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

INSTRUCTORS:

Mike Copp (217) 782-4879 Michael.Copp@illinois.gov

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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

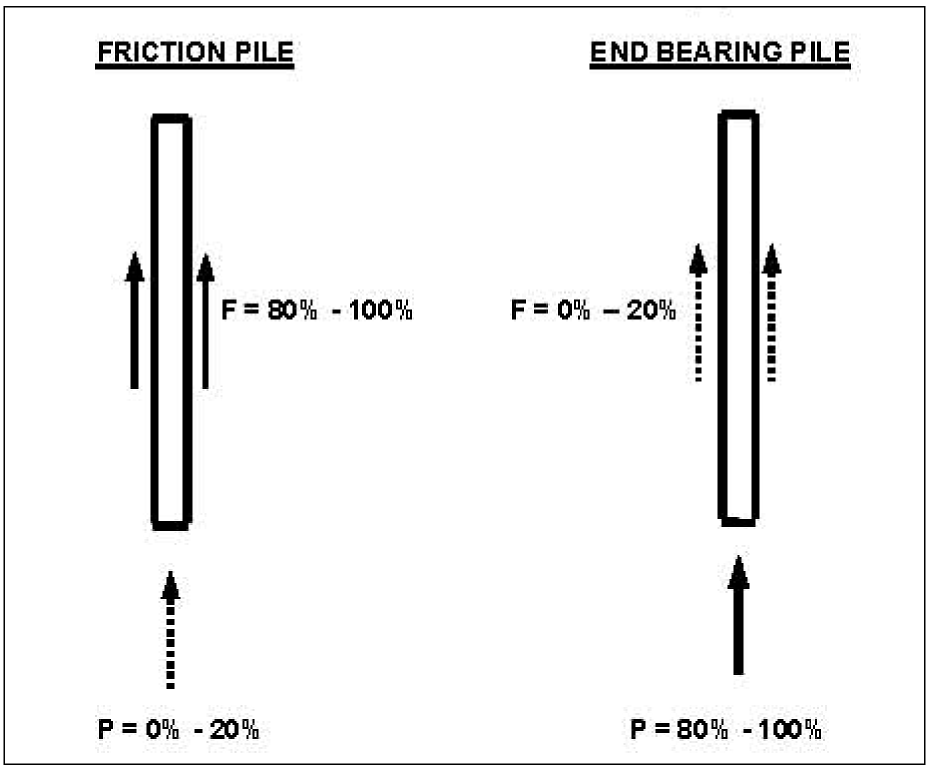
Design engineers classify piles according to their Structural Pile Type to reference the structural element to be used for the piles and according to their Geotechnical Pile Type to define a pile's primary mechanism for developing the required bearing. IDOT uses piles to provide foundation support for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

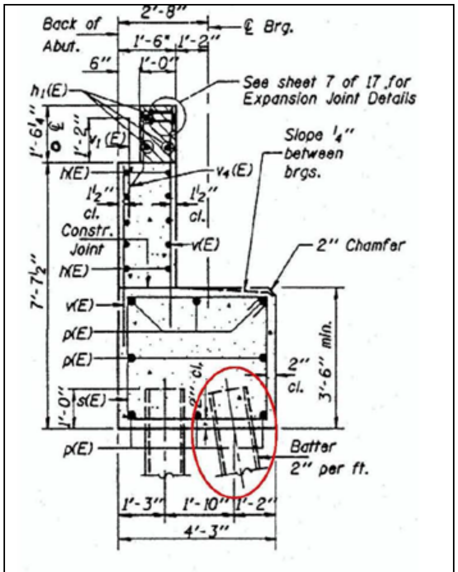
2.3 Pile Uses

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):

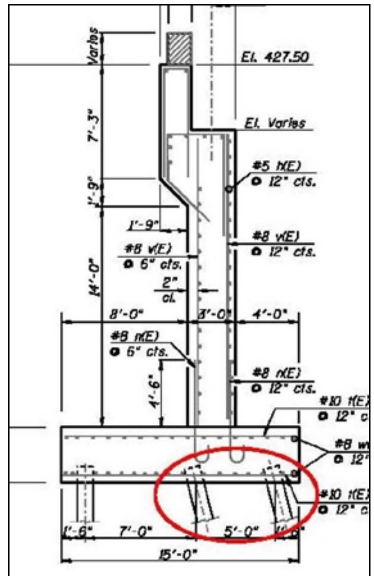
- Rather short in height
- Front row of piles are battered
- Allows superstructure movement



SECTION THRU ABUT.
(at Right Angles)

Closed Abutments:

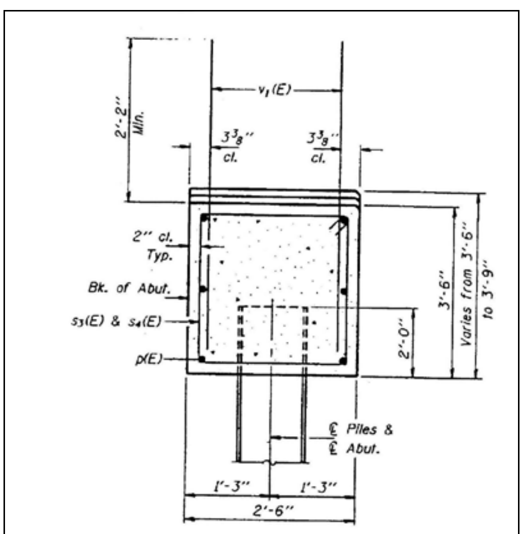
- Rather tall in height
- Combination retaining wall/abutment
- Concrete stem on pile supported footing
- Front row of piles battered at a minimum
- Allows superstructure movement



SECTION A-A

Integral Abutments:

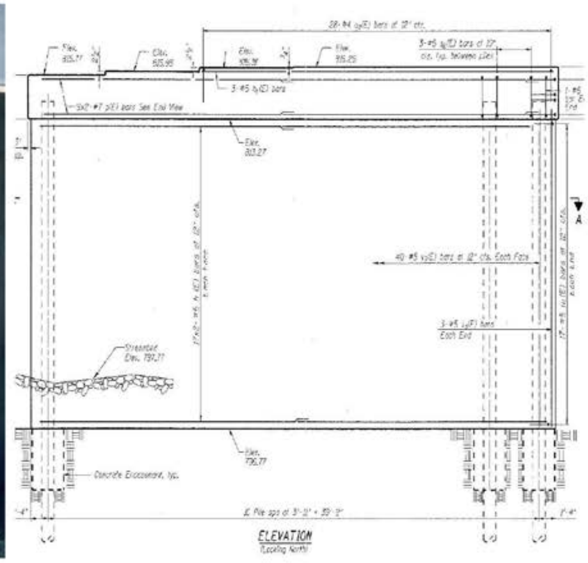
- Also short in height
- Single row of vertical piles
- Has a rigid connection with superstructure
- Piles flex with superstructure movement



SEC. THRU ABUT.
(Dimensions at Rt. ∟'s)

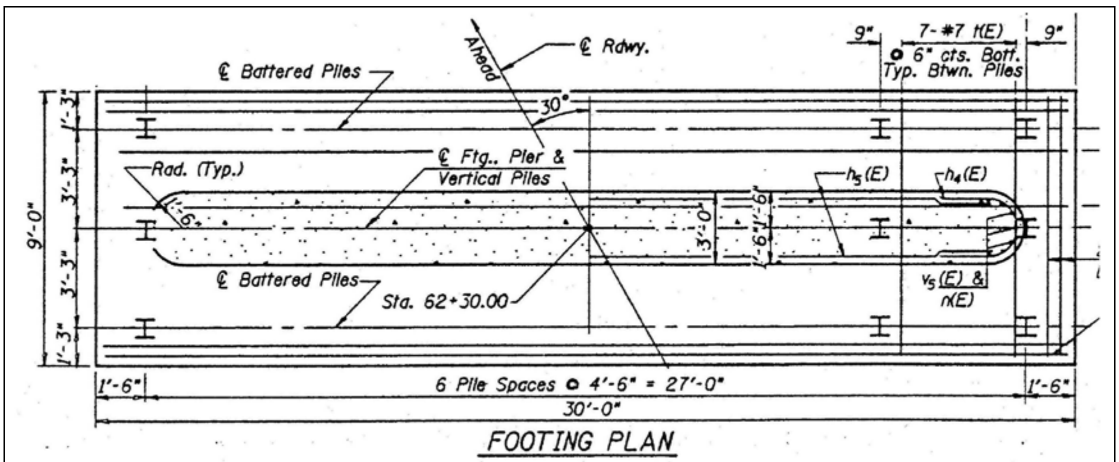
Pile Bent Piers:

