KANSAS STATE
POLYTECHNIC

PILE DRIVING INSPECTION WORKBOOK

2019-2020

CIT Program

AD ASTRA PER ASPERA
Kansas
Department of Transportation

Pile Driving Inspection
Class Agenda

Kansas Department of Transportation

Day 1

1:00 PM	Course Introductions
1:15 PM	Overview of Pile Foundation - Design and Construction
1:30 PM	Pile Types
2:00 PM	Pile Driving Equipment
2:40 PM	Break
3:00 PM	Plan Sheets and Geology
3:30 PM	The Bearing Formula
4:10 PM	Break
4:20 PM	Record Keeping - Form 217
5:00 PM	Adjourn

Day 2

8:00 AM	Welded Pile Splices
8:40 AM	Test Piles and Test Pile (Specials)
9:00 AM	The Pile Drive Analyzer
9:40 AM	Break
10:00 AM	The Inspector's Role
10:45 AM	Field Problems
11:30 AM	Lunch
12:45 PM	KDOT Specifications
1:45 PM	Questions, discussion and catch up
2:00 PM	Test

KANSAS STATE
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www.polytechnic.k-state.edu

Campus Parking Permit Key

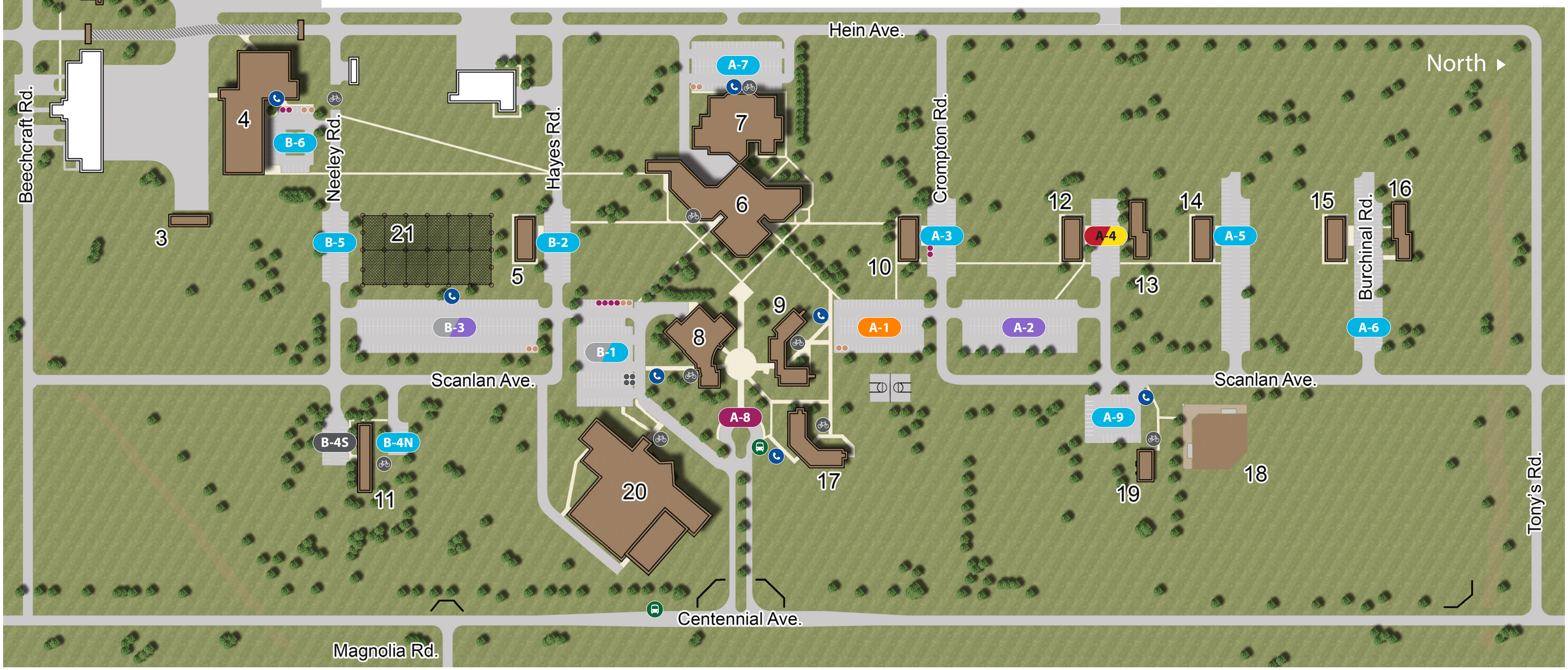
(cyan)	**T**	O, W, E, K or V
(orange)	**R**	R or V
(purple)	**Z**	Any K-State Permit
(gray)	**SLC**	SLC
(tan)	**M**	M
(yellow)	**K**	K
(red)	**W**	W, E or V
(dark gray)	**Visitor**	No permit required
(magenta)	**Metered**	No permit required

Lots enforced M-F, 7 a.m. - 5 p.m. (R lots at all times).

Visit **www.k-state.edu/parking** for permit purchasing information & regulations

Other Transportation

- Bicycle Rack
- Salina CityGo® Bus Stop
- **Emergency Phone**



1 Aeronautical West Hangar
2 Aeronautical East Hangar
3 Composite Building
4 Aviation Center/Stevens Flight Center
5 U.A.S. Laboratory
6 Technology Center
7 Technology Center West
8 College Center
9 Schilling Hall
10 Tullis Building
11 Welcome Center
12 Outreach Center
13 Science Center/K-State Research Extension
14 Construction Lab
15 Facilities Maintenance - Shops
16 Facilities Maintenance - Offices
17 Harbin Hall
18 Thaemert Park/Sports Field
19 Sports Support Facility
20 Student Life Center
21 U.A.S. Flight Pavilion

DIRECTIONS TO CAMPUS

If you are traveling east or west on I-70, stay on I-70 until the I-70/I135 interchange. Travel south on I-135 to the Magnolia St. exit (No. 90). Go west on Magnolia to Centennial Rd. Turn right and proceed to Kansas State University Polytechnic Campus.

If you are traveling north or south on I-135, take the Magnolia St. exit (No.90). Go west on Magnolia to Centennial Rd. Turn right and proceed to Kansas State University Polytechnic Campus.

08/18

Reasons for Certified Inspector Training (CIT) Training Program

Overview

The Kansas Department of Transportation (KDOT) has established this training program to educate, test and certify those individuals responsible for performing inspection and testing functions on KDOT construction projects. KDOT's Bureau of Construction and Materials has responsibility for the establishment and administration of the materials portion of the KDOT's Quality Control/Quality Assurance (QC/QA) Program. The Bureau develops standards and specifications for materials, establishes sampling procedures and frequencies, and test procedures used in the laboratory and the field in order to assure compliance with specifications. It performs materials testing to assist each of the six KDOT districts in administering quality assurance functions of the QC/QA Program. Such testing includes tests on materials purchased by contractors or the State for use in maintenance or construction activities. The Bureau also conducts tests on soils, concrete, bituminous mixtures and numerous other specialized materials, the results of which are used by others for a variety of reasons.

Quality control and quality assurance activities involve the routine sampling, testing and analysis of various materials to determine the quality of a given product and to attain a quality product. The goal of the Certified Inspection and Testing Training Program (CIT^2) is to provide persons engaged in the inspection and/or testing of KDOT construction projects specific training in, but not limited to, soils, aggregates, and concrete and/or asphalt disciplines.

Each student is required to demonstrate specific abilities as defined by the training modules described in the CIT^2 manual. The manual can be found online at: http://www.ksdot.org/descons.asp#CIT.

Federal Funding

On projects involving federal funds, KDOT must certify to the Federal Highway Administration as to the quality of each type of material used on each project before the State is completely reimbursed by the federal government.

The certification and training requirements contained in this manual are intended to comply with the requirements of 23 CFR Part 637 which states, "After June 29, 2000, all sampling and testing data to be used in the acceptance decision or the IA (Independent Assurance) program shall be executed by qualified sampling and testing personnel."

Reasons for Quality Control/Quality Assurance

Inspectors fulfill a very important job on any project—they safeguard the public interest in a number of ways.

The primary reason for materials inspection, sampling and testing requirements is to verify that all materials incorporated into the work will meet the requirements of the contract documents, including the plans, specifications, and special provisions.

Plans and specifications are prepared to require the use of certain specific materials known or expected to perform satisfactorily with minimum maintenance throughout the life of the facility or infrastructure project. Any material that deviates appreciably from the specifications requirements will not perform as expected and, in all probability, will shorten the useful life of the facility or add unexpected costs in maintenance. Because there are limited dollars available for transportation infrastructure, the useful life and long-term maintenance costs of every project are critical considerations.

Secondly, all contractors bidding or furnishing materials to a project should be treated equally. That is, the contract documents provide a fair and uniform basis for bidding because they define the requirements to be met--ideally with the least possible difference of interpretation. The contractor commits to furnish materials and complete work that will equal or exceed such requirements. For this reason it is essential that quality assurance be correctly understood and applied uniformly by engineers and inspectors from project-to-project so that all contractors and suppliers are treated alike.

Thirdly, the expenditure of public funds must be documented to substantiate whether taxpayers actually received the quantity and quality of materials specified in exchange for tax dollars spent. Whether or not to pay the costs invoiced by contractors is a decision which relies heavily upon inspection reports and test results. In a fundamental way, inspectors play a key role in serving the public--to justify the expenditure of public monies and the acceptance of any contractor’s work. Through the work of knowledgeable, competent and skilled inspectors, KDOT can verify and confirm whether or not the contractor has fulfilled its obligations to build the project as intended.

Finally, the specification requirements for materials are constantly evolving, based on new developments, past performance of material in the field, research and technological innovations. Accurate recordkeeping of materials and test results using consistent inspection practices provides a basis to compare results over time—an indispensable advantage for meaningful research. Data properly collected and recorded by inspectors can confirm whether or not changes in material specifications and testing requirements have, in fact, resulted in a better product, state-wide or in a particular location or application.

All inspectors should review the applicable clauses of the Standard Specifications at regular intervals to refresh their understanding of material and testing requirements.

Overview of Pile Foundations

Driven Pile Types

Pile Driving Equipment

Plan Sheets and the Geology

The Bearing Formula and Problems with Dynamic

Record Keeping

Welded Pile Splices

Test Piles and Test Piles (Special)

The Pile Driving Analyzer and Restrike Testing

Inspector’s Role

Field Problems

KDOT Standard Specifications

Section 704 - Piling

Bridge Construction Manual Pile 5.3

Overview of Pile Foundation Design and Construction

1

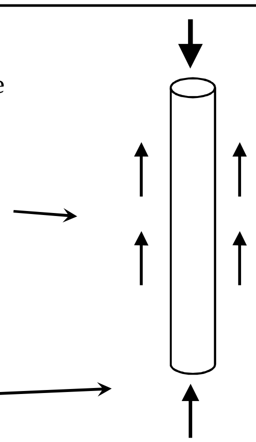
This class is concerned with the installation of driven pile.

Driven pile are hammered into the ground, where they develop resistance from the soil or rock.

2

The bridge load is transferred to the soil or rock by resistance along the length of the pile…

…and resistance from the tip.



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Piles which get most of their resistance from friction along the side are commonly called friction piles.

4

Piles which get most of their resistance from the tip are referred to as end-bearing piles.

5

Pile foundations are used for bridges in two general ways:

1) Abutments of most KDOT bridges

Current KDOT design practice prefers piling for abutments. Pile abutments tend to flex better with changes in temperature, putting less strain on the spans.

6

Pile foundations are used for bridges in two general ways:

2) Both Abutments and Piers of bridges in many parts of the state.

In central and western Kansas, bedrock is often too deep to use spread footings or drilled shafts.

7

This means you will be driving piles:

to a required resistance (usually)

or to a predetermined depth (occasionally, to get below a certain elevation in case some of the soils get scoured away during a storm)

8

At the same time, you will be expected to make sure we:

Don't damage the piling

Avoid expensive overruns by driving more than necessary

9

Unfortunately…

There is a complex interaction between the pile and the surrounding soil. And so things can get complicated in the field.

10

So what are we trying to learn here?

11

Pile driving terms and equipment

How to prepare for a piling project

How to calculate resistance

Where to find what you need in KDOT specifications and manuals

12

What to do in the field, and where to start if you have problems

How to read a Geology Report and Engineering Geology sheet like a champ

13

1

General Pile Types

- **Foundation piles**
  - Structural Support
- **Sheet pile**
  - Retention

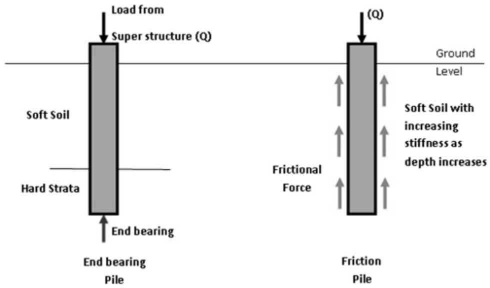
2

General Pile Types

- **Foundation piles**
  - Structural Support
- **Sheet pile**
  - Retention

3

Pile Design Designation



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Pile Arrangement

- Pile Bents
- Pile Groups

5

Pile Arrangement

- Pile Bents
- Pile Groups

6

Pile Arrangement

- **Pile Bents**
  - Pile extends into the superstructure
  - Usually a single row of piles
  - Encased in concrete wall

7

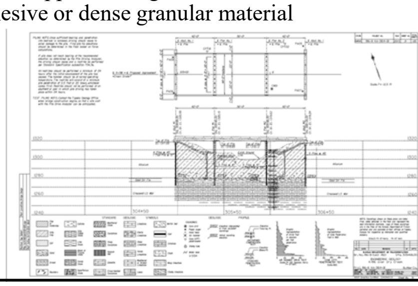
Pile Arrangement

- **Pile Bents**
  - Pile extends into the superstructure
  - Usually a single row of piles
  - Encased in concrete wall

8

Pile Arrangement

- **Pile Bents cont.**
  - Pile within the bents shall penetrate not less than 1/3 the unsupported length or not less than 10 feet into hard cohesive or dense granular material



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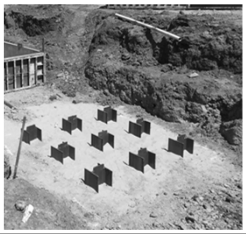
Pile Arrangement

- **Pile groups**
  - Piles are driven to bearing in groups
    - Usually 6 or more per group, 9 common
  - Cutoff elevation is below ground
    - And usually below scour line



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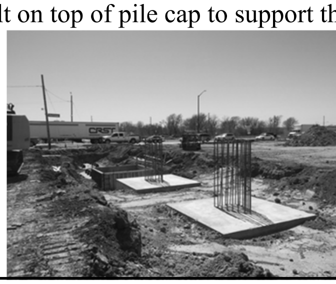
Pile Arrangement

- **Pile groups cont.**
  - Pile cap is constructed on top of the group
  - Pier column built on top of pile cap to support the superstructure



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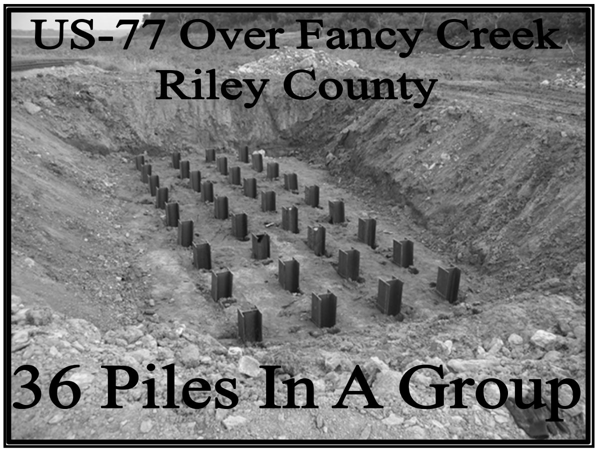

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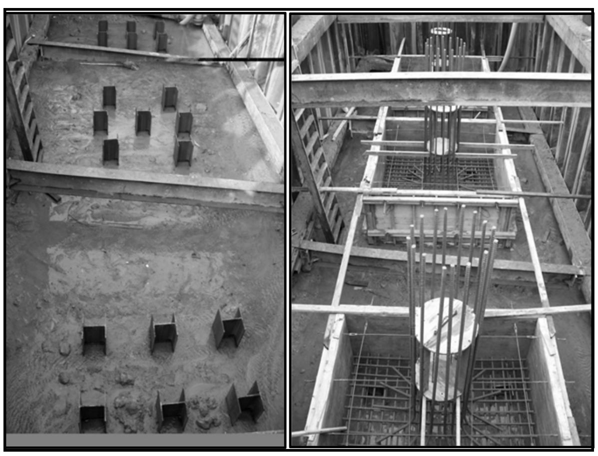

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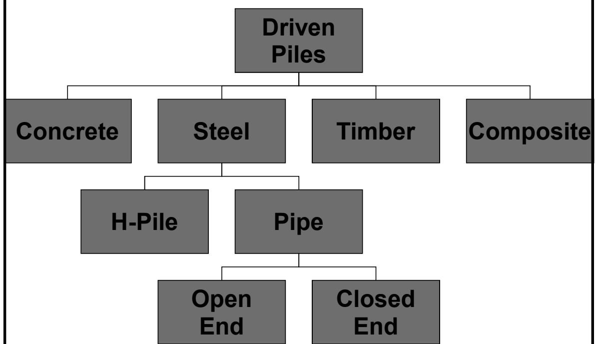

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Timber Piles

Only used for False Work, which is not inspected by KDOT

23

Composite Piles

- Two different materials
- Good qualities are taken advantage of
- Used in special circumstances
- Preferential Use
  - Geology
  - Structure
  - Durability
  - Cost

24

Composite Pile Variations

- Concrete and H-pile
- Steel pipe and H-pile
- Steel pipe and concrete
- Concrete filled pipe


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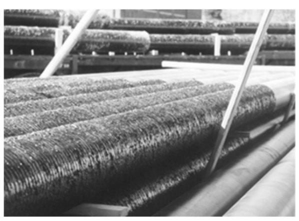
Composite Pile Variations Cont.

- Fiberglass
- Fiberglass shell filled with concrete
- Corrugated shell and timber
- Numerous others

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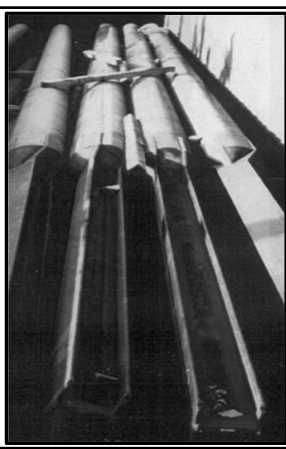

Pipe & H-pile

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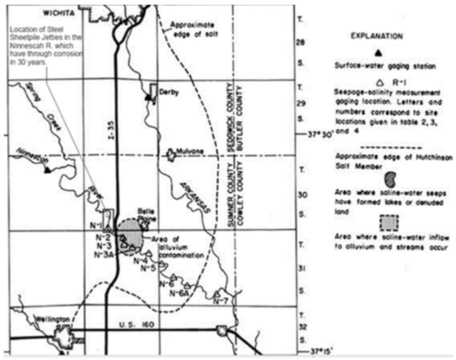
High Salinity Location



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Need for Composite Pile

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Composite Piles

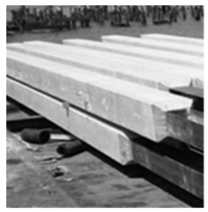
- Typical Lengths 50 to 200 feet
- Maximum Design Stress: Dependent upon pile material
- Stresses Driving Stress: Dependent upon pile material
- Design Loads 30 to 200 tons
- Remarks Weakest material governs allowable stresses and capacity

30

Composite Piles

Advantages:

- May be applied in unusual design or installation situations
- High capacities possible but dependent on materials
- Could reduce foundation cost
- Some types offer corrosion protection



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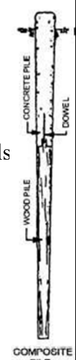
Composite Piles

Disadvantages:

- May be difficult to splice
- May be difficult to attain good joint between materials
- Vulnerable to decay above water unless treated



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Concrete Piles Overview

Typical Lengths: 30 to 130 feet

Design Loads: 45 to 500 tons

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Concrete Piles

34

Concrete Pile Bent

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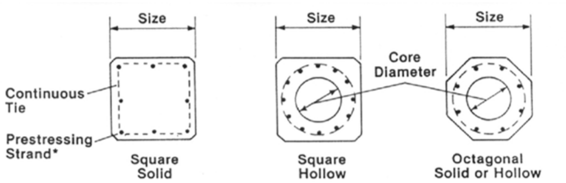
Concrete Pile Detail



Size:	**10"and up**	**20 to 36" could have 11 to 18" hollow center**	**10 to 24" could have 11 to 15" hollow center**

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Concrete Pile Cushion

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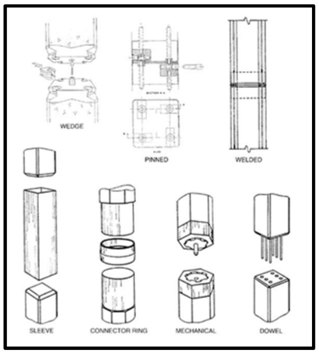
Concrete Pile Splice



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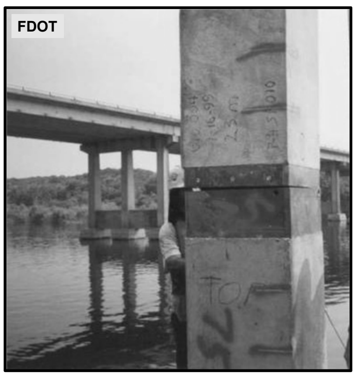
Concrete Pile Splice



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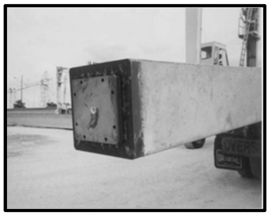
Concrete Pile Splice

24 inch octagon

42

Concrete Pile Splice



30 inch square
Male/Female ends

43

Concrete Pile Damage

44

45

Concrete Pile Advantages

- High load capacity
- Can be made for corrosion resistance
- Hard driving possible
- Cylinder piles suited for bending resistance

46

Concrete Pile Disadvantages

- Relatively high breakage
- Unless pre-stressed, vulnerable to handling damage
- Considerable soil displacement
- Difficult to splice
- High initial cost

47

H-Pile

- Most common pile type used by KDOT
- Typical lengths range from 15 to 130 feet
- Typical design loads 45 to 225 tons
- Suited for either end or friction bearing

48

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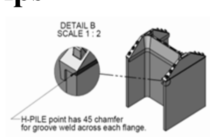
Battered Pile K-4 over Delaware River
Valley Falls, Kansas

50

H-Pile With Tips

- Helpful for reaching plan tip
- Embedding into hard bedrock
- Encountering obstructions



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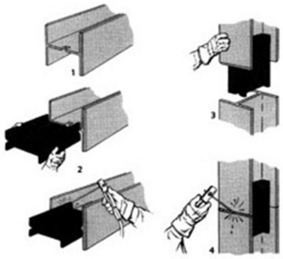
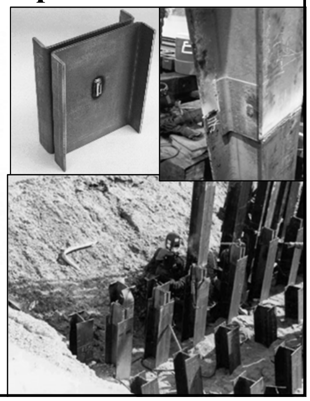
H-Pile Splice



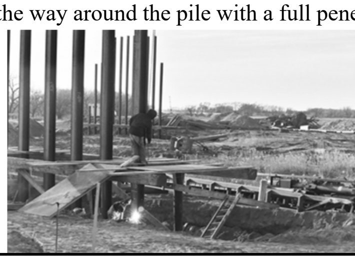


KDOT does not use this method

52

Usual KDOT H-Pile Splice

- Butt weld with no plate
- Certified Welder
- Grind both ends of pile to form a bevel recess
- Square and level two pile ends
- Weld all the way around the pile with a full penetration welds



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H-Pile Advantages

- Available in Various Lengths and Sizes
- Easy to Splice and to Cutoff
- High Capacity
- Close Spacing
- Low Soil Displacement
- Deep Penetration

54

H-Pile Disadvantages

- Vulnerable to Corrosion When Exposed
- Can Deflect Easily if Obstructions Are Encountered
- Not Recommended as Friction Pile in Granular Soils

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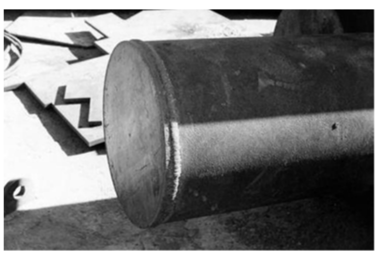
Closed End Pipe Pile

- **Typical Lengths: 15 to 120 feet**
- **Material Specs: F_y = 45 ksi**
- **Typical Design Loads 40 to 300 tons**



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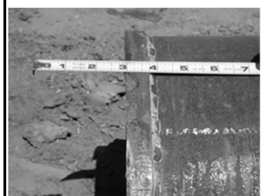
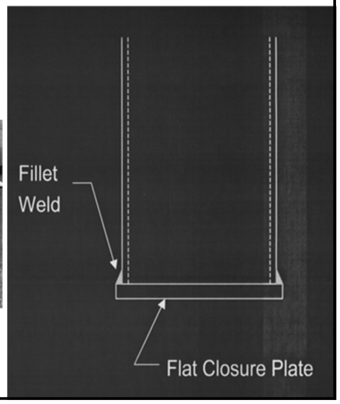
Typical KDOT Pipe Pile Plate





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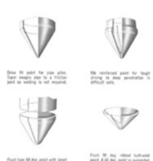
Closed End Pipe Pile

Using Conical Points

59

Closed End Pipe Pile

Using Conical Points



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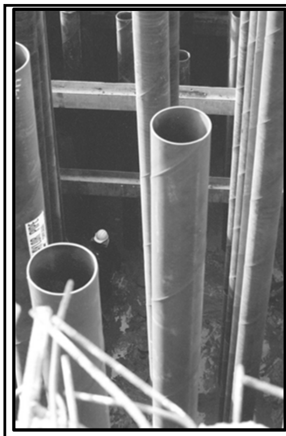

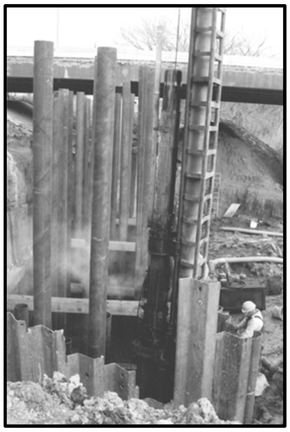

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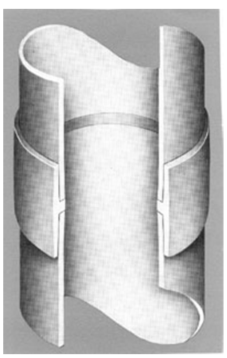
Pipe Pile Splice



Splicing Rings---KDOT Does Not Use

62

Usual KDOT Pipe Pile Splice

- Butt weld with no plate
- Grind both ends of pile to form a bevel recess
- Square and level two pile ends
- Weld all the way around the pile with a full penetration weld

63

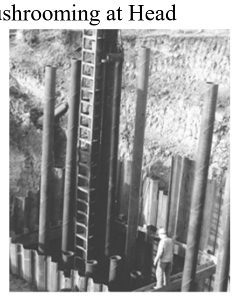
Pipe Pile Advantages

- Available in Various Lengths, Diameters & Wall Thickness
- Easy to Splice
- High Capacity Potential
- High Bending Resistance Where Unsupported
- Length is Loaded Laterally

64

Pipe Pile Disadvantages

- Vulnerable to Corrosion
- Could Hinder Required Penetration Depth
- Susceptible to Bending or Mushrooming at Head
- High Soil Displacement



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Other Types of Driven Pile

66

Tapertube Piles

67

Mono Tube Pile

68

Cylinder Concrete Pile

69

Spin Fin Pipe Pile

70

Questions?
Comments!

