy range for the hammer. Inspectors should also visually inspect the hammer so that they will understand how to verify the hammer energy during driving including being able to determine the bounce chamber pressure for double acting hammers and the stroke height of the ram for single acting hammers.

It is also recommended that Inspectors have on hand the acceptable range and value of $N_b$ that corresponds to the anticipated operating energy for the hammer and $R_N$. Inspectors will need to establish a reference for measuring $N_b$ as the pile is being driven and penetrates the ground. Inspectors will typically find that there are markings located on the pile leads that will assist in

measuring $N_b$ by serving as a reference mark relative to the 1 ft increments that are marked on the piles.

Inspectors are also required to verify that position and alignment of the piles are within the tolerance specified in Article 512.12 of the Standard Specifications and summarized below.

- The variation from vertical or specified vertical alignment shall be no more than 0.25 in. per ft.
- No visible portion of the pile shall be out of plan dimension by more than 6 in. provided that a design modification is not necessary or forcing the pile into tolerance will not cause damage to the pile.

The pile leads play a critical role in ensuring that the piles are driven within the tolerances required by the specifications. Standard Specification Article 512.10 requires that the leads be long enough to drive piles 10 ft longer than the estimated plan length unless that length is greater than 55 ft or the project has vertical clearance restrictions.

To assist in maintaining alignment, swinging leads are required to be set or toed into the ground. Restraints, such as chains or wood blocking, may also be necessary between the leads and the piles as the piles are being driven to maintain alignment of the piles and satisfy the required tolerances.

## 10.3 Penetration of Piles

Piles shall be installed to a penetration where the $R_{NDB}$ is greater than or equal to $R_N$ where $R_{NDB}$ shall be calculated using the WSDOT formula. In addition, piles shall be driven to a minimum tip elevation when specified on the plans or a minimum tip elevation that is at least 10 ft below the bottom of the footing or 10 ft into undisturbed earth.

Except to satisfy the minimum required tip elevations, Standard Specification Article 512.11 specifies that piles are not required to be driven:

- More than 1 additional foot after $R_{NDB} \geq R_N$
- More than 3 additional inches after $R_{NDB} > 1.1*R_N$
- More than 1 additional inch after $R_{NDB} > 1.5*R_N$

Piles that have been driven to approximately their full furnished length and have not been driven to the full nominal required bearing may be left for a waiting period, as specified in Article 512.11, to allow soil set-up to occur. Soil set-up refers to the dissipation of excess pore water pressures and reconsolidation of the soil around the pile that occurs over time resulting in an increase in pile capacity.

$R_{NDB}$ at the beginning of redrive (BOR) shall be determined after warming the hammer up (by applying at least 20 blows to another pile or fixed object). Once the hammer is warm, the $R_{NDB}$ at BOR is determined by recording the number of blows and hammer energy within each 1/2 in (13 mm) of pile penetration for the first 2 in (50 mm) of pile movement. The $R_{NDB}$ for the pile shall be taken as the largest bearing computed at each of the four 1/2 in. (13 mm) increments using the formula in Article 512.14.

If the data from driving the pile an additional 2 inches indicates that $R_{NDB} \geq R_N$, then the pile shall be accepted. Otherwise, additional retests and/or additional pile length will be required..

Other piles within a footing or substructure not having obtained the nominal required bearing at the end of initial driving will be accepted as having a nominal driven bearing equal to the retested pile provided that:

(a) These piles indicated higher nominal driven bearing than the retested pile at the end of the initial driving.

(b) These piles exhibited a similar driving behavior and are within 20 ft (6 m) of the retested pile.

(c) No more than five piles within the footing or substructure are being accepted based on one retested pile.

Minimum tip elevations may be specified on the plans to ensure that the embedment of the pile is sufficient to develop the required geotechnical capacity of the pile. Locations that are considered susceptible to significant scouring (erosion of the channel or streambed due to stream flow) will often have a minimum tip elevation specified on the plan to ensure that the required capacity of the pile is developed below the maximum depth of estimated scour. All structure plans involving stream crossings will have a Design Scour Elevation Table provided with the general plan and elevation view of the structure indicating the depth of the estimated scour that was considered in the design of the structure.

Inspectors should pay close attention to the operating energy of the hammer to ensure that the maximum permissible hammer energy is not exceeded. Also, Inspectors have been observed in the past instructing piles to be driven a nominal amount after the required nominal driven bearing has been achieved as an added factor of safety. Exceeding the maximum allowed hammer energy and driving piles beyond the required bearing may result in damage to the pile and should be avoided. The BBS should be contacted for further disposition in the event that piles become damaged during driving.

Inspectors are required according to Article 512.04(c) to inspect the interior of all driven metal shells for damage and deformations using a Contractor supplied lamp or mirror. The interior of metal shell piles are typically very cloudy immediately following driving and may need to be inspected at a later time. The tops of metal shell piles shall be temporarily seal off following inspection if the piles will not be filled with concrete shortly after being driven.

Provided below are examples of piles that were damaged during driving.

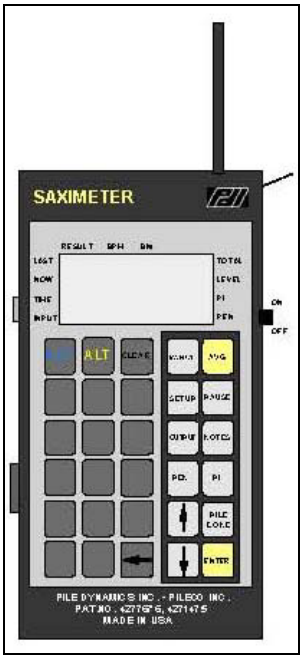
**Damaged H-pile**

**Damaged Metal Shell Pile**

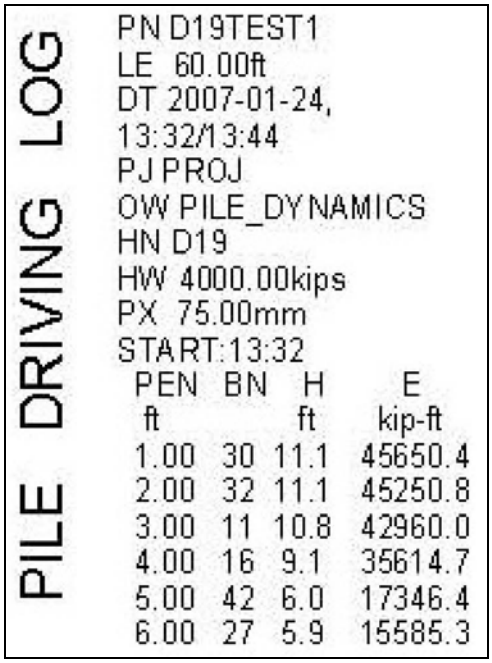
## 10.4 Advanced Inspection Tools

The continuing evolution of technology has brought about some advanced tools to assist Inspectors with monitoring pile driving. One such tool is the Saximeter. The Saximeter is a wireless handheld device that detects and counts hammer blows through sound recognition as an impact type hammer strikes the piles. The device records BPM's and blow count versus depth where the depth of penetration can either be automatically recorded using optional depth sensors mounted to the hammer or the depth of penetration can be manually recorded by the Inspector with the push of a button as the 1 ft increments marked on the pile pass the chosen reference plane. There are also optional sensors that can be mounted to the hammer to directly determine the hammer energy at the point of impact. For single acting diesel hammers, the Saximeter will also estimate the fall height of the ram and hammer energy based upon the recorded BPM. Data recorded by the Saximeter can either be printed in the field or downloaded to a PC for further processing.

Shown below is a schematic of a Saximeter and a sample output. Additional information for the Saximeter can be found at http://www.pile.com/.




**Saximeter Recording Device**



PILE DRIVING LOG

PN D19TEST1
LE 60.00ft
DT 2007-01-24,
13:32/13:44
PJ PROJ
OW PILE_DYNAMICS
HN D19
HW 4000.00kips
PX 75.00mm
START:13:32

| PEN ft | BN | H ft | E kip-ft |
|---|---|---|---|
| 1.00 | 30 | 11.1 | 45650.4 |
| 2.00 | 32 | 11.1 | 45250.8 |
| 3.00 | 11 | 10.8 | 42960.0 |
| 4.00 | 16 | 9.1 | 35614.7 |
| 5.00 | 42 | 6.0 | 17346.4 |
| 6.00 | 27 | 5.9 | 15585.3 |

**Example Saximeter Output**

Another tool that is useful for determining $R_{NDB}$ is a Pile Driving Analyzer (PDA). The PDA is a data acquisition system that measures the strain and particle acceleration in a pile due to the hammer impact. Acceleration and strain sensors are required to be attached to the piles to measure the data. The data is transferred to a data collection device and analyzed to determine the driving stresses and $R_{NDB}$. The PDA data can also be downloaded to a PC and analyzed with the computer software CAPWAP to provide a more refined assessment of the driving stresses and $R_{NDB}$.

The $R_{NDB}$ determined from the PDA is considered to be a more accurate measure of the $R_{NDB}$ than that predicted by the WSDOT formula. IDOT has purchased PDA equipment and is currently using it in conjunction with the second phase of a pile research project with the U of I. IDOT will retain ownership of the PDA equipment at the end of the research and IDOT staff is currently being trained on its use as the research progresses. The PDA equipment has been brought in and used on a few past projects where the $R_{NDB}$ estimated with the pile driving data and dynamic formulas contained in the specifications seemed suspect. Inspectors may contact the BBS and request use of the PDA equipment if they believe they are experiencing problems with the pile driving data on their project.

**PDA Wireless Data Collection Device**

**Pile Mounted PDA Sensors**

# 11 Pile Splices

Pile splices are generally needed because the required pile lengths are too long for hauling or allowing the piles to be driven in one piece or because low headroom or height restrictions exist. These splices are commonly referred to as planned splices. Pile splices may also be required due to a variance in field conditions and need to drive additional pile length to attain the required $R_N$. These splices are generally considered to be unplanned splices. The splicing requirements vary depending upon pile types as discussed below.

## 11.1 Timber Pile Splices

Timber pile splices are covered by Article 512.06 of the Standard Specifications. Planned timber pile splices are not allowed and unplanned splices shall be made using galvanized metal components consisting of 4 plates or a pipe sleeve that is anchored above and below the splice joint as indicated in the specifications.

## 11.2 Precast Concrete Piles

Splices for the purpose of driving additional pile length is not allowed as indicated in Article 512.03 of the Standard Specifications. If the top of the driven pile elevation needs to be increased to satisfy the required cut-off elevation, the piles shall be extended by field casting additional length onto the top of the piles using the pile extension details indicated on the standard base sheet for precast concrete piles.

## 11.3 Metal Shell and H-piles

Planned splices for metal shell and H-piles may be used when the estimated pile lengths shown in the plans exceed 55 ft, vertical clearance restrictions exist. The location of planned splices shall be approved by the Engineer. Attempts should be made to locate planned splices a minimum of 10 ft below the bottom of the footing, abutment of pier.

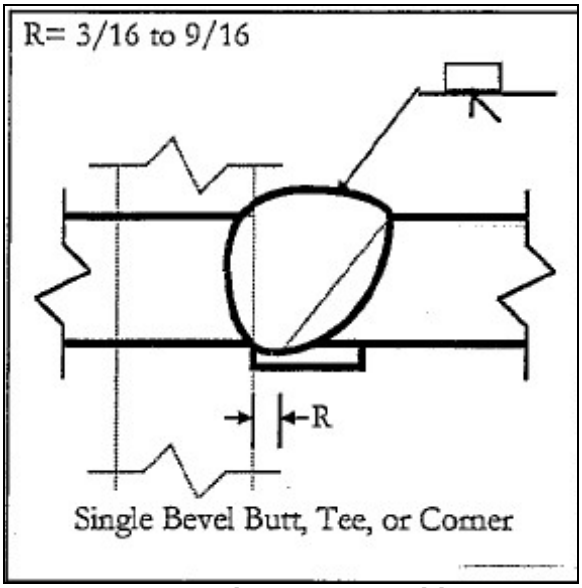
Unplanned splices may be used for metal shell and H-piles when the length of pile required to be driven to achieve the plan $R_N$ exceeds the estimated length specified in the plans.

All splices for metal shell and H-piles are required to develop the full axial and bending capacity of the piles and shall be made using welded splices that are in compliance with the splice details provided on the standard base sheets for each of the pile types (provided in the Appendix). Splices for H-piles may be made using welding splice plates or with the combination of a commercial splicer and flanges that are spliced using a full penetration weld or with welded splice plates. Metal shell piles may be spliced using a full penetration weld along with an interior backing ring or with a commercial splicer that permits a fillet weld around the exterior circumference of the shell. Full penetration welds (i.e., full thickness groove welds) require greater preparation effort and are usually more difficult to complete. Also, all splice plate material and commercial splicers are required to satisfy the same material and certification requirements as for the piles.

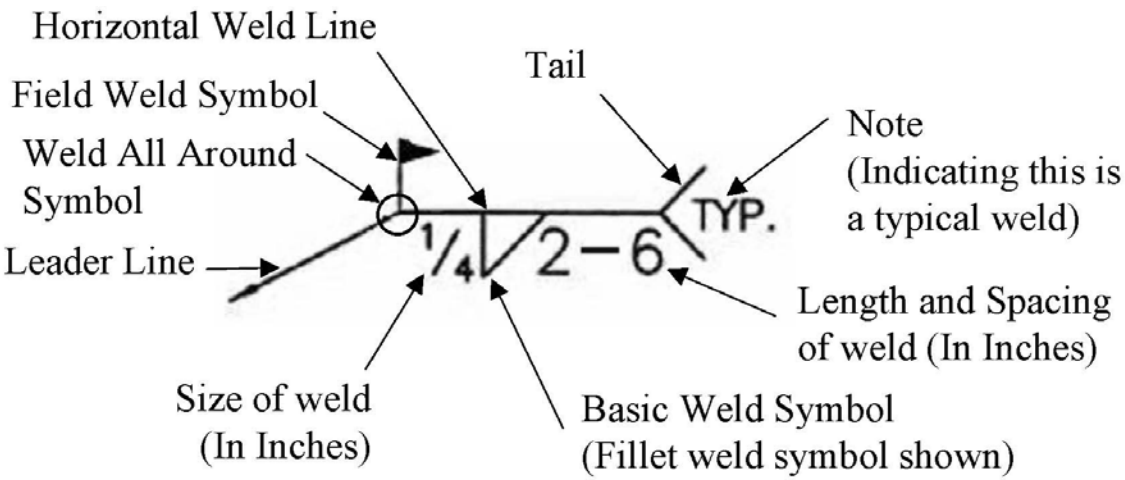
All welding shall be performed by welders that are certified according to the requirements of American Welding Society (AWS D1.1) (Structural Welding Code) or D1.5 (Bridge Welding Code) as stated in Article 512.07 of the Standard Specifications. Inspectors should obtain written weld procedure certifications from the Contractor indicating that the welder has exhibited tested skill and ability to deposit sound metal for the proposed welding process, weld type (fillet or groove weld), and welding position (generally flat, horizontal, vertical, or overhead). It is not the intent of the specification for the inspector to qualify a welder for the purpose of splicing piles. (I.e. the Welder and/or Contractor shall produce Evidence of Prequalification to perform the intended welding.) An example of an AWS welder certification card and description of the certification abbreviations is provided in the Appendix. In addition, AWS welder certification can be verified at https://app.aws.org/certification/cw_search.html.

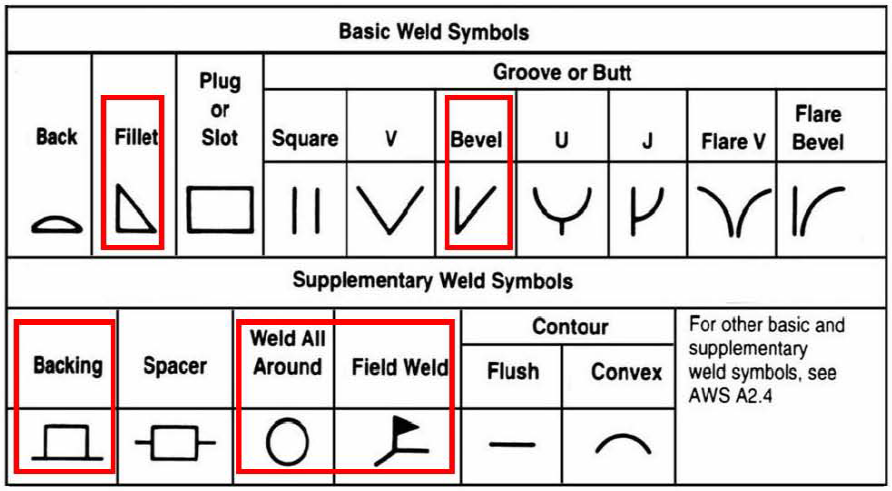
Inspectors should review the various weld symbols indicated on the base sheet and become familiar with their meaning. Inspectors should verify that joints have been properly prepared for the type of weld. For example, full penetration groove welds require that the plate material on one side of the splice be beveled for the full thickness of the specimen and that backing plates be provided. Inspectors should also verify that welds are the correct size and length. (It is worth noting, fillets welds greater than 5/16 inches and most full penetration groove welds require that the welds be completed with multiple passes. Inspectors should inspect the quality of the weld for evidence of porosity in the weld or narrow beads of weld that would suggest too fast of a travel speed during the welding which can indicate improper fusion or penetration. Non-destructive testing of pile splices by the Contractor is not required unless visual inspection by the Engineer indicates significant anomalies.

Following is a brief description of welding symbol terminologies with the weld symbols common to the pile splices highlighted.




**Example Groove Weld**




**Weld Terminology Description**

# 12 Pile Cutoffs

The pile cutoff elevation refers to the top of pile elevation indicated in the plans and “pile cutoff” refers to the excess length of furnished pile above this elevation. After piles have been driven to the minimum tip elevation or required $R_N$, the cutoff elevation shall be marked on the piles and the piles cut off perpendicular to their longitudinal axis in accordance with Article 512.13 of the Standard Specifications. The remaining pile shall be free of damage or bruising and the pile cutoffs retained on site and properly stored until the pile driving operating is complete in case pile splices are required at other locations.

The pile cutoff data shall be recorded in the field book and all final field recorded pile driving data shall be transferred to Form BBS 2184: Production Pile Driving Data. A completed example of the form is provided in the Appendix and the form may be downloaded from: http://www.idot.illinois.gov/doing-business/procurements/construction-services/contractors-resources/index

# 13 Filling Metal Shell Piles with Concrete

Metal shell piles are required to be filled with concrete in accordance with Article 512.04(e) of the Standard Specifications. Prior to filling the metal shells with concrete, the interior of the piles should be inspected again to ensure they remain free of water and other foreign substances. The pile driving operation and filling the metal shell piles with concrete shall be coordinated so that no piles are driven within 15 ft of a filled shell until a minimum of 24 hours has passed.