- 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

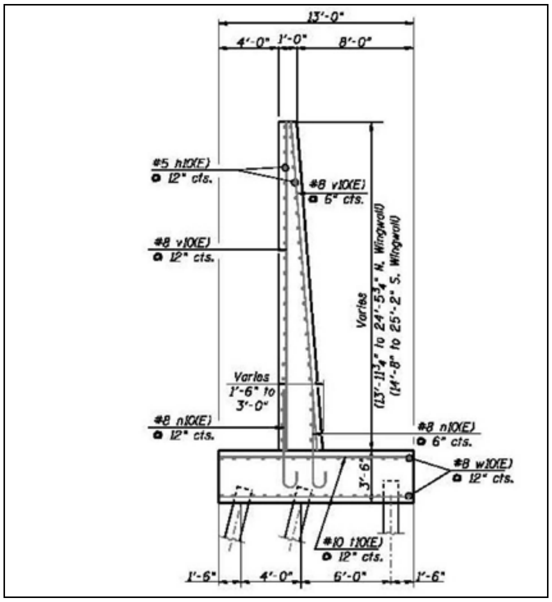


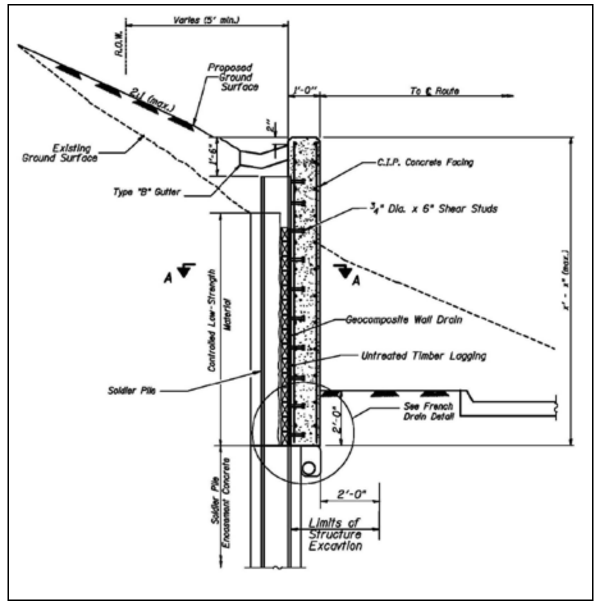
T-type Retaining Walls:

- 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.

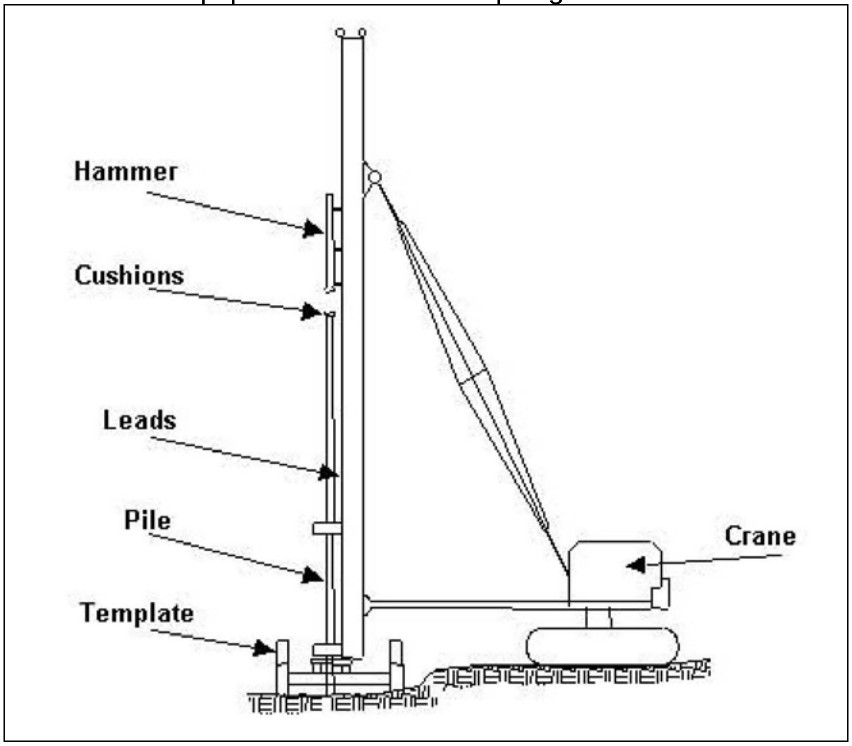
Inspectors are also encouraged to obtain and review a copy of the Structure Geotechnical Report (SGR) from the District. The SGR is prepared during the planning phase of a project with the purpose of identifying and communicating geotechnical considerations and foundation design recommendations, such 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

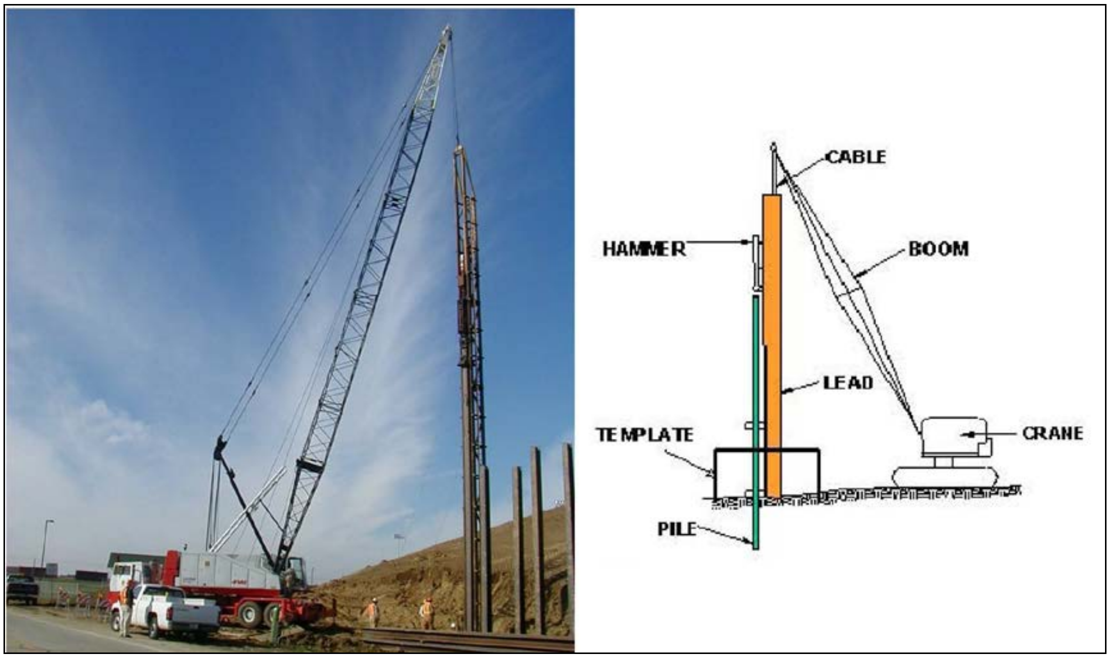
Leads are generally a box shaped frame used to align the pile and hammer during driving and must be long enough to accommodate the length of the pile segments, the hammer, and other equipment as required for the project. Types of leads include swinging, fixed, or semi-fixed leads depending upon the connection 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:

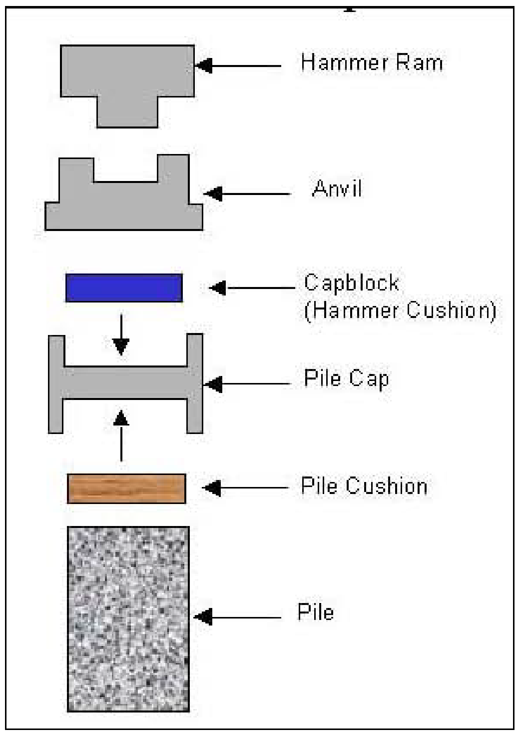
    - Fueled by a hydraulic unit with the hammer energy correlated through pressure readings.
        - A wave equation analysis is required to aid in determining the adequacy of the hammer and to indicate the nominal driven bearing of the pile.

- 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

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

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 $\approx$ 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

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

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).