71

Pile Driving Equipment

1

The task of successfully installing piles involves selecting the most cost-effective equipment to drive each pile to its specified resistance or depth without damage in the least amount of time.

2

THE LEADS

Keep the hammer and pile aligned during driving

Guide the hammer

Brace long piles until they are driven enough to support themselves

3

SWINGING LEADS

Swinging Leads are widely-used because they're:

Simple

Lightweight

Low cost

4

SWINGING LEADS

Swinging leads can be moved easily to align the hammer and the pile head, without moving the crane

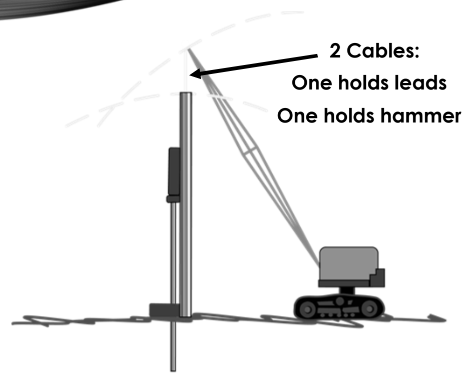
5

SWINGING LEADS

Swinging leads are lightweight, which gives the crane a large operating radius. In other words, the contractor doesn't need to move the whole crane for every pile.

6

Most common setup for swinging leads



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For years and years, KDOT contactors could leave swinging leads hanging in the air

8

A specification (starting in the 2007 version) now says that piling leads must always be spiked into the ground

9

It helps with hammer-pile alignment, and is also a safety matter

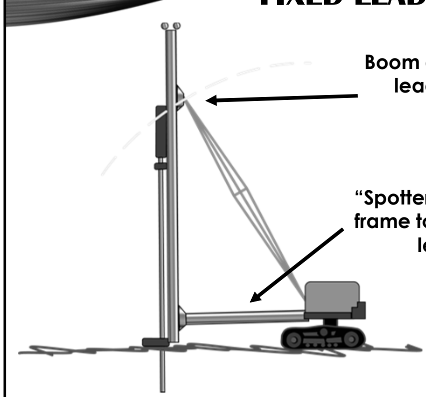
10

FIXED LEADS

Fixed Leads are attached to the crane boom, and have a brace running from the bottom of the leads to the crane frame.

11

FIXED LEADS



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FIXED LEADS

Fixed leads hold the pile in a more true alignment during driving, but require much more time to set up.

13

FIXED LEADS

Fixed leads are used for large piling on large projects.

You will rarely see fixed leads on Kansas bridge projects.

14

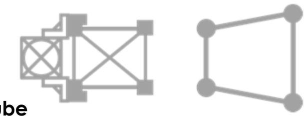
COMMON TYPES OF LEADS

Truss
Triangular
Box
H-Beam
Pipe

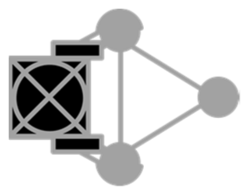
15

Truss Lead

Square and Round Tube



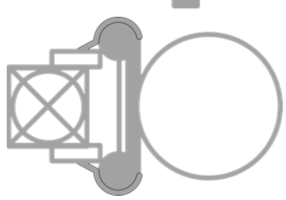
Triangular Lead



16

Box Lead

Pipe Lead



17

H-Beam Lead

Square and Round Tube

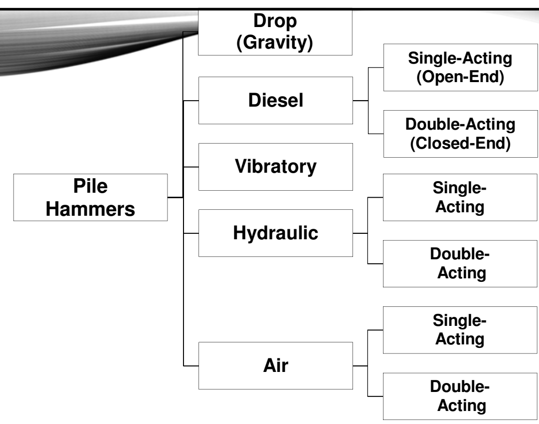
18

Pile Gate

At bottom of leads

Used to keep lower portion of the pile centered in the leads

19



20

Drop (Gravity) Hammer

Suitable for all types of piling except concrete

Very high dynamic forces can break concrete piling in easy driving if drop is not controlled

21

Drop (Gravity) Hammer

Cheap to Buy

Cheap and easy to maintain

22

Drop (Gravity) Hammer

- Low pile driving productivity
  (Only 4 to 8 blows per minute on average)
- Hard to control the fall height of the weight
- Hard to control the impact efficiency
- On KDOT projects, mainly used to start pile
- Often used to drive sheet pile

23

Drop (Gravity) Hammer

You'll occasionally still see all piling on a bridge driven with a gravity hammer

Mostly obsolete, but still occasionally useful (like me)

24

Vibratory Hammer

Don't require leads

Fastest way to install a pile

- **12 to 30 pulses per second—eccentric weights**

High initial cost

High maintenance cost

Needs a separate power supply—runs on electricity or hydraulics (usually hydraulics)

25

Vibratory Hammer

Suitable for steel H-pile, pipe pile, and sheet pile.

No good for concrete piles. Not at all.

A vibratory hammer would shake apart a concrete pile in about 3 seconds.

26

Vibratory Hammer

Suitable for end-bearing

Not recommended for friction piles

Very useful in granular soils

Not too effective in stiff, clayey soils

Can be used for driving or pulling piles

27

Vibratory Hammer

How do you know when to stop it?

Have to use another method to confirm pile capacity

28

Single-Acting (open-end) Diesel Hammer

Suitable for all types of pile

40 to 60 blows per minute

Carry their own fuel—they power themselves

Stroke of the piston is directly related to pile resistance

29

Single-Acting (open-end) Diesel Hammer

Expensive to buy

Fairly easy to maintain

Pollutes the air and gets diesel fuel all over you

Low blows per minute at high pile resistances

Most popular hammer on KDOT projects

30

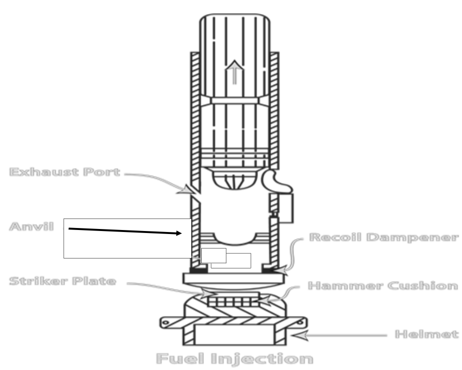
Most diesel hammers on our projects carry between 5 and 20 gallons of fuel.

The capacity is such that a hammer can work all day on one tank.

They also carry lubricating oil. The two tanks are side-by-side.

31

SINGLE-ACTING DIESEL HAMMER



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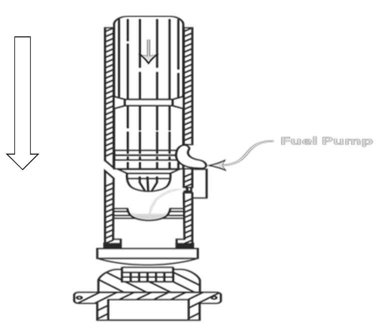

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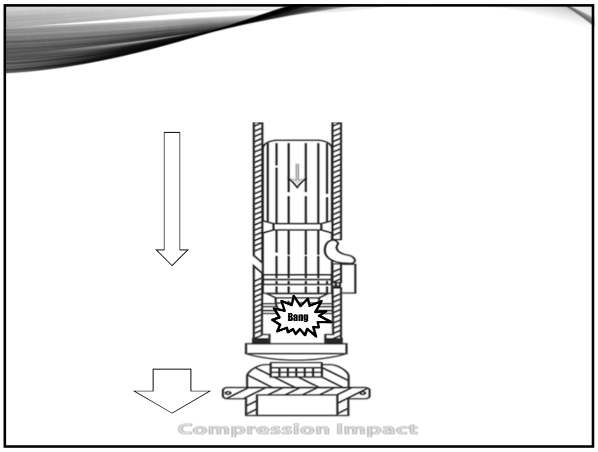

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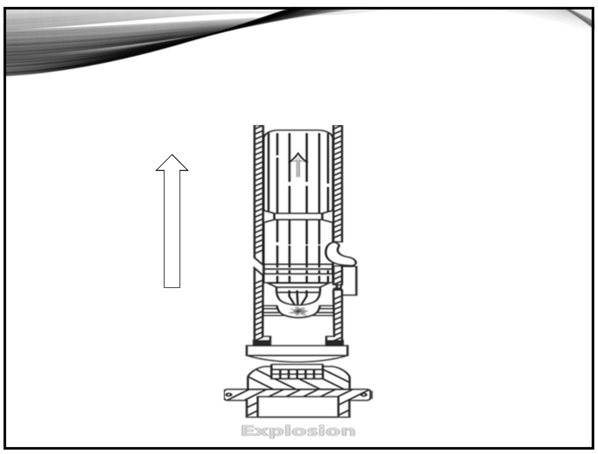

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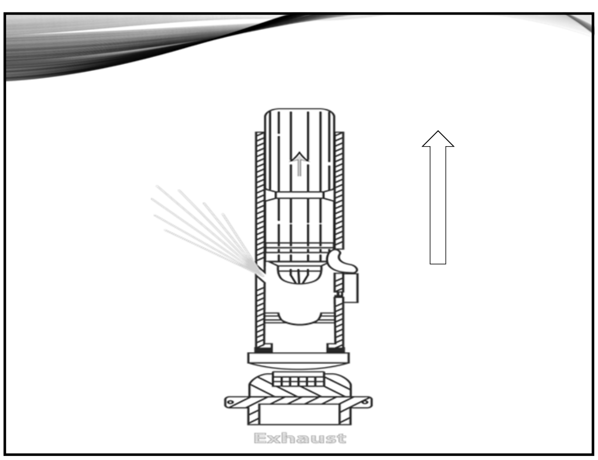

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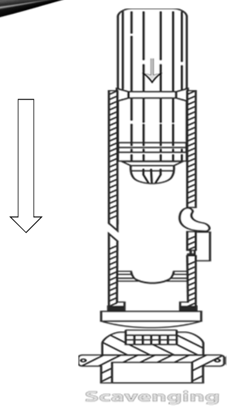
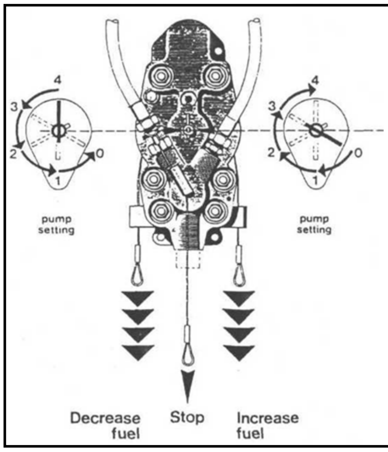


37



APE/Delmag Fuel Pump

38

Range of Energy per Blow, by Pump Setting:

Example: Delmag D19-42

Position 4:	**100 % =**	**42,800 ft-lbs**
Position 3:	**88 % =**	**37,660 ft-lbs**
Position 2:	**67 % =**	**28,680 ft-lbs**
Position 1:	**48 % =**	**20,540 ft-lbs**

39

Sometimes a contractor will drive different size pile or drive to different resistances with one large hammer. He will adjust the fuel setting accordingly.

40

You also have to be careful with concrete piles and may want to use a lower fuel setting to control the hammer energy

41

Ouija

Graduated Rod

Jump Stick

Yardstick

Make up your own name

42

Hydraulic Hammer

Suitable for all types of pile

30 to 50 blows per minute (single-acting)

40 to 90 blows per minute (double-acting)

Energy is adjustable

43

Hydraulic Hammer

Double-acting can be used for underwater driving

Expensive to buy

More complex maintenance than other hammers

Have to use another method to confirm pile capacity

44

Hydraulic Hammer

Not allowed on KDOT projects

Can’t stop it fast enough

45

Air Hammer

Suitable for all types of pile

35 to 60 blows per minute (single-acting)

95 to 300 blows per minute (double-acting)

Double-acting can be used for underwater driving

46

Air Hammer

Only moderately expensive to buy

Fairly easy to maintain

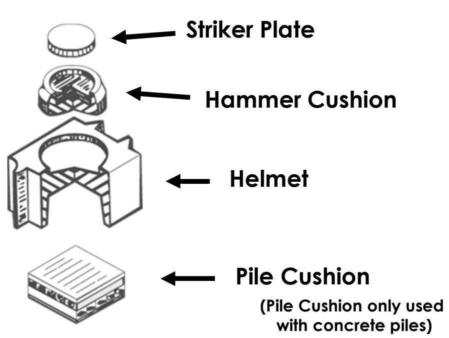
Need air compressor to run it

Heavy compared to most diesel hammers

Rarely seen on KDOT projects

47

PILE HELMET



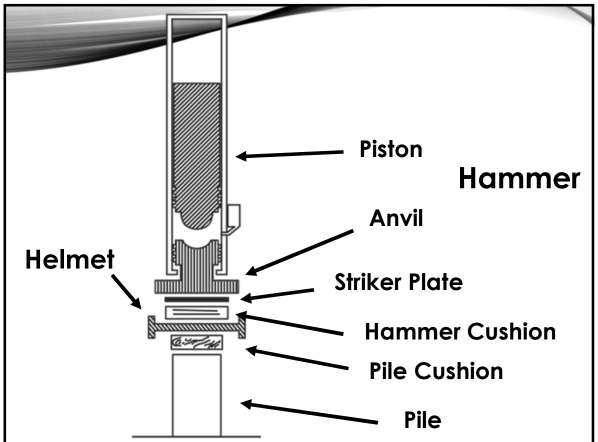
48

The bearing formula asks for the weight of the cap and anvil.

The “cap” is the pile helmet.

The “anvil” is the lowest piece of the hammer.

49



50

Normally, we call this piece the Helmet, because “pile cap” is also a structural term.

We don’t need to confuse things any more than they already are.

51

Entire assembly is referred to as the "Helmet" or "Cap"

Lowest piece is sometimes called the "Adapter"

52

Hammer-helmet-pile alignment *must* be maintained, especially when driving concrete pile and thin-walled steel pipe piles.

53

Hammer Cushions

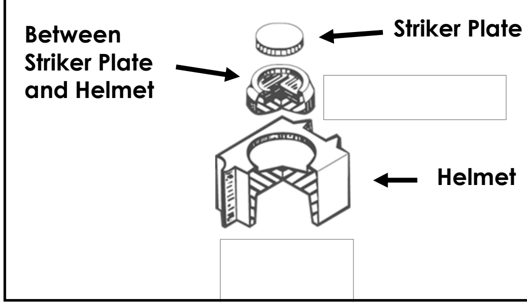
A hammer cushion is used between the hammer and the helmet to absorb some of the impact shock. This protects the hammer.

54

Sometimes also called a "cushion block"

55

HAMMER CUSHION



56

Worn-out hammer cushions cause bad things to happen…

Damage to the hammer, helmet or even the pile itself

Result in lower transferred energy to pile

Can result in increased bending stresses on pile

57

Acceptable Hammer Cushion Material

Micarta (phenolic fiber and aluminum)

Replace when it starts to powderize

58

Acceptable Hammer Cushion Material

Reinforced Phenolic Resin

59

Acceptable Hammer Cushion Material

Nylon (usually blue)

Replace when you see horizontal cracks (vertical cracks OK)

60

Acceptable Hammer Cushion Material

Nylon (usually blue)

Conbest is a popular brand of nylon cushion

61

Acceptable Hammer Cushion Material

Hammortex (a reel of fiber or Kevlar sheeting backed with aluminum)

Replace when it begins disintegrating

62

Acceptable Hammer Cushion Material

Urethane materials

Polymer materials

63

Aluminum may be present in laminations in hammer cushions, but only acts to transfer heat out of the cushion. This prolongs its life.

Wood, wire rope, and asbestos are *not* acceptable as a hammer cushion on KDOT projects.

(Wood can be used on gravity hammers)

64

No matter what the material, KDOT requires the contractor to replace a hammer cushion when it looks like it's deteriorating, or when it's lost 25% of the original thickness.

65

Most hammers on KDOT projects need cushions that are 2" to 3" thick.

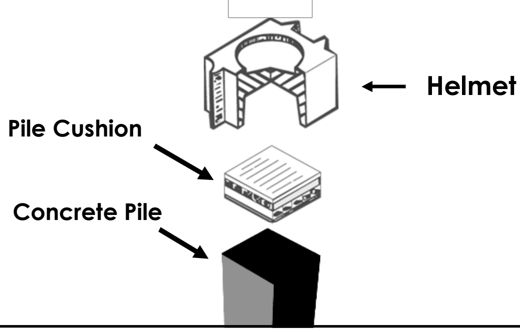
It is OK to use 2 thinner cushions to make up the needed thickness.

66

It’s not uncommon to have 2 thinner cushions of different materials, such as nylon and Micarta.

67

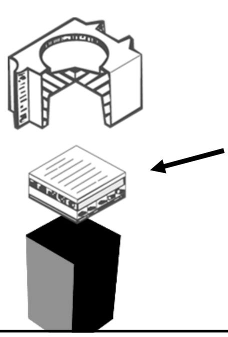
PILE CUSHION



68

PILE CUSHION

Concrete Pile



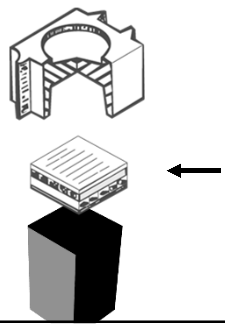
A **pile cushion** is required for concrete piles only

This protects the concrete from driving stresses

69

PILE CUSHION

Concrete Pile



It will almost always consist of a stack of plywood sheets cut to fit inside the helmet.

It will try to catch fire after the hammer heats up during driving. Keep an eye on it.