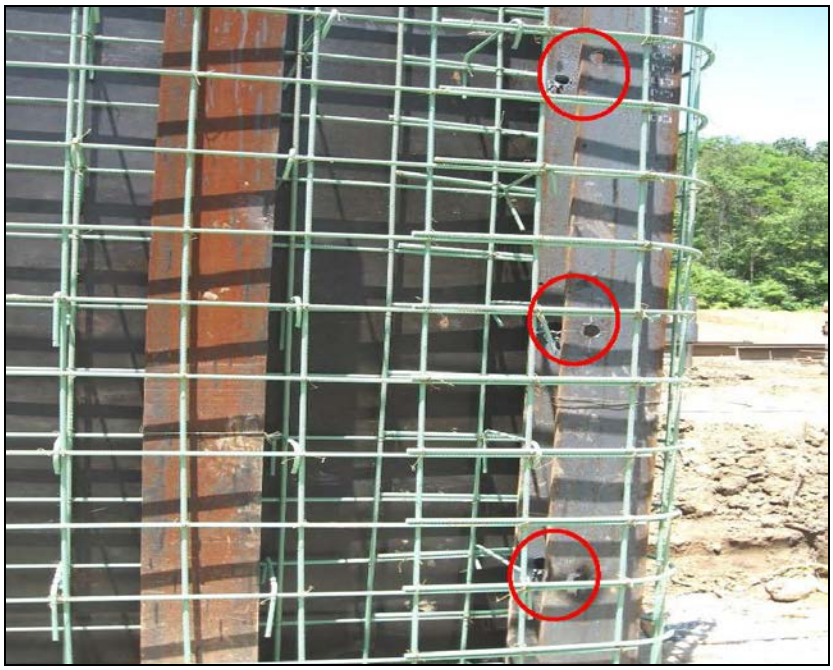
In addition, any reinforcement that is required to be placed in the top of the pile as indicated in the plans shall be rigidly tied together and lowered into the shell prior to placing the concrete per Article 512.04(d) of the Standard Specifications. Finally, the top 10 ft of concrete shall be internally vibrated as the piles are being filled.

# 14 Piles, Formwork, & Reinforcement

As the substructure construction continues following pile driving, it may become apparent that the pile locations interfere with the plan placement of the substructure reinforcement or the Contractor’s form ties for the formwork. Inspectors need to monitor such interference as Contractors have cut holes or notches in the piles to provide clearance for the reinforcement or to accommodate the form ties. The potential undesirable impact of such holes or notches is the same as that previously discussed for lifting holes placed in piles.

Reinforcement should typically be detailed in the plans to allow it to be placed and spaced around the piles. If pile interference is a problem for placing the reinforcement in accordance with the structure plans, the BBS should be contacted for further disposition. Provided below is an unacceptable practice of notching piles to facilitate reinforcement placement.

**Example of Unacceptable Notches Cut into Piles**



**Example of Holes Cut in Piles for Form Ties**

*The Department does not have a firm policy regarding the use of holes to accommodate form ties. It is preferred that the Contractor's formwork and means and methods of construction avoid the need to provide such holes in piles. If such holes are required for the form ties, it is recommended that they satisfy the same recommendations previously discussed for lifting holes and be spaced no closer than 8 inches vertically. Inspectors should contact the Bureau of Bridges and Structures (BBS) with any concerns that they may have.*

# 15 Determining & Documenting Final Contract Quantities

## 15.1 Methods of Payment & Units of Measurement

Provided below is a description of the methods of payment and units of measurement to be used for payment per Articles 512.17 and 512.18 of the Standard Specifications.

- **Test Piles** – Each
- **Pile Shoes** – Each

  - These pay items shall be paid for at the contract unit price each.
  - Enter these items in the Quantity Book according to the date and location.
  - Shoes for test piles are paid for separately. (i.e. the shoes are not included in the cost of the test pile.)

- **Furnishing Piles** (of the type specified) – Foot (Meter)

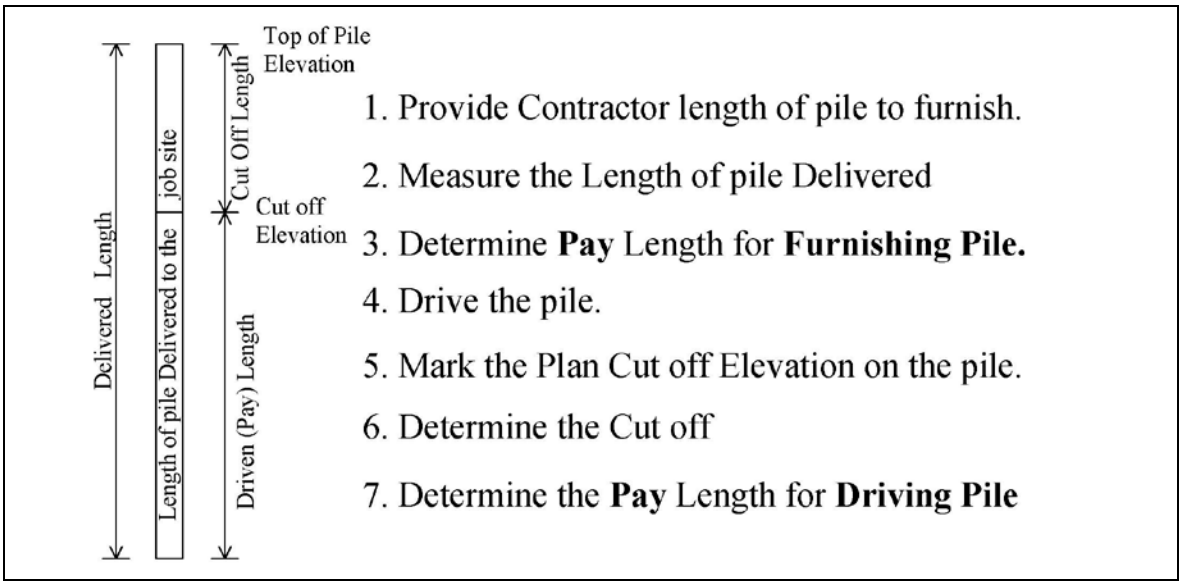
  - Payment will be made for the total lineal feet (meters) of all piles delivered to the site of work in accordance with the itemized list furnished by the Engineer. Field measurements must be on record.
  - Extra compensation as “furnishing piles” will not be allowed for portions of piles extended using pile cutoffs (provided the cutoff material is paid for as part of the pile it was removed from).
  - Other authorized pile lengths for the purpose of field extensions or “build-ups” will be allowed for payment.

- **Driving Piles** – Foot (Meter)

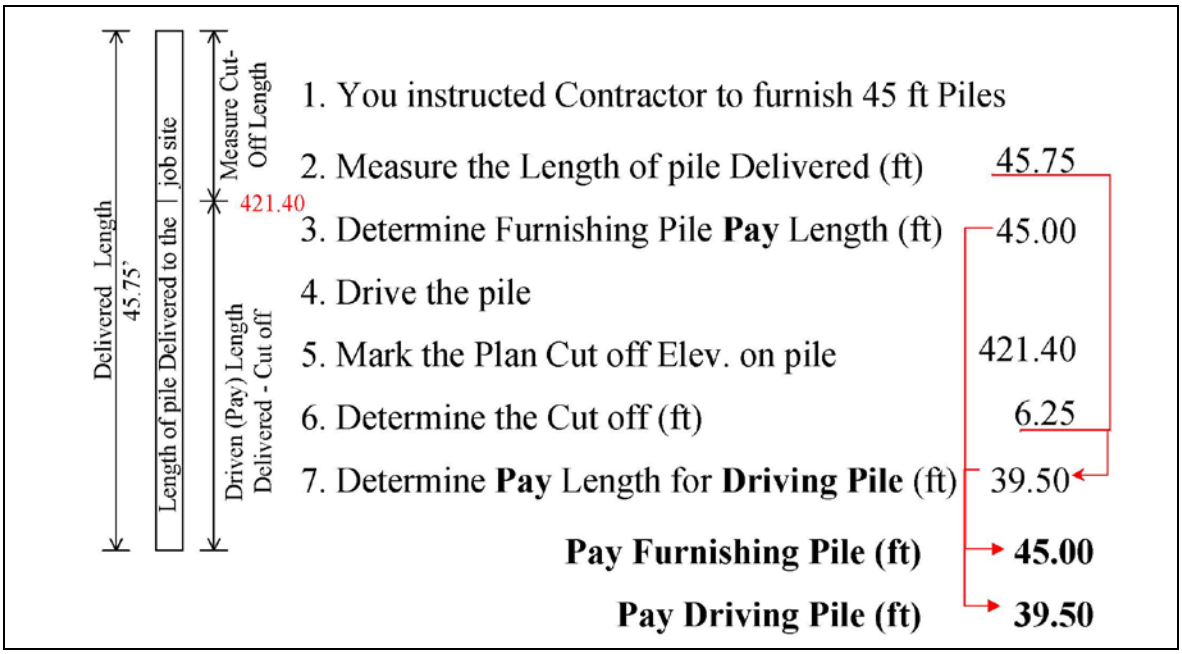
  - Payment will be made for the total linear feet (meters) of all piles left in place below the pile cutoff elevations. Field measurements must be record.
  - Additional unplanned splices will be paid for as extra work in accordance with Article 109.04 of the Standard Specifications. (Additional unplanned splices equal the total number of splices actually provided minus the number of splices the Contractor could have anticipated when preparing their bid.) Form BC-635, Extra Work Daily Report, should be used to document this work and may be accessed at: http://www.idot.illinois.gov/doing-business/procurements/construction-services/contractors-resources/index.

## 15.2 Determining Pile Pay Lengths

The information recorded on the Pile Driving Data Form previously discussed should be used to determine the Pile Pay Lengths for the Final Payment Estimate. Following is a procedure for determining the Pile Pay Lengths.




Following is an illustration for the procedure discussed above.



## 15.3 Determining Pile Pay Lengths: Class Problem #3

Determine the pile pay lengths for furnishing piles and driving piles and fill in the table below. In addition, determine which splices are paid for via force account.

Given:
Estimated Plan length = 50'
There is a vertical clearance restriction at one location as noted
All piles will be end bearing on bedrock

| Authorized Furnished Length (by Letter) | Delivered Length* | Added Splice Length | Cut Off Length | Pay Length | |
|---|---|---|---|---|---|
| | | | | Furnish | Drive |
| 50 | 50 | - | 3 | | |
| 50 | 55 | - | 3 | | |
| 50 | 45[4] | - | 3 | | |
| 50 | 55 | - | 10 | | |
| 50 | 50 | 10[1] | 2 | | |
| 50 | 50 | 10[2] | 2 | | |
| 50[3] | 2@25 | | 1 | | |
| | | | Total | | |

* As Measured in the field.

1. State furnished splice length.
2. Contractor furnished splice length.
3. Overhead power lines restrict equipment height to 40'
4. The Engineer allowed the use of a 45' pile with the stipulation the pile would be extracted and replaced with a longer (end bearing) pile if 45' is too short.

## 15.4 Determining Pile Pay Lengths: Class Problem #4

Determine the pile pay lengths for furnishing piles and driving piles and fill in the table below. In addition, determine which splices are paid for via force account.

Given:
Estimated Plan length = 70'
Contractor's equipment capable of driving a 50' segment

| Authorized Furnished Length (by Letter) | Delivered Length* | Added Splice Length | Cut Off Length | Pay Length | |
|---|---|---|---|---|---|
| | | | | Furnish | Drive |
| **70** | **2@40** | **-** | **20** | | |
| **110** | **3@40** | **10**[1] | **5** | | |
| **100** | **2@50** | **-** | **1** | | |
| | | | **Total** | | |

***** As Measured in the field.

1. State furnished splice length.

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# APPENDIX A

# Construction Inspector's Checklist for Piling

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State of Illinois
Department of Transportation

**CONSTRUCTION INSPECTOR'S CHECKLIST**
**FOR**
**PILING**

While it is not required, this checklist has been prepared to provide for the field inspector a summary of easy-to-read step-by-step requirements for the installation and inspection of foundation piling (Section 512). The following questions are based on the requirements found in the Standard and Supplemental Specifications and appropriate sections of the Construction Manual.

## 1. PLAN AND SPECIFICATION REVIEW

Prior to starting work on an item, have you checked the contract Special Provisions and plans to see if any changes or modifications have been made to the Standard and Supplemental Specifications? ____

On bridge construction and reconstruction contracts have you checked the proposed or existing span lengths prior to starting work? (The contract may make this the responsibility of the Contractor.) ____

On bridge construction and reconstruction contracts have you checked the existing or proposed vertical or horizontal clearances? ____

Prior to the start of construction, have you checked the plan elevations of the bottom of footings, intermediate substructure components and bearing seat elevations of abutments and piers to ensure they correspond to the appropriate top of deck elevations and dimensions shown on the superstructure plans? ____

Have you reviewed the appropriate sections of the Construction Manual (Structures), Documentation Section, Project Procedures Guide and Forms? ____

Has the structure been surveyed to establish the baseline of the structure, bearing lines of piers and backs of abutments? Has an independent check of your calculations and layout been performed before the Contractor starts work? (Construction Manual Survey Section) ____

## 2. DETERMINE HAMMER ENERGY REQUIREMENTS

Has the contractor provided you with the data and necessary correlation charts for determining the energy "E" developed by the hammer per blow for the pile hammer proposed for driving piles? (512.10(a)) ____

If the contract indicates a Wave Equation analysis will be used (or if the contractor will be using a hydraulic hammer) to drive the project piles, have you submitted the contractor's analysis to central Bureau of Bridges and Structures for their review and approval? (512.10(a)) ____

If a WAVE Equation analysis is not being used, does the hammer meet the following energy requirements: (512.10(a)) ____

A. Minimum Hammer Energy:

$E \geq 32.90 \times R_N \div F_{eff}$ (English) $E \geq 10.00 \times R_N \div F_{eff}$ (metric)

B. Maximum Hammer Energy:

$E \leq 65.80 \times R_N \div F_{eff}$ (English) $E \leq 20.00 \times R_N \div F_{eff}$ (metric)

Where:
$R_N$ = Nominal Required bearing in kips (kN)
E = Energy developed by the hammer per blow in ft-lbs (J)
$F_{eff}$ = Hammer efficiency factor defined as follows:
= 0.55 for air/steam hammers
= 0.37 for open-ended diesel hammers and concrete or timber piles
= 0.47 for open-ended diesel hammers and steel piles or metal shell piles
= 0.35 for closed-ended diesel hammers
= 0.28 for drop hammers

**Additional Hammer Requirements (by Hammer type): (512.10(a))**

**Air/Steam Hammers**
Is the total weight of the striking parts at least 1.4 tons (1.3 metric tons) and not less than 1/3 the weight (mass) of the Pile and drive cap? ____

**Diesel Hammers**
Open-end (single acting) hammer: Is the hammer either equipped with a device to measure ram impact velocity or speed of operation (with the necessary correlation charts) or designed such that the stroke height can be directly observed? ____

Closed-end (double acting) hammer: Is the hammer equipped with a bounce chamber pressure gauge that is easily readable? ____

Closed-end (double acting) hammer: Has the Contractor provided the correlation chart and hammer data for the hose length and diameter to determine the energy developed by the hammer with each blow? ____

**Drop hammers**
Shall not be used for driving:
Precast and Precast Prestressed Concrete Piles.
Piles with a Nominal Required Bearing ($R_N$) > 120 kips (533 kN)

Is the hammer ram weight (mass) at least 1 ton (0.9 metric tons)? ____

Is the Ram weight at least equal to the combined weight of the pile and drive cap? ____

Does the fall of the ram not exceed 15 ft. (4.6 m)? ____

**Hydraulic hammers**:
Is the hammer equipped with an energy reading device? ____

Has the contractor provided a wave equation analysis for the proposed hammer? (The modified Gates & WSDOT formulas are NOT acceptable) ____

## 3. DETERMINE THE NUMBER OF REQUIRED HAMMER BLOWS

Have you determined minimum number of blows/inch (blows/25mm) "$N_b$", to obtain a Nominal Driven Bearing ($R_{NDB}$) of the pile equal to or exceeding the Nominal Required Bearing ($R_N$) shown on the plans? (512.14) ____

$$N_b = \frac{e^{\left[\frac{1000 R_N}{6.6 F_{eff} E}\right]}}{10} \quad \textit{(English)} \qquad N_b = \frac{e^{\left[\frac{1000 R_N}{21.7 F_{eff} E}\right]}}{10} \quad \textit{(Metric)}$$

Where:

$R_N$ = the Nominal Required Bearing in kips (kN)
E = the Energy developed by the hammer per Blow in ft-lbs (J)
$N_b$ = the number of hammer blows per inch (25mm) of pile penetration
$F_{eff}$ = the hammer efficiency factor

## 4. TEST PILES

When test piles are specified, are the following requirements being met:

a. Location. Are the test piles being located at the substructure foundation designated in the plans? ____

Within the designated substructure foundation, are you locating the test pile as far as possible away from the nearest soil boring? ____

Are Test piles driven in a production location cut off as production piles? ____

Are Steel test piles driven in a production location painted when painting is specified for the production steel piles? ____

Are Test piles not driven as production piles cutoff or pulled as directed by the Engineer? (512.15) ____

b. Driving Elevation. Has the excavation or embankment placement at the test pile location been completed to an elevation within 2 ft (600 mm) of the plan bottom of footing or plan pre-core elevation? (512.15) ____

c. Pile Material. Is the test pile the same material and size as specified for the production piles? (512.15) ____

d. If pile shoes are specified for the production piles, is the test pile driven with the required pile shoe? (512.15) ____

e. Length. Is the test pile at least 10 ft (3 m) longer than the estimated length of the production piles shown on the plans? (512.15) ____

f. Hammer. Is the hammer proposed to drive the test pile the same hammer that will be used to drive the production pile? (512.15) ____

g. Notification. Are you notifying the District Office prior to driving the test pile? ____

h. Bearing. Are all test piles being driven to a Nominal Driven Bearing ($R_{NDB}$) = 1.1 x Nominal Required Bearing ($R_N$) shown on the plans? (512.15) ____

Are all Nominal Driven Bearing ($R_{NDB}$) being determined by the WSDOT formula? (Wave Equation only required when specified by special provision or hydraulic hammer is used.) ____