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

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?*

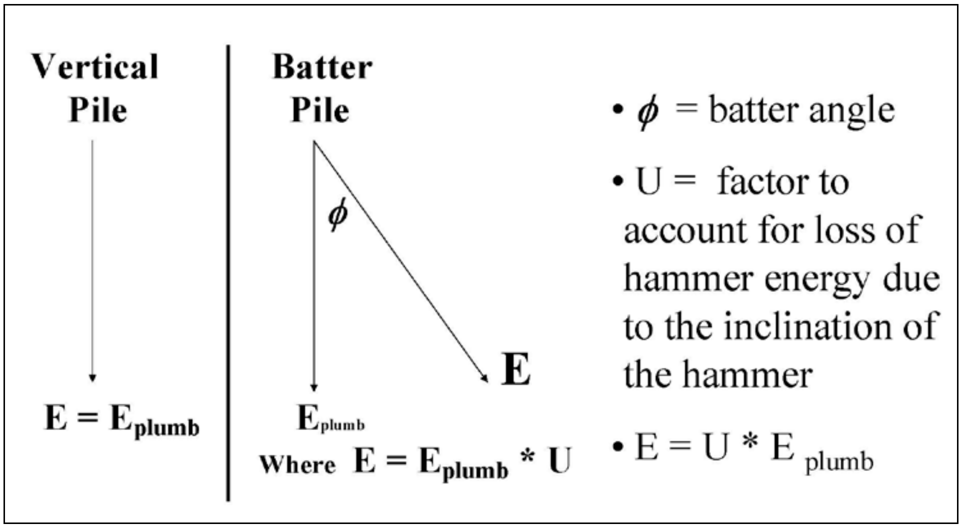
Given: The ram weight is 7,940 lbs and has a fall height range of 4.5 to 9 ft.

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.

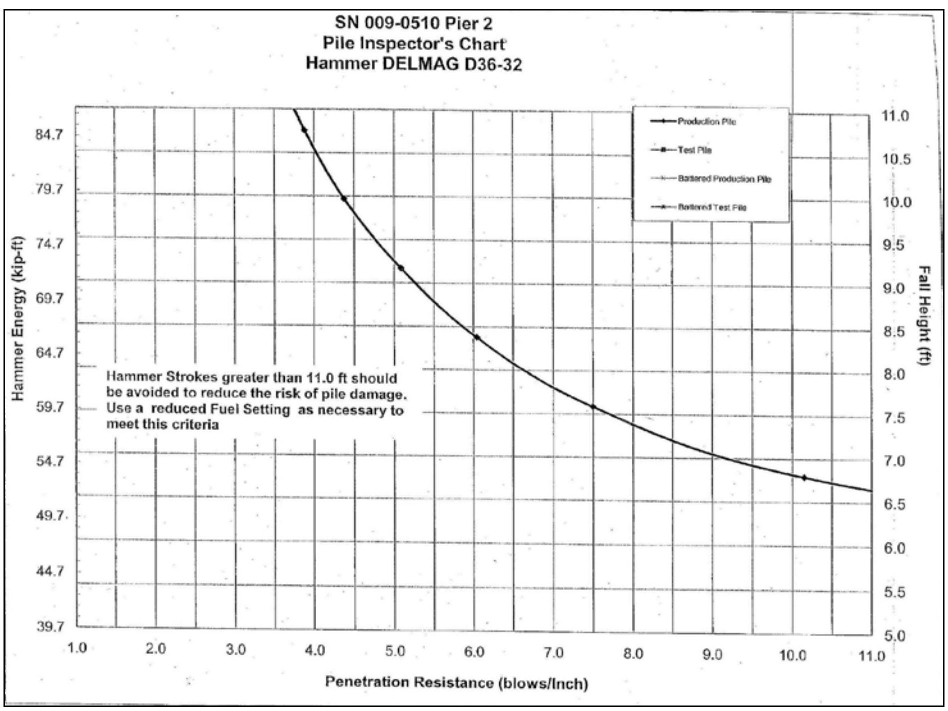
The Appendix contains a table of calculated U values for various batter angles. The WSDOT Pile Bering Verification spreadsheet (examples shown in the Appendix for Examples A and B) also calculates the U value and reduces the hammer energy for battered piles based upon the batter angle input by the user.

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

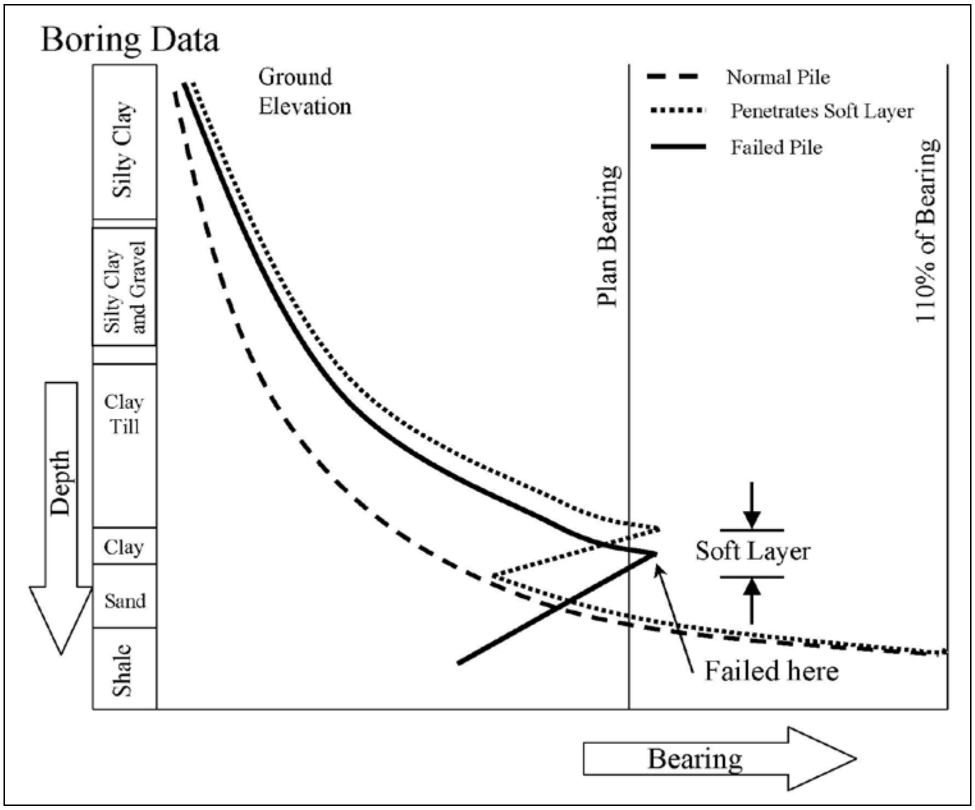
Test piles are specified to provide site specific pile bearing vs. length data, which is used by the Department during construction to verify the required length to be ordered for the production piles. As such, test piles shall be driven prior to ordering the production piles. The abutment and pier plan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

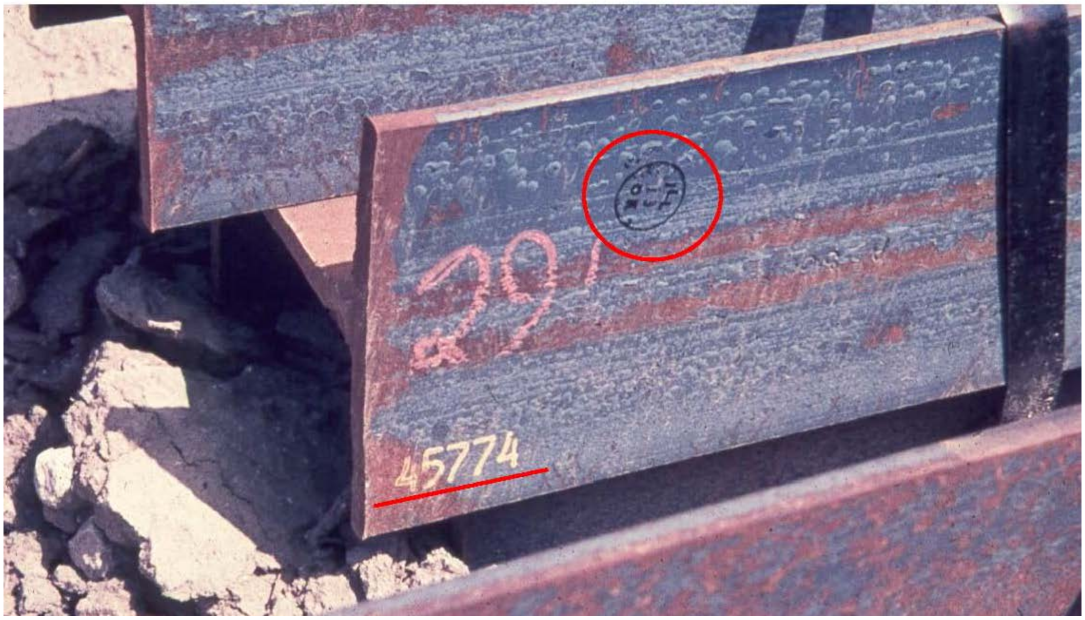
9.1 Material Inspection

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 sufficient 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"