70

Follower

Used as an extension of the pile between the hammer and the pile head

71

Problems with followers

The follower will have a different weight per unit length from the pile

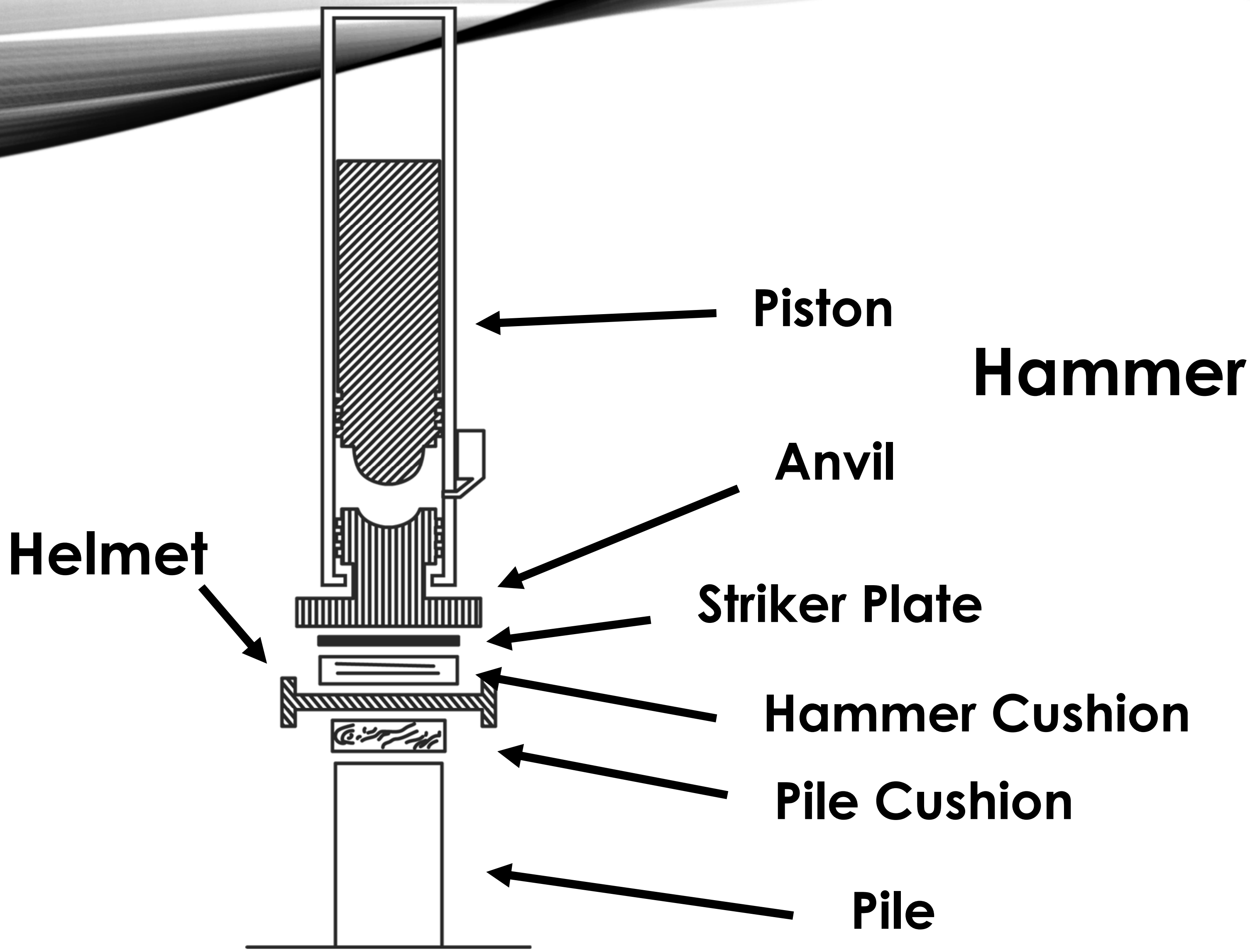
Hard to keep aligned

Allows for additional energy loss due to the compression of the follower and energy losses at the connections

72

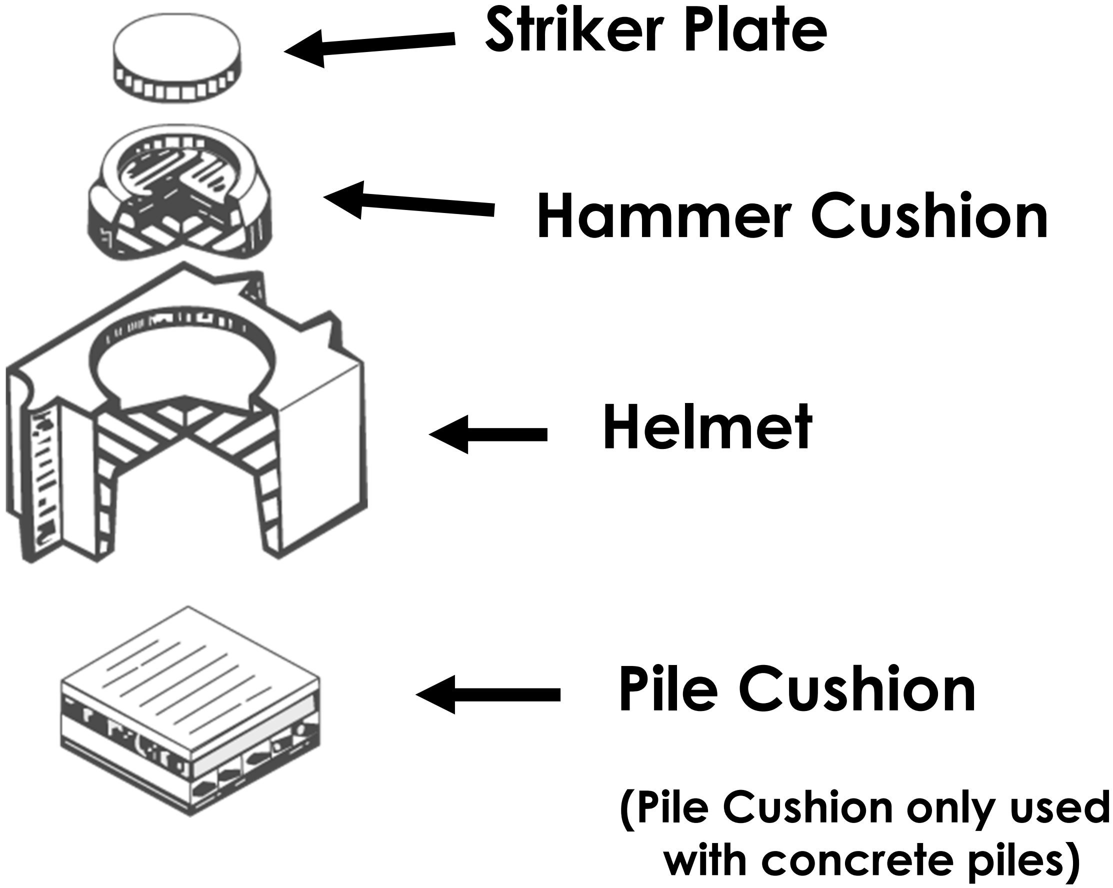
For these reasons, followers are not allowed on KDOT projects, except with the written permission of the Engineer

73



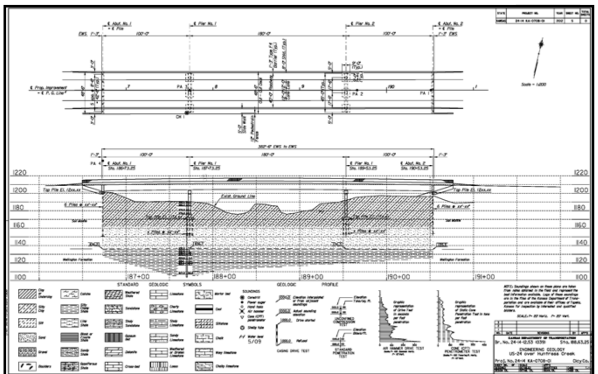
Piston
Hammer
Anvil
Helmet
Striker Plate
Hammer Cushion
Pile Cushion
Pile

PILE HELMET


Striker Plate
Hammer Cushion
Helmet
Pile Cushion
(Pile Cushion only used
with concrete piles)

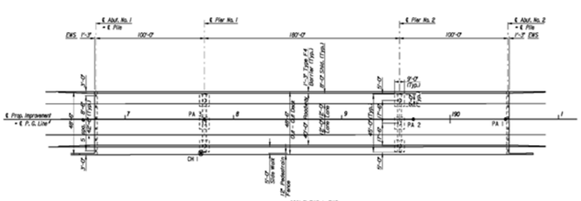
Plan Sheets and Geology

1



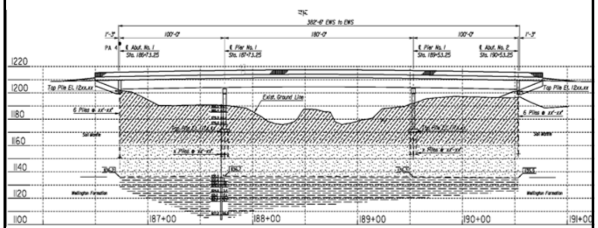
Let's look at the Engineering Geology sheet

2



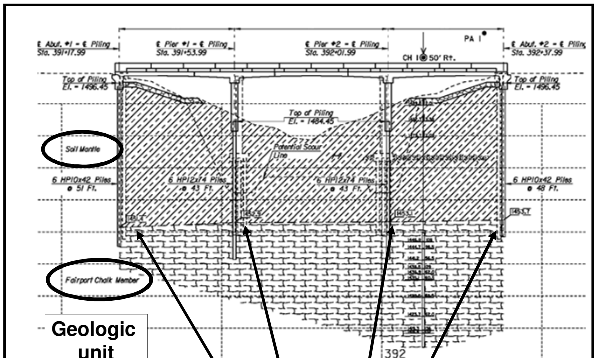
Top half of page shows plan view of bridge with our drill locations

3



Bottom half of page shows a cross-section of the subsurface, with geology drawn in

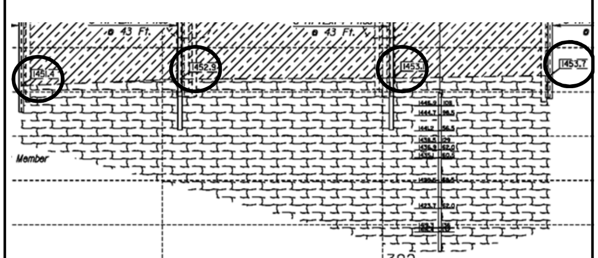
4



Geologic unit names

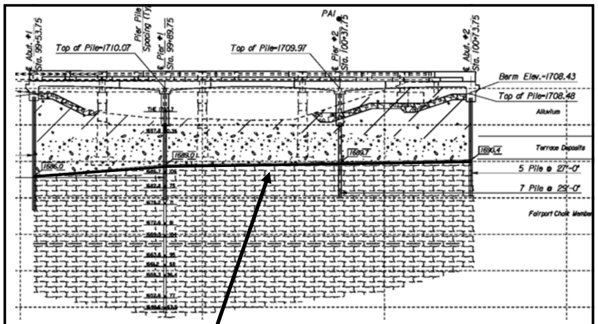
Bedrock elevation contacts

5



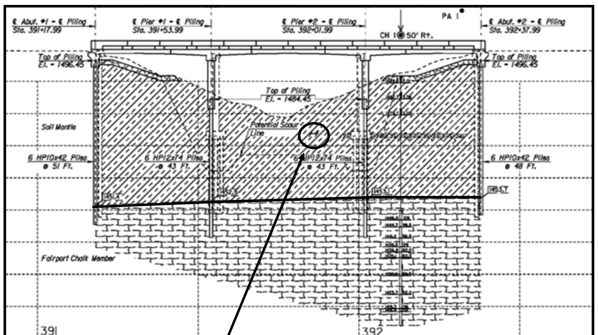
Bedrock elevation contacts

6



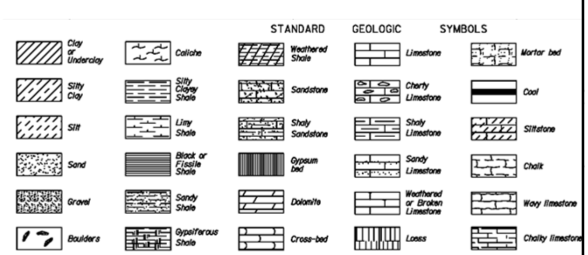
Top-of-Bedrock

7



Water Level Symbol

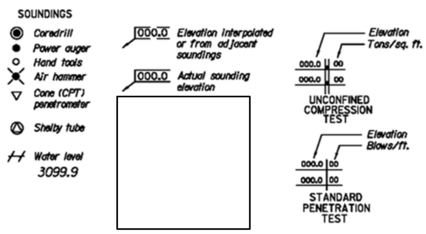
8



Standard Geology Symbols

Lower left corner of Engineering Geology sheet

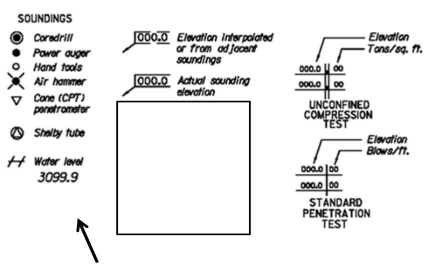
9



Legend

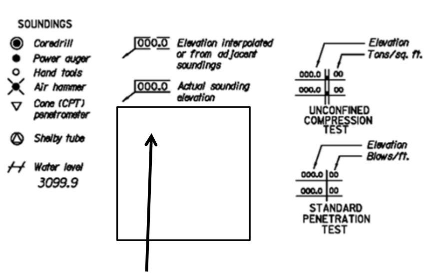
Bottom of Engineering Geology sheet

10



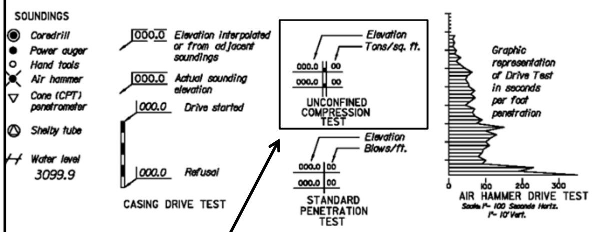
Symbols used on page

11



Examples of elevation callouts on cross-section view

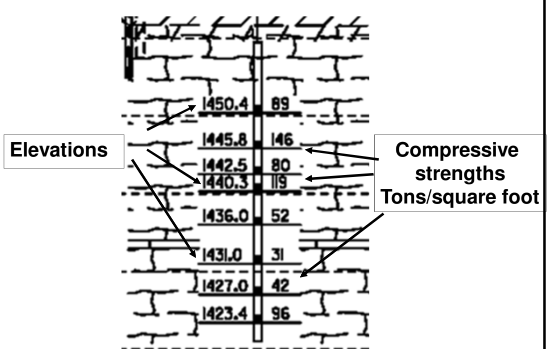
12



Format of results of lab strength tests on core samples

13

"Core Tree" on Engineering Geology Sheet
Results of lab tests on soil and rock samples



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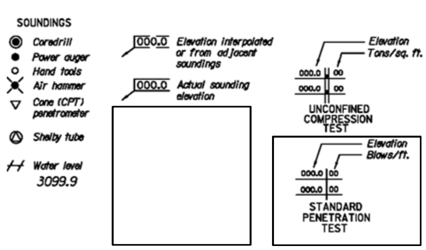


Format of standard penetration test results

15

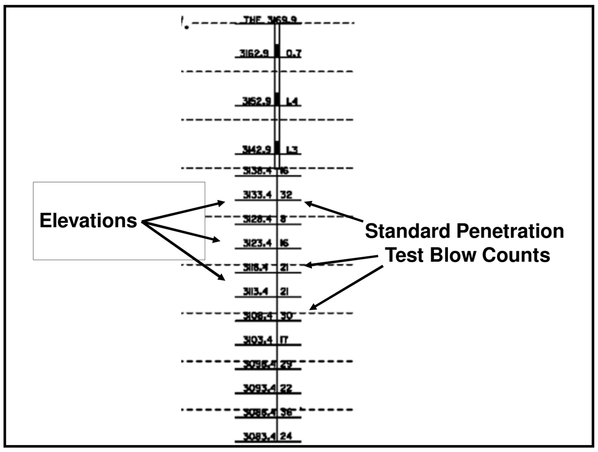
Standard Penetration Test

Gives both a relative resistance of the soil and a sample of it

Been around since the 1920's

Used all over the world

16



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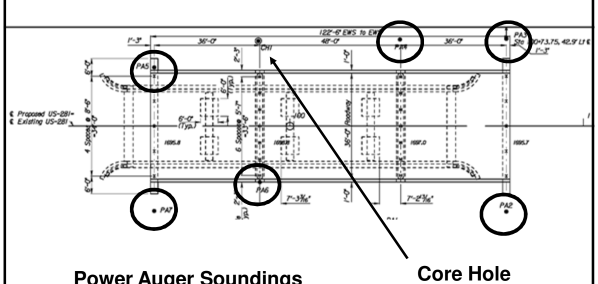

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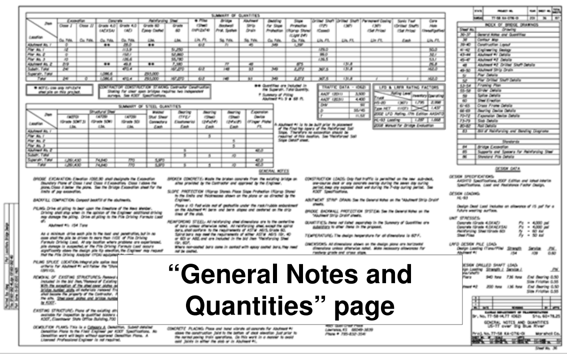

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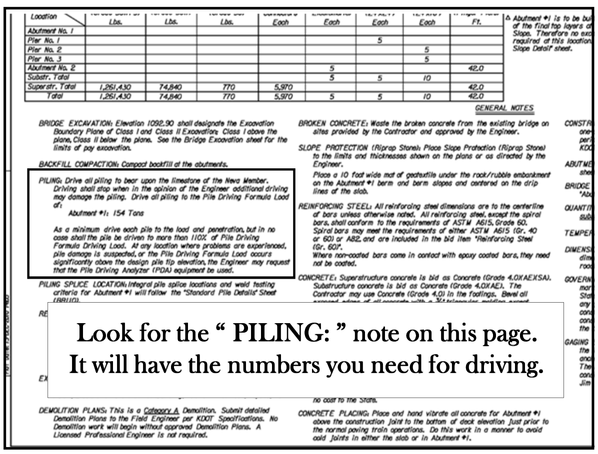


20

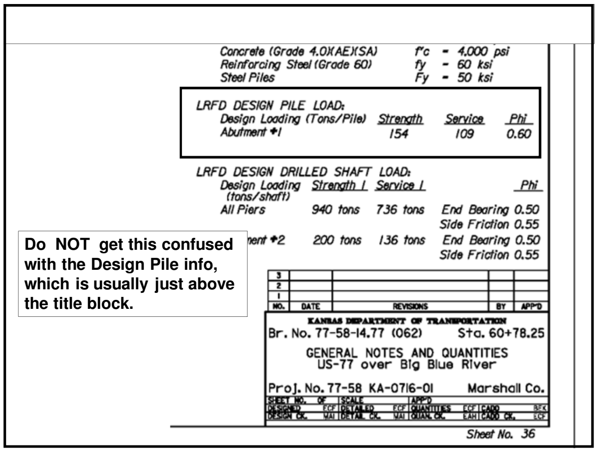
PILING: Drive all piling to bear upon the limestone of the Neva Member. Driving shall stop when in the opinion of the Engineer additional driving may damage the piling. Drive all piling to the Pile Driving Formula Load of:

Abutment #1: 154 Tons

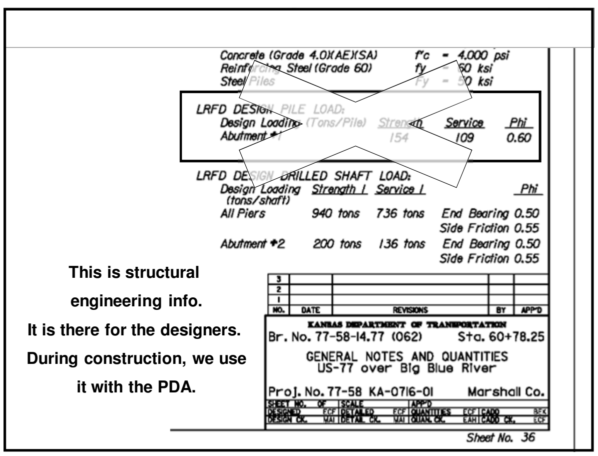
As a minimum drive each pile to the load and penetration, but in no case shall the pile be driven to more than 110% of Pile Driving Formula Driving Load. At any location where problems are experienced, pile damage is suspected, or the Pile Driving Formula Load occurs significantly above the design pile tip elevation, the Engineer may request that the Pile Driving Analyzer (PDA) equipment be used.

This is what you're interested in.

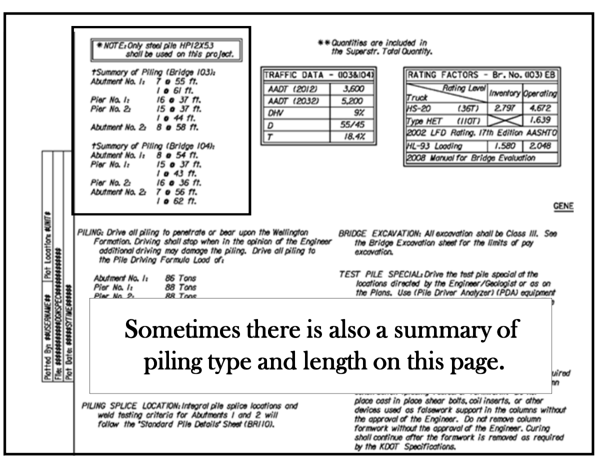
21


Concrete (Grade 4.0)(AE)(SA) f'c = 4,000 psi
Reinforcing Steel (Grade 60) fy = 60 ksi
Steel Piles Fy = 50 ksi
LRFD DESIGN PILE LOAD:
Design Loading (Tons/Pile) Strength Service Phi
Abutment #1 154 109 0.60
LRFD DESIGN DRILLED SHAFT LOAD:
Design Loading (tons/shaft) Strength I Service I Phi
All Piers 940 tons 736 tons End Bearing 0.50
Side Friction 0.55
Abutment #2 200 tons 136 tons End Bearing 0.50
Side Friction 0.55
Do NOT get this confused with the Design Pile info, which is usually just above the title block.
KANSAS DEPARTMENT OF TRANSPORTATION
Br. No. 77-58-14.77 (062) Sta. 60+78.25
GENERAL NOTES AND QUANTITIES
US-77 over Big Blue River
Proj. No. 77-58 KA-0716-01 Marshall Co.
Sheet No. 36

22


Concrete (Grade 4.0)(AE)(SA) f'c = 4,000 psi
Reinforcing Steel (Grade 60) fy = 60 ksi
Steel Piles Fy = 50 ksi
LRFD DESIGN PILE LOAD:
Design Loading (Tons/Pile) Strength Service Phi
Abutment #1 154 109 0.60
LRFD DESIGN DRILLED SHAFT LOAD:
Design Loading (tons/shaft) Strength I Service I Phi
All Piers 940 tons 736 tons End Bearing 0.50
Side Friction 0.55
Abutment #2 200 tons 136 tons End Bearing 0.50
Side Friction 0.55
This is structural engineering info.
It is there for the designers.
During construction, we use it with the PDA.
KANSAS DEPARTMENT OF TRANSPORTATION
Br. No. 77-58-14.77 (062) Sta. 60+78.25
GENERAL NOTES AND QUANTITIES
US-77 over Big Blue River
Proj. No. 77-58 KA-0716-01 Marshall Co.
Sheet No. 36

23


* NOTE: Only steel pile HP12X53 shall be used on this project.
†Summary of Piling (Bridge 103):
Abutment No. 1: 7 @ 55 ft. 1 @ 61 ft.
Pier No. 1: 16 @ 37 ft.
Pier No. 2: 15 @ 37 ft. 1 @ 44 ft.
Abutment No. 2: 8 @ 58 ft.
†Summary of Piling (Bridge 104):
Abutment No. 1: 8 @ 54 ft.
Pier No. 1: 15 @ 37 ft. 1 @ 43 ft.
Pier No. 2: 16 @ 36 ft.
Abutment No. 2: 7 @ 56 ft. 1 @ 62 ft.
** Quantities are included in the Superstr. Total Quantity.
TRAFFIC DATA - (103&104)
AADT (2012) 3,600
AADT (2032) 5,200
DHV 9%
D 55/45
T 18.4%
RATING FACTORS - Br. No. (103) EB
Rating Level Truck Inventory Operating
HS-20 (36T) 2.797 4.672
Type HET (110T) 1.639
2002 LFD Rating, 17th Edition AASHTO
HL-93 Loading 1.580 2.048
2008 Manual for Bridge Evaluation
PILING: Drive all piling to penetrate or bear upon the Wellington Formation. Driving shall stop when in the opinion of the Engineer additional driving may damage the piling. Drive all piling to the Pile Driving Formula Load of:
Abutment No. 1: 86 Tons
Pier No. 1: 88 Tons
BRIDGE EXCAVATION: All excavation shall be Class III. See the Bridge Excavation sheet for the limits of pay excavation.
TEST PILE SPECIAL: Drive the test pile special at the locations directed by the Engineer/Geologist or as on the Plans. Use (Pile Driver Analyzer) (PDA) equipment
Sometimes there is also a summary of piling type and length on this page.
PILING SPLICE LOCATION: Integral pile splice locations and weld testing criteria for Abutments 1 and 2 will follow the "Standard Pile Details" Sheet (BR110).
place cast in place shear bolts, coil inserts, or other devices used as falsework support in the columns without the approval of the Engineer. Do not remove column formwork without the approval of the Engineer. Curing shall continue after the formwork is removed as required by the KDOT Specifications.

24

LRFD – Load and Resistance Factor Design

The current approach to structural design. The US now uses this system to design bridges.

Changes the way "safety factors" are used, to keep bridges from being overdesigned.

25

LRFD – Load and Resistance Factor Design

The loads on the foundation and columns and so forth are factored

The resistances that work against those loads are factored, too—in our case, the soil and rock that support the piling

Mandated by the Federal Highway Administration to save money

26

For years at KDOT, we drove piling to the *Allowable Load*.

Under LRFD, it is called the *Pile Driving Formula Load* .

27

If necessary, **we can drive to 110 % of the Pile Driving Formula Load.**

That's usually *not* necessary.

Most of the time, you should drive to the pile driving formula load and then stop.

28

If necessary, **we can drive to 110 % of the Pile Driving Formula Load.**

If you are driving to a certain depth, then the 110 % rule can be handy.

On most projects, going over the specified load is wasting money at best.

29

If necessary, **we can drive to 110 % of the Pile Driving Formula Load.**

At worst, you could damage the pile.

Make sure you have a good reason for driving much past the specified load.

30

Let's take another example….

Plotted By: $$USERNAME$$ | Plot Location: $UN
File: $$$$$$$$$$DGNSPEC$$$$$$$$$$$$$$$
Plot Date: $$$$SYTIME$$$$$$

PILING: Drive all piling to penetrate or bear upon the Wellington Formation. Driving shall stop when in the opinion of the Engineer additional driving may damage the piling. Drive all piling to the Pile Driving Formula Load of:

Abutment No. 1:	*86 Tons*
Pier No. 1:	*88 Tons*
Pier No. 2:	*88 Tons*
Abutment No. 2:	*86 Tons*

As a minimum drive each pile to the load and penetration, but in no case shall the pile be driven to more than 110% of Pile Driving Formula Driving Load. At any location where problems are experienced, pile damage is suspected, or the Pile Driving Formula Load occurs significantly above the design pile tip elevation, the Engineer may request that the Pile Driving Analyzer (PDA) equipment be used.