Does the pile penetrate to at least the minimum pile tip elevation specified, or if none is specified, at least 10 ft (3 m) below the bottom of footing elevation or 10 ft (3 m) below undisturbed earth? (512.11(b)) ____

i. Records. Are the test piles marked off in 1 ft (300 mm) increments and the blows/inch recorded over each 1 ft (300 mm) on Form BBS 757, Test Pile Driving Record? (512.15) ____

j. Length Determination. Are the lengths of the production piles being determined from an analysis of the test pile data, boring data and estimated plan lengths? ____

Have you given the Contractor a written itemized list of pile lengths to be furnished? (512.16) ____

Is a copy of this list being retained in the contract documentation files? ____

Are you preparing and sending a copy of the BBS 757 to the Bureau of Bridges and Structures (BBS)? ____

## 5. STORAGE AND HANDLING

a. Timber Piles. Are the treated timber piles stored at the site of the work in accordance with the requirements of 1007.13 and handled in accordance with Articles 507.05 and 1007.13? (512.08(a)) ____

Are the piles being stored off the ground on solid timbers of size and so arranged as to support treated materials without producing noticeable distortion and not subjected to standing water? (1007.13/AWPA Std M4) ____

Are the piles being handled with rope slings and in accordance with Article 507.05(a) and 1007.13? (512.08(a)) ____

b. Precast Concrete Piles. Are precast and precast prestressed concrete piles being lifted and stored at the bridle points shown on the precast shop plans? (512.08(b)) ____

c. Steel piles. Are steel H-piles being supported on skids or other supports sufficiently spaced to keep the piles clean and free from injury? (512.08)(c)/505.08(c) & Construction Manual Section 512.08) ____

d. Metal Shell Piles. Are metal shell piles being stored off the ground and in a manner to prevent dirt, water or other foreign material from entering the shell? (512.08(d)) ____

Are metal shell piles being stored on sufficient cribbing to prevent bending, distortion or other damage to the shell? (512.08(d)) ____

## 6. PREPARATION FOR DRIVING

a. Prior to the start of driving piling, has the footing been excavated to grade? (512.09) ____

b. Have cross sections been taken to determine pay quantities for structure excavation? ____

c. Have the pile locations been staked and checked? ____

d. Has the entire length of all Precast Concrete Piles been kept saturated at least six hours prior to driving? (512.09(b)) ____

e. If pre-coring of the embankment is specified on the plans, has the contractor pre-cored to the required depth and diameter shown on the plans? ____

## 7. PILING DOCUMENTATION

Are you preparing a field book or other record so that a permanent record can be made of the following: (Construction Manual Section 512.11) ____

a. A numbered diagram of the location of piles in each substructure location. ____

b. The authorized length to be furnished as per the written itemized list provided to the Contractor. ____

c. The actual measured length of each piling delivered. ____

d. The actual measured length of each cutoff ____

e. The length driven (i.e. length of pile furnished minus the cutoff length) ____

f. The hammer blows per inch (25 mm) "$N_b$", Hammer energy "E" imparted and corresponding calculated Nominal Driven Bearing ($R_{NDB}$) at the final bearing. ____

## 8. MATERIAL INSPECTION

a. Have you inspected all piling to see if they have been approved prior to shipment? (Construction Manual Section 512.08 & PPG) ____

b. Are you inspecting piling delivered for possible damage in transit? ____

c. If pile shoes are specified, do they meet the requirements indicated in the plans & 1006.05(e)? ____

## 9. EQUIPMENT

a. Drive Head. Are the heads of all piles being protected with a suitable driving head? (512.10(b)) ____

b. Pile Cushion. Are the heads of all Timber, Precast Concrete and Precast Prestressed Concrete piles being protected by a Pile cushion? (512.10(c)) ____

Is the thickness of the Pile head cushion at least 3 inches (75 mm)? ____

Are you requiring the contractor to replace the cushion when it compresses to less than 60% of its original thickness or begins to burn? ____

c. Hammer Cushion. Are you inspecting the Hammer cushion, when one is required by the manufacturer prior to driving and after each 50 hours of operation? (512.10(c)) ____

Is the hammer cushion being replaced when it is reduced to less than 75% of its original thickness? ____

d. Leads. Is the pile and hammer being held in accurate alignment with pile leads? (512.10(d)) ____

Is the equipment adequate for driving piles at least 10 ft (3 m) longer than the estimated pile length at each location specified in the contract plans without splicing (unless the estimated pile length exceeds 55 ft (17 m) or prevented by vertical clearance restrictions)? (512.10) ____

If swinging leads are used, are they firmly toed into the ground prior to starting the pile driving operation? (512.10(d)) ____

e. Followers. If the contractor requests permission to use a follower to drive pile, have you agreed to its use in writing? (512.10(e)) ____

Is the first pile in every group of ten being driven without a follower and the data from that pile used to determine the average Nominal Driven Bearing ($R_{NDB}$) of the other piles in the group? ____

f. Jets. If jets are proposed, have you approved their use? (512.10(f)) ____

Following termination of use of jets in a substructure unit, are you further driving each pile in that unit to ensure the Nominal Driven Bearing ($R_{NDB}$) is equal to or greater than the Nominal Required Bearing ($R_N$)? ____

## 10. TOLERANCES IN DRIVING

a. Are foundation piles being driven with a variation from the vertical or required batter alignment of not more than $^1/_4$ in/ft (20 mm/m). (512.12) ____

b. Are piles driven such that no visible portion of the pile is more than 6 inches (150 mm) out of plan position, when such alignment does not require a design modification and forcing in to this position does not result in injury to the pile? (512.12) ____

## 11. PENETRATION REQUIREMENTS

a. Are you observing the hammer blows per inch (25 mm) to ensure the piling is driven to a Nominal Driven Bearing ($R_{NDB}$) equal to or larger than the Nominal Required Bearing ($R_N$) shown on the plans? (512.11(a)) ____

b. If a pile has not achieved Nominal Required Bearing ($R_N$) at the full furnished length are you allowing the pile to set during a waiting period to achieve soil setup before splicing and driving and additional length? (512.11) ____

When checking the Nominal Driven Bearing ($R_{NDB}$) for soil setup, before setting back on the pile, has the hammer been warmed up by applying at least 20 blows to another pile or fixed object? (512.11) ____

If multiple piles within a footing or substructure failed to achieve $R_N$ at the full furnished length, are you selecting the appropriate pile(s) for re-driving to minimize the number of retests required? (512.11) ____

Has the $R_{NDB}$ at beginning of re-drive (BOR) been determined by recording the number of blows and hammer energy within each 1/2 in (13 mm) of pile penetration for the first 2 in (50 mm) of pile movement and is $R_{NDB}$ taken as the largest bearing computed at each of the four 1/2 in. (13 mm) increments using the formula in Article 512.14? (512.11) ____

c. When a minimum tip elevation is shown on the plans, is the penetration of all foundation piles below the minimum tip elevation? (512.11(b)) ____

When a minimum tip elevation is not shown on the plans are the piles being driven to a penetration at least 10 ft (3 m) below the bottom of footing or into undisturbed earth, whichever is greater? (512.11(b)) ____

Note: When driving timber piles, if you are having problems achieving this penetration, are you asking the Contractor to point the timber piles, or allowing water and/or air jets (512.10(f)) in combination with the hammer?

d. Are you checking that piles in stream beds or on banks of streams, where erosion or scour is expected (as shown on the scour table shown on the plans) that the pile tip penetrates to the minimum tip elevation shown on the plans, or well below the scour elevation shown? ____

## 12. FIELD SPLICING OF PILES

When it becomes necessary to splice onto a partially driven pile because it has become damaged in driving or because Nominal Required Bearing ($R_N$) shown on the plans has not yet been reached, is the splice being performed in accordance with the plan details and the following? ____

a. Precast or Precast Prestressed Concrete Piles.
NO splices are allowed in Precast or Precast Prestressed Concrete Piles. (512.03(a)) ____

If an extension is required, it should be constructed as shown on the plans. (Pile is NOT redriven following constructing the extension) (512.03(b)) ____

If the Nominal Required Bearing ($R_N$) cannot be achieved, have you notified your supervisor to contact the Bureau of Bridges and Structures for further instructions? ____

b. Metal Shell Piles.
Planned Splice: Are planned splices being denied unless the estimated pile length exceed 55 ft (17 m) or vertical restrictions exist? (512.10 and 512.04(a)(1))) ____

Have you approved the location of planned splices at locations which minimize the chance they will be located within 10 ft (3 m) below the base of the footing, abutment, or pier? ____

Unplanned Splice: Are pile lengths required to be furnished beyond the estimated plan length resulting in <u>additional</u> splices? (512.04(a)(2)) ____

Is the Splice being accomplished by:

1. A Complete Joint Penetration (CJP) weld of the entire cross-section as shown on the plans?

2. Use of a commercial splicer with a Department approved commercial splicer welding detail as shown on the plans? ____

Is the welder making the splice certified according to either the American Welding Society (AWS) D1.1 or D1.5 for the weld process, weld type, and weld position being performed? (512.07) ____

c. Steel "H" Piles.
Planned Splice: Are planned splices being denied unless the estimated pile length exceeds 55 ft (17 m), or vertical restrictions exist? (512.10 and 512.05(a)(1)) ____

Have you approved the location of planned splices at locations which minimize the chance they will be located within 10 ft (3 m) below the base of the footing, abutment, or pier? ____

Unplanned Splice: Are pile lengths required to be furnished beyond he estimated plan length resulting in <u>additional</u> splices? (512.05(a)(2)) ____

Is the splice being accomplished by:

1. The Department's standard steel pile field splices shown on the plans?

2. Use of a commercial splicer with a Department approved commercial splicer welding detail and flange splices as shown on the plans? ____

Is the welder making the splice certified according to either the American Welding Society (AWS) D1.1 or D1.5 for the weld process, weld type, and weld position being performed? (512.07) ____

d. Timber Piles. Planned splicing of timber pile is NOT allowed. For an unplanned splice, is the added piece cut flush with and attached to the main pile with the use of at least 4 galvanized steel plates or a metal pipe sleeve? (512.06) ____

## 13. PILE CUTOFFS

a. Are you marking each pile at the cutoff elevation so that the Contractor can cut them off square (perpendicular) to the axis of the pile? (512.13) ____

b. Once you determine that the pile cutoffs will not be needed as splices for any of the other production piles, are you informing the Contractor that the cutoffs are theirs and are to be disposed of at no additional expense to the State? (512.13) ____

## 14. INSPECTION OF METAL SHELL PILES AFTER DRIVING

a. Are you inspecting the interior of all driven metal shell piles for bends or other deformations that would impair the strength of the pile with a Contractor supplied suitable light? (512.04(c)) ____

b. After you have inspected and approved the metal shell piles, is the Contractor temporarily sealing the top of the metal shell piles to prevent the entrance of water or foreign substance? (512.04(c)) ____

**15. FILLING METAL SHELL PILES WITH CONCRETE**

a. If all piles in a bent, pier or abutment cannot be driven before any concrete is placed in the metal shell piles, is driving of the additional piles within 15 feet (4.5 m) being deferred until the concrete in the metal shell piles within this zone is at least 24 hours old? (512.04(b)) ____

b. If reinforcement is specified on the plans, is the reinforcement rigidly fastened together and lowered into the shell before placing concrete? Are spacers used to maintain the proper clearance into the top of the piles? (512.04(d)) ____

c. Just prior to filling metal shell piles with Class DS Concrete, are you inspecting the interior with a suitable light to be sure that all water and foreign substance has been removed? (512.04(e)) ____

d. When filling the metal shell piles with concrete, is the top 10 feet (3 meters) of concrete being consolidated with internal vibration? (512.04(e)) ____

**16. BACKFILLING PRECORED HOLES**

Are all pre-cored holes being backfilled with loose, dry sand after the piles are driven? (512.09(c)) ____

**17. PILING DIAGRAM**

Is a BBS 2184 being prepared for each substructure/footing for submittal to BBS? (Construction Manual 512.11) ____

Have you included a diagram numbering the piles driven and indicating their locations and any deviations from plan locations? ____

**18. DOCUMENTATION OF FINAL CONTRACT QUANTITIES**

TEST PILES - Each
PILE SHOES - Each

Shall be paid for at the contract unit price each. Enter in Quantity Book by date and location. (512.18) ____

FURNISHING PILES (Of the various types and sizes specified) - Foot (Meter)

Payment will be made for the total lineal feet (meters) of all piles delivered to the work in accordance with the written itemized list of furnished lengths provided by the Engineer. Field measurements of the delivered lengths must be on record. (512.18) ____

If cutoffs are used in splicing on additional lengths, no extra length compensation will be allowed. ____

Other authorized field additions or “build-ups” will be allowed for payment. ____

DRIVING PILES - Foot (Meter)

Payment will be made for the total lineal feet (meters) of all piles left in place below cutoff elevation. Field measurements must be on record. (512.17 and 512.18) ____

Authorized, unplanned additional splices will be paid for as extra work in accordance with Article 109.04. Use Form BC 635 to document this work. (512.18(d)) ____

I.e. “additional” field splices (for metal shells and steel piles) required to provide the lengths beyond the estimated length will be paid according to Article 109.04. “Additional” field splices are field splices in addition to the number of field splices already planned by the Contractor. Use Form BC 635 to document this work. ____

Revised to conform with the
Standard Specifications for Road and Bridge Construction
Adopted April 1, 2016

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# APPENDIX B

## Hammer Energy Reduction Coefficients for Battered Piles

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**Hammer Energy Reduction Coefficients**
**for**
**BATTERED PILES**

NOTE: If the hammer has internal ram velocity monitoring, no friction losses or stroke reductions should be used. Because the measured impact velocity is used to control the nominal energy delivered to the pile, losses are internally corrected by the hammer operating system.

u = A coefficient less than unity

m = Tangent of the Angle of Batter Horizontal dimension / Vertical dimension

| | Driven with Drop Hammer | Driven with All other Hammers |
|---|---|---|
| | $u = \frac{0.25\,(4-m)}{(1+m^2)^{0.5}}$ | $u = \frac{0.1\,(10-m)}{(1+m^2)^{0.5}}$ |
| Batter V:H | "u" | "u" |
| 12:1/2 | 0.989 | 0.995 |
| 12:1 | 0.976 | 0.988 |
| 12:1 ½ | 0.961 | 0.98 |
| 12:2 | 0.945 | 0.97 |
| 12:2 ½ | 0.928 | 0.959 |
| 12:3 | 0.91 | 0.946 |
| 12:3 ½ | 0.89 | 0.932 |
| 12:4 | 0.87 | 0.917 |

Example: Determine the Energy Developed by the Hammer per blow on a pile with a 12:2 (V:H) batter if the Energy Developed for vertical bearing is 25,000 ft-lbs and an air hammer is used:

25,000 Ft-lbs x 0.97 = 24,250 ft-lbs

The Energy Developed by the Hammer on a pile battered at 2 in 12 is 24,250 ft-lbs

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# APPENDIX C

## Example Pile Hammer Data

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PILE HAMMER DATA (ENGLISH)

| Mfgr. | Model | Type | Blows Per Min. | Stroke At Rated Energy, In. | Ram Weight, Lbs. | Rated Energy Ft. Lbs. |
|---|---|---|---|---|---|---|
| Link-Belt | 105 | Dbl-Act | 90-98 | 35.23 | 1,445 | 7,500 |
| (Diesel) | 180 | Dbl-Act | 90-95 | 37.60 | 1,725 | 8,100 |
| ** | 312 | Dbl-Act | 100-105 | 30.89 | 3,857 | 15,000 |
| | 440 | Dbl-Act | 86-90 | 38.40 | 4,000 | 18,200 |
| | 520 | Dbl-Act | 80-84 | 43.17 | 5,070 | 26,300 |
| Vulcan | 18C | Dbl-Act | 150 | 10 1/2 | 1,800 | 3,600 |
| (Steam-Air) | 2 | Sgl-Act | 70 | 29 | 3,000 | 7,260 |
| | 30C | Dbl-Act | 133 | 12 1/2 | 3,000 | 7,260 |
| | 1 | Sgl-Act | 60 | 36 | 5,000 | 15,000 |
| | 50C | Dbl-Act | 120 | 15 1/2 | 5,000 | 15,100 |
| | 65C | Dbl-Act | 117 | 15 1/2 | 6,500 | 19,200 |
| | 06 | Sgl-Act | 60 | 36 | 6,500 | 19,500 |
| | 0 | Sgl-Act | 50 | 39 | 7,500 | 24,375 |
| | 80C | Dbl-Act | 111 | 16 1/2 | 8,000 | 24,450 |
| | 08 | Sgl-Act | 50 | 39 | 8,000 | 26,000 |
| | OR | Sgl-Act | 80 | 39 | 9,300 | 30,225 |
| | 010 | Sgl-Act | 50 | 39 | 10,000 | 32,500 |
| | 140C | Dbl-Act | 103 | 15 1/2 | 14,000 | 36,000 |
| | 014 | Sgl-Act | 60 | 36 | 14,000 | 42,000 |
| | 016 | Sgl-Act | 60 | 36 | 16,250 | 48,750 |
| | 020 | Sgl-Act | 60 | 36 | 20,000 | 60,000 |
| | 030 | Sgl-Act | 55 | 36 | 30,000 | 90,000 |
| | 400C | Diff | 100 | 16 1/2 | 40,000 | 113,488 |
| McKiernan- | DE-10 | Sgl-Act | 48-52 | Var.* | 1,100 | 8,800 |
| Terry | DE-20 | Sgl-Act | 48-52 | Var.* | 2,000 | 16,000 |
| (Diesel) | DE-30 | Sgl-Act | 48-52 | Var.* | 2,800 | 22,400 |
| | DE-40 | Sgl-Act | 48-52 | Var.* | 4,000 | 32,000 |
| | DA-35 | Sgl-Act | 48-82 | Var.* | 2,800 | 22,400 |
| | DA-35 | Dbl-Act | 48-82 | | 2,800 | 21,000 |
| | DA-55 | Sgl-Act | 48-82 | Var.* | 5,000 | 40,000 |
| | DA-55 | Dbl-Act | 48-82 | | 5,000 | 38,000 |
| | DE-50 | Sgl-Act | 40-50 | Var.* | 5,000 | 40,000 |
| | DE-70 | Sgl-Act | 40-50 | Var.* | 7,000 | 56,000 |
| McKiernan- | 9-B-2 | Dbl-Act | 140 | 16 | 1,500 | 8,200 |
| Terry | 9-B-3 | Dbl-Act | 145 | 17 | 1,600 | 8,750 |
| (Steam-Air) | S-3 | Sgl-Act | 65 | 36 | 3,000 | 9,000 |
| | C-3 | Dbl-Act | 130-140 | 16 | 3,000 | 9,000 |
| | 10-B-3 | Dbl-Act | 105 | 19 | 3,000 | 13,100 |
| | 10-B-2 | Dbl-Act | 115 | 20 | 2,500 | 15,000 |
| | C-5 | Dbl-Act | 100-110 | 18 | 5,000 | 16,000 |
| | S-5 | Sgl-Act | 60 | 39 | 5,000 | 16,250 |
| | 11-B-3 | Dbl-Act | 95 | 19 | 5,000 | 19,150 |