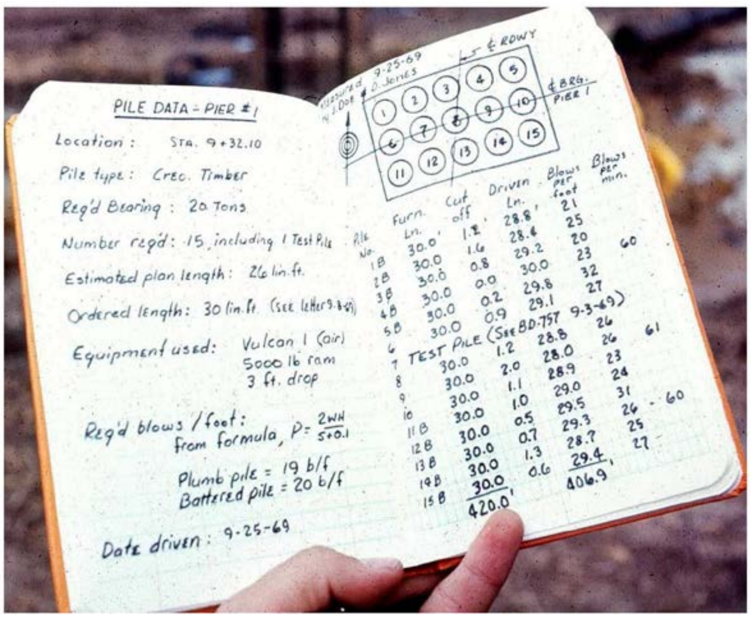
Recommended Maximum Hole Sizes in H-pile Webs and Flanges

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.

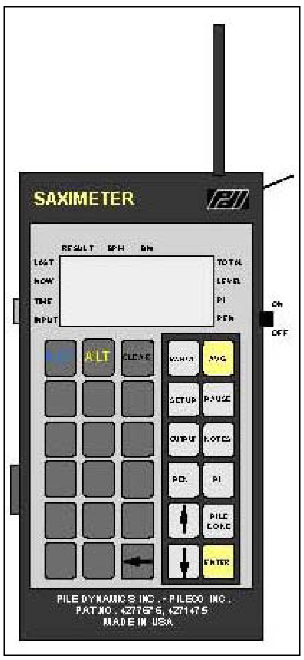
Damaged H-pile

Damaged Metal Shell Pile

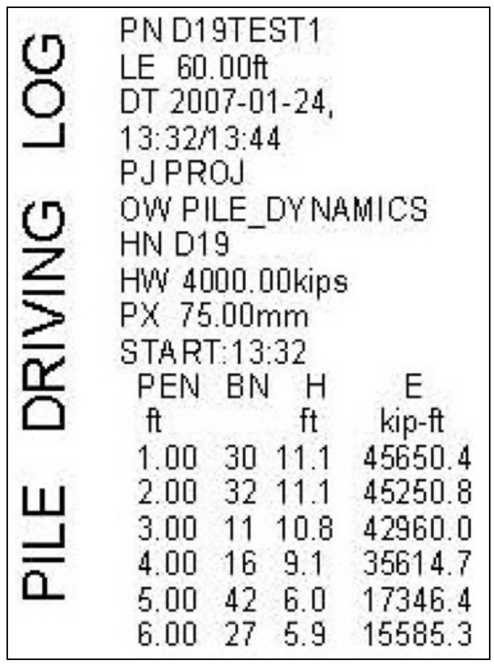
10.4 Advanced Inspection Tools

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.

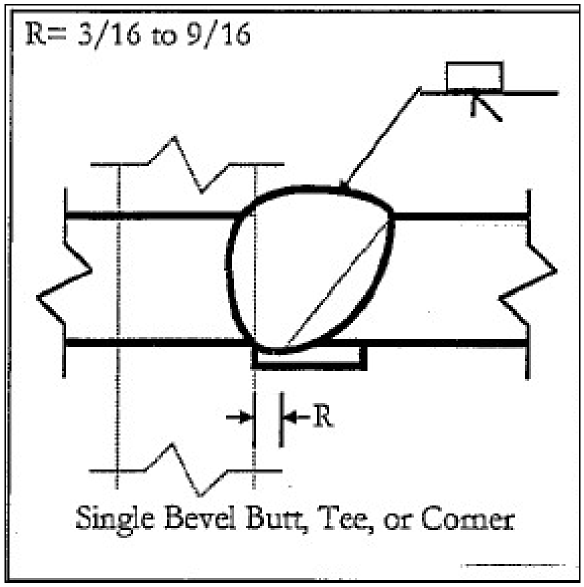
Unplanned splices may be used for metal shell and H-piles when the length of pile required to be driven to achieve the plan R_N exceeds the estimated length specified in the plans.

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.

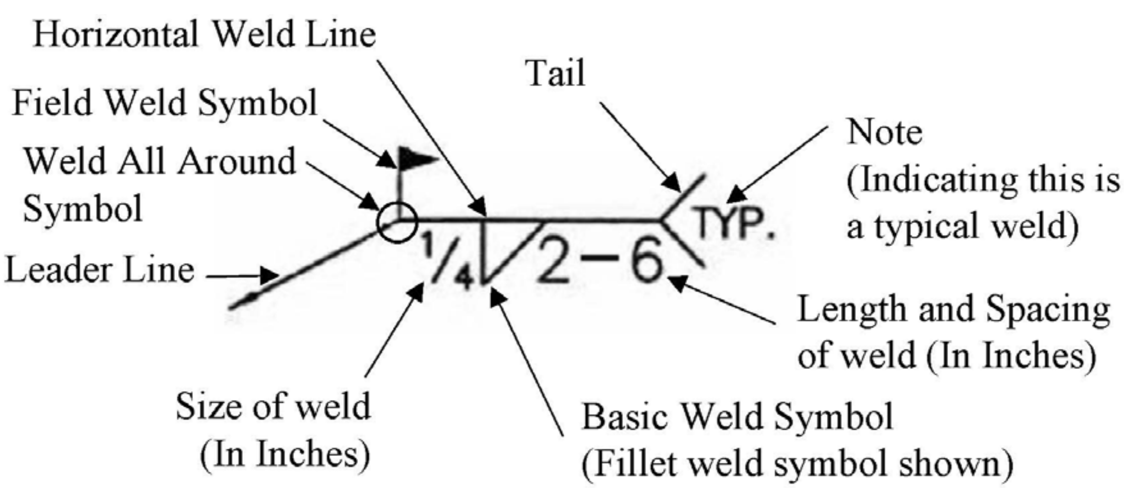
All welding shall be performed by welders that are certified according to the requirements of American Welding Society (AWS D1.1) (Structural Welding Code) or D1.5 (Bridge Welding Code) as stated in Article 512.07 of the Standard Specifications. Inspectors should obtain written weld procedure certifications 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.

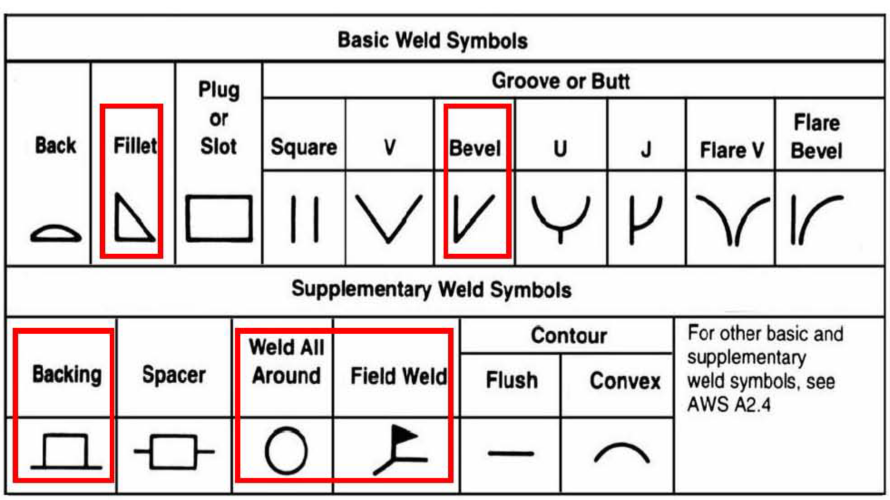
Inspectors should review the various weld symbols indicated on the base sheet and become familiar with their meaning. Inspectors should verify that joints have been properly prepared for the type of weld. For example, full penetration groove welds require that the plate material on one side of the splice 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.