31

Abutment No. 1	**86**	**Tons**
Pier No. 1	**88**	**Tons**
Pier No. 2	**88**	**Tons**
Abutment No. 2	**86**	**Tons**

Let's do Abutment 2….

86 tons x 1.1 = 94.6 tons

So we'd drive to 86 tons. If necessary, we could go to 95 tons.

32

Sometimes you will go a little over the 110% when checking the resistance 20 blows at a time.

33

That's OK. Write it down the way it happened. Just as long as we aren't deliberately driving it too much.

34

Bridge Foundation Geology Report

BRIDGE FOUNDATION GEOLOGY REPORT

Bridge Replacement Project
36-79 KA-2085-01
Bridge No. 15.84 (069)
US 36 over Riley Creek

Republic County

ROBERT W. HENTHORNE, P.G.
CHIEF GEOLOGIST

By

Jeffrey W. Geist, P.G., Professional Geologist II
Neil M. Croxton, P.G., CPG, Regional Geologist

November, 2012

Kansas Department of Transportation

BUREAU of MATERIALS and RESEARCH

GEOTECHNICAL UNIT

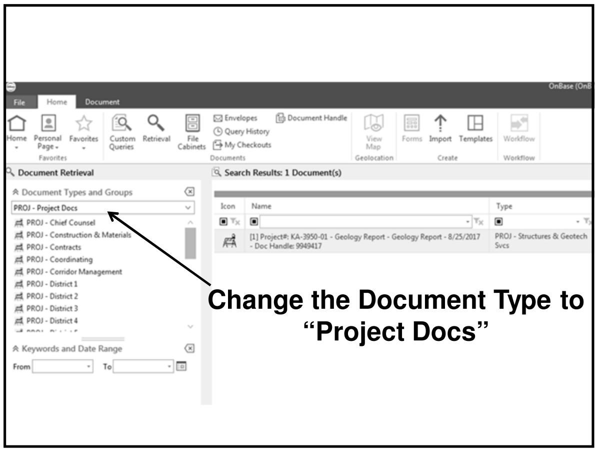
35

To find Geology Reports on Document Management from KDOT computer:

Open OnBase

Go to the Retrieval tab

36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"Project Docs"

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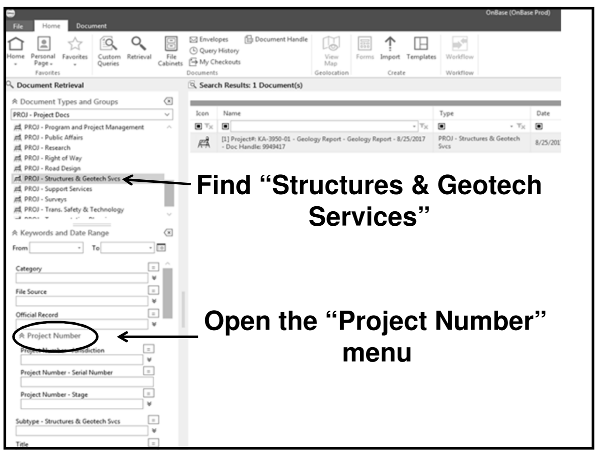
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Services"
Open the "Project Number"
menu

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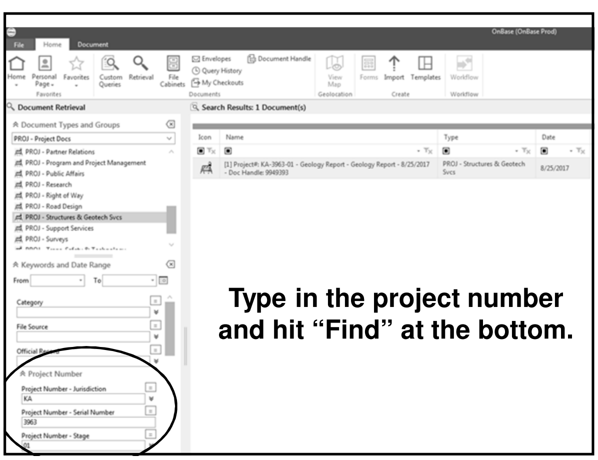
Type in the project number
and hit "Find" at the bottom.

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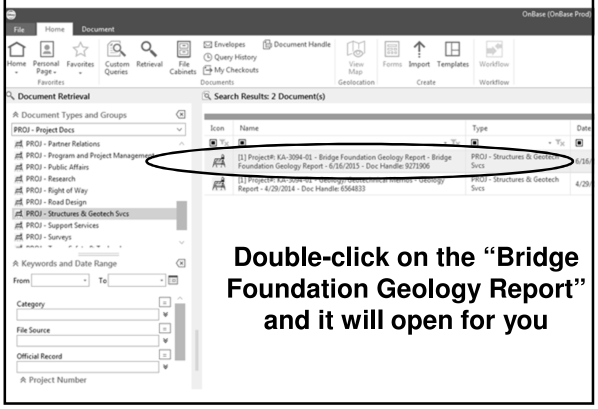


Double-click on the "Bridge Foundation Geology Report" and it will open for you

40

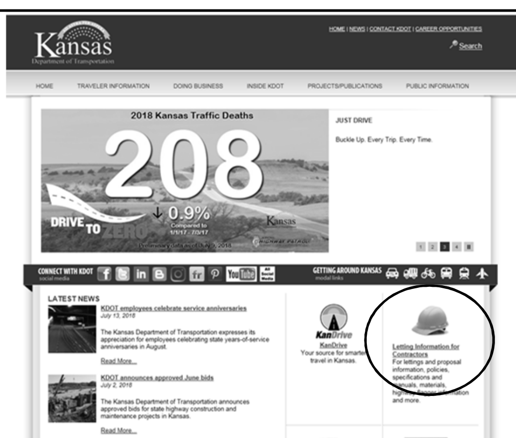
To find Geology Reports from an outside computer:

https://www.ksdot.org

"Letting Information for Highway Contractors"

"Exploratory and Project Reports"

41



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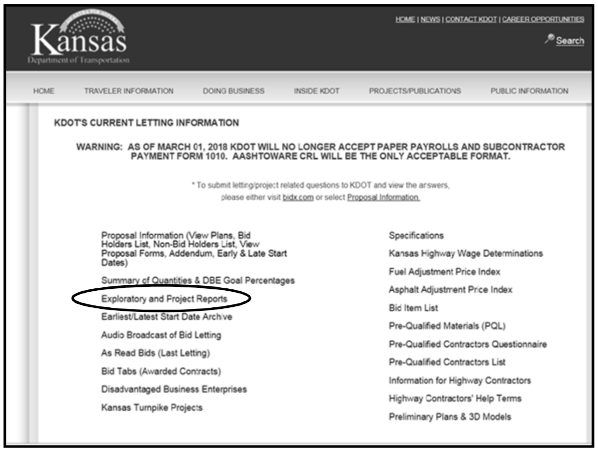

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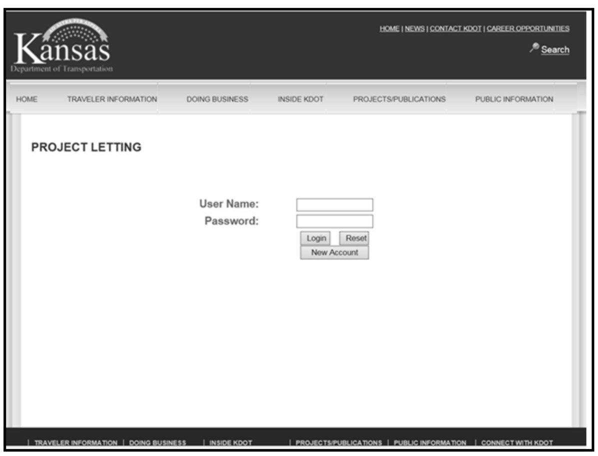


44

Reading the Geology Report is one of the first things you should do on a piling project.

It will describe the geology of the site in great detail, and tell you what to expect in the field when pile driving starts. It will warn you about any problems you might have with stray boulders, groundwater, strange pile lengths, or whatever.

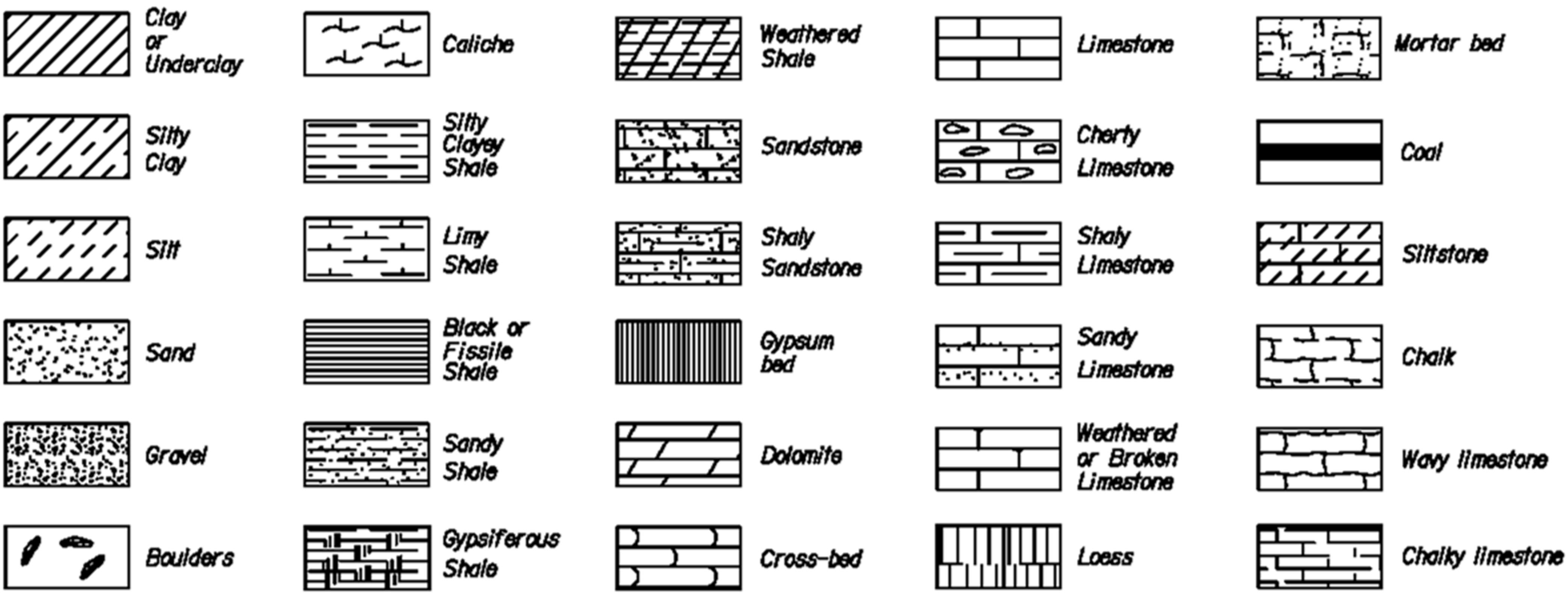
45

Knowing the geology of your project ahead of time is important because you can damage piling if you try to drive it into hard bedrock

46

Call your Regional Geologist with any questions about how the geology of your project will affect pile driving.

47



Standard Geology Symbols

The Bearing Formula & Problems with Dynamic Formulas

1

List of the Formulas

- **Standard Specifications**
- **Version July 2015**
- **Section 704**
- **Table 704-1 Pile Formulas**
- **Page 700-19**

2

List of the Formulas

- **Bridge Construction Manual**
- **Version Oct 2009(updated** 5-21-13**)**
- **Chapter 5.3 Driven Pile**
- **Section 5.3.8.2 Pile Driving Formulas**
- **Page 39**

3

TABLE 704-1: PILE FORMULAS

Hammer	Pile Type	Formula
Gravity	Steel Steel Shell Steel Sheet	$P=\frac{3\ W\ H}{S+0.35}\left(\frac{W}{(W+X)}\right)$
Air/Steam (Single Acting)	All Types	$P=\frac{2\ W\ H}{S+0.1}$
Air/Steam (Double Acting)	All Types	$P=\frac{2\ E}{S+0.1}$
Delmag and McKierman-Terry*	All Types	$P=\frac{1.6\ W\ H}{S+0.1\left(\frac{X^{**}}{W}\right)}$
Link-Belt*	All Types	$P=\frac{1.6\ E}{S+0.1\left(\frac{X^{**}}{W}\right)}$

*diesel hammers
** For diesel hammers, the quantity X/W shall not be less than 1.
P = safe bearing power in pounds
W = weight in pounds, of striking part of hammer
H = height of fall in feet
E = energy of ram in foot-pounds per blow
S = the average penetration in inches per blow for the last 5 blows for gravity hammers and the last 20 blows for air/steam or diesel hammers
X = weight in pounds of the pile plus the weight of any cap and/or anvil used on the pile during driving

4

Computer Version of the Bearing Formulas

- Field Pile Driving Guide
- Download from Forms Warehouse
- Form 217b (new forms)

5

Bearing Formula – English Version

P= 1.6 W H (Delmag Diesel Hammer)
S + [0.1(X / W)]

$$P=\frac{1.6\ W\ H}{S+[0.1(X/W)]}$$

P= Bearing in pounds
W= Weight of hammer ram in pounds
H= Fall height of the ram (stroke) in feet
S= Average set per blow in inches
X= Pile weight + anvil weight + cap weight in pounds

- **For diesel hammers (x/w) is dropped if less than one**
- **Most commonly used formula on KDOT jobs**
- **Also known as the Engineering News Record (ENR) formula**

6

Using the Bearing Formula

- **Piles should be driven to a minimum bearing capacity equal to the <u>Pile Driving Formula Load</u> listed in the plans**
- **For LRFD projects began-110% of the pile driving formula load will be the max allowed**

7

Determining Max. Capacity

Pile driving formula load listed is 55 tons

- Using the bearing formula, the **minimum** bearing capacity needed is **___tons**
- The **maximum** capacity the pile can be driven to is 55 tons x 110% = **___tons**

8

Determining Max. Capacity

Pile driving formula load listed is 55 tons

- **Using the bearing formula, the minimum bearing capacity needed is <u>55 tons</u>**
- **The maximum capacity the pile can be driven to is 55 tons x 110% = <u>60.5 tons</u>**

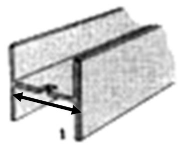
9

Pile Call Out

What do the numbers on H-pile represent?

Size and **Weight**

- **For H-pile HP10x42**
  - The **10** represents the width of the web in inches
  - **42** represents the weight of the pile per linear foot (pounds/ft)



10

Class Problem using the Bearing Formula For A Delmag Hammer

$$P = \frac{1.6\ W\ H}{S + [0.1(X / W)]}$$

11

- **You are driving HP 10 x 42 using a Delmag D12 hammer.**
- **Hammer ram weight is 2820 pounds (from contractor)**
- ~~**Cap + Anvil weight is 2710 pounds (from contractor)**~~
- **24 feet of pile placed in the leads**
- **PDF Load is 55 tons (max is 55 x 110% = 60.5 tons)**
- **You have a stroke of 7.5 feet**
- **You record 3 inches of movement in 20 blows**

$$P = \frac{1.6\ W\ H}{S + 0.1(X / W)}$$

12

- You are driving HP 10 x 42 using a Delmag D12 hammer.
- Hammer ram weight is 2820 pounds (from contractor)
- Cap + Anvil weight is 2710 pounds (from contractor)
- 24 feet of pile placed in the leads
- PDF load is 55 tons (max is 55 x 110% = 60.5 tons)
- You have a stroke of 7.5 feet
- You record 3 inches of movement in 20 blows

$$P = \frac{1.6\,W\,H}{S + 0.1(X / W)}$$

W = Weight of Hammer Ram = 2820 pounds
H = Stroke of Hammer = 7.5 feet
S = Set per blow (3 inches/20blows) = .15 inch
Cap + Anvil weight = 2710 pounds
Pile weight (24 feet x 42 pounds) = 1008 pounds
X = Cap + Anvil + Pile weight = 2710 + 1008 = 3718 pounds
X/W= 3718/2820 = 1.3

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W= ram weight = 2820 lbs
H= stroke height = 7.5 feet
S= average set per blow = .15 inch
X= Cap + Anvil + Pile weight = 3718 pounds
X/W = 3718/2820 = 1.3≥1.0
Pile Driving Formula load = 55 tons

$$P = \frac{1.6\,W\,H}{S + [0.1(X / W)]}$$

$$P = \frac{1.6\,(2820)(7.5)}{0.15 + (0.1 \times 1.3)} = \frac{33840}{0.15 + 0.13}$$

$$P = \frac{33840}{0.28} = 120857 \text{ Pounds}$$

$$P = \frac{120857}{2000} \text{ (to get to tons)}$$

P= 60.4 tons (Minimum Bearing Needed is 55 tons)

You Have the Required Bearing

14

Delmag McKierman Terry (Diesel Hammer) Example

Summary			Formula	Entry Data			
Hammer Wt.	4200	lbs	$P = \frac{1.6 \cdot W \cdot H}{S + 0.1 \cdot \left(\frac{X^{**}}{W}\right)}$	Weight per foot of piling (lbs/ft):	42 lbs/ft.	Minimum Hammer Drop	
Cap/Anvil Wt.	980	lbs		Length of Pile:	52.3 feet	4	ft.
Pile Type				X:	3177 lbs	Maximum Hammer Drop	
Min. Res.	60	tons		Minimum "S":	0.000 inches/blow		
Max. Res.	90	tons		Maximum "S":	0.500 inches/blow	10	ft.

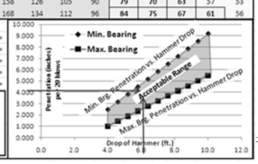
PROJECT SCOPE: HP10x42 pile, 52.3 ft long...Observed approximately 4 to 4.25 inches in 20 blows with about 6 feet hammer drop.

Penetration per 20 blows (in.)		0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000
Average Penetration per blow (in.) "S"		0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500
Drop of Hammer (Stroke) (ft.)	Drop of Hammer "H" in feet.	Computed Resistance (tons)										
	4.0	134	90	67	54	45	38	34	30	27	24	22
	4.6	155	103	77	62	52	44	39	34	31	28	26
Calculated Bearing is HIGH	5.2	175	116	87	70	[illegible]						
	5.8	195	130	97	78	65						
	6.4	215	143	108	86	72						
Calculated Bearing is GOOD	7.0	235	157	118	94	78						
	7.6	255	170	128	102	85						
	8.2	276	184	138	110	92	79	69	61	55	50	46
Calculated Bearing is LOW	8.8	296	197	148	118	99	84	74	66	59	54	49
	9.4	316	211	158	126	105	90	79	70	63	57	53
	10.0	336	224	168	134	112	96	84	75	67	61	56

Based on a hammer drop of around 6.0 ft.
Based on around 4 inches of penetration in the last 20 blows.
Bearing is within acceptable range: it is between 65 ton and 72 ton.

Drop of Hammer "H" in feet.	Required per 20 blows Resistance (in.)	Required per 20 blows Resistance (in.)	
4.0	2.480	0.987	->
4.6	3.152	1.435	->
5.2	3.824	1.883	->
5.8	4.496	2.331	->
6.4	5.168	2.779	->

Minimum Bearing is achieved if penetration is LESS than a number between 4.496" and 5.168". 4" is less, so OK.
Maximum Bearing is not exceeded if penetration is MORE than a number between 2.331" and 2.779". 4" is more, so OK.
Graphically, to the right, the penetration per 20 blows of about 4" with a hammer drop of 6 feet is in the acceptable range.



15

Class Problem

You are inspecting a pile driving operation in which the contractor is using a Delmag D15 open end diesel hammer to drive 12 X 53 H-pile that is 50 feet long. The contractor has supplied you with the following hammer specification information:

Ram (piston) weight	**3300 pounds**
Cap weight	**1323 pounds**
Anvil weight	**311 pounds**
Total hammer weight	**6603 pounds**

With a pile penetration depth of 42.5 feet you record a pile movement of 3.5 inches in 20 blows and observe a hammer stroke of 6.5 feet. Using the KDOT bearing formula for a Delmag hammer what is the bearing capacity of the pile at that time?

$$P = \frac{1.6\,W\,H}{S + 0.1(X / W)}$$

P = bearing capacity in pounds **W = weight of ram in pounds**

H = height of stroke in feet, **S = set per blow in inches**

X = weight of pile, anvil, and cap in pounds

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W= Mass of ram = 3300 pounds

H= Stroke or fall height = 6.5 feet

S= set per blow = 3.5 inches/20 blows = .175 inch

X= mass of anvil + cap + pile = 311+1323+(50 X 53)

= 311+1323+2650 = 4284 pounds

X/W = 4284/3300 = 1.3$\geq$1.0 OK

$$P = \frac{(1.6)(3300)(6.5)}{0.175 + [0.1(1.3)]} = \frac{34320}{0.175 + 0.13}$$

$$P = \frac{34320}{0.305} = 112524.59 \text{ pounds}$$

$$P = \frac{112524.59}{2000} = 56.26 \text{ tons}$$

17

Other uses of the Bearing Formula

- Checking the size of the hammer
- Calculating the required set in 20 blows

18

Checking the size of the Hammer

The inspector should check to see if the contractors hammer is big enough to drive the pile

To do this you will need the hammer specs
(these are provided by the contractor)

Assume a practical refusal of 10 blows/inch

Use the maximum stroke the hammer can achieve

Plug the number into the bearing formula

Your answer should be
- Now with LRFD projects
  - Pile Driving Formula Load < P < 110%PDFL

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Where to find an example

- Bridge Construction Manual
- Version Oct 2009(updated 2012)
- Chapter 5.3 Driven Pile
- Section 5.3.6.2 Preparing to Drive Pile
- Pages 19-20

20

Checking the size of the hammer

Driving 40 feet of 10x42 H-pile using a Delmag D12

Piston weight = **2750** pounds **(W)**

Cap and anvil weight = 2690 pounds

Pile weight = 40 feet x 42 lbs./ft = 1680 lbs.

Weight of pile + weight of cap and anvil=
2690 + 1680 = **4370** pounds **(X)**

$$P = \frac{1.6\,W\,H}{S + 0.1(X / W)}$$

Maximum stroke = **8.17** feet **(H)**

1inch/10blows = **0.1** inch/blow **(S)**

P= Pile Driving Formula Load = 112,000 pounds or 56 tons.

110% of design load is 123,200 pounds or 62 ton

21

W= 2750 pounds X= 4370 pounds

H= 8.17 feet S= 0.1 inch

X/W= 1.6

Pile Driving Formula Load=112,000 pounds or 56 tons
110% = 123,200 pounds or 62 tons

$$P = \frac{1.6\,W\,H}{S + 0.1(X / W)} = \frac{(1.6)(2750)(8.17)}{0.1 + [(0.1)(1.6)]}$$

P=138,261 pounds = 69 tons

112,000 pounds<123,200 pounds<138,261 pounds

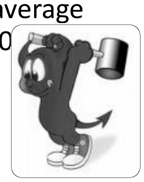
56 tons < 62 tons < 69 tons

However use caution as the Hammer is Capable of overdriving the pile

22

Calculating the required set in 20 blows

Now that the hammer has been found to be okay you can calculate the actual average penetration required for the last 20 needed to achieve bearing



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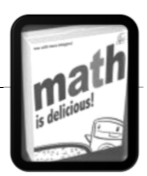
$$P = \frac{1.6\,W\,H}{S + 0.1(X / W)}$$

$$S = \frac{1.6\,W\,H}{P} - 0.1(X/W)$$



$$S = \frac{(1.6)(2750)(8.17)}{112{,}000} - 0.1(1.589)$$

S = 0.321 – 0.159 = 0.16 inch/blow

This means that for the last 20 blows the pile should be driven down 3.2 inches (0.16inch per blow x 20 blows) or less.

If the pile is driven further than 3.2 inches for 20 blows, then the pile does **NOT** have the required bearing yet.

24

Problems with Dynamic Formulas

Dynamic formulas are based on physics and transfer of energy with built in assumptions

25

Formula components

1. **Driving system**
2. **Soil resistance**
3. **Pile**

26

Formula components

1. **Driving system**
2. **Soil resistance**
3. **Pile**

27

1. The Driving System

Dynamic formulas offer a poor representation of the driving system and the energy losses of the drive system components

28

The Driving System

- Equipment performance variability is typically not considered
  - Driving systems include many elements in addition to the ram such as the anvil, helmet, hammer cushion, and pile cushion
- These components affect the hammer energy at and after impact which influences the magnitude and duration of peak force
- Peak force and duration determines the ability of the driving system to advance the pile into the soil.