| | | | | | | |
|---|---|---|---|---|---|---|
| McKiernan-Terry (Steam-Air) | 11-B-2 | Dbl-Act | 120 | 20 | 3,625 | 22,080 |
| | C-826 | Dbl-Act | 85-95 | 18 | 8,000 | 24,000 |
| | S-8 | Sgl-Act | 55 | 39 | 8,000 | 26,000 |
| | C-8 | Dbl-Act | 77-85 | 20 | 8,000 | 26,000 |
| | S-10 | Sgl-Act | 55 | 39 | 10,000 | 32,500 |
| | S-14 | Sgl-Act | 60 | 32 | 14,000 | 37,500 |
| Union (Stream) | 00 | Dbl-Act | 85 | 36 | 6,000 | 54,900 |
| | 0A | Dbl-Act | 90 | 21 | 5,000 | 22,050 |
| | 0 | Dbl-Act | 110 | 24 | 3,000 | 19,850 |
| | 1 | Dbl-Act | 130 | 21 | 1,850 | 13,100 |
| | 1A | Dbl-Act | 120 | 18 | 1,600 | 10,020 |
| | 1 1/2A | Dbl-Act | 125 | 18 | 1,500 | 8,680 |
| | 2 | Dbl-Act | 145 | 16 | 1,025 | 5,755 |
| Delmag (Diesel) | D-5 | Sgl-Act | 50-60 | Var.* | 1,100 | 9,050 |
| | D-12 | Sgl-Act | 50-60 | Var.* | 2,750 | 22,610 |
| | D-15 | Sgl-Act | 50-60 | Var.* | 3,300 | 27,000 |
| | D-22 | Sgl-Act | 50-60 | Var.* | 4,850 | 39,780 |
| | D-30 | Sgl-Act | 39-60 | Var.* | 6,600 | 54,200 |
| | D-36 | Sgl-Act | 37-53 | Var.* | 7,940 | 73,780 |
| | D-44 | Sgl-Act | 37-55 | Var.* | 9,460 | 87,000 |
| | D-55 | Sgl-Act | 36-47 | Var.* | 11,860 | 117,175 |
| Conmaco | 50 | Sgl-Act | 60 | 36 | 5,000 | 15,000 |
| | 65 | Sgl-Act | 60 | 36 | 6,500 | 19,500 |
| | 80 | Sgl-Act | 50 | 39 | 8,000 | 26,000 |
| | 100 | Sgl-Act | 50 | 39 | 10,000 | 32,500 |
| | 115 | Sgl-Act | 50 | 39 | 11,500 | 37,375 |
| | 125 | Sgl-Act | 50 | 39 | 12,500 | 40,625 |
| | 140 | Sgl-Act | 60 | 36 | 14,000 | 42,000 |
| | 160 | Sgl-Act | 60 | 36 | 16,250 | 48,750 |
| | 200 | Sgl-Act | 60 | 36 | 20,000 | 60,000 |
| | 300 | Sgl-Act | 55 | 36 | 30,000 | 90,000 |
| Kobe | K-13 | Sgl-Act | 45-60 | 102 | 2,860 | 24,400 |
| | K-22 | Sgl-Act | 45-60 | 102 | 4,850 | 41,300 |
| | K-25 | Sgl-Act | 39-60 | 110 | 5,510 | 50,700 |
| | K-32 | Sgl-Act | 45-60 | 102 | 7,050 | 60,100 |
| | K-35 | Sgl-Act | 39-60 | 110 | 7,700 | 70,800 |
| | K-42 | Sgl-Act | 45-60 | 102 | 9,260 | 79,000 |
| | K-45 | Sgl-Act | 39-60 | 110 | 9,900 | 91,100 |
| | K-60 | Sgl-Act | 35-60 | 102 | 13,200 | 112,600 |

* Use actual length of stoke as observed in field. Rated energy is determined by stoke which increases with driving resistance.

** Equivalent HW energy is obtained by plotting the observed bounce chamber pressure on the corresponding chart provided in the gage box.

PILE HAMMER DATA (METRIC)

| Mfgr. | Model | Type | Blows Per Min. | Stroke At Rated Energy, mm | Ram Weight, kN | Rated Energy J |
|---|---|---|---|---|---|---|
| Link-Belt | 105 | Dbl-Act | 90-98 | 895 | 6.42 | 10,169 |
| (Diesel) | 180 | Dbl-Act | 90-95 | 955 | 7.67 | 10,982 |
| ** | 312 | Dbl-Act | 100-105 | 785 | 17.16 | 20,337 |
| | 440 | Dbl-Act | 86-90 | 975 | 17.79 | 24,676 |
| | 520 | Dbl-Act | 80-84 | 1,097 | 22.55 | 35,658 |
| Vulcan | 18C | Dbl-Act | 150 | 267 | 8.00 | 4,881 |
| (Steam-Air) | 2 | Sgl-Act | 70 | 737 | 13.34 | 9,843 |
| | 30C | Dbl-Act | 133 | 318 | 13.34 | 9,843 |
| | 1 | Sgl-Act | 60 | 914 | 22.24 | 20,337 |
| | 50C | Dbl-Act | 120 | 394 | 22.24 | 20,473 |
| | 65C | Dbl-Act | 117 | 394 | 28.91 | 26,032 |
| | 06 | Sgl-Act | 60 | 914 | 28.91 | 26,438 |
| | 0 | Sgl-Act | 50 | 991 | 33.36 | 33,048 |
| | 80C | Dbl-Act | 111 | 419 | 35.58 | 33,150 |
| | 08 | Sgl-Act | 50 | 991 | 35.58 | 35,251 |
| | OR | Sgl-Act | 80 | 991 | 41.36 | 40,980 |
| | 010 | Sgl-Act | 50 | 991 | 44.48 | 44,064 |
| | 140C | Dbl-Act | 103 | 394 | 62.26 | 48,810 |
| | 014 | Sgl-Act | 60 | 914 | 62.26 | 56,944 |
| | 016 | Sgl-Act | 60 | 914 | 72.27 | 66,096 |
| | 020 | Sgl-Act | 60 | 914 | 88.95 | 81,349 |
| | 030 | Sgl-Act | 55 | 914 | 133.43 | 122,024 |
| | 400C | Diff | 100 | 419 | 177.90 | 153.869 |
| McKiernan- | DE-10 | Sgl-Act | 48-52 | Var.* | 4.89 | 11,931 |
| Terry | DE-20 | Sgl-Act | 48-52 | Var.* | 8.89 | 21,693 |
| (Diesel) | DE-30 | Sgl-Act | 48-52 | Var.* | 12.45 | 30,370 |
| | DE-40 | Sgl-Act | 48-52 | Var.* | 17.79 | 43,386 |
| | DA-35 | Sgl-Act | 48-82 | Var.* | 12.45 | 30,370 |
| | DA-35 | Dbl-Act | 48-82 | Var.* | 12.45 | 28,472 |
| | DA-55 | Sgl-Act | 48-82 | Var.* | 22.24 | 54,233 |
| | DA-55 | Dbl-Act | 48-82 | Var.* | 22.24 | 51,521 |
| | DE-50 | Sgl-Act | 40-50 | Var.* | 22.24 | 54,233 |
| | DE-70 | Sgl-Act | 40-50 | Var.* | 31.13 | 75,926 |
| McKiernan- | 9-B-2 | Dbl-Act | 140 | 406 | 6.67 | 11,118 |
| Terry | 9-B-3 | Dbl-Act | 145 | 432 | 7.12 | 11,863 |
| (Steam-Air) | S-3 | Sgl-Act | 65 | 914 | 13.34 | 12,202 |
| | C-3 | Dbl-Act | 130-140 | 406 | 13.34 | 12,202 |
| | 10-B-3 | Dbl-Act | 105 | 483 | 13.34 | 17,761 |
| | 10-B-2 | Dbl-Act | 115 | 508 | 11.12 | 20,337 |
| | C-5 | Dbl-Act | 100-110 | 457 | 22.24 | 21,693 |
| | S-5 | Sgl-Act | 60 | 991 | 22.24 | 22,032 |
| | 11-B-3 | Dbl-Act | 95 | 483 | 22.24 | 25,964 |

| | | | | | | |
|---|---|---|---|---|---|---|
| McKiernan-Terry (Steam-Air) | 11-B-2 | Dbl-Act | 120 | 508 | 16.12 | 29,937 |
| | C-826 | Dbl-Act | 85-95 | 457 | 35.58 | 32,540 |
| | S-8 | Sgl-Act | 55 | 991 | 35.58 | 35,251 |
| | C-8 | Dbl-Act | 77-85 | 508 | 35.58 | 35,251 |
| | S-10 | Sgl-Act | 55 | 991 | 44.48 | 44,064 |
| | S-14 | Sgl-Act | 60 | 813 | 62.26 | 50,843 |
| Union (Stream) | 00 | Dbl-Act | 85 | 914 | 26.69 | 74,435 |
| | 0A | Dbl-Act | 90 | 533 | 22.24 | 29,896 |
| | 0 | Dbl-Act | 110 | 610 | 13.34 | 26,913 |
| | 1 | Dbl-Act | 130 | 533 | 8.23 | 17,761 |
| | 1A | Dbl-Act | 120 | 457 | 7.12 | 13,585 |
| | 1 1/2A | Dbl-Act | 125 | 457 | 6.67 | 11,769 |
| | 2 | Dbl-Act | 145 | 406 | 4.56 | 7,803 |
| Delmag (Diesel) | D-5 | Sgl-Act | 50-60 | Var.* | 4.89 | 12,270 |
| | D-12 | Sgl-Act | 50-60 | Var.* | 12.23 | 30,655 |
| | D-15 | Sgl-Act | 50-60 | Var.* | 14.68 | 36,607 |
| | D-22 | Sgl-Act | 50-60 | Var.* | 21.57 | 53,935 |
| | D-30 | Sgl-Act | 39-60 | Var.* | 29.36 | 73,485 |
| | D-36 | Sgl-Act | 37-53 | Var.* | 35.32 | 100,032 |
| | D-44 | Sgl-Act | 37-55 | Var.* | 42.07 | 117,956 |
| | D-55 | Sgl-Act | 36-47 | Var.* | 52.75 | 158,868 |
| Conmaco | 50 | Sgl-Act | 60 | 914 | 22.24 | 20,337 |
| | 65 | Sgl-Act | 60 | 914 | 28.91 | 26,438 |
| | 80 | Sgl-Act | 50 | 991 | 35.58 | 35,251 |
| | 100 | Sgl-Act | 50 | 991 | 44.48 | 44,064 |
| | 115 | Sgl-Act | 50 | 991 | 51.14 | 50,674 |
| | 125 | Sgl-Act | 50 | 991 | 55.59 | 55,080 |
| | 140 | Sgl-Act | 60 | 914 | 62.26 | 56,944 |
| | 160 | Sgl-Act | 60 | 914 | 72.27 | 66,096 |
| | 200 | Sgl-Act | 60 | 914 | 88.95 | 81,349 |
| | 300 | Sgl-Act | 55 | 914 | 133.43 | 122,024 |
| Kobe | K-13 | Sgl-Act | 45-60 | 2,591 | 12.72 | 33,082 |
| | K-22 | Sgl-Act | 45-60 | 2,591 | 21.57 | 55,995 |
| | K-25 | Sgl-Act | 39-60 | 2,794 | 24.51 | 68,740 |
| | K-32 | Sgl-Act | 45-60 | 2,591 | 31.36 | 81,485 |
| | K-35 | Sgl-Act | 39-60 | 2,794 | 34.25 | 95,992 |
| | K-42 | Sgl-Act | 45-60 | 2,591 | 41.18 | 107,110 |
| | K-45 | Sgl-Act | 39-60 | 2,794 | 44.03 | 123,515 |
| | K-60 | Sgl-Act | 35-60 | 2,591 | 58.70 | 152,665 |

* Use actual length of stoke as observed in field. Rated energy is determined by stoke which increases with driving resistance.

** Equivalent HW energy is obtained by plotting the observed bounce chamber pressure on the corresponding chart provided in the gage box.

# APPENDIX D

# Project Procedures Guide Excerpt

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# Project Procedures Guide

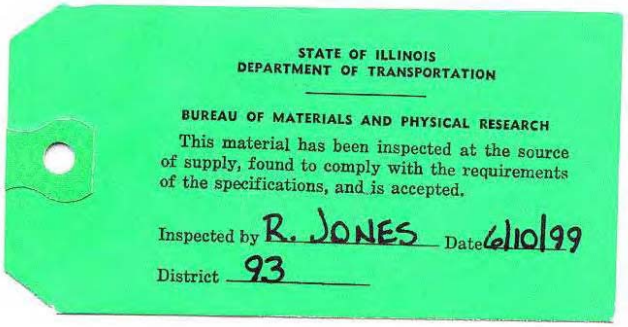
## Sampling Frequencies for Materials Testing and Inspection

**June 1, 2009**

Illinois Department of Transportation
Bureau of Materials and Physical Research
126 East Ash Street / Springfield, Illinois / 62704-4766

This stamp indicates the product was approved at the source

**This stamp shows the product has been sampled. It does NOT indicate the product is approved**




This tag is attached to products to indicate product was approved at source.

| EVIDENCE | COMMENT |
|---|---|
| BBS 59 | Report of acceptance of fabrication of structural steel. The Bureau of Bridges and Structures usually performs this type of inspection and testing. |
| BILL OF LADING | A shipping ticket that accompanies a product to the job site and which identifies the product, source, and lot. |
| BMPR | Bureau of Materials & Physical Research approval letter. |
| CERT | Manufacturer's written certification that indicates material complies with the specifications or contract. |
| DAILY PLANT REPORTS | For PCC and HMA, reports generated that provide mixture test results and other production data. For non-**QC/QA** projects, Daily Plant Reports are the responsibility of the **Inspector**. For **QC/QA** projects, refer to the appropriate special provisions to determine responsibility for Daily Plant Reports. |
| IL OK | Material is stamped by an IDOT **Inspector** with an "IL OK" stamp indicating prior inspection and acceptance. An inspection tag may be used as **Evidence of Materials Inspection** and approval. |
| LA 15 | This **Department** form is a supplier's certification indicating material is from approved stock. The form is sometimes used as a Bill of Lading to indicate prior approval. The form should include supplier, proper contract/job designation, material description, manufacturer, specific approved material (test ID number, lots, or batches), and quantity. Additional information on LA 15's is provided in Attachment 1. |
| LIST | The material appears on a current list of **Department**-approved products or approved sources found at the **Department's** web site, www.dot.il.gov under "Doing Business/Materials ". Contact the inspecting district's Materials Office for information on aggregates. |
| MARK | A commercial label, tag, or other marking which indicates product specification compliance and/or an approved source/manufacturer. |
| TEST | Approved test result available via the **MISTIC** system or from locally performed lab or field tests (e.g., soil density). |
| TICK | A ticket from an approved source indicating **Department** material or aggregate quality and gradation, job designation, purchaser, and weight (if applicable). |
| VIS | A RE memo denoting visual inspection is required in the project file, and input into **MISTIC** is required. |
| VIS EXAM | Same as VIS, but no RE memo or input into **MISTIC** is required. |

| Product | Material Series | Evidence of Materials Inspection | Jobsite Sample | Responsible Lab | Sample Size | Container | Small Quant. Per Contract |
|---|---|---|---|---|---|---|---|
| **PAVEMENT MARKING** | | | | | | | |
| ► Glass Beads | 604 | LA 15 or IL OK | NR | AC | 3 QT | 5 | 100 LB |
| ► Raised Pavement Marker | 708 | LIST | NR | AC | 3 EA | 8 | N/A |
| ► Temporary Pavement Tape | 705 | LA 15 or (IL OK + Batch/Lot Number) | NR | AC | 10 LF | 8 | N/A |
| ► Thermo Letters & Symbols | 705 | CERT OR LA 15 | NR | AC | - | - | N/A |
| ► Thermoplastic - granular/block | 706 | LA 15 or IL OK | NR | AC | 1 Gal from 3 dif. Bags | 5 or 8 | 100 LB |
| ► Thermoplastic Tape | 705 | LA 15 or IL OK | NR | AC | 1 SF | 8 | 150 LF |
| **PILING** | | | | | | | |
| ► Metal Shell, Steel H, Steel Sheet or Steel Soldier | 367 | CERT or LA 15 or IL OK | NR | MT | 1 @ 24" | 8 | N/A |
| ► Precast Concrete | 366 | LIST | NR | - | - | - | N/A |
| ► Precast, Prestressed Concrete | 366 | IL OK | NR | - | - | - | N/A |
| ► Timber | 370 | CERT OR MARK OR LA 15 | NR | MT | - | - | N/A |
| **PIPE, CULVERT & DRAIN** | | | | | | | |
| ► Cast or Ductile Iron Pipe | 511 | CERT or LA 15 | NR | MT | - | - | 100 LF |
| ► Clay Pipe & Drain Tile | 500 | LA 15 or IL OK or TEST | NR | MT | - | - | 100 LF |
| ► Metal Corrugated & Components | 452 | CERT or IL OK or LA 15 | NR | MT | - | - | 100 LF |
| ► Pipe - Plastic, PVC, HDPE - water/sewer | 491 | IL OK or LA 15 or TEST | NR | MT | 4 LF | 8 | 100 LF |
| ► Pipe Fittings - PE, PVC | 492 | VIS | NR | MT | - | - | N/A |
| ► Pipe Liner - PE, PVC | 496 | IL OK or LA 15 or TEST | NR | MT | 4 LF | 8 | 100 LF |
| ► Pipe Underdrain | 493 | IL OK or LA 15 or TEST | NR | MT | 3 @ 3 LF | 8 | 100LF |
| ► Plastic Deck Drain | 499 | CERT | NR | MT | - | - | N/A |
| ► Precast Concrete Pipe or Box Culvert | 475 | LIST + MARK | NR | - | - | - | N/A |
| ► Underdrain Mat, Wall Drain | 496 | LA 15 or TEST | NR | MT | 3 LF Full Width | 8 | 500 LF |

# APPENDIX E

## Standard Pile Details
## Pile Plan Base Sheets

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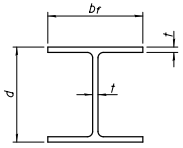
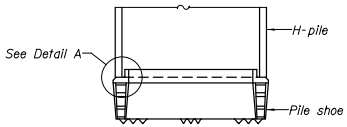
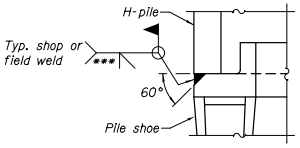