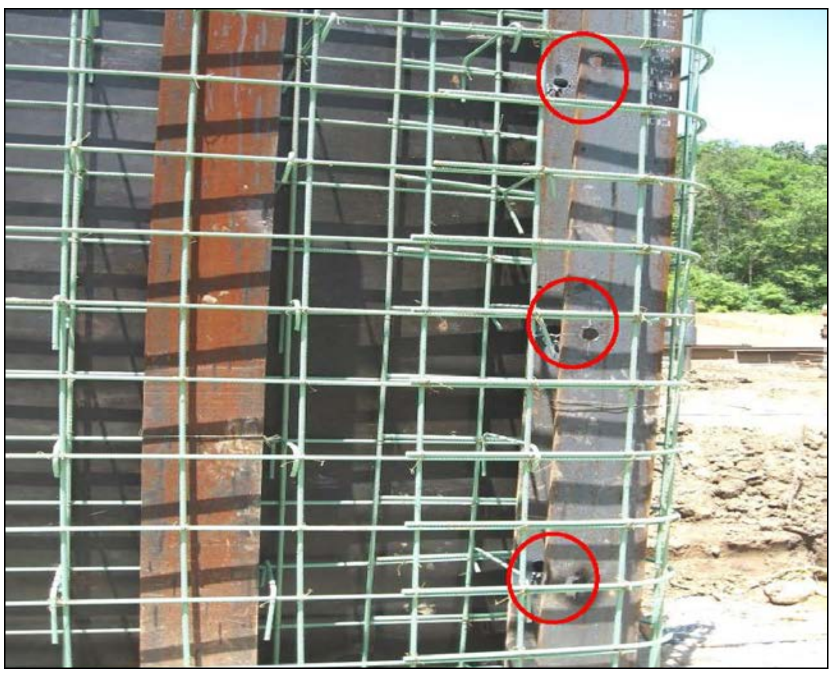
In addition, any reinforcement that is required to be placed in the top of the pile as indicated in the plans shall be rigidly tied together and lowered into the shell prior to placing the concrete per Article 512.04(d) of the Standard Specifications. Finally, the top 10 ft of concrete shall be internally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

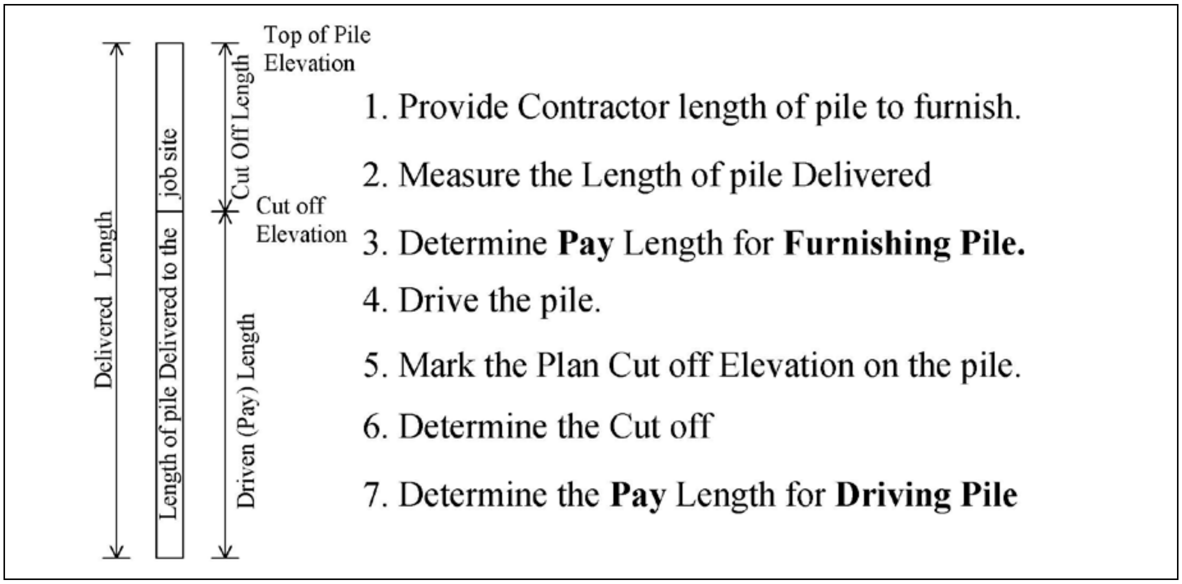
- **Test Piles** – Each
- **Pile Shoes** – Each
  - These pay items shall be paid for at the contract unit price each.
  - Enter these items in the Quantity Book according to the date and location.
  - Shoes for test piles are paid for separately. (i.e. the shoes are not included in the cost of the test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

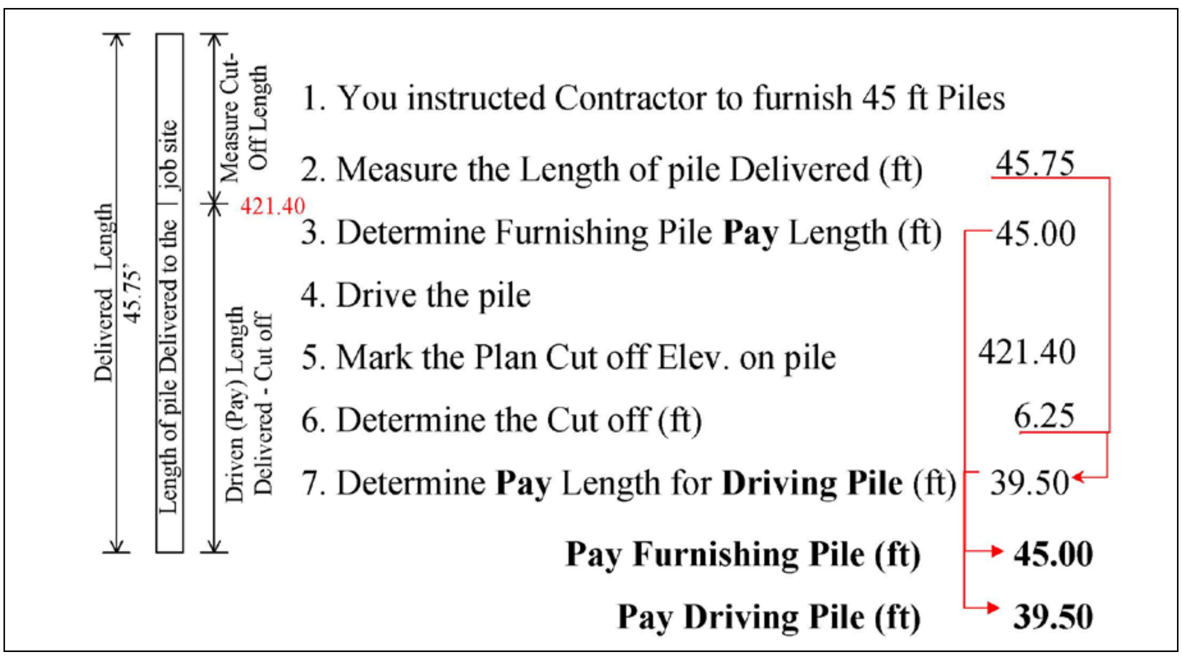
- **Driving Piles** – Foot (Meter)
  - Payment will be made for the total linear feet (meters) of all piles left in place below the pile cutoff elevations. Field measurements must be record.
  - Additional unplanned splices will be paid for as extra work in accordance with Article 109.04 of the Standard 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) ____

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

$$N_b = \frac{e^{\left[\frac{1000R_N}{21.7F_{eff}E}\right]}}{10}$$ *(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 additional 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. <u>PILE CUTOFFS</u>

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. <u>INSPECTION OF METAL SHELL PILES AFTER DRIVING</u>

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-	11-B-2	Dbl-Act	120	20	3,625	22,080
Terry	C-826	Dbl-Act	85-95	18	8,000	24,000
(Steam-Air)	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	00	Dbl-Act	85	36	6,000	54,900
(Stream)	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	D-5	Sgl-Act	50-60	Var.*	1,100	9,050
(Diesel)	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-	11-B-2	Dbl-Act	120	508	16.12	29,937
Terry	C-826	Dbl-Act	85-95	457	35.58	32,540
(Steam-Air)	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	00	Dbl-Act	85	914	26.69	74,435
(Stream)	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	D-5	Sgl-Act	50-60	Var.*	4.89	12,270
(Diesel)	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

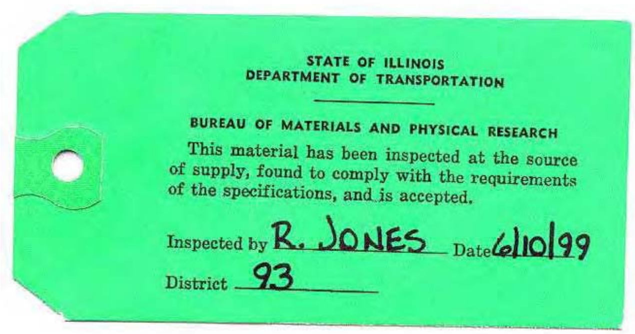
Sampling Frequencies for
Materials Testing and Inspection

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.idot.illinois.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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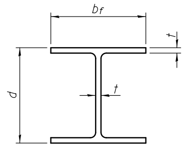
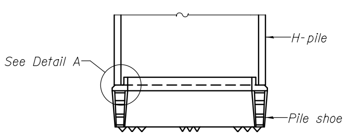
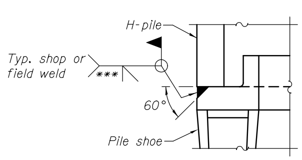