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Formula components

1. Driving system
2. Soil resistance
3. Pile

30

2. The Soil Resistance

- Assumes soil resistance is a constant force
  - This assumption neglects obvious characteristics of real soil behavior
- Dynamic soil resistance is the resistance of the soil to rapid penetration produced by a hammer blow
  - This resistance is not equal to static soil resistance
  - Most dynamic formulas consider the resistance during driving to be equal to static resistance or pile capacity
    - In most cases capacity will increase or decrease with time due to soil set up or relaxation

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Formula components

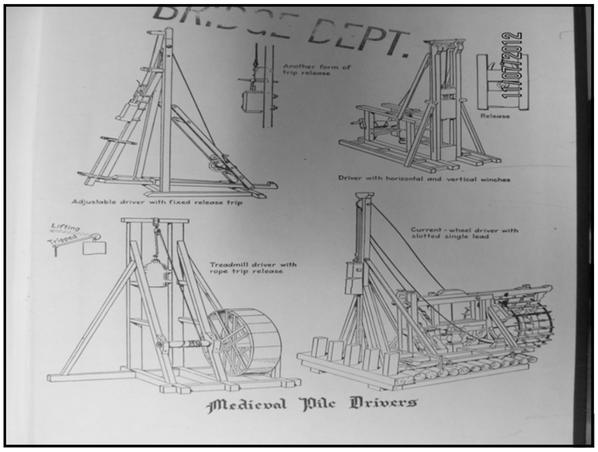
1. Driving system
2. Soil resistance
3. Pile

32

3. The Pile

- The dynamic formulas assume a rigid pile
  - Piles have flexure allowing them to penetrate the soil
  - Pile also have elastic properties
    - These compressive waves are responsible for advancing the pile into the ground
- Some formulas do not take the weight of the pile into account
  - KDOT's formula does

33



34

Case Histories

Take a look at a few cases where dynamic formulas gave inaccurate results

4 Cases

- 2 outside of KDOT
  - Various pile types and hammer types
  - Engineering News formula and Gates formula
  - PDA and static load test
- 2 KDOT projects
  - Our formula
  - PDA

35

Case 1

- 24 inch square pre-stressed concrete pile
- 12 inch diameter void in center of pile
- Pile was driven to a final penetration of 34 blows per foot (end of drive)
- Re-strike test 13 days later penetration was 118 blows per foot
- Pile was then static load tested

36

Case 1 Results

- Using end of drive data
  - The ENR formula predicted an allowable design load of 153 tons
- Dynamic testing with PDA on re-strike gave an ultimate pile capacity of 462 tons
- Static test had a failure load of 475 tons
- Hence:
  - The formulas significantly under predicted the allowable and ultimate pile capacity

37

Case 2

- 14 inch closed end pipe pile
- Design load 110 tons
- Pile was driven to a final penetration of 148 blows per foot (end of drive)
- Restrike was preformed
- Pile was static load tested

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Case 2

- End of drive data
  - ENR formula predicted an allowable design load of 245 tons
  - PDA at end of drive ultimate capacity 229 tons
- PDA on re-strike showed decrease of ultimate capacity to 205 tons
- Static test had a failure load of 210 tons
  - PDA re-strike testing nearly matches static load testing
- Assuming a safety factor of 2, allowable capacity would be 105 tons (210 tons/2)

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In this case:

- ENR formula over predicted the allowable design load by more than 230%
- Over prediction partially due to soil relaxation

40

Case 3 KDOT

- H-pile 14x73
- Pile pre-drilled to scour line
- Driven through silty sand and gravel into the Ogallala Formation
- Pile Driving formula load 91 tons; 100 tons (max)
- Re-strike test 24 hours later

41

Case 3 Results

- End of Drive
  - Bearing Formula 73 tons (need 91 tons)
  - PDA 185 tons (needed 140 tons)
- 24 hour re-strike
  - Bearing Formula 93 tons
  - PDA 207 tons
- In this case:
  - KDOT formula under predicted capacity by 2.2 to 2.5
- Result would have been to continue to drive pile

42

Case 4 KDOT

- H-pile 10x42
- Driven through silty sand at south abutment of highway 400 over Arkansas River near Dodge City
- Pile driving formula load 70 tons; 77 tons (max)
- Re-strike test 24 hours later

43

Case 4 Results

- End of Drive
  - Bearing Formula 51.6 tons (need 70 tons)
  - PDA 102 tons (needed 140 tons)
- 24 hour re-strike
  - Bearing Formula 69 tons
  - PDA 170 tons

Without the PDA we would have had to continue to drive pile

44

- The ENR formula is still a good tool for KDOT inspectors to use to calculate bearing
- Will be conservative in most cases for Kansas Native Soil types
- Could over predict if relaxation occurs
- Should always consider options before just splicing on more pile to drive deeper
  - Can the pile set for a period of time and see what the bearing is after a restrike
  - Are there other pile drive records in the area for review
  - Consult the Engineer in charge

45

LRFD

- Load and Resistance Factor Design (LRFD) does require more test pile and the use of the PDA:
  - 26 to 50 piles in the bridge structure
    - 1 to 3 piles (2-5% of total piles)
  - 51 to 100 piles in the bridge structure
    - 1 to 5 piles (2-5% of total piles)
- Penalizes only using the bearing formula
- Bearing Formula will change to better reflect PDA capacity estimations

46

Questions?

Rail Road Steam Pile Driver 1912

47

Example problem—bearing equation

Hammer is a D19-52

Piston weight 4190 lbs = W
Cap & Anvil weight 3400 lbs
Final penetration 0.6” in 5 blows
Stroke 10.25’ = H
12 x 63 H-pile, 70’ long

1) calculate movement (set) per hammer blow *in inches*

$$S = 0.6" \div 5 \text{ blows} = 0.12" \text{ / blow}$$

2) calculate the weight of the pile

$$\text{Pile weight} = 63 \text{ lbs/ft} \times 70 \text{ ft} = 4410 \text{ lbs}$$

3) add up X, the weight of everything below the hammer

$$X = \text{cap} + \text{anvil} + \text{pile weights} = 3400 \text{ lbs} + 4410 \text{ lbs} = 7810 \text{ lbs}$$

4) now plug everything into the equation

$$P = \frac{1.6 \times \mathrm{W} \times \mathrm{H}}{\mathrm{S} + \left[0.1 \times \frac{X}{W}\right]}$$

$$P = \frac{1.6 \times 4190 \text{ lbs} \times 10.25 \text{ ft}}{0.12" + \left[0.1 \times \frac{7810 \text{ lbs}}{4190 \text{ lbs}}\right]}$$

use only 3 significant figures—that is, round to 3 digits

$$P = \frac{68700 \text{ lbs}}{0.306} \qquad P = 225{,}000 \text{ lbs}$$

225,000 lbs ÷ 2000 lb / ton = **112 ton**

Record Keeping

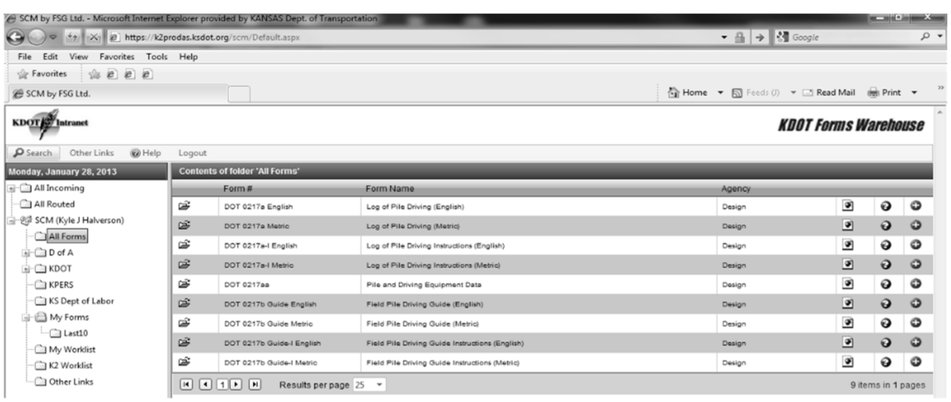
The Form 217

Either Way You Look At It, It Has To Be Done!

Explanation of the Forms are Found

- Bridge Construction Manual
  - Chapter 5.3 Driven Pile* Updated 10-21-09
  - Section 5.3.8 Log of Pile Driving
  - Page 26 through 36
- Forms Warehouse
  - **Form 217a 271b (English and Metric both available)**

Where to find form 217? kdotweb-forms warehouse-search-form number-217 217a is the form and 217a-1 is the instructions



General Information

The Top Portion of the Form

	A–Z
1	Log of Pile - Form 217
2	**General Information**
3	(This information is common to all sheets in the Workbook)
4	**Hammer Information** / **PROJECT INFORMATION**
5	Go to "View" tab, "Arrange All", and hit "OK" in the window that pops up if you can not see colored tabs
6	for different hammers at the bottom of the screen.
7	Type of Hammer / **County**
8	**Project**
9	Hammer (Ram) Weight lbs / **(Br. No.) and/or Sta**
10	Type of Pile
11	Cap and/or Anvil Weight lbs
12	Plan Note Overdrive % %
13	Energy Rating ft-lbs / Min. Bearing Required tons
14	Max. Bearing Allowed tons

Information carries forward to all forms.

Record keeping portion

Abutment **Pier** **County**
Project
Type of Hammer **(Br. No.) and/or Sta**
Wt. of Hammer lbs **Type of Pile**
Wt. of Cap and/or Anvil lbs **Min. Bearing Required** ton
Energy Rating ft-lbs **Max. Bearing Allowed** ton
Number, Individual Length, and Total Length of Pile: **Bearing Formula Used:** 1.6 W H / S + 0.1 (X/W **)
Footing Sketch (Please Complete)
Plan Cutoff Elev. (ft) = ft
Wt. per foot piling (lbs/ft): lbs/ft
Type of Cushion Mat'l:

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range

Bottom Section is for recapping the top section.

Total Accepted Length =	ft
Production Pile Pay Length =	ft
Test Pile Pay Length =	ft
Production Pile Pay Cutoff =	ft
Non Pay Cutoff =	ft
Test Pile Cutoff =	ft
No. of Test Pile Pay Splices =	
No. of Pay Splices =	**0**

********Contract Line Item Number*********

Remarks:

CUTOFF ADJUSTMENTS	Reg	Test
Non Pay Cutoff used for Splice =		
Pay Cutoff used for Splice =		
Total Cutoff used for Splice =	0.00	0.00

Refer to 704.4 Measurement and Payment

Abutment ______ Pier ______

Inspected By:

Checked By:

Submitted By:

County

Project

(Br. No.) and/or Sta

Second page used for continuous Log of Pile. Used for Test pile and PDA piling when required.

Pile No.	Total Pile Length	Length Driven From	Length Driven To	Number of Blows (Blow Count)	Drop of Hammer (Stroke) (ft.)	Average Penetration (in.)	Computed Resistance (tons)	Computed vs. Specified
		0.00						

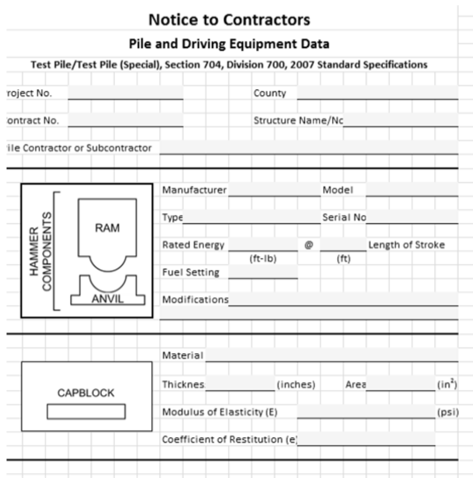
General Information

- County, Project Number, Bridge No. and Station for the structure
- Enter number the of the Abutment or Pier where the pile was driven
- Type and size of pile – enter entire description
  - Some Examples:
    - Pile (steel) HP10 x 42
    - Test Pile Special (steel) HP12 x 53
    - Pile (prestressed concrete) 12 inch

General Information

- Type of hammer
  - Type, brand, model & size
  - Example: Diesel-Delmag D15
- Weight of the hammer (piston/ram)
  - Denoted on the hammer specification plate furnished by the contractor
  - Or look up in the reference chart in the Bridge Construction Manual
  - Online at: http://www.ksdot.org/Assets/wwwksdotorg/bureaus/burStructGeotech/ConstructionManual/pile.pdf

217-aa Pile driving and Equipment data



Notice to Contractors

Pile and Driving Equipment Data

Test Pile/Test Pile (Special), Section 704, Division 700, 2007 Standard Specifications

roject No. ____ County ____

ontract No. ____ Structure Name/Nc ____

ile Contractor or Subcontractor ____

HAMMER COMPONENTS: RAM, ANVIL

Manufacturer ____ Model ____

Type ____ Serial No ____

Rated Energy ____ (ft-lb) @ ____ (ft) Length of Stroke

Fuel Setting ____

Modifications ____

CAPBLOCK

Material ____

Thicknes ____ (inches) Area ____ (in²)

Modulus of Elasticity (E) ____ (psi)

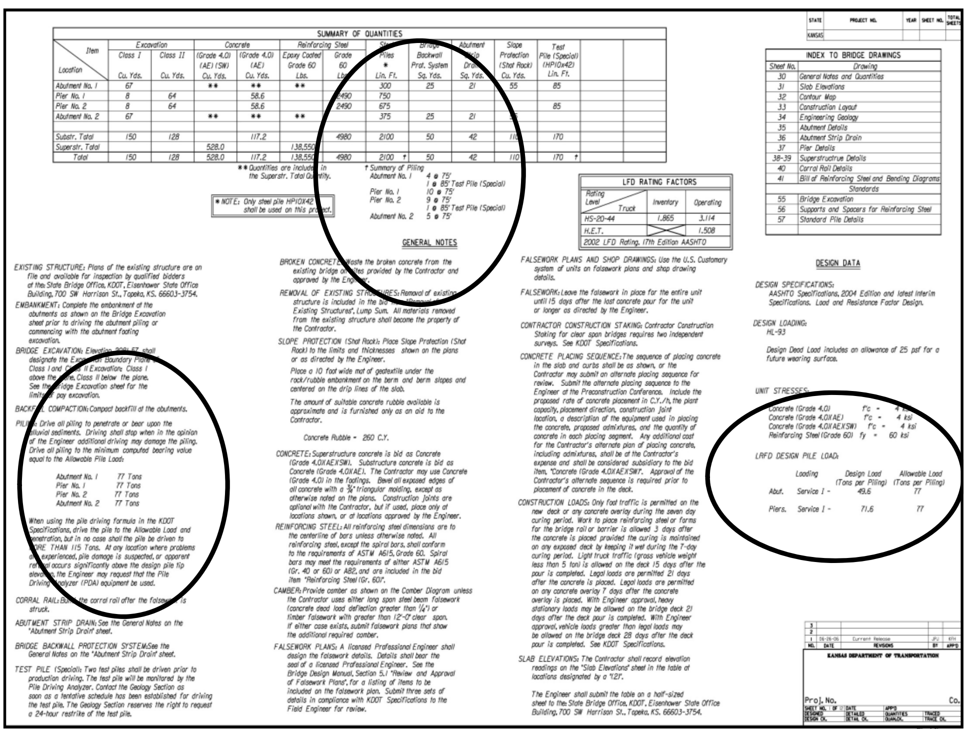
Coefficient of Restitution (e) ____

General Information

- Weight of the Cap and/or Anvil
  - Supplied by the contractor
  - May be welded on, or listed on a plate
- Energy rating of the hammer
  - Denoted on the hammer specification plate
  - Can look it up in the Bridge Construction Manual
  - Online at: http://www.ksdot.org/Assets/wwwksdotorg/bureaus/burStructGeotech/ConstructionManual/pile.pdf

General Information

- Minimum bearing required
  - This is the **Allowable** load
    - Do not confuse this with the design load
    - Found on the **Summary of Quantities and General Notes Page**
- Maximum bearing allowed
  - **110% of allowable load**



designate the Excavation Boundary Plane of Class I and Class II Excavation; Class I above the plane, Class II below the plane. See the Bridge Excavation sheet for the limits of pay excavation.

BACKFILL COMPACTION: Compact backfill at the abutments.

PILING: Drive all piling to penetrate or bear upon the alluvial sediments. Driving shall stop when in the opinion of the Engineer additional driving may damage the piling. Drive all piling to the minimum computed bearing value equal to the Allowable Pile Load:

Abutment No. 1	77 Tons
Pier No. 1	77 Tons
Pier No. 2	77 Tons
Abutment No. 2	77 Tons

When using the pile driving formula in the KDOT Specifications, drive the pile to the Allowable Load and penetration, but in no case shall the pile be driven to MORE THAN 115 Tons. At any location where problems are experienced, pile damage is suspected, or apparent refusal occurs significantly above the design pile tip elevation, the Engineer may request that the Pile Driving Analyzer (PDA) equipment be used.

CORRAL RAIL: Build the corral rail after the falsework is struck.

ABUTMENT STRIP DRAIN: See the General Notes on the "Abutment Strip Drain" sheet.

BRIDGE BACKWALL PROTECTION SYSTEM: See the General Notes on the "Abutment Strip Drain" sheet.

TEST PILE (Special): Two test piles shall be driven prior to production driving. The test pile will be monitored by the Pile Driving Analyzer. Contact the Geology Section as soon as a tentative schedule has been established for driving the test pile. The Geology Section reserves the right to request a 24-hour restrike of the test pile.

LRFD DESIGN PILE LOAD:

	Loading	Design Load (Tons per Piling)	Allowable Load (Tons per Piling)
Abut.	Service I -	49.6	77
Piers.	Service I -	71.6	77

NO.	DATE	REVISIONS	BY	APP'D
3				
2				
1	06-26-06	Current Release	JPJ	KFH

KANSAS DEPARTMENT OF TRANSPORTATION

Proj. No. Co.

SHEET NO. 1 OF 12	DATE	APP'D	
DESIGNED	DETAILED	QUANTITIES	TRACED
DESIGN CK.	DETAIL CK.	QUAN.CK.	TRACE CK.

General Notes for LRFD Pile Design:

PILING: Drive all piling to [penetrate or bear upon the ___________ formation](or)[a minimum elevation of _______]. Driving shall stop when in the opinion of the Engineer additional driving may damage the piling. Drive all piling to the **Pile Driving Formula Load** of:

Abutment No. 1	________	Tons
Pier No. 1	________	Tons
Pier No. 2	________	Tons
Abutment No. 2	________	Tons

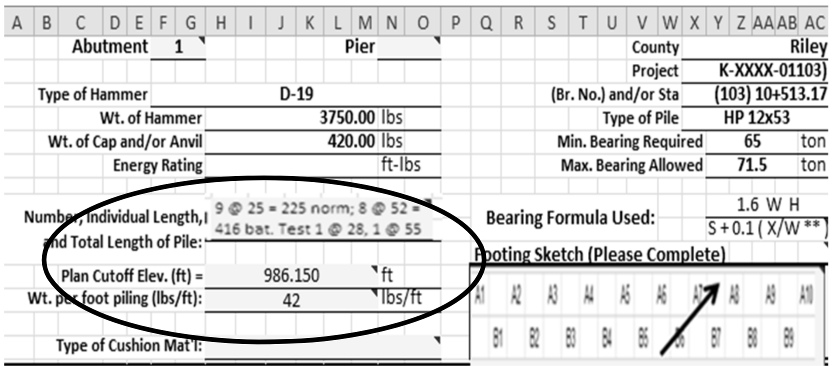
As a minimum drive each pile to the load and penetration, but in **no case shall the pile be driven to MORE THAN 110%** of Pile Driving Formula Driving Load. At any location where problems are experienced, pile damage is suspected, or the Pile Driving Formula Load occurs significantly above the design pile tip elevation, the Engineer may request that the Pile Driving Analyzer (PDA) equipment be used.

***** The Designer will fill in the above <u>blanks</u> in Tons with the controlling Strength I Limit State*****

***When the PDA is used, the piles are driven to a Strength/phi resistance value.

•

More General Information Information in blue circle comes from plan sheet.



A B C D E F G H I J K L M N O P Q R S T U V W X Y Z AA AB AC

Abutment 1 Pier

County Riley

Project K-XXXX-01103)

Type of Hammer D-19

(Br. No.) and/or Sta (103) 10+513.17

Wt. of Hammer 3750.00 lbs

Type of Pile HP 12x53

Wt. of Cap and/or Anvil 420.00 lbs

Min. Bearing Required 65 ton

Energy Rating ft-lbs

Max. Bearing Allowed 71.5 ton

Number, Individual Length, and Total Length of Pile: 9 @ 25 = 225 norm; 8 @ 52 = 416 bat. Test 1 @ 28, 1 @ 55

Bearing Formula Used: $\frac{1.6\ W\ H}{S + 0.1\ (X/W^{**})}$

Plan Cutoff Elev. (ft) = 986.150 ft

Wt. per foot piling (lbs/ft): 42 lbs/ft

Type of Cushion Mat'l:

Footing Sketch (Please Complete)

A1 A2 A3 A4 A5 A6 A7 A8 A9 A10

B1 B2 B3 B4 B5 B6 B7 B8 B9

General Information

- Number, Individual Length and Total Length of Pile

  - Enter the total length for the abutment or pier represented
  - Also give a breakdown of the number and the length of piles used
    - Example: 4@50 ft. and 4@42 ft. = 368 ft.
    - This will not change if driven length is different.

General Information

- Plan cutoff elevation as shown on plans
  - Enter top of pile elevation as shown on plans
- Type of cushioning material used for the hammer or pile
  - Example: Conbest, micarta
  - Maybe plywood for a pile cushion on concrete pile

General Information

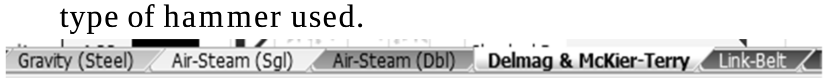
- Weight per unit length of pile
  - For H-pile HP10x42
    - The 10 represents the width of the web in inches
    - 42 represents the weight of the pile per foot (pounds/ft)
  - For steel pipe pile
    - weight per length can be found on the mill test/lading ticket from the supplier

General Information

- Weight per unit length of pile
  - For pre-stressed concrete
    - Weight per length should be given in test report
    - Or one can use a density of 150 lbs/ft^3 to calculate a theoretical weight per unit length
      - 12" square = 150 lbs/ft.
      - 14" square = 204.22 lbs/ft.
      - 16" octagonal = 219.6 lbs/ft.

General Information

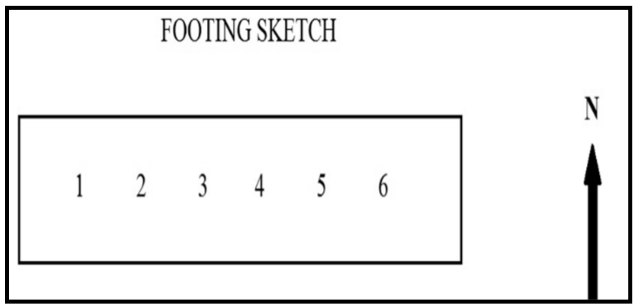
- Bearing formula
  - Bearing formula is automatically entered based on type of hammer used.



- Footing sketch
  - Draw a sketch of the footing with piles numbered to represent the numbers listed in the "Pile No." column on the form
  - A north arrow must be shown

Driving Information

- **Represents the location of the pile no. listed in the data section.**



Driving Information

The Middle Portion of the Form

Number, Individual Length, and Total Length of Pile:

Plan Cutoff Elev. (ft) = 100.000 ft

Wt. per foot piling (lbs/ft): 42 lbs/ft

Type of Cushion Mat'l:

Bearing Formula Used: $\frac{1.6\ W\ H}{S + 0.1\ (X/W\ ^{**})}$

Footing Sketch (Please Complete)

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range

Driving Information

- Report pile length to the nearest
  - one hundredth of a foot (0.01 ft)
- Elevations are calculated to
  - One hundredth of a foot (0.01 ft)
  - Computer generated.