STEEL PILE TABLE

| Designation | Depth d | Flange width $b_f$ | Web and Flange thickness t | Encasement diameter A |
|---|---|---|---|---|
| HP 14x117 | 14 1/4" | 14 7/8" | 13/16" | 30" |
| x102 | 14" | 14 3/4" | 11/16" | 30" |
| x89 | 13 7/8" | 14 3/4" | 5/8" | 30" |
| x73 | 13 5/8" | 14 5/8" | 1/2" | 30" |
| HP 12x84 | 12 1/4" | 12 1/4" | 11/16" | 24" |
| x74 | 12 1/8" | 12 1/4" | 5/8" | 24" |
| x63 | 12" | 12 1/8" | 1/2" | 24" |
| x53 | 11 3/4" | 12" | 7/16" | 24" |
| HP 10x57 | 10" | 10 1/4" | 9/16" | 24" |
| x42 | 9 3/4" | 10 1/8" | 7/16" | 24" |
| HP 8x36 | 8" | 8 1/8" | 7/16" | 18" |

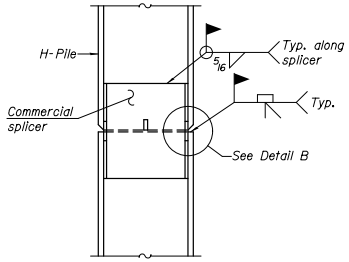



ELEVATION

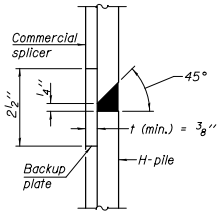



DETAIL A

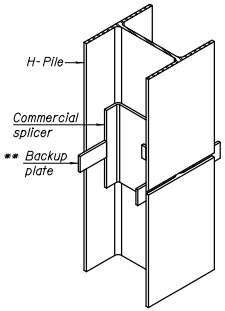
H-PILE SHOE ATTACHMENT




ELEVATION

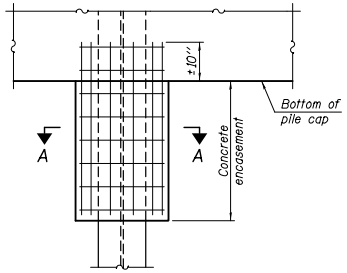



DETAIL "B"

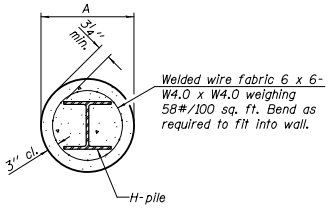



ISOMETRIC VIEW

WELDED COMMERCIAL SPLICE



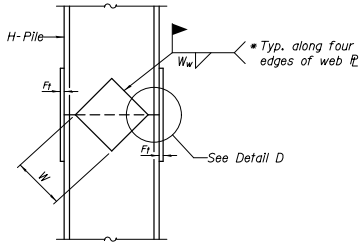

ELEVATION



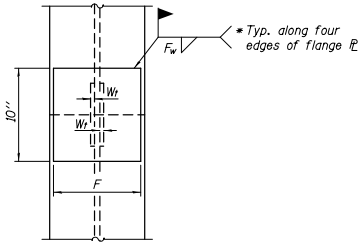

Note:
Forms for encasement may be omitted when soil conditions permit.

SECTION A-A

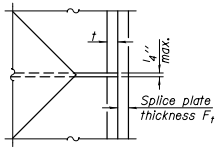
PILE ENCASEMENT




ELEVATION



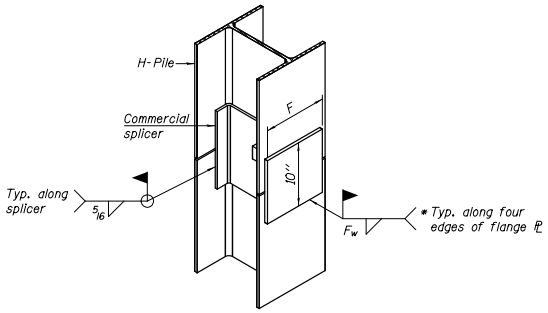

END VIEW




DETAIL D

| Designation | F | $F_t$ | $F_w$ | W | $W_t$ | $W_w$ |
|---|---|---|---|---|---|---|
| HP 14x117 | 12 1/2" | 1" | 7/8" | 7 3/4" | 5/8" | 1/2" |
| x102 | 12 1/2" | 7/8" | 3/4" | 7 3/4" | 5/8" | 1/2" |
| x89 | 12 1/2" | 3/4" | 11/16" | 7 3/4" | 5/8" | 1/2" |
| x73 | 12 1/2" | 5/8" | 9/16" | 7 3/4" | 5/8" | 1/2" |
| HP 12x84 | 10" | 7/8" | 11/16" | 6 1/2" | 5/8" | 1/2" |
| x74 | 10" | 7/8" | 11/16" | 6 1/2" | 5/8" | 1/2" |
| x63 | 10" | 5/8" | 1/2" | 6 1/2" | 1/2" | 1/2" |
| x53 | 10" | 5/8" | 1/2" | 6 1/2" | 1/2" | 1/2" |
| HP 10x57 | 8" | 3/4" | 9/16" | 5 1/4" | 1/2" | 1/2" |
| x42 | 8" | 5/8" | 9/16" | 5 1/4" | 1/2" | 1/2" |
| HP 8x36 | 7" | 5/8" | 7/16" | 4 1/4" | 1/2" | 1/2" |

WELDED PLATE FIELD SPLICE




ISOMETRIC VIEW

WELDED COMMERCIAL SPLICE ALTERNATE

* Interrupt welds 1/4" from end of web and/or each flange.

** Remove portions of backup plates that extend outside the flanges.

*** Weld size per pile shoe manufacturer (5/16" min.).

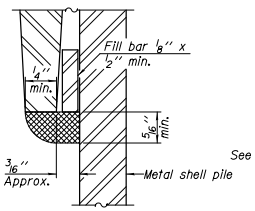
Note:
The steel H-piles shall be according to AASHTO M270 Grade 50.

F-HP 1-27-12

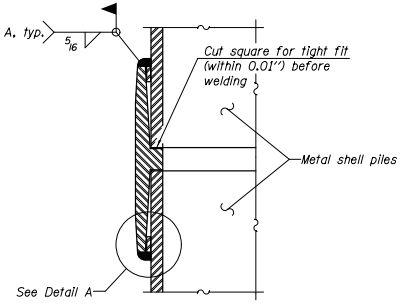
| FILE NAME = | USER NAME = | DESIGNED - | REVISED | STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION | HP PILE DETAILS STRUCTURE NO. | F.A. RTE. | SECTION | COUNTY | TOTAL SHEETS | SHEET NO. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CHECKED - | REVISED | | | | | | | |
| | PLOT SCALE = | DRAWN - | REVISED | | | | | CONTRACT NO. | | |
| | PLOT DATE = | CHECKED - | REVISED | | SHEET NO. OF SHEETS | | | ILLINOIS FED. AID PROJECT | | |

## METAL SHELL PILE TABLE

| Designation and outside diameter | Wall thickness t | Weight per foot (Lbs./ft.) | Inside volume (yd.³/ft.) |
|---|---|---|---|
| PP12 | 0.179″ | 22.60 | 0.0274 |
| PP12 | 0.250″ | 31.37 | 0.0267 |
| PP14 | 0.250″ | 36.71 | 0.0368 |
| PP14 | 0.312″ | 45.61 | 0.0361 |

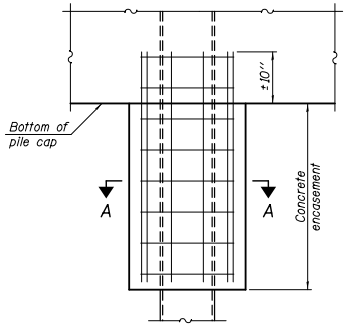



DETAIL A

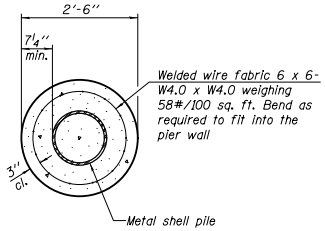



Notes:
The 1/8″ x 1/2″ min. fill bar may be constructed of 2 bars with a 1/8″ max. gap between them.
Pile segments shall be driven to solid contact with splicer before welding.

WELDED COMMERCIAL SPLICE



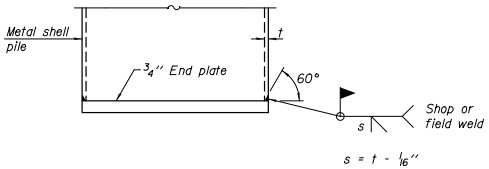

ELEVATION



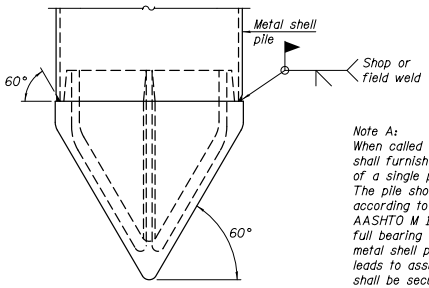

SECTION A-A

Note:
Forms for encasement may be omitted when soil conditions permit.

CONCRETE ENCASEMENT AT PIERS



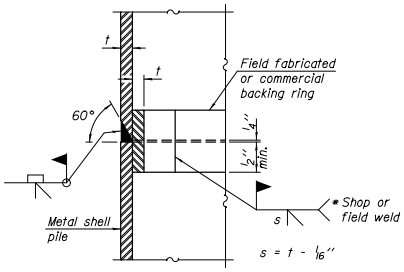

END PLATE ATTACHMENT




Note A:
When called for on the plans, the Contractor shall furnish metal shell pile shoes consisting of a single piece conical pile point as shown. The pile shoes shall be cast in one piece steel according to either ASTM A 148 Grade 90-60 or AASHTO M 103 Grade 65-35 and shall provide full bearing over the full circumference of the metal shell pile. The pile shoe shall have tapered leads to assure proper alignment and fitting and shall be secured to the pile with a circumferential weld.

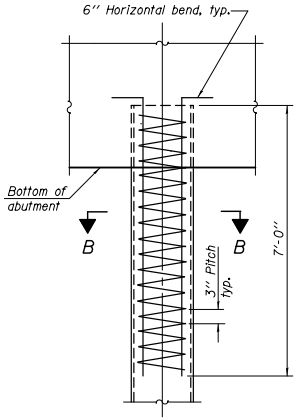
METAL SHELL PILE SHOE ATTACHMENT

(See Note A)

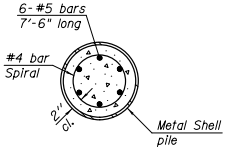



COMPLETE PENETRATION WELD SPLICE

* Field fabricated backing ring may be made from pile shell by removing segment to allow reducing circumference and vertically rejoin with partial joint penetration weld.




ELEVATION




SECTION B-B

METAL SHELL REINFORCEMENT AT ABUTMENTS

Note:
The metal shell piles shall be according to ASTM A 252 Grade 3.

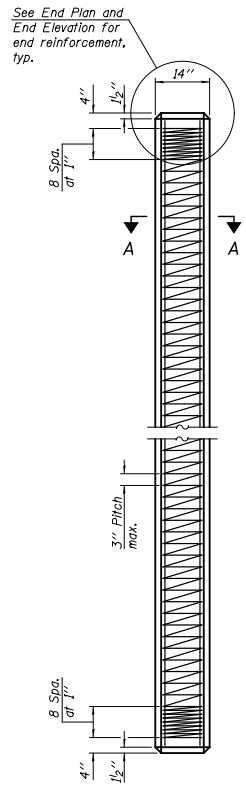
F-MS 1-27-12

| FILE NAME = | USER NAME = | DESIGNED - | REVISED |
|---|---|---|---|
| | | CHECKED - | REVISED |
| | PLOT SCALE = | DRAWN - | REVISED |
| | PLOT DATE = | CHECKED - | REVISED |

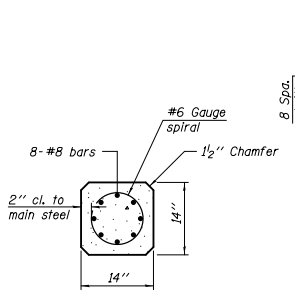
STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

METAL SHELL PILE DETAILS
STRUCTURE NO.
SHEET NO. OF SHEETS

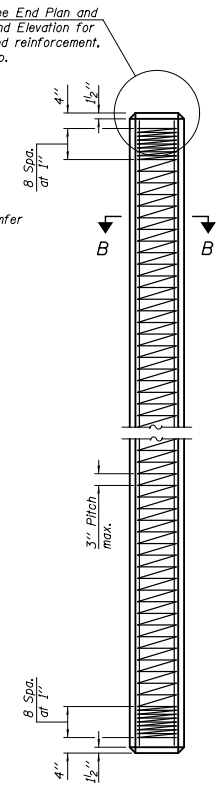
| F.A. RTE. | SECTION | COUNTY | TOTAL SHEETS | SHEET NO. |
|---|---|---|---|---|
| | | | | |
| | | CONTRACT NO. | | |
| | | ILLINOIS FED. AID PROJECT | | |



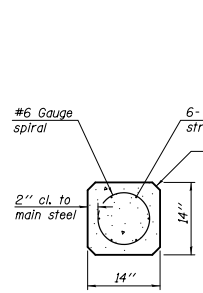

PRECAST CONCRETE PILE



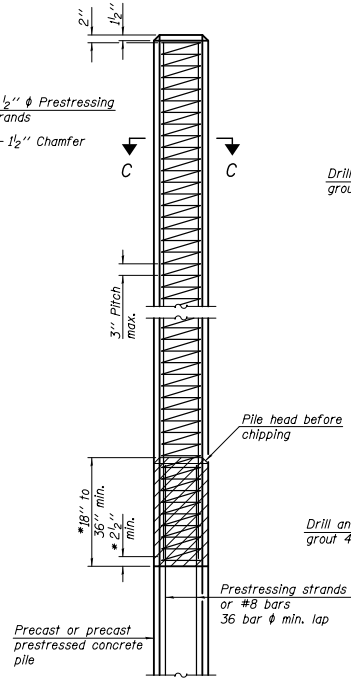

SECTION A-A



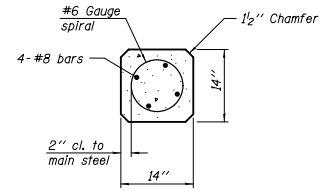

PRECAST PRESTRESSED CONCRETE PILE



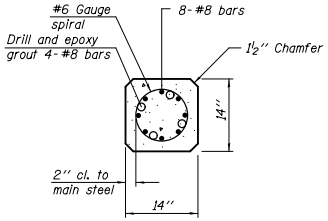

SECTION B-B



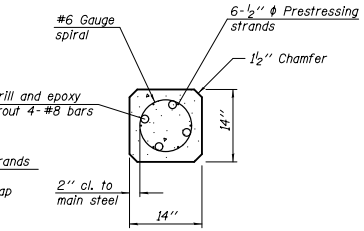

STANDARD PILE EXTENSION



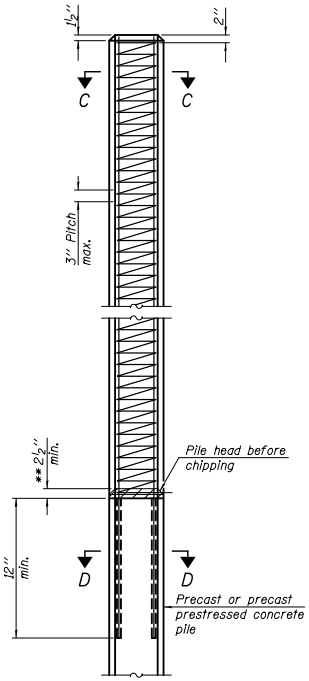

SECTION C-C




SECTION D-D
(Precast)



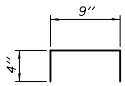

SECTION D-D
(Precast prestressed)




ALTERNATE PILE EXTENSION

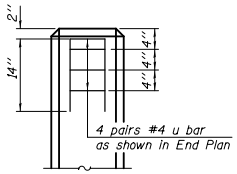
* To construct pile extension , chip top of pile back 36 bar ϕ min. to expose vertical bars and lap vertical buildup bars. Remove spiral to 2½'' min. above chipping and provide full strength lap weld exterior face (4'' min. length).

** To construct pile extension, chip top of pile back 2½'' to expose wire spiral and provide full strength lap weld exterior face (4'' min. length).




BAR u

END PLAN
(End reinforcement only)




END ELEVATION
(End reinforcement only)

## NOTES

Prestressing steel shall be uncoated high strength, low-relaxation 7-wire strand. The nominal diameter shall be ½'' with a cross-sectional area of 0.153 in².

For Pile lengths up to 65', use two slings placed at a distance of 0.21 L* from each end. For Piles longer than 65', use three slings placed at a distance of 0.12 L* from each end and at midpoint of pile. *L= Overall length of pile to be handled.

For handling pile lengths up to 45', use two slings placed at a distance of 0.21 L from each end. For handling piles longer than 45', use three slings placed at a distance of 0.12 L from each end and at midpoint of pile.