STEEL PILE TABLE

Designation	Depth d	Flange width b_f	Web and Flange thickness t	Encasement diameter A
HP 14x117	$14\frac{1}{4}''$	$14\frac{7}{8}''$	$\frac{13}{16}''$	30″
x102	14″	$14\frac{3}{4}''$	$\frac{11}{16}''$	30″
x89	$13\frac{7}{8}''$	$14\frac{3}{4}''$	$\frac{5}{8}''$	30″
x73	$13\frac{5}{8}''$	$14\frac{5}{8}''$	$\frac{1}{2}''$	30″
HP 12x84	$12\frac{1}{4}''$	$12\frac{1}{4}''$	$\frac{11}{16}''$	24″
x74	$12\frac{1}{8}''$	$12\frac{1}{4}''$	$\frac{5}{8}''$	24″
x63	12″	$12\frac{1}{8}''$	$\frac{1}{2}''$	24″
x53	$11\frac{3}{4}''$	12″	$\frac{7}{16}''$	24″
HP 10x57	10″	$10\frac{1}{4}''$	$\frac{9}{16}''$	24″
x42	$9\frac{3}{4}''$	$10\frac{1}{8}''$	$\frac{7}{16}''$	24″
HP 8x36	8″	$8\frac{1}{8}''$	$\frac{7}{16}''$	18″

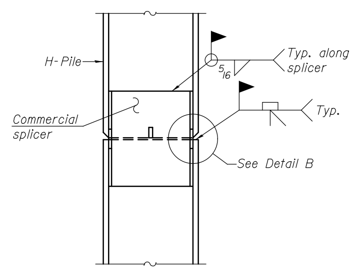


ELEVATION



DETAIL A

H-PILE SHOE ATTACHMENT



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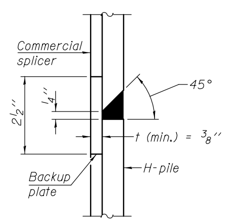
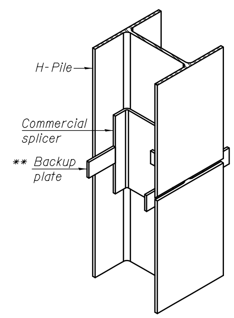
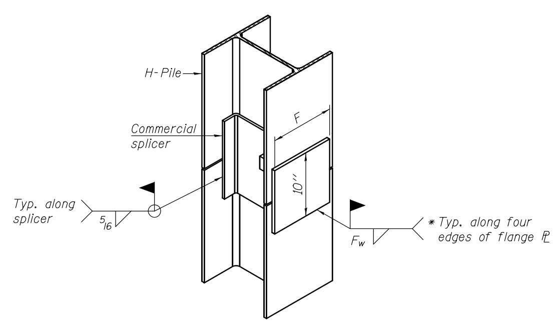


DETAIL "B"



ISOMETRIC VIEW

WELDED COMMERCIAL SPLICE



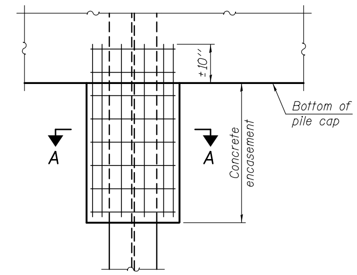
ISOMETRIC VIEW

WELDED COMMERCIAL SPLICE ALTERNATE

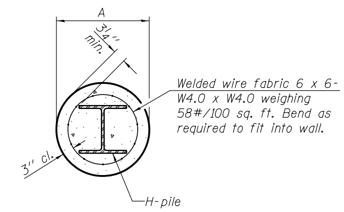
* Interrupt welds $\frac{1}{4}''$ from end of web and/or each flange.

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

*** Weld size per pile shoe manufacturer ($\frac{5}{16}''$ min.).



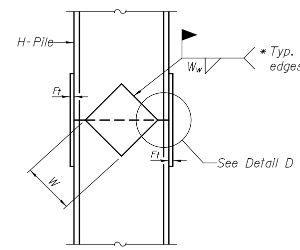
ELEVATION



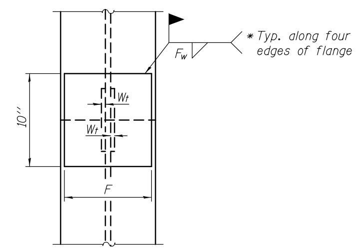
Note:
Forms for encasement may be omitted when soil conditions permit.

SECTION A-A

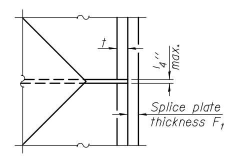
PILE ENCASEMENT



ELEVATION



END VIEW



DETAIL D

Designation	F	F_t	F_w	W	W_f	W_w
HP 14x117	$12\frac{1}{2}''$	1″	$\frac{7}{8}''$	$7\frac{3}{4}''$	$\frac{5}{8}''$	$\frac{1}{2}''$
x102	$12\frac{1}{2}''$	$\frac{7}{8}''$	$\frac{3}{4}''$	$7\frac{3}{4}''$	$\frac{5}{8}''$	$\frac{1}{2}''$
x89	$12\frac{1}{2}''$	$\frac{3}{4}''$	$\frac{11}{16}''$	$7\frac{3}{4}''$	$\frac{5}{8}''$	$\frac{1}{2}''$
x73	$12\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{9}{16}''$	$7\frac{3}{4}''$	$\frac{5}{8}''$	$\frac{1}{2}''$
HP 12x84	10″	$\frac{7}{8}''$	$\frac{11}{16}''$	$6\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{1}{2}''$
x74	10″	$\frac{7}{8}''$	$\frac{11}{16}''$	$6\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{1}{2}''$
x63	10″	$\frac{5}{8}''$	$\frac{1}{2}''$	$6\frac{1}{2}''$	$\frac{1}{2}''$	$\frac{3}{8}''$
x53	10″	$\frac{5}{8}''$	$\frac{1}{2}''$	$6\frac{1}{2}''$	$\frac{1}{2}''$	$\frac{3}{8}''$
HP 10x57	8″	$\frac{3}{4}''$	$\frac{9}{16}''$	$5\frac{1}{4}''$	$\frac{1}{2}''$	$\frac{3}{8}''$
x42	8″	$\frac{5}{8}''$	$\frac{9}{16}''$	$5\frac{1}{4}''$	$\frac{1}{2}''$	$\frac{3}{8}''$
HP 8x36	7″	$\frac{5}{8}''$	$\frac{7}{16}''$	$4\frac{1}{4}''$	$\frac{1}{2}''$	$\frac{3}{8}''$

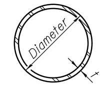
WELDED PLATE FIELD SPLICE

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

F-HP

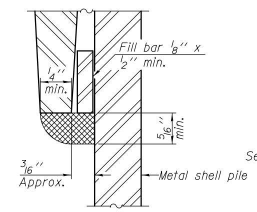
1-27-12

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					CONTRACT NO.		
	PLOT SCALE =	DRAWN -	REVISED							
	PLOT DATE =	CHECKED -	REVISED		SHEET NO. OF SHEETS		ILLINOIS FED. AID PROJECT			

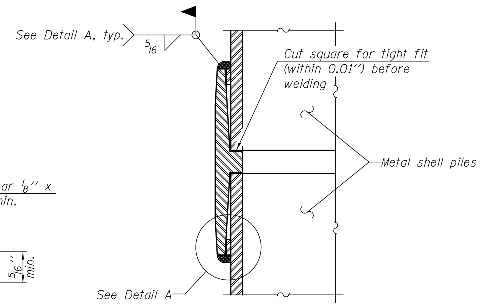


METAL SHELL PILE TABLE

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

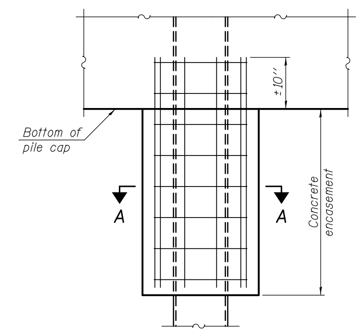


DETAIL A

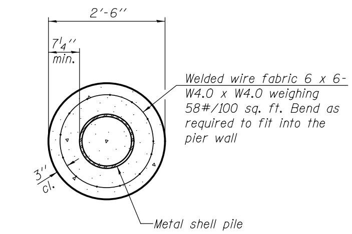


Notes:
The 1/8″ x 1/2″ min. fill bar may be constructed of 2 bars with a 1/8″ max. gap between them.
Pile segments shall be driven to solid contact with splicer before welding.