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range
A!		3/20	1000.000	30.00	25.00		5.25		24.75	975.25	9.00	0.2500	77.1	High
A2		3/20		28.00	26.75		1.25	1	26.75	959.40	9.50	0.3000	71.3	OK
A3	y	3/20		29.00	28.00		3.25		25.75	960.40	10.00	0.2000	100.0	High
A4		3/20		25.30	25.30		0.00		25.30	960.85	10.00	0.3500	66.7	OK
A5		3/20		25.00	25.00		1.50		23.50	962.65	10.00	0.2500	85.7	High
A6		3/20		25.00	25.00		3.00		22.00	964.15	11.00	0.3000	82.5	High
A7		3/20		25.00	25.00		1.70		23.30	962.85	9.50	0.3000	71.3	OK
A8		3/20		25.00	25.00		1.70		23.30	962.85	10.00	0.3500	66.7	OK
A9		3/20		25.00	27.00	2.00	0.00	1	27.00	959.15	10.00	0.2500	85.7	High
A10		3/20		25.50	25.00		1.40		24.10	962.05	10.00	0.2500	85.7	High
B1		3/20		52.00	52.00		1.90		50.10	936.05	10.00	0.2500	85.7	High
B2		3/20		52.00	52.00		3.50		48.50	937.65	11.00	0.2500	94.3	High
B3		3/24		52.00	52.00		4.00		48.00	938.15	9.00	0.3000	67.5	OK
B4		3/24		52.00	52.00		5.00		47.00	939.15	10.00	0.3000	75.0	High
B5		3/24		52.00	54.00	2.00	0.00	1	54.00	932.15	10.00	0.3500	66.7	OK
B6		3/24		52.00	52.00		1.55		50.45	935.70	10.00	0.2500	85.7	High
B7		3/24		52.00	52.00		1.70		50.30	935.85	10.00	0.2500	85.7	High
B8	y	3/25		75.00	55.00		23.80		51.20	934.95	11.00	0.1500	132.0	High
B9		3/25		52.30	52.00		1.90		50.40	935.75	11.00	0.2500	94.3	High
				754.10	730.05	4.00	62.40		695.70					

Actual Length Placed in Leads

Driving Information

- 1. “Actual Length Placed in Leads”
  - This is the length the Contractor opts to use
  - It is used to calculate weight of pile for use in the bearing formula
  - When driving first starts, the “Actual Length Placed in Leads” is equal to the length picked up in the leads
    - can change as driving progresses if splices are made

Driving Information

- 2. “Actual Length Placed in Leads”
  - a. If bearing is not achieved and a splice is required, the **new** value for “Actual Length Placed in Leads” becomes:
    - The original length placed in the leads **plus** the length of pile spliced onto it.

Example 1

- 45 feet picked up to start.
- 15 feet spliced on and driven to achieve bearing.
- 60 feet = “Actual Length Placed in Leads”

Driving Information

- 3. “Actual Length Placed in Leads”
  - b. If bearing is achieved prior to splicing and the splice is made solely to achieve plan cutoff (no more driving to be done on the pile), the “Length Placed in Leads” remains the original length in the leads
    - In this situation the “Ordered and Accepted Length” (original length + splice length) is greater than the “Length Placed in Leads”

Situations in which the "Ordered and Accepted" length will differ from the plans

- 4. Ordered and Accepted

2015 Specifications 704.3a
The order list is the same as the estimated quantity (number and length of piles) shown in the Contract Documents.

Driving Information

- 5. Ordered and Accepted
  - Typically is the length the Engineer instructs the Contractor to use
    - i.e. the length of pile indicated on the plans
  - But in situations the "Ordered and Accepted" length will differ from the plans

Example 2

- 25 feet picked up and driven to bearing
- 2 feet spliced on to bring the pile top up to cut off elevation but no more driving occurred
- "Actual Length Placed in Leads" = 25 feet
- "Ordered and Accepted Length" = 27 feet
- "Length Left in Foundation" = 27 feet

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range
A1		3/20	1000.000	30.00	25.00		5.25		24.75	975.25	9.00	0.2500	77.1	High
A2		3/20		28.00	26.75		1.25	1	26.75	959.40	9.50	0.3000	71.3	OK
A3	y	3/20		29.00	28.00		3.25		25.75	960.40	10.00	0.2000	100.0	High
A4		3/20		25.30	25.30		0.00		25.30	960.85	10.00	0.3500	66.7	OK
A5		3/20		25.00	25.00		1.50		23.50	962.65	10.00	0.2500	85.7	High
A6		3/20		25.00	25.00		3.00		22.00	964.15	11.00	0.3000	82.5	High
A7		3/20		25.00	25.00		1.70		23.30	962.85	9.50	0.3000	71.3	OK
A8		3/20		25.00	25.00		1.70		23.30	962.85	10.00	0.3500	66.7	OK
A9		3/20		25.00	27.00	2.00	0.00	1	27.00	959.15	10.00	0.2500	85.7	High
A10		3/20		25.50	25.00		1.40		24.10	962.05	10.00	0.2500	85.7	High
B1		3/20		52.00	52.00		1.90		50.10	936.05	10.00	0.2500	85.7	High
B2		3/20		52.00	52.00		3.50		48.50	937.65	11.00	0.2500	94.3	High
B3		3/24		52.00	52.00		4.00		48.00	938.15	9.00	0.3000	67.5	OK
B4		3/24		52.00	52.00		5.00		47.00	939.15	10.00	0.3000	75.0	High
B5		3/24		52.00	54.00	2.00	0.00	1	54.00	932.15	10.00	0.3500	66.7	OK
B6		3/24		52.00	52.00		1.55		50.45	935.70	10.00	0.2500	85.7	High
B7		3/24		52.00	52.00		1.70		50.30	935.85	10.00	0.2500	85.7	High
B8	y	3/25		75.00	55.00		23.80		51.20	934.95	11.00	0.1500	123.5	High
B9		3/25		52.30	52.00		1.90		50.40	935.75	11.00	0.2500	94.3	High
				[illegible]	[illegible]		[illegible]		[illegible]					

Ordered and Accepted

Situations in which the "Ordered and Accepted" length will differ from the plans

- 3. Ordered and Accepted
  - a. If the length listed on the plans is too short and additional pile length is needed, the contractor is authorized to add the additional length.
    - "Ordered and Accepted" length is now equal to the original length on the plans **plus** the additional length authorized to be spliced on

Example 3

- 45 feet listed on plans picked up and driven but bearing is not achieved
- 15 feet authorized to be spliced on
- 60 feet = "Ordered and Accepted Length"
- 60 feet = "Actual Length Placed in Leads"

Situations in which the "Ordered and Accepted" length will differ from the plans

- 4. Ordered and Accepted
  - b. If the Contractor opts to use a longer pile than called for and the additional length, in whole or part, is needed to achieved bearing and "Plan Cutoff Elevation", the "Ordered and Accepted" length is equal to the length of pile left in place.
    - Now "Ordered and Accepted" length and "Length Left in Foundation" are equal.

Example 4

- 45 feet called for on the plans
- Contractor picks up a 50 footer to drive
- 48 feet was needed to achieve bearing
- "Ordered and Accepted Length" = "Length Left in Foundation" = 48 feet
- "Actual Length Placed in Leads" = 50 feet

Driving Information

- 5. Actual Measured Cutoff
  - The actual length of pile cutoff is the difference between the "Actual Length in Leads" length and what is left in footing.

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range
A1		3/20	1000.000	30.00	25.00		5.25		24.75	975.25	9.00	0.2500	77.1	High
A2		3/20		28.00	26.75		1.25	1	26.75	959.40	9.50	0.3000	71.3	OK
A3	y	3/20		29.00	28.00		3.25		25.75	960.40	10.00	0.2000	100.0	High
A4		3/20		25.30	25.30		0.00		25.30	960.85	10.00	0.3500	66.7	OK
A5		3/20		25.00	25.00		1.50		23.50	962.65	10.00	0.2500	85.7	High
A6		3/20		25.00	25.00		3.00		22.00	964.15	11.00	0.3000	82.5	High
A7		3/20		25.00	25.00		1.70		23.30	962.85	9.50	0.3000	71.3	OK
A8		3/20		25.00	25.00		1.70		23.30	962.85	10.00	0.3500	66.7	OK
A9		3/20		25.00	27.00	2.00	0.00	1	27.00	959.15	10.00	0.2500	85.7	High
A10		3/20		25.50	25.00		1.40		24.10	962.05	10.00	0.2500	85.7	High
B1		3/20		52.00	52.00		1.90		50.10	936.05	10.00	0.2500	85.7	High
B2		3/20		52.00	52.00		3.50		48.50	937.65	11.00	0.2500	94.3	High
B3		3/24		52.00	52.00		4.00		48.00	938.15	9.00	0.3000	67.5	OK
B4		3/24		52.00	52.00		5.00		47.00	939.15	10.00	0.3000	75.0	High
B5		3/24		52.00	54.00	2.00	0.00	1	54.00	932.15	10.00	0.3500	66.7	OK
B6		3/24		52.00	52.00		1.55		50.45	935.70	10.00	0.2500	85.7	High
B7		3/24		52.00	52.00		1.70		50.30	935.85	10.00	0.2500	85.7	High
B8	y	3/25		75.00	55.00		23.80		51.20	934.95	11.00	0.1500	123.5	High
B9		3/25		52.30	52.00		1.90		50.40	935.75	11.00	0.2500	94.3	High
				754.10	730.05		62.40		695.70					

Actual Measured Cutoff

Driving Information

- 6. Actual Measured Cutoff
  - a. The “Actual Measured Cutoff” may not equal “Pay Cutoff”
    - If the Contractor elects to use a longer pile than was specified, the length in excess of the length specified is considered “Non Pay Cutoff”

Driving Information

- 7. Splicing Cutoff on another pile
  - The “Actual Measured Cutoff” from one pile may be spliced in part, or in whole, to another pile.
    - It may become part of the “Ordered and Accepted Length” on the pile that received the splice
      - This depends on the length of pile the Contractor was directed to use.

Be sure to track where the cutoff came from and where it is going to. If the cutoff from one pile is used in a different bent, then you will need to address that in the remarks of both locations.

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range
A!		3/20	1000.000	30.00	25.00		5.25		24.75	975.25	9.00	0.2500	77.1	High
A2		3/20		28.00	26.75		1.25	1	26.75	959.40	9.50	0.3000	71.3	OK
A3	y	3/20		29.00	28.00		3.25		25.75	960.40	10.00	0.2000	100.0	High
A4		3/20		25.30	25.30		0.00		25.30	960.85	10.00	0.3500	66.7	OK
A5		3/20		25.00	25.00		1.50		23.50	962.65	10.00	0.2500	85.7	High
A6		3/20		25.00	25.00		3.00		22.00	964.15	11.00	0.3000	82.5	High
A7		3/20		25.00	25.00		1.70		23.30	962.85	9.50	0.3000	71.3	OK
A8		3/20		25.00	25.00		1.70		23.30	962.85	10.00	0.3500	66.7	OK
A9		3/20		25.00	27.00	2.00	0.00	1	27.00	959.15	10.00	0.2500	85.7	High
A10		3/20		25.50	25.00		1.40		24.10	962.05	10.00	0.2500	85.7	High
B1		3/20		52.00	52.00		1.90		50.10	936.05	10.00	0.2500	85.7	High
B2		3/20		52.00	52.00		3.50		48.50	937.65	11.00	0.2500	94.3	High
B3		3/24		52.00	52.00		4.00		48.00	938.15	9.00	0.3000	67.5	OK
B4		3/24		52.00	52.00		5.00		47.00	939.15	10.00	0.3000	75.0	High
B5		3/24		52.00	54.00	2.00	0.00	1	54.00	932.15	10.00	0.3500	66.7	OK
B6		3/24		52.00	52.00		1.55		50.45	935.70	10.00	0.2500	85.7	High
B7		3/24		52.00	52.00		1.70		50.30	935.85	10.00	0.2500	85.7	High
B8	y	3/25		75.00	55.00		23.80		51.20	934.95	11.00	0.1500	132.0	High
B9		3/25		52.30	52.00		1.90		50.[illegible]	935.75	11.00	0.2500	9[illegible]	High
				754.10	730.05	4.00	62.40		695.70					

Length Left in Foundation

Driving Information

- 8. Length left in foundation:
  - Is **The Pay Length:** The length of pile left after any cutoff is removed or the addition of a splice is made after driving to achieve the desired elevation. If splice is made after bearing is achieved, the new "Order and Acceptance" length is equal to pay length provided the new length is equal to or greater than the plan length.

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range
A1		3/20	1000.000	30.00	25.00		5.25		24.75	975.25	9.00	0.2500	77.1	High
A2		3/20		28.00	26.75		1.25	1	26.75	959.40	9.50	0.3000	71.3	OK
A3	y	3/20		29.00	28.00		3.25		25.75	960.40	10.00	0.2000	100.0	High
A4		3/20		25.30	25.30		0.00		25.30	960.85	10.00	0.3500	66.7	OK
A5		3/20		25.00	25.00		1.50		23.50	962.65	10.00	0.2500	85.7	High
A6		3/20		25.00	25.00		3.00		22.00	964.15	11.00	0.3000	82.5	High
A7		3/20		25.00	25.00		1.70		23.30	962.85	9.50	0.3000	71.3	OK
A8		3/20		25.00	25.00		1.70		23.30	962.85	10.00	0.3500	66.7	OK
A9		3/20		25.00	27.00	2.00	0.00	1	27.00	959.15	10.00	0.2500	85.7	High
A10		3/20		25.50	25.00		1.40		24.10	962.05	10.00	0.2500	85.7	High
B1		3/20		52.00	52.00		1.90		50.10	936.05	10.00	0.2500	85.7	High
B2		3/20		52.00	52.00		3.50		48.50	937.65	11.00	0.2500	94.3	High
B3		3/24		52.00	52.00		4.00		48.00	938.15	9.00	0.3000	67.5	OK
B4		3/24		52.00	52.00		5.00		47.00	939.15	10.00	0.3000	75.0	High
B5		3/24		52.00	54.00	2.00	0.00	1	54.00	932.15	10.00	0.3500	66.7	OK
B6		3/24		52.00	52.00		1.55		50.45	935.70	10.00	0.2500	85.7	High
B7		3/24		52.00	52.00		1.70		50.30	935.85	10.00	0.2500	85.7	High
B8	y	3/25		75.00	55.00		23.80		51.20	934.95	11.00	0.1500	123.5	High
B9		3/25		52.30	52.00		1.90		50.40	935.75	11.00	0.2500	94.3	High
				754.10	730.05		62.40		695.70					

Pile Tip Elevation

Driving Information

- 9. Pile tip elevation
  - Is typically the "plan cutoff elevation" minus the length left in foundation
  - If battered piles are used, the batter needs to be taken into account to determine the tip elevation

Pile No.	Test Pile	Date	Varied Plan Cutoff Elev.	Actual Length in Leads	Ordered & Accepted	Spliced After Drive	Actual Cutoff	Pay Splices	Length Left in Footing	Pile Tip Elev.	Stroke (Drop of Hammer)	Average Penetration (inches)	Computed Bearing Power	Range
A1		3/20	1000.000	30.00	25.00		5.25		24.75	975.25	9.00	0.2500	77.1	High
A2		3/20		28.00	26.75		1.25	1	26.75	959.40	9.50	0.3000	71.3	OK
A3	y	3/20		29.00	28.00		3.25		25.75	960.40	10.00	0.2000	100.0	High
A4		3/20		25.30	25.30		0.00		25.30	960.85	10.00	0.3500	66.7	OK
A5		3/20		25.00	25.00		1.50		23.50	962.65	10.00	0.2500	85.7	High
A6		3/20		25.00	25.00		3.00		22.00	964.15	11.00	0.3000	82.5	High
A7		3/20		25.00	25.00		1.70		23.30	962.85	9.50	0.3000	71.3	OK
A8		3/20		25.00	25.00		1.70		23.30	962.85	10.00	0.3500	66.7	OK
A9		3/20		25.00	27.00	2.00	0.00	1	27.00	959.15	10.00	0.2500	85.7	High
A10		3/20		25.50	25.00		1.40		24.10	962.05	10.00	0.2500	85.7	High
B1		3/20		52.00	52.00		1.90		50.10	936.05	10.00	0.2500	85.7	High
B2		3/20		52.00	52.00		3.50		48.50	937.65	11.00	0.2500	94.3	High
B3		3/24		52.00	52.00		4.00		48.00	938.15	9.00	0.3000	67.5	OK
B4		3/24		52.00	52.00		5.00		47.00	939.15	10.00	0.3000	75.0	High
B5		3/24		52.00	54.00	2.00	0.00	1	54.00	932.15	10.00	0.3500	66.7	OK
B6		3/24		52.00	52.00		1.55		50.45	935.70	10.00	0.2500	85.7	High
B7		3/24		52.00	52.00		1.70		50.30	935.85	10.00	0.2500	85.7	High
[illegible]	[illegible]	3/25		75.00	[illegible]		[illegible]		[illegible]	934.95	11.00	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]		52.30	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				754.10	730.05		62.40		695.70					

Stroke Penetration Bearing

Driving Information

- 10. Stroke or Drop of Hammer
  - Observed by the inspector and recorded
- 11. Average penetration
  - The penetration per 20 blows divided by 20
    - Example 5 inches per 20 blows = .25 inch per blow
    - Could be less than 20 blows i.e. 5 blows.
- 12. Computed Bearing capacity of pile
  - Computed by the inspector or computer
    - Note: All inspectors are required to know how to manually calculate bearing using the bearing formula

Totals

			754.10	730.05	4.00	62.40		695.70			

		********Contract Line Item Number*********	27
Total Accepted Length =	730.05 ft	Remarks:	
Production Pile Pay Length =	618.75 ft	Pile A1 thru A10 are normal pile	
Test Pile Pay Length =	79.20 ft	Pile B1 thru B9 are battered at 15 degrees	
Production Pile Pay Cutoff =	24.30 ft	Pile A3 and B8 are test pile	
Non Pay Cutoff =	5.30 ft	Used 13.2 feet of B8 test pile non-pay cutoff to make pile B9	
Test Pile Cutoff =	23.25 ft	Used 3.8 ft. test pile cutoff B8 on B9	
		3 unplanned splices made at to A2, A9, B5	
No. of Test Pile Pay Splices =	0	A9 used 2 ft. of pay cutoff from A6 to make elevation	
No. of Pay Splices =	3	B5 used 2 ft. brom B3 to make elevation	

CUTOFF ADJUSTMENTS	Reg	Test
Non Pay Cutoff used for Splice =	1.75	3.80
Pay Cutoff used for Splice =	4.00	
Total Cutoff used for Splice =	5.75	3.80

Refer to 704.4 Measurement and Payment

Kansas Department of Transportation

Inspected By:

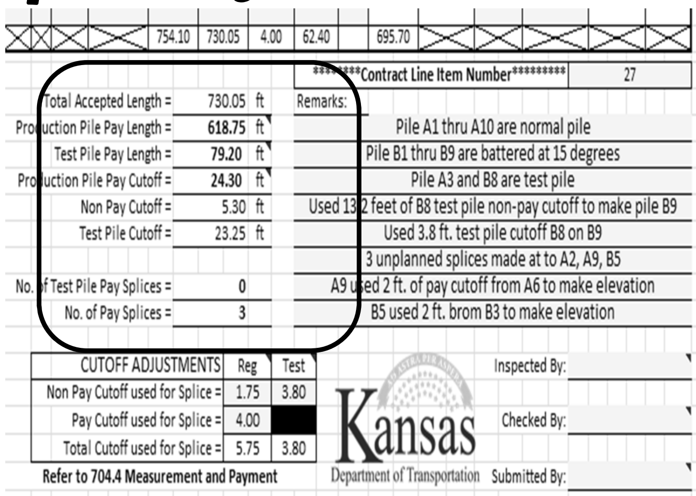
Checked By:

Submitted By:

Driving Information

- 13. "Totals" -- Total each column
  - "Actual length placed in leads"
  - "Ordered and accepted"
  - "Actual measured cutoff"
  - "Length left in foundation"

Accepted Length and Non Pay Cutoff



754.10	730.05	4.00	62.40		695.70				

********Contract Line Item Number********* 27

Total Accepted Length =	730.05	ft	Remarks:
Production Pile Pay Length =	618.75	ft	Pile A1 thru A10 are normal pile
Test Pile Pay Length =	79.20	ft	Pile B1 thru B9 are battered at 15 degrees
Production Pile Pay Cutoff =	24.30	ft	Pile A3 and B8 are test pile
Non Pay Cutoff =	5.30	ft	Used 13.2 feet of B8 test pile non-pay cutoff to make pile B9
Test Pile Cutoff =	23.25	ft	Used 3.8 ft. test pile cutoff B8 on B9
			3 unplanned splices made at to A2, A9, B5
No. of Test Pile Pay Splices =	0		A9 used 2 ft. of pay cutoff from A6 to make elevation
No. of Pay Splices =	3		B5 used 2 ft. brom B3 to make elevation

CUTOFF ADJUSTMENTS	Reg	Test
Non Pay Cutoff used for Splice =	1.75	3.80
Pay Cutoff used for Splice =	4.00	
Total Cutoff used for Splice =	5.75	3.80

Refer to 704.4 Measurement and Payment

Kansas Department of Transportation

Inspected By:

Checked By:

Submitted By:

Driving Information

- 14. "Accepted Length"
  - Equals the total from the "Ordered and Accepted" column

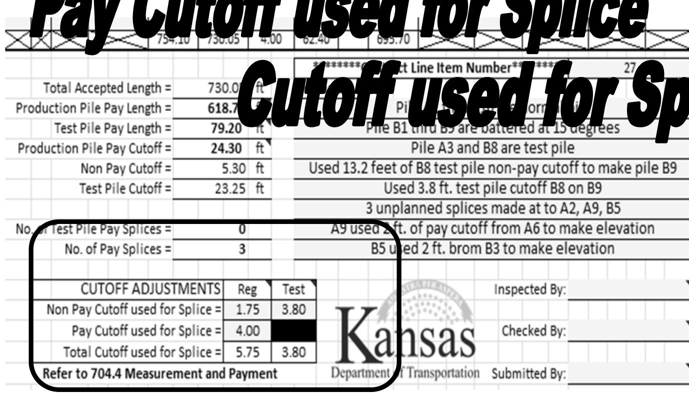
Driving Information

- 15. “Non Pay Cutoff”
  - Represents the length of pile in excess of the length specified and was cutoff
  - Equals the “Actual Measured Cutoff” column minus any “Pay Cutoff”

Non Pay Cutoff used for Splice

Pay Cutoff used for Splice

Cutoff used for Splice



Driving Information

- 16. “Non Pay Cutoff Used for Splice”
  - Is the length of pile that was originally considered part of “Non Pay Cutoff”, but was spliced to another pile to achieve “Plan Cutoff Elevation” and/or bearing

Example 9

- 45 feet called for on the plans
- Contractor picks up a 50 footer to drive
- 45 feet was needed to achieve bearing
  - Contractor cuts off the other 5 feet as “Non Pay Cut Off”
- This 5 feet is spliced to another pile and becomes “Non Pay Cut Off Used For Splice”

Driving Information

- 17. Pay cutoff used for splice
  - Is the length that was originally considered part of the "Pay Cutoff" from one pile but was spliced to another pile to achieve "Plan Cutoff Elevation" and/or bearing.
  - Since this cutoff was previously considered "Pay Cutoff" deduct it from the "Pay Cutoff" total so it is not paid for as "Pay Length" and "Pay Cutoff".
  - If came from different location, the first report will need to be amended to track pile cutoff to new location.