## DESIGN STRESSES

$f'_c$ = 5,000 p.s.i.(prestressed)
$f'_c$ = 4,500 p.s.i. (precast)
$f'_{ci}$ = 4,000 p.s.i.
$f'_s$ = 270,000 p.s.i. (41,300 lbs.-½'' ϕ)
$f_{si}$ = 189,000 p.s.i. (28,900 lbs.-½'' ϕ)

F-PC 7-1-10

| FILE NAME = | USER NAME = | DESIGNED - | REVISED |
|---|---|---|---|
| | | CHECKED - | REVISED |
| | PLOT SCALE = | DRAWN - | REVISED |
| | PLOT DATE = | CHECKED - | REVISED |

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

PRECAST PILE DETAILS
STRUCTURE NO.
SHEET NO. OF SHEETS

| F.A. RTE. | SECTION | COUNTY | TOTAL SHEETS | SHEET NO. |
|---|---|---|---|---|
| | | | | |
| | | CONTRACT NO. | | |
| | | ILLINOIS FED. AID PROJECT | | |

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# APPENDIX F

## Example A:
## Pile Bearing Table and Graph

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# WSDOT PILE BEARING TABLE AND GRAPH

I.D.O.T. BBS FOUNDATIONS AND GEOTECHNICAL UNIT

Modified on 7/12/09

**Production Pile - Nominal Required Bearing** 330 kips

Min. Required Hammer Energy (Production) **23100** ft-lbs

Max. Allowable Hammer Energy (Production): **46200** ft-lbs

**Test Pile - Nominal Requird Bearing**: **363** kips

Min. Recommended Hammer Energy (Test) **25410** ft-lbs

Max. Recommended Hammer Energy (Test): **50820** ft-lbs

**Batter Pile Slope:** 2 " horz. / 12" vert.

**Hammer Energy Reduction Coef. "U":** **0.970**

**Hammer Make & Model:** Delmag D22

**Type (Diesel, Air/steam, Drop):** Open-Ended Diesel Hammer and Steel Piles or Metal Shell Piles

**Minimum Visible Fall Height:** 3 ft.

**Max. Operating Fall Height:** 8 ft.

**Ram Weight:** 4850 lbs

Red values indicate not within Contract Requirements

Blue values indicate not within Hammer Operating Range

## Production Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 12125 | 14550 | 16975 | 19400 | 21825 | 24250 | 26675 | 29100 | 31525 | 33950 | 36375 | 38800 | 41225 | 43650 | 46075 | 48500 | 50925 | 53350 | 55775 |
| **Nb (blows/inch)** | *646.3* | *149.7* | *52.7* | *24.1* | *13.1* | *8.0* | *5.4* | *3.9* | *2.9* | *2.3* | *1.9* | *1.6* | *1.3* | *1.1* | *1.0* | *0.9* | *0.8* | *0.7* | *0.7* |
| ***1*** | 87 | 104 | 121 | 139 | 156 | 173 | 191 | 208 | 225 | 242 | 260 | 277 | 294 | 312 | 329 | 346 | 364 | 381 | 398 |
| ***2*** | 113 | 135 | 158 | 180 | 203 | 225 | 248 | 270 | 293 | 315 | **338** | **361** | **383** | **406** | **428** | 451 | 473 | 496 | 518 |
| ***3*** | 128 | 154 | 179 | 205 | 230 | 256 | 281 | 307 | **333** | **358** | **384** | **409** | **435** | **461** | **486** | 512 | 537 | 563 | 588 |
| ***4*** | 139 | 166 | 194 | 222 | 250 | 277 | 305 | **333** | **361** | **388** | **416** | **444** | **472** | **499** | **527** | 555 | 583 | 610 | 638 |
| ***5*** | 147 | 177 | 206 | 235 | 265 | 294 | 324 | **353** | **383** | **412** | **441** | **471** | **500** | **530** | **559** | 589 | 618 | 647 | 677 |
| ***6*** | 154 | 185 | 216 | 246 | 277 | 308 | **339** | **370** | **400** | **431** | **462** | **493** | **524** | **554** | **585** | 616 | 647 | 678 | 708 |
| ***7*** | 160 | 192 | 224 | 256 | 288 | 320 | **352** | **384** | **415** | **447** | **479** | **511** | **543** | **575** | **607** | 639 | 671 | 703 | 735 |
| ***8*** | 165 | 198 | 231 | 264 | 297 | 330 | **363** | **396** | **429** | **461** | **494** | **527** | **560** | **593** | **626** | 659 | 692 | 725 | 758 |
| ***9*** | 169 | 203 | 237 | 271 | 305 | **338** | **372** | **406** | **440** | **474** | **508** | **542** | **575** | **609** | **643** | 677 | 711 | 745 | 779 |
| ***10*** | 173 | 208 | 242 | 277 | 312 | **346** | **381** | **416** | **450** | **485** | **520** | **554** | **589** | **624** | **658** | 693 | 727 | 762 | 797 |
| *11* | 177 | 212 | 248 | 283 | 318 | 354 | 389 | 424 | 460 | 495 | 530 | 566 | 601 | 636 | 672 | 707 | 743 | 778 | 813 |

## Test Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 12125 | 14550 | 16975 | 19400 | 21825 | 24250 | 26675 | 29100 | 31525 | 33950 | 36375 | 38800 | 41225 | 43650 | 46075 | 48500 | 50925 | 53350 | 55775 |
| **Nb (blows/inch)** | *1554.1* | *311.1* | *98.6* | *41.7* | *21.3* | *12.5* | *8.0* | *5.6* | *4.1* | *3.1* | *2.5* | *2.0* | *1.7* | *1.5* | *1.3* | *1.1* | *1.0* | *0.9* | *0.8* |
| ***1*** | 87 | 104 | 121 | 139 | 156 | 173 | 191 | 208 | 225 | 242 | 260 | 277 | 294 | 312 | 329 | 346 | 364 | 381 | 398 |
| ***2*** | 113 | 135 | 158 | 180 | 203 | 225 | 248 | 270 | 293 | 315 | 338 | 361 | **383** | **406** | **428** | **451** | 473 | 496 | 518 |
| ***3*** | 128 | 154 | 179 | 205 | 230 | 256 | 281 | 307 | 333 | 358 | **384** | **409** | **435** | **461** | **486** | **512** | 537 | 563 | 588 |
| ***4*** | 139 | 166 | 194 | 222 | 250 | 277 | 305 | 333 | 361 | **388** | **416** | **444** | **472** | **499** | **527** | **555** | 583 | 610 | 638 |
| ***5*** | 147 | 177 | 206 | 235 | 265 | 294 | 324 | 353 | **383** | **412** | **441** | **471** | **500** | **530** | **559** | **589** | 618 | 647 | 677 |
| ***6*** | 154 | 185 | 216 | 246 | 277 | 308 | 339 | **370** | **400** | **431** | **462** | **493** | **524** | **554** | **585** | **616** | 647 | 678 | 708 |
| ***7*** | 160 | 192 | 224 | 256 | 288 | 320 | 352 | **384** | **415** | **447** | **479** | **511** | **543** | **575** | **607** | **639** | 671 | 703 | 735 |
| ***8*** | 165 | 198 | 231 | 264 | 297 | 330 | 363 | **396** | **429** | **461** | **494** | **527** | **560** | **593** | **626** | **659** | 692 | 725 | 758 |
| ***9*** | 169 | 203 | 237 | 271 | 305 | 338 | **372** | **406** | **440** | **474** | **508** | **542** | **575** | **609** | **643** | **677** | 711 | 745 | 779 |
| ***10*** | 173 | 208 | 242 | 277 | 312 | 346 | **381** | **416** | **450** | **485** | **520** | **554** | **589** | **624** | **658** | **693** | 727 | 762 | 797 |
| *11* | 177 | 212 | 248 | 283 | 318 | 354 | 389 | 424 | 460 | 495 | 530 | 566 | 601 | 636 | 672 | 707 | 743 | 778 | 813 |

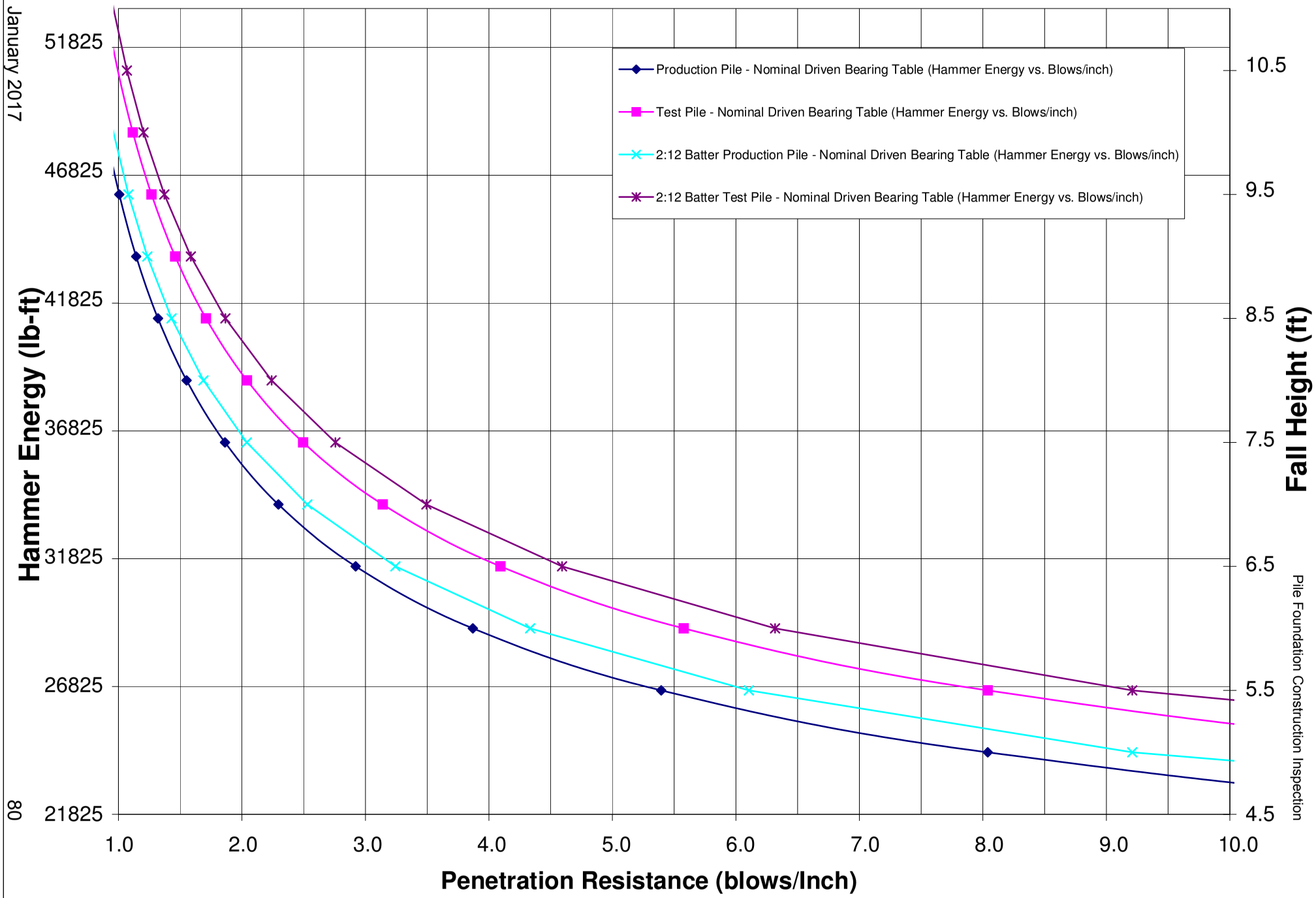
## 2:12 Batter Production Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 12125 | 14550 | 16975 | 19400 | 21825 | 24250 | 26675 | 29100 | 31525 | 33950 | 36375 | 38800 | 41225 | 43650 | 46075 | 48500 | 50925 | 53350 | 55775 |
| Energy x "U" | 11761 | 14113 | 16465 | 18817 | 21169 | 23521 | 25874 | 28226 | 30578 | 32930 | 35282 | 37634 | 39986 | 42338 | 44691 | 47043 | 49395 | 51747 | 54099 |
| **Nb (blows/inch)** | *848.1* | *187.8* | *64.0* | *28.5* | *15.2* | *9.2* | *6.1* | *4.3* | *3.2* | *2.5* | *2.0* | *1.7* | *1.4* | *1.2* | *1.1* | *1.0* | *0.9* | *0.8* | *0.7* |
| ***1*** | 84 | 101 | 118 | 134 | 151 | 168 | 185 | 202 | 218 | 235 | 252 | 269 | 286 | 302 | 319 | 336 | 353 | 370 | 386 |
| ***2*** | 109 | 131 | 153 | 175 | 197 | 219 | 240 | 262 | 284 | 306 | 328 | **350** | **372** | **393** | **415** | 437 | 459 | 481 | 503 |
| ***3*** | 124 | 149 | 174 | 199 | 223 | 248 | 273 | 298 | 323 | **347** | **372** | **397** | **422** | **447** | **472** | 496 | 521 | 546 | 571 |
| ***4*** | 135 | 161 | 188 | 215 | 242 | 269 | 296 | 323 | **350** | **377** | **404** | **431** | **458** | **484** | **511** | 538 | 565 | 592 | 619 |
| ***5*** | 143 | 171 | 200 | 228 | 257 | 285 | 314 | **343** | **371** | **400** | **428** | **457** | **485** | **514** | **542** | 571 | 599 | 628 | 656 |
| ***6*** | 149 | 179 | 209 | 239 | 269 | 299 | 329 | **358** | **388** | **418** | **448** | **478** | **508** | **538** | **568** | 597 | 627 | 657 | 687 |
| ***7*** | 155 | 186 | 217 | 248 | 279 | 310 | **341** | **372** | **403** | **434** | **465** | **496** | **527** | **558** | **589** | 620 | 651 | 682 | 713 |
| ***8*** | 160 | 192 | 224 | 256 | 288 | 320 | **352** | **384** | **416** | **448** | **480** | **512** | **544** | **576** | **607** | 639 | 671 | 703 | 735 |
| ***9*** | 164 | 197 | 230 | 263 | 295 | 328 | **361** | **394** | **427** | **460** | **492** | **525** | **558** | **591** | **624** | 657 | 689 | 722 | 755 |
| ***10*** | 168 | 202 | 235 | 269 | 302 | **336** | **370** | **403** | **437** | **470** | **504** | **538** | **571** | **605** | **638** | 672 | 706 | 739 | 773 |
| *11* | 171 | 206 | 240 | 274 | 309 | 343 | 377 | 412 | 446 | 480 | 514 | 549 | 583 | 617 | 652 | 686 | 720 | 755 | 789 |

## 2:12 Batter Test Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 12125 | 14550 | 16975 | 19400 | 21825 | 24250 | 26675 | 29100 | 31525 | 33950 | 36375 | 38800 | 41225 | 43650 | 46075 | 48500 | 50925 | 53350 | 55775 |
| Energy x "U" | 11761 | 14113 | 16465 | 18817 | 21169 | 23521 | 25874 | 28226 | 30578 | 32930 | 35282 | 37634 | 39986 | 42338 | 44691 | 47043 | 49395 | 51747 | 54099 |
| **Nb (blows/inch)** | *2095.6* | *399.1* | *122.1* | *50.2* | *25.2* | *14.5* | *9.2* | *6.3* | *4.6* | *3.5* | *2.8* | *2.2* | *1.9* | *1.6* | *1.4* | *1.2* | *1.1* | *1.0* | *0.9* |
| ***1*** | 84 | 101 | 118 | 134 | 151 | 168 | 185 | 202 | 218 | 235 | 252 | 269 | 286 | 302 | 319 | 336 | 353 | 370 | 386 |
| ***2*** | 109 | 131 | 153 | 175 | 197 | 219 | 240 | 262 | 284 | 306 | 328 | 350 | **372** | **393** | **415** | **437** | **459** | 481 | 503 |
| ***3*** | 124 | 149 | 174 | 199 | 223 | 248 | 273 | 298 | 323 | 347 | **372** | **397** | **422** | **447** | **472** | **496** | **521** | 546 | 571 |
| ***4*** | 135 | 161 | 188 | 215 | 242 | 269 | 296 | 323 | 350 | **377** | **404** | **431** | **458** | **484** | **511** | **538** | **565** | 592 | 619 |
| ***5*** | 143 | 171 | 200 | 228 | 257 | 285 | 314 | 343 | **371** | **400** | **428** | **457** | **485** | **514** | **542** | **571** | **599** | 628 | 656 |
| ***6*** | 149 | 179 | 209 | 239 | 269 | 299 | 329 | 358 | **388** | **418** | **448** | **478** | **508** | **538** | **568** | **597** | **627** | 657 | 687 |
| ***7*** | 155 | 186 | 217 | 248 | 279 | 310 | 341 | **372** | **403** | **434** | **465** | **496** | **527** | **558** | **589** | **620** | **651** | 682 | 713 |
| ***8*** | 160 | 192 | 224 | 256 | 288 | 320 | 352 | **384** | **416** | **448** | **480** | **512** | **544** | **576** | **607** | **639** | **671** | 703 | 735 |
| ***9*** | 164 | 197 | 230 | 263 | 295 | 328 | 361 | **394** | **427** | **460** | **492** | **525** | **558** | **591** | **624** | **657** | **689** | 722 | 755 |
| ***10*** | 168 | 202 | 235 | 269 | 302 | 336 | **370** | **403** | **437** | **470** | **504** | **538** | **571** | **605** | **638** | **672** | **706** | 739 | 773 |
| *11* | 171 | 206 | 240 | 274 | 309 | 343 | 377 | 412 | 446 | 480 | 514 | 549 | 583 | 617 | 652 | 686 | 720 | 755 | 789 |

# WSDOT Pile Inspectors Chart



# APPENDIX G

## Example B:
## Pile Bearing Table and Graph

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# WSDOT PILE BEARING TABLE AND GRAPH

I.D.O.T. BBS FOUNDATIONS AND GEOTECHNICAL UNIT

Modified on 7/12/09

**Production Pile - Nominal Required Bearing** 189 kips

Min. Required Hammer Energy (Production) **11306** ft-lbs

Max. Allowable Hammer Energy (Production): **22611** ft-lbs

**Test Pile - Nominal Requird Bearing**: **207.9** kips

Min. Recommended Hammer Energy (Test) **12436** ft-lbs

Max. Recommended Hammer Energy (Test): **24872** ft-lbs

**Batter Pile Slope:** 3 " horz. / 12" vert.

**Hammer Energy Reduction Coef. "U":** **0.946**

**Hammer Make & Model:** Vulcan #1

**Type (Diesel, Air/steam, Drop):** Air / Steam Hammer

**Action (Single or Double Acting):** Single

**Minimum Visible Fall Height**: 1.5 ft.

**Max. Operating Fall Height:** 3 ft.

**Ram Weight:** 5000 lbs

Red values indicate not within Contract Requirements

Blue values indicate not within Hammer Operating Range

## Production Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 6250 | 7500 | 8750 | 10000 | 11250 | 12500 | 13750 | 15000 | 16250 | 17500 | 18750 | 20000 | 21250 | 22500 | 23750 | 25000 | 26250 | 27500 | 28750 |
| **Nb (blows/inch)** | *414.9* | *103.5* | *38.4* | *18.2* | *10.2* | *6.4* | *4.4* | *3.2* | *2.5* | *2.0* | *1.6* | *1.4* | *1.2* | *1.0* | *0.9* | *0.8* | *0.7* | *0.7* | *0.6* |
| *1* | 52 | 63 | 73 | 84 | 94 | 104 | 115 | 125 | 136 | 146 | 157 | 167 | 178 | 188 | 199 | 209 | 219 | 230 | 240 |
| *2* | 68 | 82 | 95 | 109 | 122 | 136 | 150 | 163 | 177 | 190 | 204 | 217 | 231 | 245 | 258 | 272 | 285 | 299 | 313 |
| *3* | 77 | 93 | 108 | 123 | 139 | 154 | 170 | 185 | 201 | 216 | 231 | 247 | 262 | 278 | 293 | 309 | 324 | 340 | 355 |
| *4* | 84 | 100 | 117 | 134 | 151 | 167 | 184 | 201 | 218 | 234 | 251 | 268 | 285 | 301 | 318 | 335 | 352 | 368 | 385 |
| *5* | 89 | 107 | 124 | 142 | 160 | 178 | 195 | 213 | 231 | 249 | 266 | 284 | 302 | 320 | 337 | 355 | 373 | 391 | 408 |
| *6* | 93 | 111 | 130 | 149 | 167 | 186 | 204 | 223 | 242 | 260 | 279 | 297 | 316 | 334 | 353 | 372 | 390 | 409 | 427 |
| *7* | 96 | 116 | 135 | 154 | 173 | 193 | 212 | 231 | 251 | 270 | 289 | 308 | 328 | 347 | 366 | 386 | 405 | 424 | 443 |
| *8* | 99 | 119 | 139 | 159 | 179 | 199 | 219 | 239 | 258 | 278 | 298 | 318 | 338 | 358 | 378 | 398 | 418 | 437 | 457 |
| *9* | 102 | 123 | 143 | 163 | 184 | 204 | 225 | 245 | 265 | 286 | 306 | 327 | 347 | 368 | 388 | 408 | 429 | 449 | 470 |
| *10* | 104 | 125 | 146 | 167 | 188 | 209 | 230 | 251 | 272 | 293 | 313 | 334 | 355 | 376 | 397 | 418 | 439 | 460 | 481 |
| *11* | 107 | 128 | 149 | 171 | 192 | 213 | 235 | 256 | 277 | 299 | 320 | 341 | 363 | 384 | 405 | 427 | 448 | 469 | 491 |