WELDED COMMERCIAL SPLICE



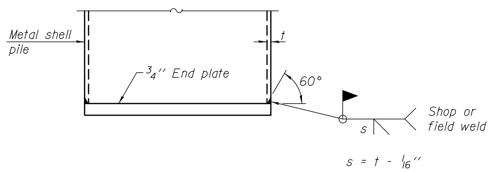
ELEVATION



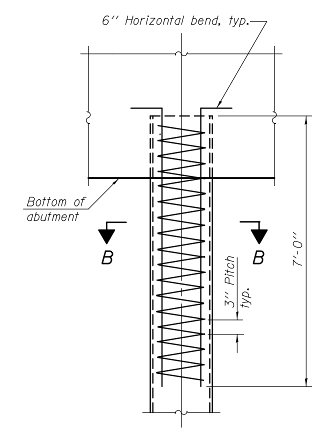
SECTION A-A

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

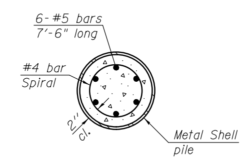
CONCRETE ENCASEMENT AT PIERS



END PLATE ATTACHMENT

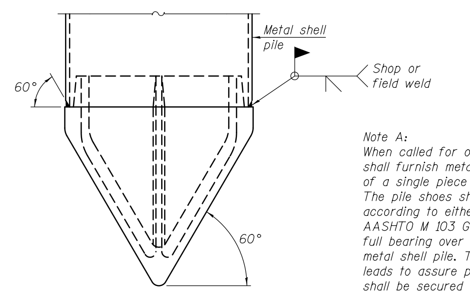


ELEVATION



SECTION B-B

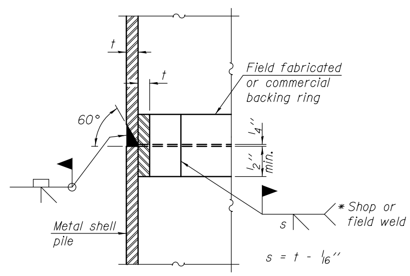
METAL SHELL REINFORCEMENT AT ABUTMENTS



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

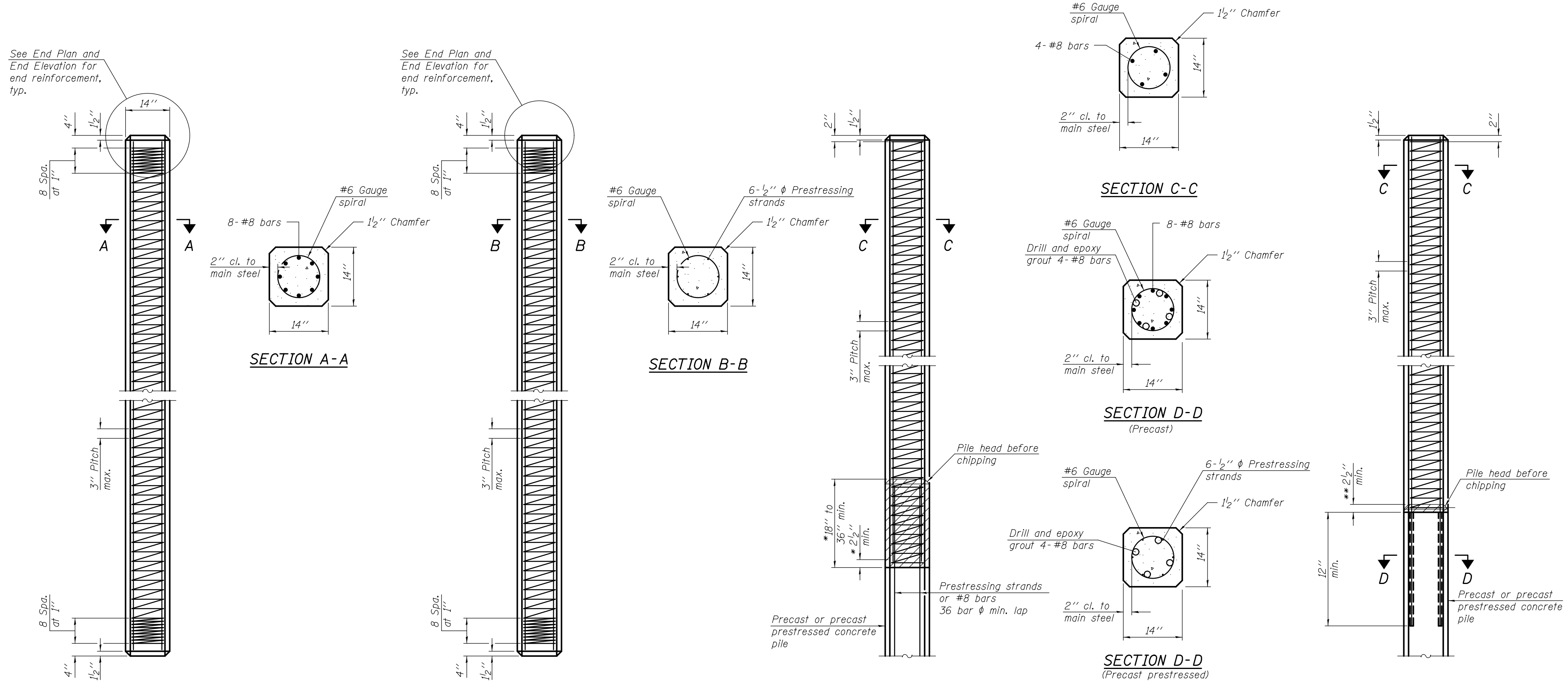
* Field fabricated backing ring may be made from pile shell by removing segment to allow reducing circumference and vertically rejoin with partial joint penetration weld.

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	STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	METAL SHELL 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				

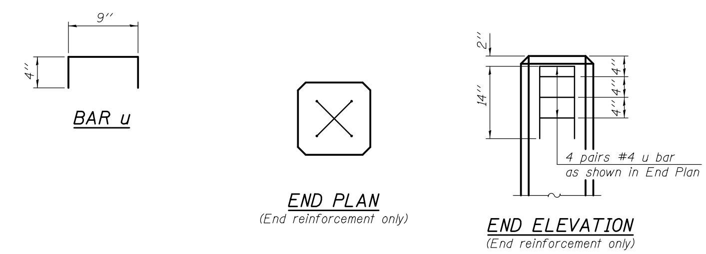


PRECAST CONCRETE PILE

PRECAST PRESTRESSED CONCRETE PILE

STANDARD PILE EXTENSION

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).

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	STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	PRECAST 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				

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APPENDIX F

Example A:
Pile Bearing Table and Graph

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W S D O T   P I L E   B E A R I N G   T A B L E   A N D   G R A P H

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

Test Pile - Nominal Requird Bearing: 363 kips
Min. Recommended Hammer Energy (Test) 25410 ft-lbs
Max. Recommended Hammer Energy (Test): 50820 ft-lbs
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

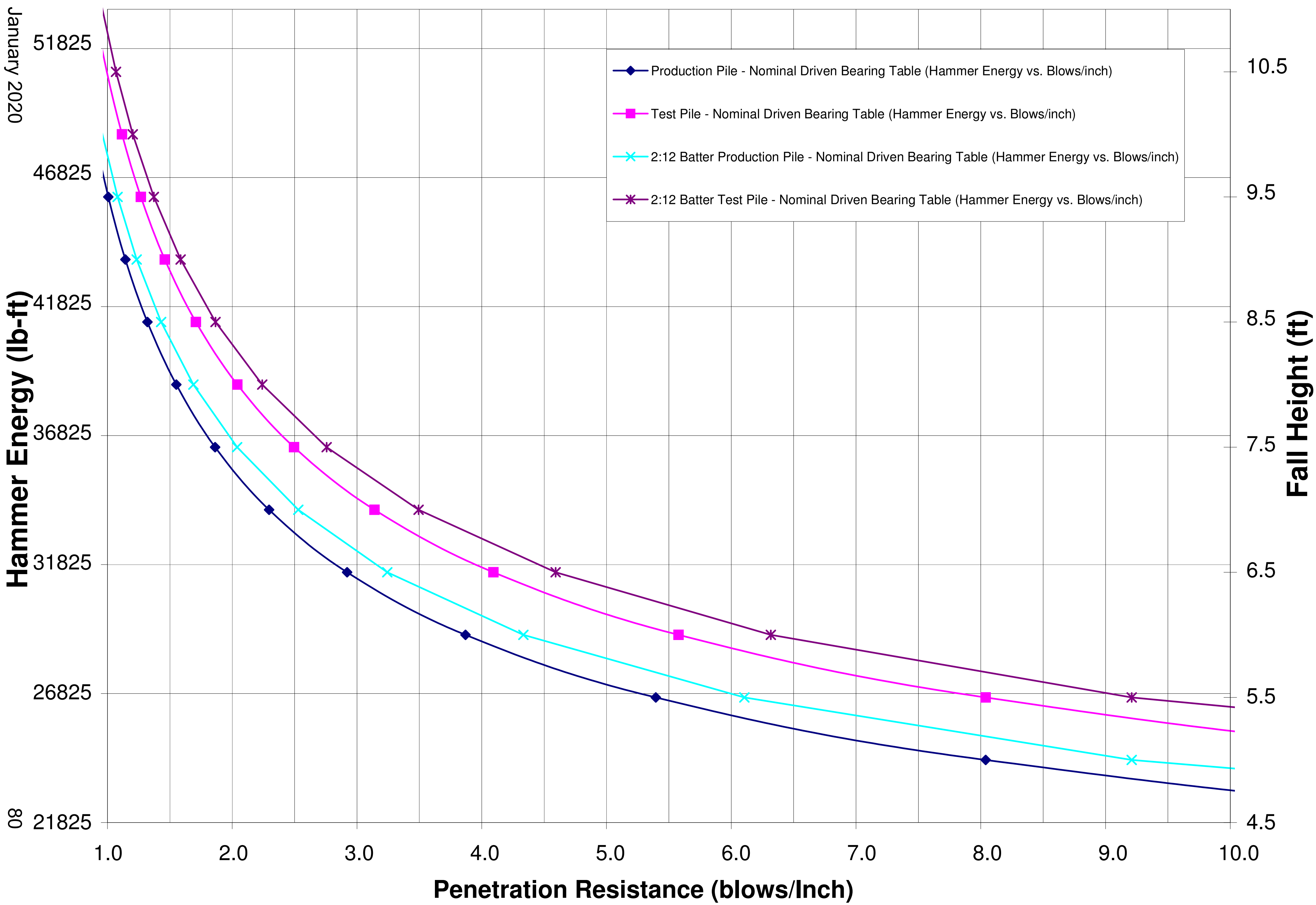
2:12 Batter Production Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