Example 10

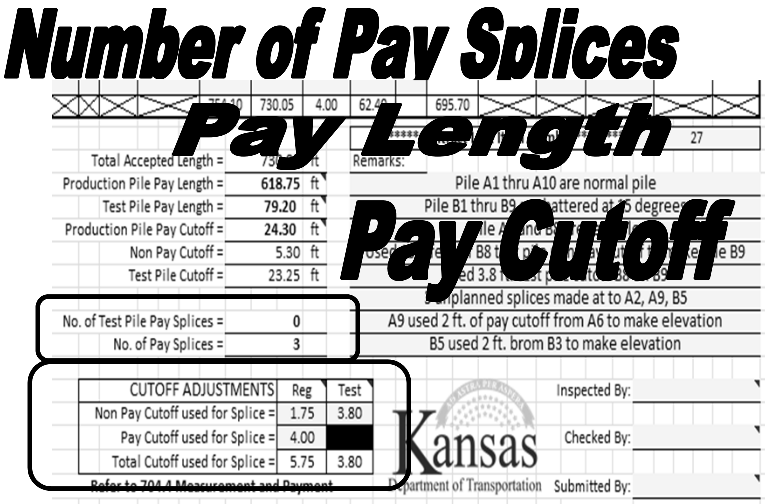
- 45 feet listed on plans picked up and driven but bearing is not achieved
- 15 feet authorized to be spliced on but only 10 feet can be driven
- 5 feet has to be cut off as "Pay Cut Off"
- This 5 feet is spliced on another pile and becomes "Pay Cut Off Used For Splice" and is now "Pay Length"

Example 10 con't

- **Since this cutoff was previously considered "Pay Cutoff" deduct it from the "Pay Cutoff" total so it is not paid for as "Pay Length" and "Pay Cutoff".**

Driving Information

- 18. "Cutoff Used for Splice"
  - Equals the "Non Pay Cutoff Used for Splice" **plus** "Pay Cutoff Used for Splice"



Driving Information

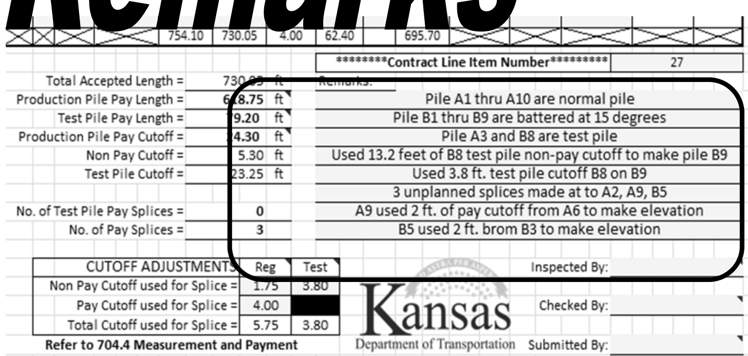
- 19. "Number Pay Splices"
  - Total number of splices ordered by KDOT to extend the pile beyond the original "Ordered and Accepted Length"
  - Splices made for contractor's convenience are not considered pay splices

Driving Information

- 20. "Pay Length"
  - Equals the total from the "Length Left in Foundation" column
- 21. "Pay Cutoff" equals the

"Actual Length in Leads"
minus "Length Left in Foundation"
minus "Test & Non Pay Cutoff"

Remarks



754.10	730.05	4.00	62.40		695.70		

		********Contract Line Item Number*********	27
Total Accepted Length =	730.[illegible]5 ft	Remarks:	
Production Pile Pay Length =	6[illegible]8.75 ft	Pile A1 thru A10 are normal pile	
Test Pile Pay Length =	[illegible]9.20 ft	Pile B1 thru B9 are battered at 15 degrees	
Production Pile Pay Cutoff =	[illegible]4.30 ft	Pile A3 and B8 are test pile	
Non Pay Cutoff =	5.30 ft	Used 13.2 feet of B8 test pile non-pay cutoff to make pile B9	
Test Pile Cutoff =	[illegible]23.25 ft	Used 3.8 ft. test pile cutoff B8 on B9	
		3 unplanned splices made at to A2, A9, B5	
No. of Test Pile Pay Splices =	0	A9 used 2 ft. of pay cutoff from A6 to make elevation	
No. of Pay Splices =	3	B5 used 2 ft. brom B3 to make elevation	

CUTOFF ADJUSTMENTS	Reg	Test
Non Pay Cutoff used for Splice =	1.75	3.80
Pay Cutoff used for Splice =	4.00	[redacted]
Total Cutoff used for Splice =	5.75	3.80

Refer to 704.4 Measurement and Payment

Kansas Department of Transportation

Inspected By:

Checked By:

Submitted By:

Driving Information

- 22. "Remarks"—provide a recap of **all** splicing information and unique information
  - a. Indicate if it was pay or non-pay splice
    (i.e. was it ordered by KDOT or was it the Contractors option)
  - b. Which pile the splice came from
  - c. Which pile the splice was spliced to
  - d. The length of the splice pile
  - e. Indicate if the splice was made after bearing was achieved
  - f. Other information as you see fit

Abutment 1 Pier ____ Project K-XXXX-01 (103)
(Br. No.) and/or Sta (103) 10+513.17

	Pile No.	Total Pile Length	Length Driven		Number of Blows (Blow Count)	Drop of Hammer (Stroke) (ft.)	Average Penetration (in.)	Computed Resistance (tons)	Computed vs. Specified
			From	To					
70	A4	25.3	1.50	4.50	10	6.00	3.60	4.9	Low
71	A4	25.3	4.50	7.00	15	6.00	2.00	8.6	Low
72	A4	25.3	7.00	11.00	20	6.50	2.40	7.8	Low
73	A4	25.3	11.00	14.50	20	7.00	2.10	9.5	Low
74	A4	25.3	14.50	17.00	20	7.50	1.50	14.1	Low
75	A4	25.3	17.00	19.00	20	8.00	1.20	18.5	Low
76	A4	25.3	19.00	20.00	20	8.50	0.60	36.4	Low
77	A4	25.3	20.00	21.50	20	8.50	0.90	25.5	Low
78	A4	25.3	21.50	22.50	20	9.00	0.60	38.6	Low
79	A4	25.3	22.50	23.15	20	10.00	0.39	61.2	Low
80	A4	25.3	23.15	23.70	20	10.00	0.33	69.8	Ok
81	A4	25.3	23.70						
82	A4	25.3							
83	B5	52.1	3.00	9.00	10	5.00	7.20	2.1	Low
84	B5	52.1	9.00	15.00	15	6.00	4.80	3.7	Low
85	B5	52.1	15.00	20.00	20	6.00	3.00	5.8	Low
86	B5	52.1	20.00	24.50	20	7.00	2.70	7.5	Low
87	B5	52.1	24.50	29.00	20	9.00	2.70	9.6	Low
88	B5	52.1	29.00	33.00	20	10.00	2.40	12.0	Low
89	B5	52.1	33.00	37.00	20	10.00	2.40	12.0	Low
90	B5	52.1	37.00	41.00	20	10.00	2.40	12.0	Low
91	B5	52.1	41.00	44.00	20	10.00	1.80	15.8	Low
92	B5	52.1	[illegible]	[illegible]	[illegible]	10.00	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	48.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
96			X.XX						
97									

Log of Continuous Pile Driving and/or Test Pile Sheet

Driving Information

- 23. Log of Continuous pile driving and/or test pile
  - Record a continuous pile driving record for a representative pile on each abutment and pier footing on the structure
  - The record should be inclusive from the beginning of drive to the final bearing

When filling out the "Log of Continuous pile driving"

- For structures under 755 feet in length, a continuous pile driving record is required on 2 footings, one in the abutment and one in the pier (opposite ends)
- For structures over 755 feet in length a continuous pile driving record is required on 3 footings, one abutment and two pier footings
- If the piers have no piling then information will be recorded on one pile from each abutment

When filling out the “Log of Continuous pile driving”

- a. Record any “set” length
  - Pile set with a gravity hammer from 0 to 16 feet
  - After pile is set, record 1 foot increments
  - Record the fractional increment just prior to achieving final bearing
    - 47 to 47.3 feet

When filling out the “Log of Continuous pile driving”

- b. Record the number of blows per 1 foot increments
- c. Record the observed hammer stroke

When filling out the "Log of Continuous pile driving"

- d. Record Average penetration per blow
  - The total 1 foot increment divided by the number of blows for that foot
  - Example: from 6.0 to 7.0 ft. you had 16 blows

  1.0 ft/16 blows = 12 inches/16 blows = .75 inch/blow

- e. Record Computed bearing capacity of pile

When filling out the "Log of Continuous pile driving"

- f. Under the last entry (the fractional increment)

  Record: 1. movement in the last 20 blows (.55 ft)

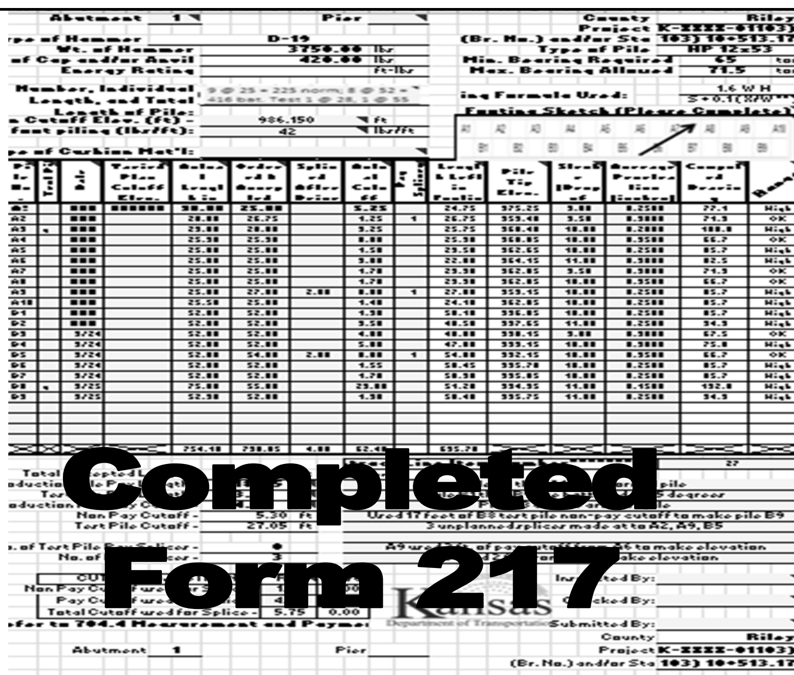
  2. average penetration per blow (0.33 in)

  3. the associated bearing (69.8 tons)

64		Abutment 1			Pier		Project		K-XXXX-01 (103)
65							(Br. No.) and/or Sta		(103) 10+513.17
66									
67–69	Pile No.	Total Pile Length	Length Driven From	Length Driven To	Number of Blows (Blow Count)	Drop of Hammer (Stroke) (ft.)	Average Penetration (in.)	Computed Resistance (tons)	Computed vs. Specified
70	A4	25.3	1.50	4.50	10	6.00	3.60	4.9	Low
71	A4	25.3	4.50	7.00	15	6.00	2.00	8.6	Low
72	A4	25.3	7.00	11.00	20	6.50	2.40	7.8	Low
73	A4	25.3	11.00	14.50	20	7.00	2.10	9.5	Low
74	A4	25.3	14.50	17.00	20	7.50	1.50	14.1	Low
75	A4	25.3	17.00	19.00	20	8.00	1.20	18.5	Low
76	A4	25.3	19.00	20.00	20	8.50	0.60	36.4	Low
77	A4	25.3	20.00	21.50	20	8.50	0.90	25.5	Low
78	A4	25.3	21.50	22.50	20	9.00	0.60	38.6	Low
79	A4	25.3	22.50	23.15	20	10.00	0.30	61.2	Low
80	A4	25.3	23.15	23.70	20	10.00	0.33	69.8	Ok
81	A4	25.3	23.70						
82	A4	25.3							

Driving Information

- 24. Distribution list--Copies to appropriate personnel
- 25. Signatures--**Always**
  - The individual that inspected the pile drive operation
  - The individual that checked any computations



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA

63				County	Riley
64	Abutment	1	Pier	Project	K-XXXX-01 (103)
65				(Br. No.) and/or Sta	(103) 10+513.17
66					

67–69	Pile No.	Total Pile Length	Length Driven From	Length Driven To	Number of Blows (Blow Count)	Drop of Hammer (Stroke) (ft.)	Average Penetration (in.)	Computed Resistance (tons)	Computed vs. Specified
70	A4	25.3	1.50	4.50	10	6.00	3.60	4.9	Low
71	A4	25.3	4.50	7.00	15	6.00	2.00	8.6	Low
72	A4	25.3	7.00	11.00	20	6.50	2.40	7.8	Low
73	A4	25.3	11.00	14.50	20	7.00	2.10	9.5	Low
74	A4	25.3	14.50	17.00	20	7.50	1.50	14.1	Low
75	A4	25.3	17.00	19.00	20	8.00	1.20	18.5	Low
76	A4	25.3	19.00	20.00	20	8.50	0.60	36.4	Low
77	A4	25.3	20.00	21.50	20	8.50	0.90	25.5	Low
78	A4	25.3	21.50	22.50	20	9.00	0.60	38.6	Low
79	A4	25.3	22.50	23.15	20	10.00	0.39	61.2	Low
80	A4	25.3	23.15	23.70	20	10.00	0.33	69.8	Ok
81	A4	25.3	23.70						
82	A4	25.3							
83	B5	52.1	3.00	9.00	10	5.00	7.20	2.1	Low
84	B5	52.1	9.00	15.00	15	6.00	4.80	3.7	Low
85	B5	52.1	15.00	20.00	20	6.00	3.00	5.8	Low
86	B5	52.1	20.00	24.50	20	7.00	2.70	7.5	Low
87	B5	52.1	24.50	29.00	20	9.00	2.70	9.6	Low
88	B5	52.1	29.00	33.00	20	10.00	2.40	12.0	Low
89	B5	52.1	33.00	37.00	20	10.00	2.40	12.0	Low
90	B5	52.1	37.00	[illegible]	20	[illegible]	[illegible]	12.0	Low
91	B5	52.1	41.00	[illegible]	[illegible]	[illegible]	[illegible]	15.8	Low
92	B5	52.1	44.00	[illegible]	[illegible]	[illegible]	[illegible]	15.8	Low
93	B5	52.1	47.00	[illegible]	[illegible]	[illegible]	[illegible]	35.3	Low
94	B5	52.1	48.25	49.00	20	10.00	0.45	54.5	Low
95	B5	52.1	49.00	49.60	20	11.00	0.36	71.7	Ok
96			X						

Completed
Log of Continuous Pile Drive

Form 271 B-the chart-make before you begin to drive pile

Field Pile Driving Guide

Enter known data in all available cells.

General Information

If you can not see colored tabs for different hammers at the bottom of the window, go to "View" tab, "Arrange All", and hit "OK" in the window that pops up.

(This information is common to all sheets in the Workbook)

Hammer Information		PROJECT INFORMATION	
Type of Hammer		**County**	
		Project	
Hammer Weight	lbs	**(Br. No.) and/or Sta**	
Cap and/or Anvil Weight	lbs	Type of Pile	
Energy Rating	ft-lbs	Plan Note Overdrive %	%
		Min. Resistance Required	tons
		Max. Resistance Allowed	tons

Guide to COMPLETING the Field Pile Driving Guide - Form 217B

1 All formulas use exactly what is entered in the cells.

2 Hover the mouse cursor over any red triangle to read information concerning what needs to be entered in the cell. Refer to the "Delmag Example" tab to view sample entry data.

Delmag McKierman Terry (Diesel Hammer)

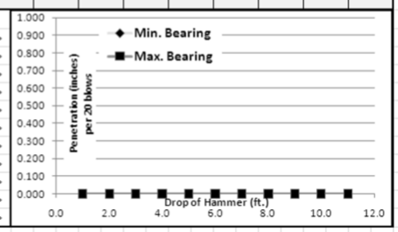
Summary			Formula	Entry Data			
Hammer Wt.		lbs	$$P = \frac{1.6 \cdot W \cdot H}{S + 0.1 \cdot \left(\frac{X^{**}}{W}\right)}$$	Weight per foot of piling (lbs/ft):		lbs/ft.	Maximum Hammer Drop
Cap/Anvil Wt.		lbs		Length of Pile:		feet	ft.
Pile Type				X:		lbs	Minimum Hammer Drop
Min. Res.		tons		Minimum "S":		inches/blow	
Max. Res.		tons		Maximum "S":		inches/blow	ft.

Field Blow count: 20

Penetration per 20 blows (in.)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average Penetration per blow (in.) "S"	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Drop of Hammer (Stroke) (ft.)	Drop of Hammer "H" in feet.	Computed Resistance (tons)
Calculated Bearing is HIGH		
Calculated Bearing is GOOD		
Calculated Bearing is LOW		

Drop of Hammer "H" in feet.	Penetration required per 20 blows to reach Minimum Resistance (in.)	Penetration required per 20 blows to reach Maximum Resistance (in.)



Delmag McKierman Terry (Diesel Hammer) Example

Summary			Formula	Entry Data				
Hammer Wt.	4200	lbs	$$P = \frac{1.6 \cdot W \cdot H}{S + 0.1 \cdot \left(\frac{X^{**}}{W}\right)}$$	Weight per foot of piling (lbs/ft):	42	lbs/ft.	Minimum Hammer Drop	
Cap/Anvil Wt.	980	lbs		Length of Pile:	52.3	feet	4	ft.
Pile Type				X:	3177	lbs	Maximum Hammer Drop	
Min. Res.	60	tons		Minimum "S":	0.000	inches/blow		
Max. Res.	90	tons		Maximum "S":	0.500	inches/blow	10	ft.

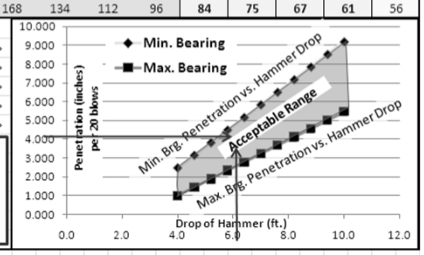
PROJECT SCOPE: HP10x42 pile, 52.3 ft long...Observed approximately 4 to 4.25 inches in 20 blows with about 6 feet hammer drop.

Penetration per 20 blows (in.)		0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000
Average Penetration per blow (in.) "S"		0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500
Drop of Hammer (Stroke) (ft.)	Drop of Hammer "H" in feet.	Computed Resistance (tons)										
	4.0	134	**90**	**67**	54	45	38	34	30	27	24	22
	4.6	155	103	**77**	**62**	52	44	39	34	31	28	26
Calculated Bearing is HIGH	5.2	175	116	**87**	**70**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5.8	195	130	97	**78**	**65**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	6.4	215	143	108	**86**	**72**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calculated Bearing is GOOD	7.0	235	157	118	94	**78**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7.6	255	170	128	102	**85**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	8.2	276	184	138	110	92	**79**	**69**	**61**	55	50	46
Calculated Bearing is LOW	8.8	296	197	148	118	99	**84**	**74**	**66**	59	54	49
	9.4	316	211	158	126	105	90	**79**	**70**	**63**	57	53
	10.0	336	224	168	134	112	96	**84**	**75**	**67**	**61**	56

Based on a hammer drop of around 6.0 ft.
Based on around 4 inches of penetration in the last 20 blows.
Bearing is within acceptable range: it is between 65 ton and 72 ton.

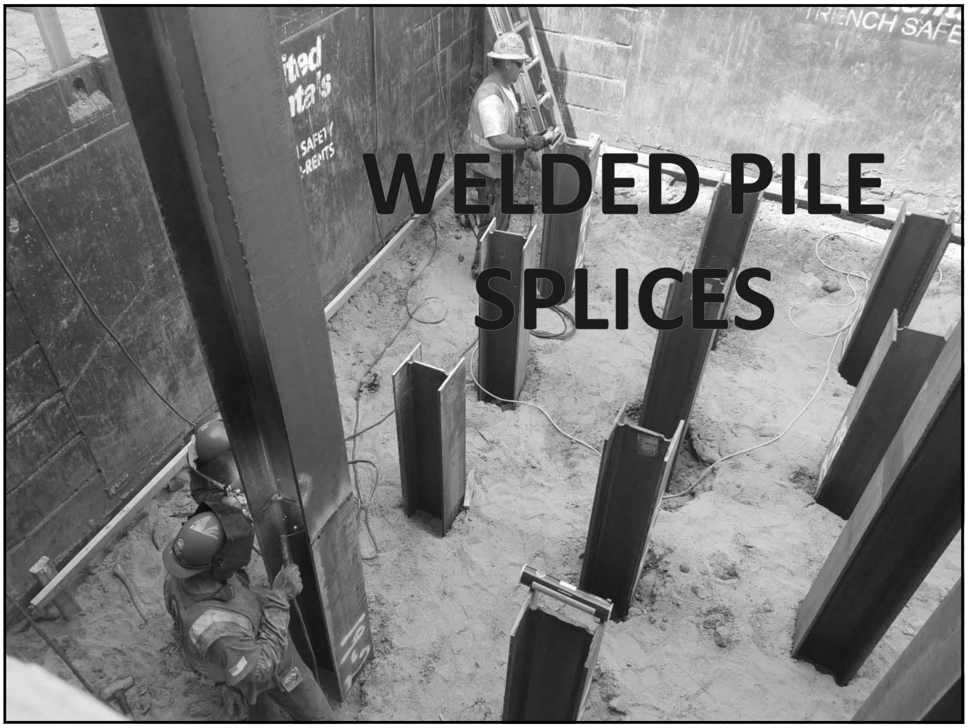
Drop of Hammer "H" in feet.	Penetration required per 20 blows to reach Minimum Resistance (in.)	Penetration required per 20 blows to reach Maximum Resistance (in.)	
4.0	2.480	0.987	->
4.6	3.152	1.435	->
5.2	3.824	1.883	->
5.8	4.496	2.331	->
6.4	5.168	2.779	->

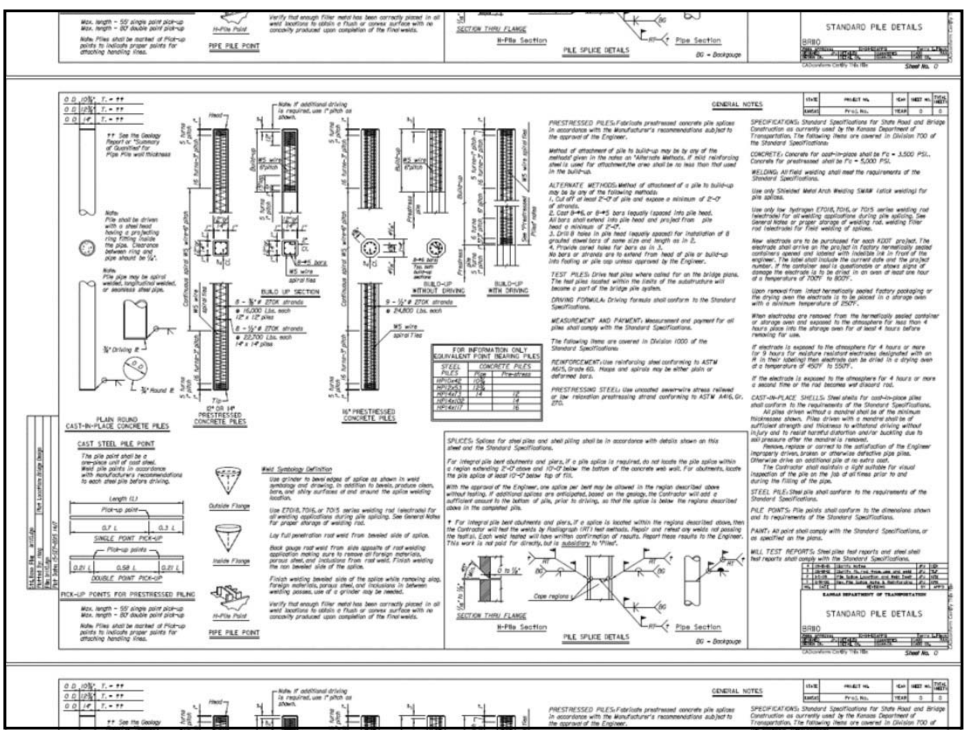
Minimum Bearing is achieved if penetration is LESS than a number between 4.496" and 5.168". 4" is less, so OK.
Maximum Bearing is not exceeded if penetration is MORE than a number between 2.331" and 2.779". 4" is more, so OK.
Graphically, to the right, the penetration per 20 blows of about 4" with a hammer drop of 6 feet is in the acceptable range.

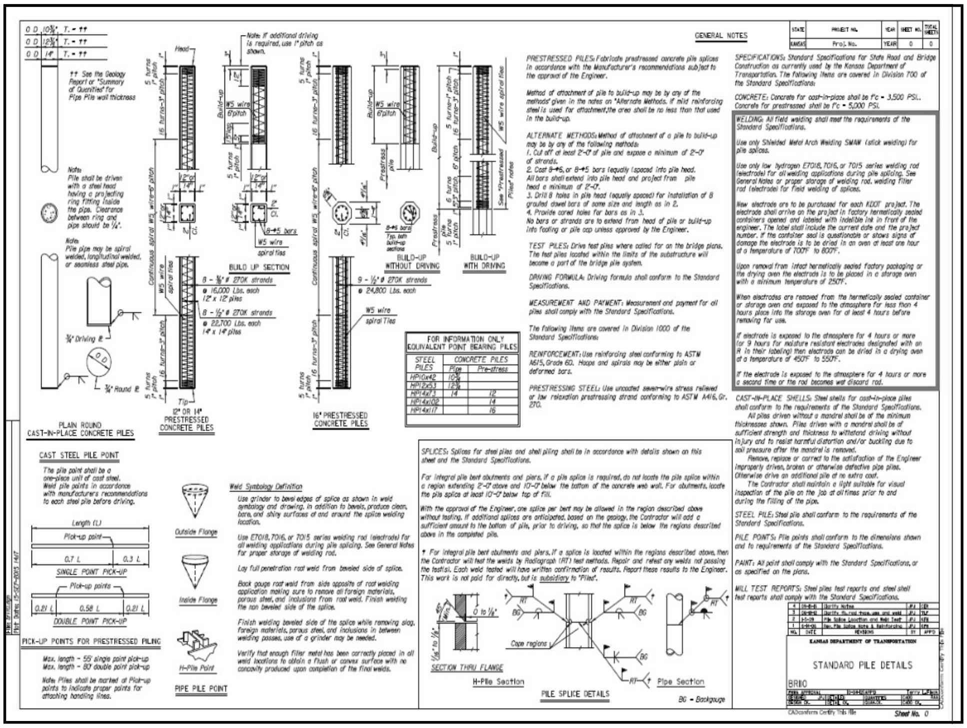



Questions
?