## Test Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 6250 | 7500 | 8750 | 10000 | 11250 | 12500 | 13750 | 15000 | 16250 | 17500 | 18750 | 20000 | 21250 | 22500 | 23750 | 25000 | 26250 | 27500 | 28750 |
| **Nb (blows/inch)** | *954.4* | *207.2* | *69.6* | *30.7* | *16.3* | *9.8* | *6.4* | *4.6* | *3.4* | *2.6* | *2.1* | *1.8* | *1.5* | *1.3* | *1.1* | *1.0* | *0.9* | *0.8* | *0.7* |
| *1* | 52 | 63 | 73 | 84 | 94 | 104 | 115 | 125 | 136 | 146 | 157 | 167 | 178 | 188 | 199 | 209 | 219 | 230 | 240 |
| *2* | 68 | 82 | 95 | 109 | 122 | 136 | 150 | 163 | 177 | 190 | 204 | 217 | 231 | 245 | 258 | 272 | 285 | 299 | 313 |
| *3* | 77 | 93 | 108 | 123 | 139 | 154 | 170 | 185 | 201 | 216 | 231 | 247 | 262 | 278 | 293 | 309 | 324 | 340 | 355 |
| *4* | 84 | 100 | 117 | 134 | 151 | 167 | 184 | 201 | 218 | 234 | 251 | 268 | 285 | 301 | 318 | 335 | 352 | 368 | 385 |
| *5* | 89 | 107 | 124 | 142 | 160 | 178 | 195 | 213 | 231 | 249 | 266 | 284 | 302 | 320 | 337 | 355 | 373 | 391 | 408 |
| *6* | 93 | 111 | 130 | 149 | 167 | 186 | 204 | 223 | 242 | 260 | 279 | 297 | 316 | 334 | 353 | 372 | 390 | 409 | 427 |
| *7* | 96 | 116 | 135 | 154 | 173 | 193 | 212 | 231 | 251 | 270 | 289 | 308 | 328 | 347 | 366 | 386 | 405 | 424 | 443 |
| *8* | 99 | 119 | 139 | 159 | 179 | 199 | 219 | 239 | 258 | 278 | 298 | 318 | 338 | 358 | 378 | 398 | 418 | 437 | 457 |
| *9* | 102 | 123 | 143 | 163 | 184 | 204 | 225 | 245 | 265 | 286 | 306 | 327 | 347 | 368 | 388 | 408 | 429 | 449 | 470 |
| *10* | 104 | 125 | 146 | 167 | 188 | 209 | 230 | 251 | 272 | 293 | 313 | 334 | 355 | 376 | 397 | 418 | 439 | 460 | 481 |
| *11* | 107 | 128 | 149 | 171 | 192 | 213 | 235 | 256 | 277 | 299 | 320 | 341 | 363 | 384 | 405 | 427 | 448 | 469 | 491 |

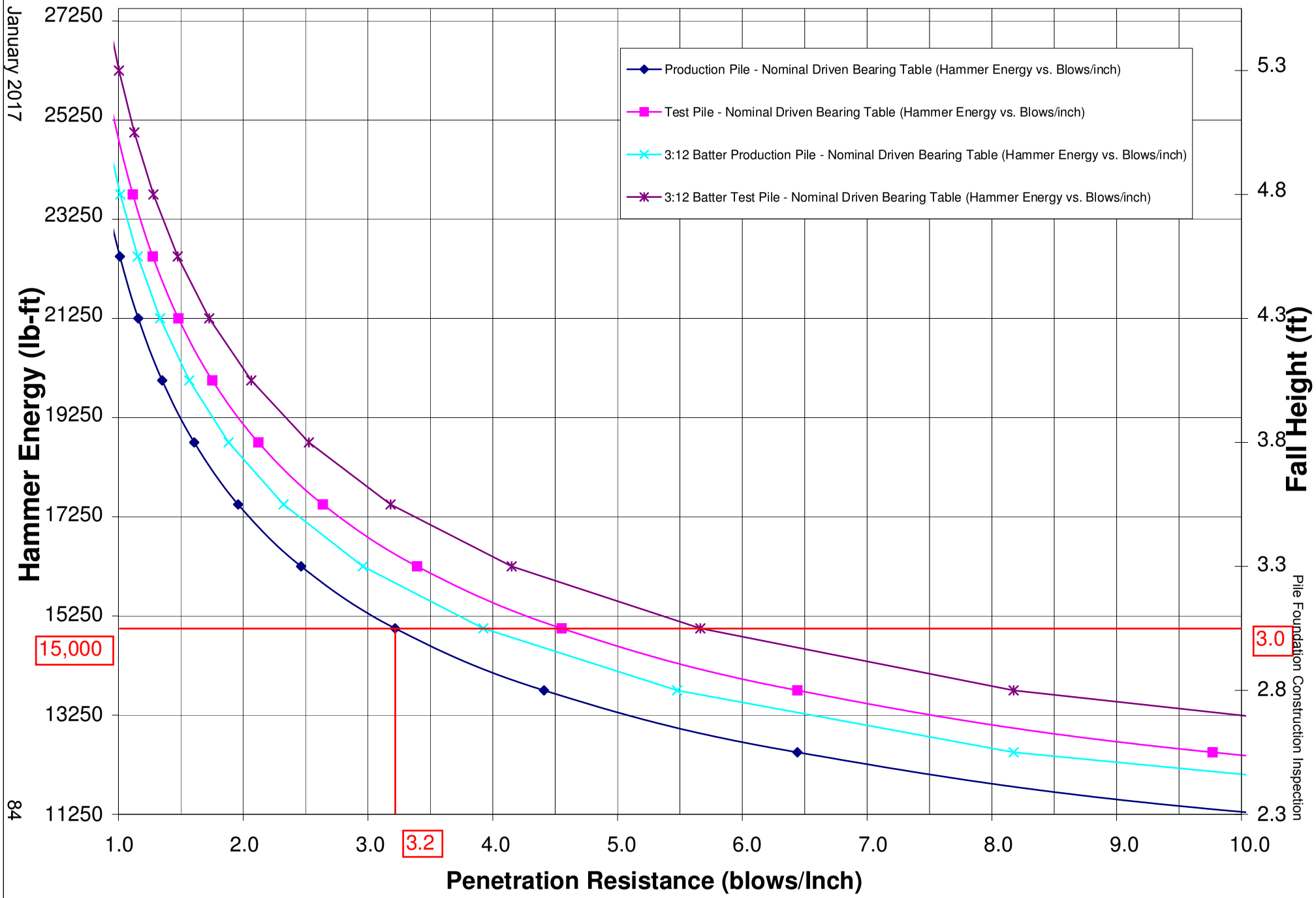
## 3:12 Batter Production Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 6250 | 7500 | 8750 | 10000 | 11250 | 12500 | 13750 | 15000 | 16250 | 17500 | 18750 | 20000 | 21250 | 22500 | 23750 | 25000 | 26250 | 27500 | 28750 |
| Energy x "U" | 5912 | 7094 | 8277 | 9459 | 10641 | 11824 | 13006 | 14188 | 15371 | 16553 | 17735 | 18918 | 20100 | 21283 | 22465 | 23647 | 24830 | 26012 | 27194 |
| **Nb (blows/inch)** | *668.2* | *154.0* | *54.0* | *24.6* | *13.3* | *8.2* | *5.5* | *3.9* | *3.0* | *2.3* | *1.9* | *1.6* | *1.3* | *1.2* | *1.0* | *0.9* | *0.8* | *0.7* | *0.7* |
| *1* | 49 | 59 | 69 | 79 | 89 | 99 | 109 | 119 | 128 | 138 | 148 | 158 | 168 | 178 | 188 | 198 | 208 | 217 | 227 |
| *2* | 64 | 77 | 90 | 103 | 116 | 129 | 141 | 154 | 167 | 180 | 193 | 206 | 219 | 231 | 244 | 257 | 270 | 283 | 296 |
| *3* | 73 | 88 | 102 | 117 | 131 | 146 | 161 | 175 | 190 | 204 | 219 | 234 | 248 | 263 | 277 | 292 | 307 | 321 | 336 |
| *4* | 79 | 95 | 111 | 127 | 142 | 158 | 174 | 190 | 206 | 222 | 237 | 253 | 269 | 285 | 301 | 317 | 332 | 348 | 364 |
| *5* | 84 | 101 | 118 | 134 | 151 | 168 | 185 | 201 | 218 | 235 | 252 | 269 | 285 | 302 | 319 | 336 | 353 | 369 | 386 |
| *6* | 88 | 105 | 123 | 141 | 158 | 176 | 193 | 211 | 228 | 246 | 264 | 281 | 299 | 316 | 334 | 351 | 369 | 387 | 404 |
| *7* | 91 | 109 | 128 | 146 | 164 | 182 | 201 | 219 | 237 | 255 | 274 | 292 | 310 | 328 | 346 | 365 | 383 | 401 | 419 |
| *8* | 94 | 113 | 132 | 150 | 169 | 188 | 207 | 226 | 244 | 263 | 282 | 301 | 320 | 339 | 357 | 376 | 395 | 414 | 433 |
| *9* | 97 | 116 | 135 | 155 | 174 | 193 | 212 | 232 | 251 | 270 | 290 | 309 | 328 | 348 | 367 | 386 | 406 | 425 | 444 |
| *10* | 99 | 119 | 138 | 158 | 178 | 198 | 217 | 237 | 257 | 277 | 296 | 316 | 336 | 356 | 376 | 395 | 415 | 435 | 455 |
| *11* | 101 | 121 | 141 | 161 | 182 | 202 | 222 | 242 | 262 | 282 | 303 | 323 | 343 | 363 | 383 | 403 | 424 | 444 | 464 |

## 3:12 Batter Test Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

| *Fall Height (ft.)* | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy (lbs-ft.) | 6250 | 7500 | 8750 | 10000 | 11250 | 12500 | 13750 | 15000 | 16250 | 17500 | 18750 | 20000 | 21250 | 22500 | 23750 | 25000 | 26250 | 27500 | 28750 |
| Energy x "U" | 5912 | 7094 | 8277 | 9459 | 10641 | 11824 | 13006 | 14188 | 15371 | 16553 | 17735 | 18918 | 20100 | 21283 | 22465 | 23647 | 24830 | 26012 | 27194 |
| **Nb (blows/inch)** | *1612.1* | *320.7* | *101.2* | *42.6* | *21.7* | *12.7* | *8.2* | *5.7* | *4.2* | *3.2* | *2.5* | *2.1* | *1.7* | *1.5* | *1.3* | *1.1* | *1.0* | *0.9* | *0.8* |
| *1* | 49 | 59 | 69 | 79 | 89 | 99 | 109 | 119 | 128 | 138 | 148 | 158 | 168 | 178 | 188 | 198 | 208 | 217 | 227 |
| *2* | 64 | 77 | 90 | 103 | 116 | 129 | 141 | 154 | 167 | 180 | 193 | 206 | 219 | 231 | 244 | 257 | 270 | 283 | 296 |
| *3* | 73 | 88 | 102 | 117 | 131 | 146 | 161 | 175 | 190 | 204 | 219 | 234 | 248 | 263 | 277 | 292 | 307 | 321 | 336 |
| *4* | 79 | 95 | 111 | 127 | 142 | 158 | 174 | 190 | 206 | 222 | 237 | 253 | 269 | 285 | 301 | 317 | 332 | 348 | 364 |
| *5* | 84 | 101 | 118 | 134 | 151 | 168 | 185 | 201 | 218 | 235 | 252 | 269 | 285 | 302 | 319 | 336 | 353 | 369 | 386 |
| *6* | 88 | 105 | 123 | 141 | 158 | 176 | 193 | 211 | 228 | 246 | 264 | 281 | 299 | 316 | 334 | 351 | 369 | 387 | 404 |
| *7* | 91 | 109 | 128 | 146 | 164 | 182 | 201 | 219 | 237 | 255 | 274 | 292 | 310 | 328 | 346 | 365 | 383 | 401 | 419 |
| *8* | 94 | 113 | 132 | 150 | 169 | 188 | 207 | 226 | 244 | 263 | 282 | 301 | 320 | 339 | 357 | 376 | 395 | 414 | 433 |
| *9* | 97 | 116 | 135 | 155 | 174 | 193 | 212 | 232 | 251 | 270 | 290 | 309 | 328 | 348 | 367 | 386 | 406 | 425 | 444 |
| *10* | 99 | 119 | 138 | 158 | 178 | 198 | 217 | 237 | 257 | 277 | 296 | 316 | 336 | 356 | 376 | 395 | 415 | 435 | 455 |
| *11* | 101 | 121 | 141 | 161 | 182 | 202 | 222 | 242 | 262 | 282 | 303 | 323 | 343 | 363 | 383 | 403 | 424 | 444 | 464 |

# WSDOT Pile Inspectors Chart



# APPENDIX H

## Class Problem Solutions

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## 7.5 Hammer Calculations: Class Problem #1 Solution

A Contractor proposes to use a Vulcan #010 single acting air/steam hammer with a drive head that weighs 895 lbs to install the following piling:

PILE DATA
Type: Metal Shell – 14 in. dia. w/ 0.25 in. walls
Nominal Required Bearing: 383 kips
Factored Resistance Available: 210 kips
Estimated Length: 65 ft

Determine:

1. *Is the hammer acceptable?*
2. *What is the blow count for the maximum hammer energy?*

Given: The unit weight of the piles is 36.7 lbs/ft.
The ram weight is 10,000 lbs and has a maximum fall height of 39 in.

For air/steam hammers, Inspectors need to verify that the striking parts of the hammer weigh more the 1.4 tons and more than 1/3 of the combined weight of the pile and drive head.

The ram for a Vulcan #010 hammer weighs 10,000 lbs which is greater than 1.4 tons. Calculate the combined weight of the pile and drive head.

Drive Head Wt. + Pile Wt. = 895 lbs + (36.7 lbs/ft)(65 ft) = 3,281 lbs

$$\frac{3{,}281\,\text{lbs}}{3} = 1{,}094\,\text{lbs} < 10{,}000\,\text{lbs}$$

Therefore, the hammer satisfies both weight requirements.

For determining $R_{NDB}$, the maximum developed energy is taken as the ram weight times the fall height:

Hammer $E_{max}$ = W x H = 10,000 lbs x 3.25 ft = 32,500 ft-lbs

The minimum required and maximum allowed hammer energy for the pile is:

| Minimum Required Energy | Maximum Allowable Energy |
|---|---|
| $E \geq 32.90 \times R_N \div F_{eff}$ | $E \leq 65.80 \times R_N \div F_{eff}$ |
| $\geq 32.90 \times 383 \div 0.55 = 22{,}910$ ft-lbs | $\leq 65.8 \times 383 \div 0.55 = 45{,}820$ ft-lbs |
| Hammer $E_{max}$ = 32,500 > 22,910 O.K. | Hammer $E_{max}$ = 32,500 < 45,820 O.K. |

The hammer is capable of driving the pile to the $R_{NDB}$ with a rate of penetration between 1 and 10 blows per inch if operated at its anticipated energy.

Determine the required $N_b$ to achieve $R_{NDB}$ at a ram fall height of 3.25 ft.

$$N_b = \frac{e^{\left[\frac{1000 \times 383}{6.6 \times 0.55 \times 32{,}500}\right]}}{10} = \frac{2.6\,\text{blows}}{\text{in.}}$$

## 7.6 Hammer Calculations: Class Problem #2 Solution

A Contractor proposes to use a Delmag D-36 single acting diesel hammer to install the following piling with an anticipated ram fall height of 5 ft:

PILE DATA
Type: HP 12 X 53
Nominal Required Bearing: 418 kips
Factored Resistance Available: 230 kips
Estimated Length: 60 ft

Determine:

1. *Is the hammer acceptable?*
2. *What is the blow count for the anticipated fall height of 5 ft?*

Given: The ram weight is 7,940 lbs and has a fall height range of 4.5 to 9 ft.

There are no requirements to be considered for single acting diesel hammers besides the minimum and maximum energy requirements.

For determining $R_{NDB}$, the maximum developed energy is taken as the ram weight times the fall height:

Hammer $E_{max}$ = W x H = 7,940 lbs x 9.0 ft ≈ 71,460 ft-lbs

The minimum required and maximum allowed hammer energy for the pile is:

Minimum Required Energy

$E \geq 32.90 \times R_N \div F_{eff}$
$\geq 32.90 \times 418 \div 0.47 = 29{,}260$ ft-lbs

Hammer $E_{max}$ = 71,460 > 29,260 O.K.

Maximum Allowable Energy

$E \leq 65.80 \times R_N \div F_{eff}$
$\leq 65.8 \times 418 \div 0.47 = 58{,}520$ ft-lbs

Hammer $E_{max}$ = 71,460 > 58,520 **N.G.**

The hammer is capable of driving the pile to the $R_{NDB}$ with a rate of penetration between 1 and 10 blows per inch but the ram fall height must be limited to restrict the maximum hammer energy.

Calculate the maximum allowable fall height of the ram.