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

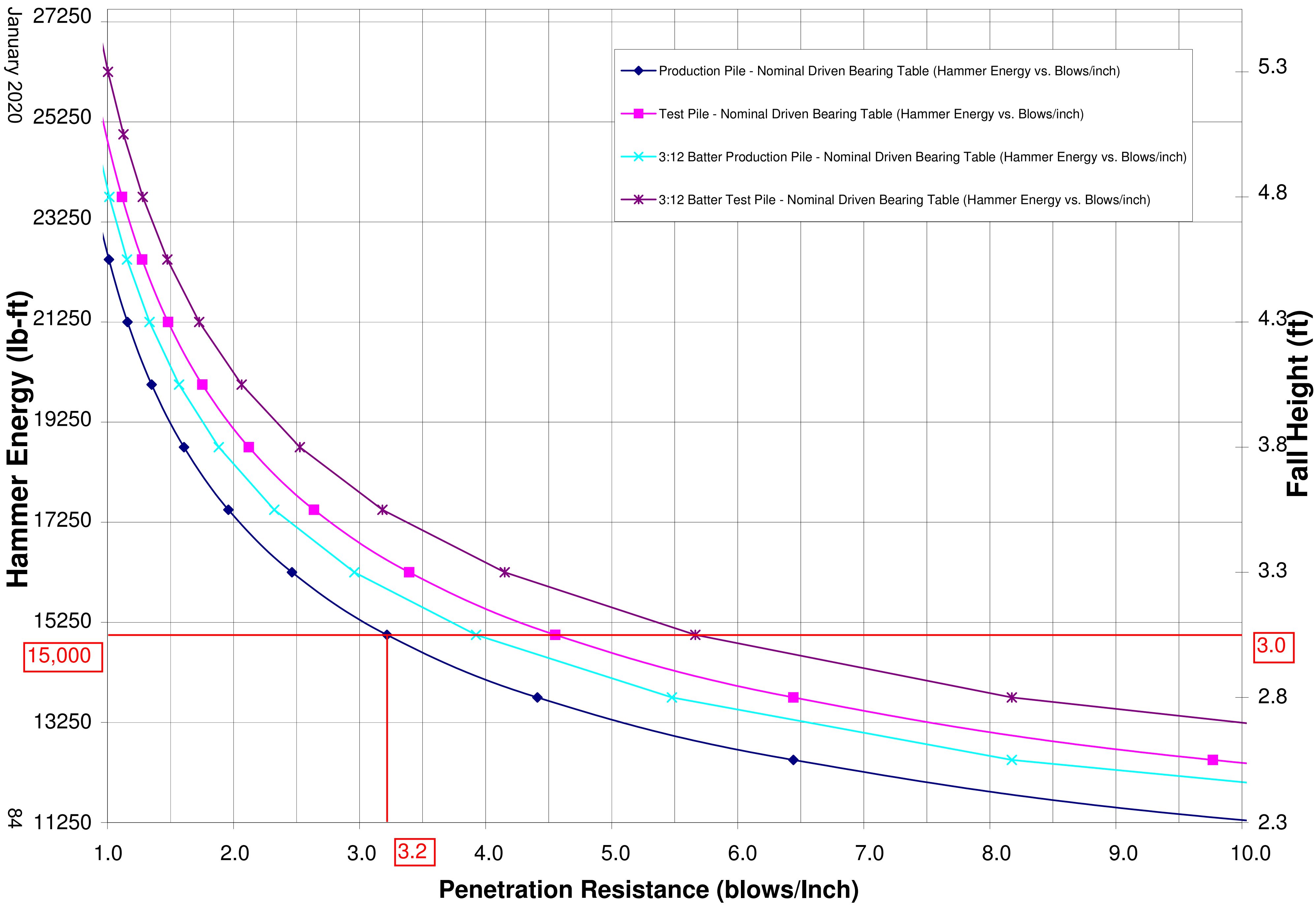
3:12 Batter Production Pile - Nominal Driven Bearing Table (Hammer Energy vs. Blows/inch)

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

$E \geq 32.90 \times R_N \div F_{eff}$
$\geq 32.90 \times 383 \div 0.55 = 22{,}910$ ft-lbs

Hammer E_{max} = 32,500 > 22,910 O.K.

Maximum Allowable Energy

$E \leq 65.80 \times R_N \div F_{eff}$
$\leq 65.8 \times 383 \div 0.55 = 45{,}820$ ft-lbs

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

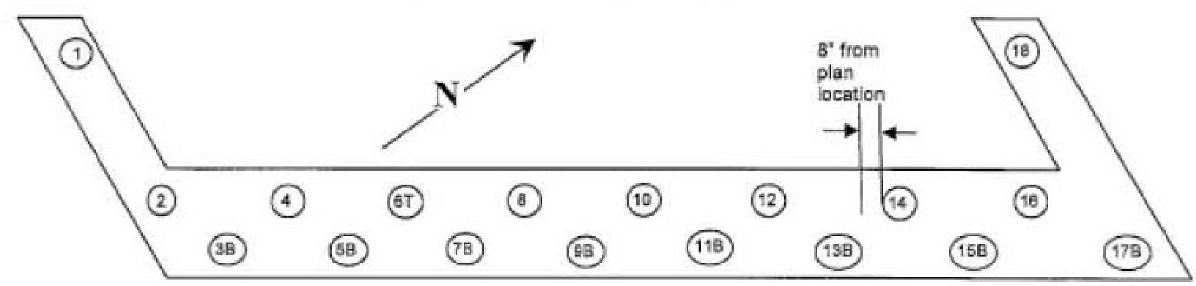
Pile Cutoff Elevation 873.77 ft. Authorized Furnished Length 78 ft. Contract 62897

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
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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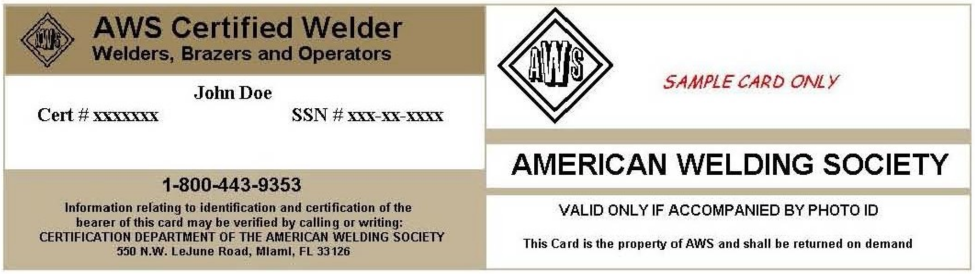


AWS Certified Welder
Welders, Brazers and Operators

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

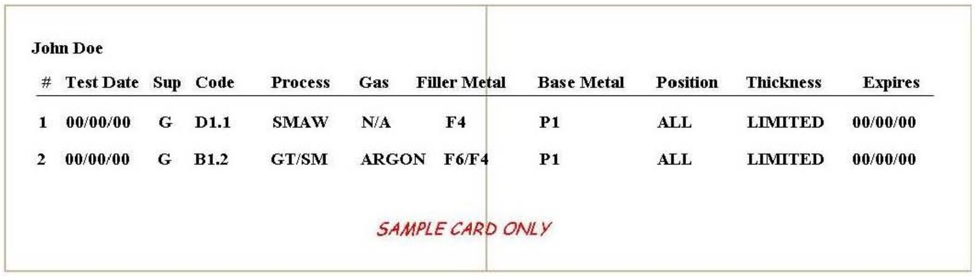
1-800-443-9353
Information relating to identification and certification of the bearer of this card may be verified by calling or writing:
CERTIFICATION DEPARTMENT OF THE AMERICAN WELDING SOCIETY
550 N.W. LeJune Road, Miami, FL 33126

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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