Given that E = W x H,
$H = E_{max\,allow} \div W$ = 58,520 ft-lbs ÷ 7,940 lbs = 7.4 ft

Therefore, the maximum fall height of the ram must not exceed 7.4 ft.

Determine the required $N_b$ to achieve $R_{NDB}$ at the Contractor's anticipated ram fall height of 5 ft.

E = 7,940 lbs x 5 ft = 39,700 ft-lbs

$$N_b = \frac{e^{\left[\frac{1000 \times 418}{6.6 \times 0.47 \times 39{,}700}\right]}}{10} = \frac{3.0\,\text{blows}}{\text{in.}}$$

## 15.3 Determining Pile Pay Lengths: Class Problem #3 Solution

Determine the pile pay lengths for furnishing piles and driving piles and fill in the table below. In addition, determine which splices are paid for via force account.

Given:
Estimated Plan length = 50'
There is a vertical clearance restriction at one location as noted
All piles will be end bearing on bedrock

| Authorized Furnished Length (by Letter) | Delivered Length* | Added Splice Length | Cut Off Length | Pay Length | |
|---|---|---|---|---|---|
| | | | | Furnish | Drive |
| 50 | 50 | - | 3 | 50 | 47 |
| 50 | 55 | - | 3 | 52 | 52 |
| 50 | 45[4] | - | 3 | 45 | 42 |
| 50 | 55 | - | 10 | 50 | 45 |
| 50 | 50 | 10[1] | 2 | 50 | 58 |
| | | | | + 1 FRC Splice | |
| 50 | 50 | 10[2] | 2 | 60 | 58 |
| | | | | + 1 FRC Splice | |
| 50[3] | 2@25 | - | 1 | 50 | 49 |
| | | | | Planned Splice: No Pay | |

* As Measured in the field.

1. State furnished splice length.
2. Contractor furnished splice length.
3. Overhead power lines restrict equipment height to 40'
4. The Engineer allowed the use of a 45' pile with the stipulation the pile would be extracted and replaced with a longer (end bearing) pile if 45' is too short.

## 15.4 Determining Pile Pay Lengths: Class Problem #4 Solution

Determine the pile pay lengths for furnishing piles and driving piles and fill in the table below.
Given:
Estimated Plan length = 70'
Contractor's equipment capable of driving a 50' segment

| Authorized Furnished Length (by Letter) | Delivered Length* | Added Splice Length | Cut Off Length | Pay Length | |
|---|---|---|---|---|---|
| | | | | Furnish | Drive |
| 70 | 2@40[A] | - | 20 | 70 | 60 |
| 110 | 3@40[B] | 10[1,C] | 5 | 120 | 125 |
| | | | | + 2 FRC Splices | |
| 100 | 2@50[D] | - | 1 | 100 | 99 |
| | | | Total | 290 | 284 |

* As Measured in the field.

1. State furnished splice length.

Splice Issues:

A. This is a planned splice. Thus no payment for the splice

B. Two splices are required because there are three segments. The contractor anticipated one splice (note the estimated plan length was 70'). Thus, there is one "additional" splice not anticipated at the time of bidding. Thus pay for the one "additional" splice (but not the planned splice).

C. An unplanned splice was required to add this additional 10 ft. segment. Thus pay for one unplanned splice.

D. This is a planned splice. Thus no payment for the splice

# APPENDIX I

## Example Piling Forms

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Illinois Department of Transportation

## Test Pile Driving Record

Structure Number 016-2861 Date Driving Started 6/21/2007 Date Completed 6/22/2007 Sheet 1 of 1
Abutment/Pier No. East Abut. (Stage 1) Calculated by RMW Route FAP 343
Pile Type & Size Metal Shell 12" dia w/.179" walls Checked by WMK Section 70D-Y-B-R & 70HB-R-1
Nominal Required Bearing 372 kips Estimated Plan Length 69 ft. County COOK
Pile Cutoff Elevation 873.77 ft. Authorized Furnished Length 78 ft. Contract 62897
Ground Surface Elev. At Pile While Driving 840.23 ft.* Closest Boring(s) B-1 & sb-5 Driven Bearing Verification Gates
Hammer Make & Model Delmag D30-32 Hammer Cushion Material & Thickness Conbest , 2" thick
Max. Operating Energy 55,898 ft.-lbs. Min. Operating Energy 25,383 ft.-lbs. Pile Helmet Weight 4250 lbs.

| Tip Elevation (Feet) | Distance Below Cut Off | Blows Per (Inch) | Hammer Energy Developed | Nominal Driven Bearing | Tip Elevation (Feet) | Distance Below Cut Off | Blows Per (Inch) | Hammer Energy Developed | Nominal Driven Bearing |
|---|---|---|---|---|---|---|---|---|---|
| 840.23 | 31.54 | | | | 811.23 | 61.54 | 1.1 | 36400 | 248 |
| 839.23 | 32.54 | | | | 810.23 | 62.54 | 1.1 | 34125 | 237 |
| 838.23 | 33.54 | | | | 809.23 | 63.54 | 1.0 | 31850 | 212 |
| 837.23 | 34.54 | | | | 808.23 | 64.54 | 0.9 | 36400 | 219 |
| 836.23 | 35.54 | | | | 807.23 | 65.54 | 1.1 | 36400 | 248 |
| 835.23 | 36.54 | | | | 806.23 | 66.54 | 1.2 | 40650 | 282 |
| 834.23 | 37.54 | <0.5 | <25383 | | 805.23 | 67.54 | 1.1 | 38675 | 258 |
| 833.23 | 38.54 | <0.5 | <25383 | | 804.23 | 68.54 | 1.3 | 40950 | 294 |
| 832.23 | 39.54 | <0.5 | <25383 | | 803.23 | 69.54 | 1.3 | 40950 | 294 |
| 831.23 | 40.54 | <0.5 | <25383 | | 802.23 | 70.54 | 1.3 | 47775 | 326 |
| 830.23 | 41.54 | <0.5 | <25383 | | 801.23 | 71.54 | 1.5 | 45500 | 339 |
| 829.23 | 42.54 | <0.5 | <25383 | | 800.23 | 72.54 | 2.5 | 45500 | 422 |
| 828.23 | 43.54 | <0.5 | <25383 | | 799.23 | 73.54 | 2.2 | 47775 | 413 |
| 827.23 | 44.54 | <0.5 | <25383 | | 798.23 | 75.54 | 2.5 | 43225 | 409 |
| 826.23 | 45.54 | 0.5 | 27300 | 102 | 797.23 | 76.54 | 2.5 | 43225 | 409 |
| 825.23 | 46.54 | 0.5 | 27300 | 102 | 796.23 | 77.54 | 2.5 | 45500 | 422 |
| 824.23 | 47.54 | 0.5 | 31850 | 118 | | | | | |
| 823.23 | 48.54 | 0.7 | 27300 | 144 | | | | | |
| 822.23 | 49.54 | 0.7 | 27300 | 144 | | | | | |
| 821.23 | 50.54 | 0.7 | 27300 | 144 | | | | | |
| 820.23 | 51.54 | 0.6 | 27300 | 125 | | | | | |
| 819.23 | 52.54 | 0.6 | 31850 | 143 | | | | | |
| 818.23 | 53.54 | 0.8 | 29575 | 172 | | | | | |
| 817.23 | 55.54 | 1 | 29575 | 201 | | | | | |
| 816.23 | 56.54 | 1 | 27300 | 189 | | | | | |
| 815.23 | 57.54 | 0.5 | 31850 | 118 | | | | | |
| 814.23 | 58.54 | 0.5 | 31850 | 118 | | | | | |
| 813.23 | 59.54 | 0.5 | 34125 | 126 | | | | | |
| 812.23 | 60.54 | 0.8 | 34125 | 192 | | | | | |

Driving Observations and Comments: Hammer would not fire until 835.23, Could not Read Energy until elevation 825.23

*reflects being driven from bottom of plan specified precored hole elevation

min. test pile driven bearing = 372kips X 1.10 = 409 kips

First consistant Bearing around 73 ft —— order ~ 78ft. since boring st-5 shows stiffer soil at deeper elevation.

cc: Bureau of Bridges and Structures

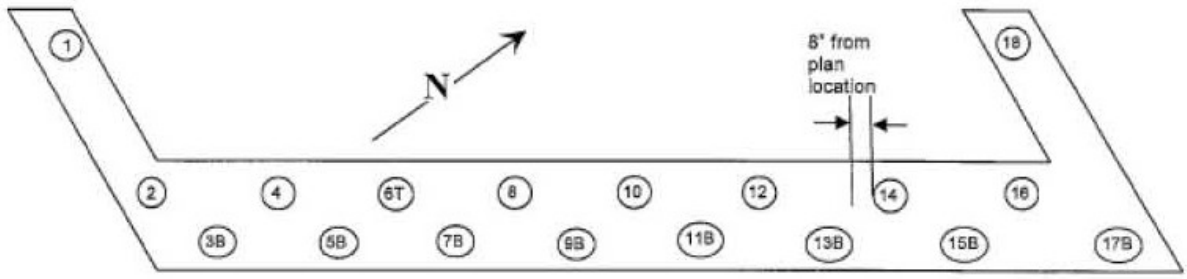
BBS 757 (Rev. 11/07)
(formerly BC 757)

Illinois Department of Transportation

## Production Pile Driving Data

Structure Number 016-2861 Date Driving Started 10/19/2007 Date Completed 10/22/2007 Sheet 1 of 1
Abutment/Pier No. East Abut. (Stage 1) Calculated by RMW Route FAP 343
Pile Type & Size Metal Shell 12" dia w/.179" walls Checked by WMK Section 70D-Y-B-R & 70HB-R-1
Nominal Required Bearing 372 kips Estimated Plan Length 69 ft. County COOK
Pile Cutoff Elevation 873.77 ft. Authorized Furnished Length 78 ft. Contract 62897
Ground Surface Elev. At Pile While Driving 840.23 ft.* Closest Boring(s) B-1 & sb-5 Driven Bearing Verification Gates
Hammer Make & Model Delmag D30-32 Hammer Cushion Material & Thickness Conbest , 2" thick
Max. Operating Energy 55,898 ft.-lbs. Min. Operating Energy 25,383 ft.-lbs. Pile Helmet Weight 4250 lbs.

As driven pile layout sketch with piles numbered, north arrow included, and any significant deviations from plan locations noted




Indicate (B) at battered piles and (T) at test piles

| Pile No. | Delivered Length (Feet) | Added Splice Length | Final Cutoff Length | Paid Driven Length | Paid Furnished Length | Blows Per (Inch) | Hammer Energy Developed | Nominal Driven Bearing | Driving Observations & Comments |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 81.8 | 0 | 3 | 78.8 | 78.8 | 2 | 43225 | 373 | 82 ft piles delevered as two 41 ft. sections |
| 2 | 81.8 | 0 | 10.5 | 71.3 | 78 | 2.5 | 38675 | 381 | |
| 3B | 82 | 0 | 5 | 77 | 78 | 3 | 34125 | 378 | |
| 4 | 82 | 0 | 4 | 78 | 78 | 2 | 43225 | 373 | Bend in Pile 4 occurred 10' prior to bearing. |
| 5B | 82 | 0 | 5 | 80 | 80 | 2.4 | 38675 | 375 | cut out bend and re-splied pile per BBS |
| 6T | ----- | ----- | ------ | ---- | ------ | 2.5 | 45500 | 422 | Test pile driven on 6/22/07 |
| 7B | 82.1 | 0 | 6 | 76.1 | 78 | 3.1 | 36400 | 398 | |
| 8 | 82.1 | 0 | 6 | 76.1 | 78 | 3.5 | 36400 | 416 | |
| 9B | 82.2 | 0 | 5 | 77.2 | 78 | 4 | 36400 | 435 | |
| 10 | 78 | 0 | 1 | 76.6 | 78 | 2.5 | 38675 | 381 | 78 ft. long piles were composed of 20+38+20 |
| 11B | 78.1 | 0 | 1.5 | 76.1 | 78 | 2 | 43225 | 373 | |
| 12 | 78.1 | 0 | 2 | 76.1 | 78 | 2.4 | 38675 | 375 | |
| 13B | 78.1 | 10.5** | 6 | 82.6 | 78 | 3 | 34125 | 378 | |
| 14 | 78.2 | 5** | 1.5 | 81.7 | 78 | 2.5 | 38675 | 381 | Pile hit something at 12' below precore and |
| 15B | 78 | 10 | 5.8 | 82.2 | 88 | 3.5 | 34125 | 399 | moved out of 6" tolerence (ok per BBS) |
| 16 | 78.1 | 10 | 5.8 | 82.2 | 88 | 3 | 36400 | 393 | |
| 17B | 78.1 | 10 | 5.9 | 82.1 | 88 | 3.1 | 34125 | 382 | |
| 18 | 78.1 | 10 | 5.2 | 82.9 | 88 | 3.4 | 31850 | 378 | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | *elevation reflects +/- 30ft. precore specified |
| | | | | | | | | | **Not paid as furnished since obtained from Cut |
| | | | | | | | | | off sections from piles 2 and 3B |

cc: Bureau of Bridges and Structures

BBS 2184 (Rev. 11/07)
(formerly BC 2184)

# APPENDIX J

# Example Authorization Letter to Furnish Pile Lengths

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(Example: Letter Notifying Contractor of Lengths)

February 26, 2007

County
Section
Route
Contract No.

Don Doe, Superintendent
ACME Construction
1200 North Easy Street
Anyplace, IL

Dear Mr. Doe:

As specified in Article 512.16 of the Standard Specifications for Road and Bridge Construction, you are hereby being provided this itemized list of authorized lengths of metal pile shells to furnish for the structure for the above route and section.

It has been determined from the test piles driven on February 19, 2007 that the following lengths should be furnished:

| | | | |
|---|---|---|---|
| E Abut | 23 pile @ 24' | = | 552 lin. ft. |
| Pier 1 | 32 pile @ 30' | = | 960 lin. ft. |
| W Abut | 23 pile @ 36' | = | 828 lin. ft. |

Very Truly Yours,

John Smith

John Smith
District Engineer

Note:
Final documentation for FURNISHING PILES consists of a copy of the itemized list which was given to the Contractor and field measurements of the delivered piling.

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# APPENDIX K

## Example Welder Certification

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**AWS Certified Welder**
**Welders, Brazers and Operators**

John Doe
Cert # xxxxxxx SSN # xxx-xx-xxxx

1-800-443-9353
Information relating to identification and certification of the bearer of this card may be verified by calling or writing:
CERTIFICATION DEPARTMENT OF THE AMERICAN WELDING SOCIETY
550 N.W. LeJune Road, Miami, FL 33126

SAMPLE CARD ONLY

**AMERICAN WELDING SOCIETY**

VALID ONLY IF ACCOMPANIED BY PHOTO ID

This Card is the property of AWS and shall be returned on demand

John Doe

| # | Test Date | Sup | Code | Process | Gas | Filler Metal | Base Metal | Position | Thickness | Expires |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 00/00/00 | G | D1.1 | SMAW | N/A | F4 | P1 | ALL | LIMITED | 00/00/00 |
| 2 | 00/00/00 | G | B1.2 | GT/SM | ARGON | F6/F4 | P1 | ALL | LIMITED | 00/00/00 |

SAMPLE CARD ONLY

**Back Side of Card**

Verify Cert. #: www.aws.org/certification/cw_search.html

**GUIDE TO INTERPRETING ABBREVIATIONS ON AWS CERTIFIED WELDER CARD**

**EXAMPLE**

| Supplement | Code | Process | Gas | Filler Metal | Base Metal | Position Qualified | Thickness Range |
|---|---|---|---|---|---|---|---|
| G | D1.1 | GTAW | AR/CO2 | E71T-1 | A106 | 6G | Unlimited |

AWS SUPPLEMENTS

| | |
|---|---|
| C | Sheet Metal Welding (AWS D9.1) |
| F | Chemical Plant and Petroleum Piping (ASME B31.3 and Sec. IX) |
| G | Generic Supplement (Company-furnished WPS and acceptance criteria) |

CODES: *(For Supplement G only, reference appropriate acceptance criteria.)*

| | |
|---|---|
| B2.1 | AWS B2.1, *Standard for Welding Procedure and Performance Qualificatio* |
| D1.1 | AWS D1.1, *Structural Welding Code - Steel* |
| D1.2 | AWS D1. 2, *Structural Welding Code - Aluminum* |
| D9.1 | AWS D9.1, *Sheet Metal Welding Code* |
| ASME IX | ASME Section IX, *Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators* |
| D15.1 | AWS D15.1, *Railroad Welding Specification - Cars and Locomotives* |
| API | API 1104, *Welding of Pipelines and Related Facilities* |
| CUST | *Other customer may be used as indicated on the employer supplied WPS* |

**Other standards may be used as indicated on the employer supplied WPS*

PROCESSES:

| | |
|---|---|
| SMAW | Shielded Metal Arc Welding (SMAW) |
| GMAW | Gas Metal Arc Welding (GMAW) |
| GMAW-S | Gas Metal Arc Welding - Short Circuit |
| FCAW | Flux Cored Arc Welding (FCAW) |
| GTAW | Gas Tungsten Arc Welding (GTAW) |
| SAW | Submerged Arc Welding (SAW) |
| BZ | Brazing |

GAS:

| | |
|---|---|
| AR | Argon |
| HE | Helium |
| $Ar/CO_2$ | Argon/Carbon Dioxide |
| $CO_2$ | Carbon Dioxide |

FILLER METAL *(AWS CLASSIFICATION NUMBER)*
ER309-L
E7018-A1L
ER70S-2
E71T-1

BASE METAL

| | |
|---|---|
| AXXX | ASTM Designations (i.e., A36) |
| M | Material Numbers from B2 |
| SAXXX | (SA106, SA105, SA304L, etc.) |
| PX | (P1, P8, P44, etc.) |

POSITION

| | |
|---|---|
| 1G | Groove Weld, Flat |
| 2G | Groove Weld, Horizontal |
| 3G | Groove Weld, Vertical |
| 4G | Groove Weld, Overhead |
| 5G | Groove Weld, (Pipe) Vertical |
| 6G | Groove Weld, (Pipe) 45° Vertical |
| 1F | Fillet Weld, Flat |
| 2F | Fillet Weld, Horizontal |
| 3F | Fillet Weld, Vertical |
| 4F | Fillet Weld, Overhead |
| V | Vertical Progression Up |
| D | Vertical Progression Down |
| A | All |

THICKNESS

| | |
|---|---|
| U | Unlimited (1/8" to Unlimited) |
| L | Limited |
| xx-xx | Range in sheet gauges (ex., 11 -18) |
| x/x | Thickness in fractions of an inch (ex:., 3/8") |
| SCH | Schedule listing for pipe thickness (ex:Sch 40) |
| WB | With backing |
| WOB | Without backing |

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