WELDED PILE SPLICES







WELDING: All field welding shall meet the requirements of the Standard Specifications.

Use only Shielded Metal Arch Welding SMAW (stick welding) for pile splices.

Use only low hydrogen E7018, 7016, or 7015 series welding rod (electrode) for all welding applications during pile splicing. See General Notes or proper storage of welding rod. welding filler rod (electrode) for field welding of splices.

New electrode are to be purchased for each KDOT project. The electrode shall arrive on the project in factory hermetically sealed containers opened and labeled with indelible ink in front of the engineer. The label shall include the current date and the project number. If the container seal is questionable or shows signs of damage the electrode is to be dried in an oven at least one hour at a temperature of 700°F to 800°F.

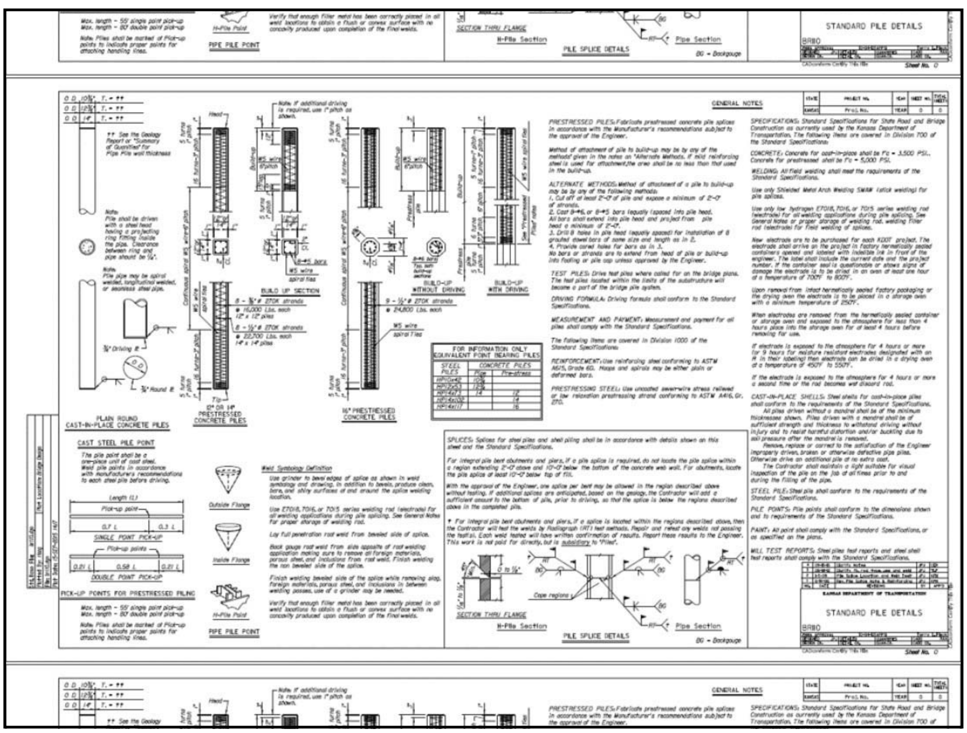
Upon removal from intact hermetically sealed factory packaging or the drying oven the electrode is to be placed in a storage oven with a minimum temperature of 250°F.

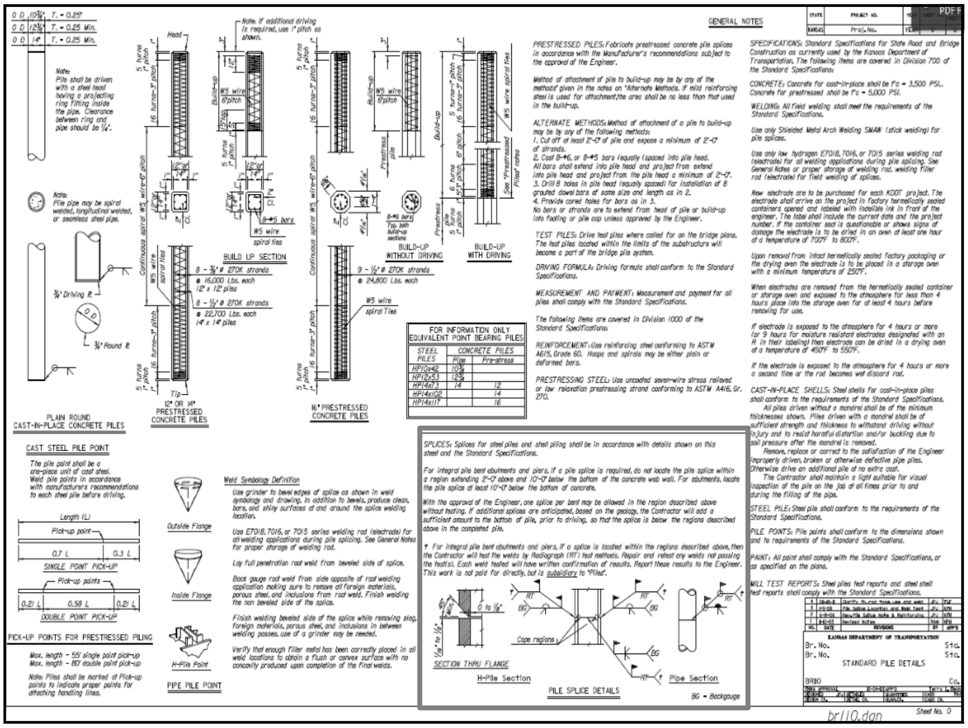
When electrodes are removed from the hermetically sealed container or storage oven and exposed to the atmosphere for less than 4 hours place into the storage oven for at least 4 hours before removing for use.

If electrode is exposed to the atmosphere for 4 hours or more (or 9 hours for moisture resistant electrodes designated with an R in their labeling) then electrode can be dried in a drying oven at a temperature of 450°F to 550°F.

If the electrode is exposed to the atmosphere for 4 hours or more a second time or the rod becomes wet discard rod.

KDOT H-PILE SPLICES



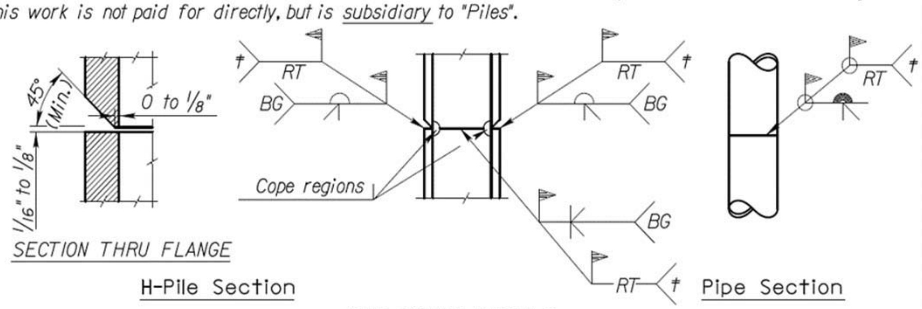


SPLICES: Splices for steel piles and shell piling shall be in accordance with details shown on this sheet and the Standard Specifications.

For integral pile bent abutments and piers, if a pile splice is required, do not locate the pile splice within a region extending 2'-0" above and 10'-0" below the bottom of the concrete web wall. For abutments, locate the pile splice at least 10'-0" below top of fill.

With the approval of the Engineer, one splice per bent may be allowed in the region described above without testing. If additional splices are anticipated, based on the geology, the Contractor will add a sufficient amount to the bottom of pile, prior to driving, so that the splice is below the regions described above in the completed pile.

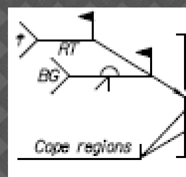
† For integral pile bent abutments and piers, if a splice is located within the regions described above, then the Contractor will test the welds by Radiograph (RT) test methods. Repair and retest any welds not passing the test(s). Each weld tested will have written confirmation of results. Report these results to the Engineer. This work is not paid for directly, but is subsidiary to "Piles".

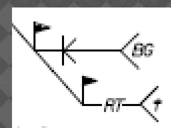


PILE SPLICE DETAILS

BG = Backgouge

WELD SYMBOLOGY MEANING

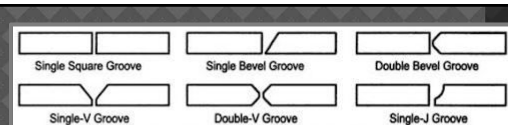


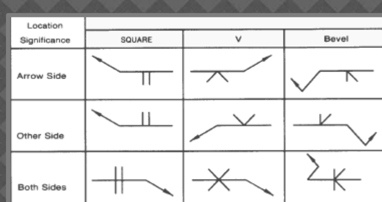


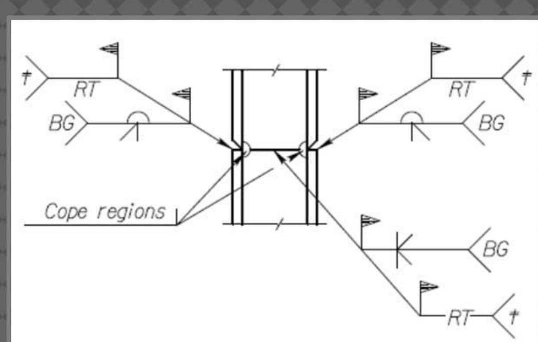
Solid Flag pointing away from work area
•Field Weld Symbol
Half circle
•Filled is: Melt Through
•Unfilled is: Backing or Backgouge

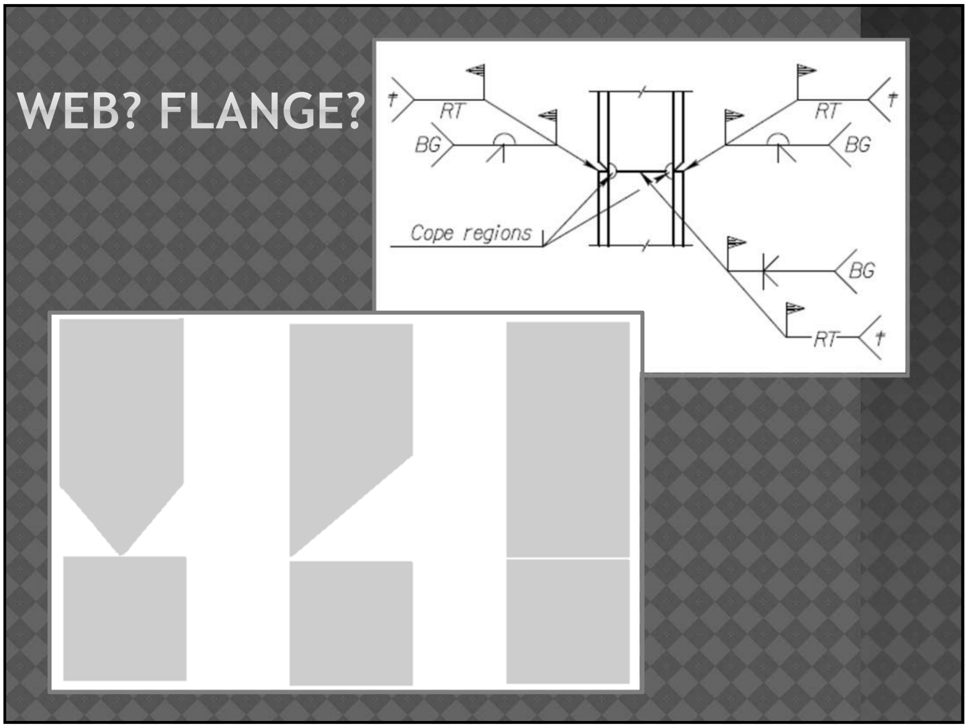
 : Single Bevel Grove

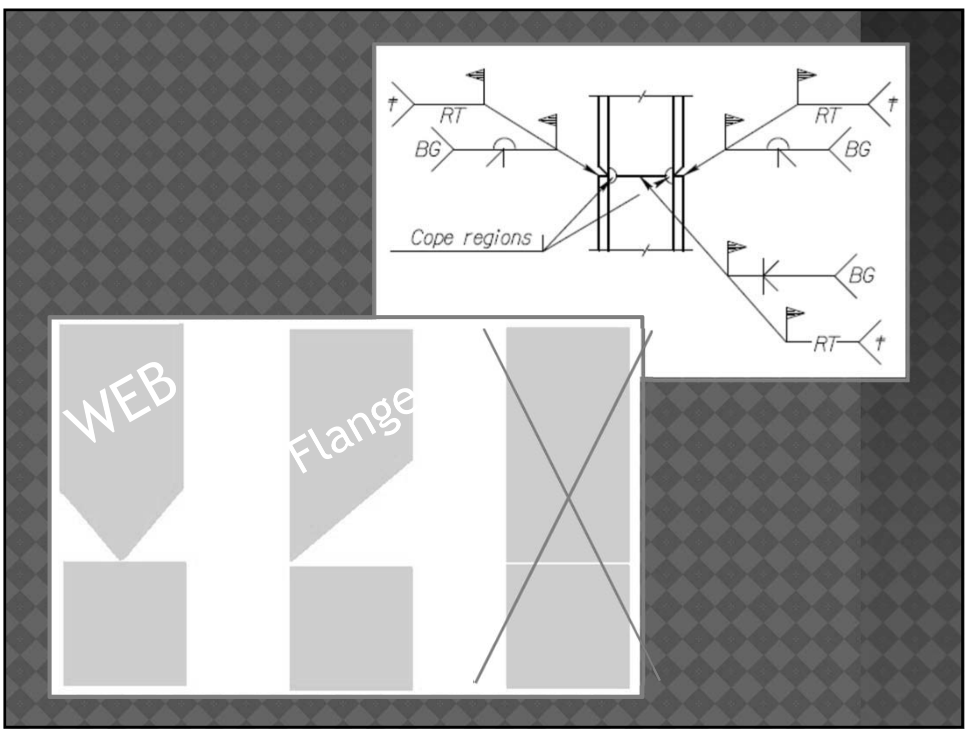
 : Double Bevel Groove

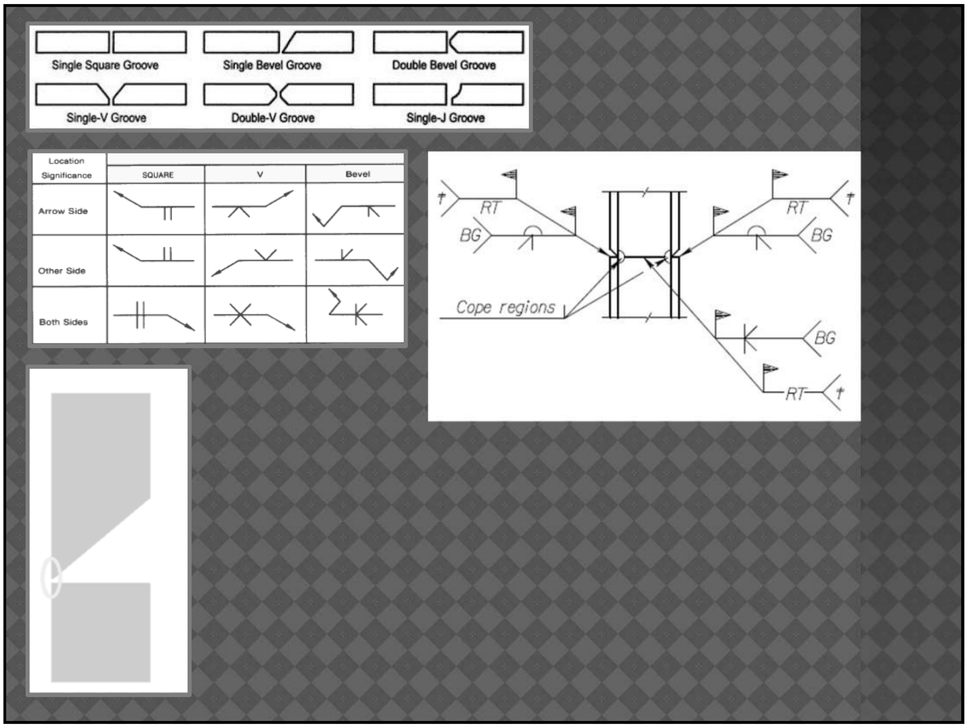




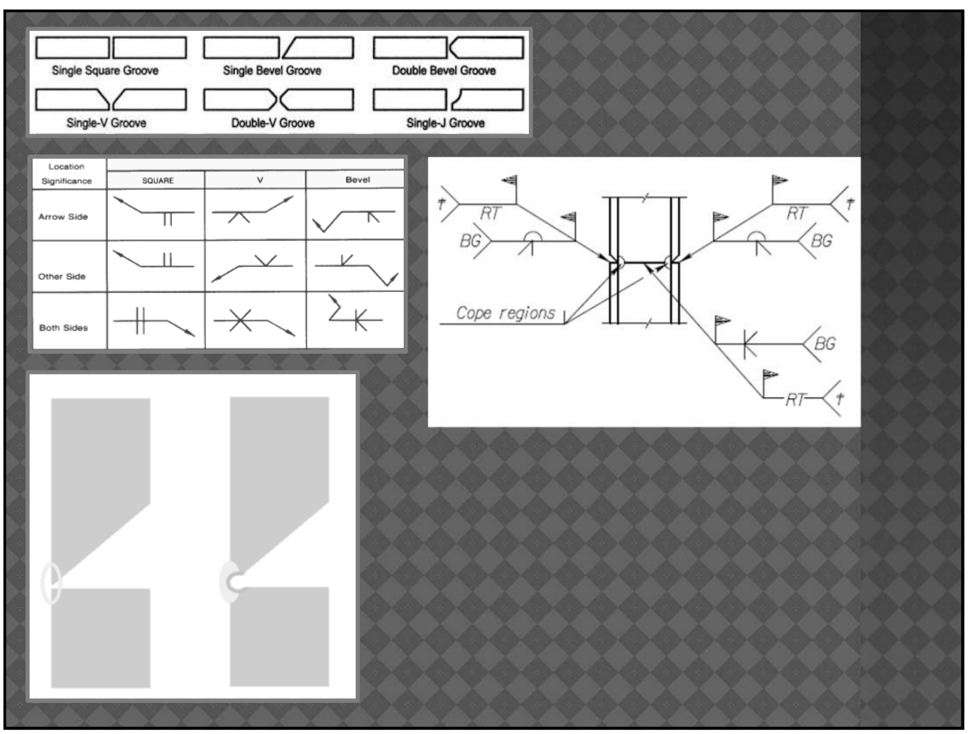



WEB? FLANGE?
RT
BG
Cope regions
RT
BG
BG
RT

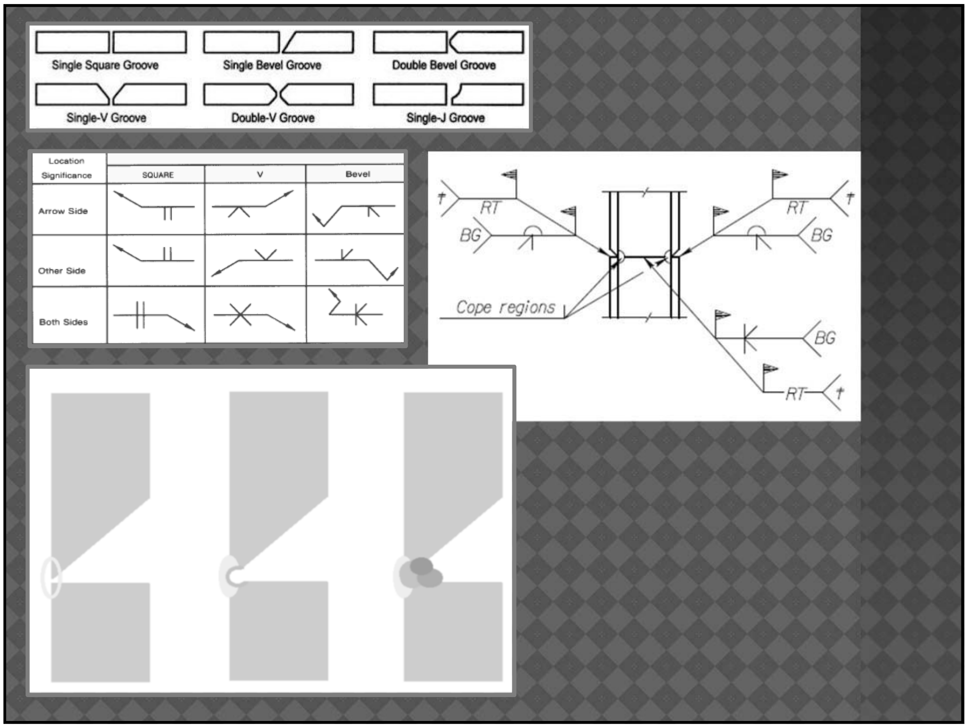

RT
BG
Cope regions
RT
BG
BG
RT
WEB
Flange

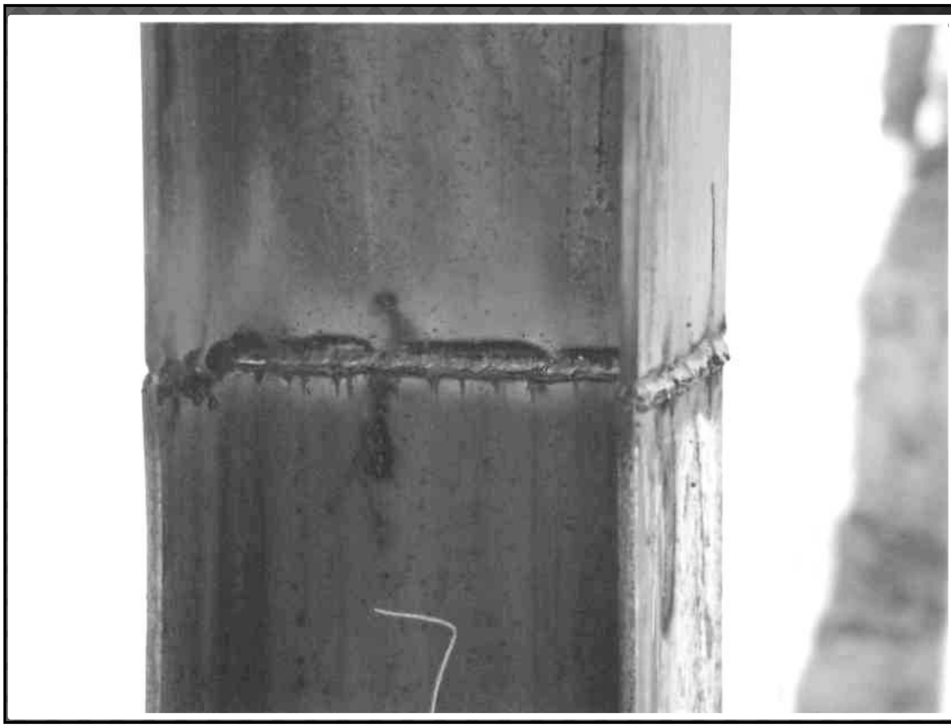


Single Square Groove
Single Bevel Groove
Double Bevel Groove
Single-V Groove
Double-V Groove
Single-J Groove
Location Significance
SQUARE
V
Bevel
Arrow Side
Other Side
Both Sides
RT
BG
RT
BG
Cope regions
BG
RT



Single Square Groove
Single Bevel Groove
Double Bevel Groove
Single-V Groove
Double-V Groove
Single-J Groove
Location Significance
SQUARE
V
Bevel
Arrow Side
Other Side
Both Sides
RT
BG
RT
BG
Cope regions
BG
RT


Single Square Groove
Single Bevel Groove
Double Bevel Groove
Single-V Groove
Double-V Groove
Single-J Groove
Location Significance
SQUARE
V
Bevel
Arrow Side
Other Side
Both Sides
RT
BG
Cope regions

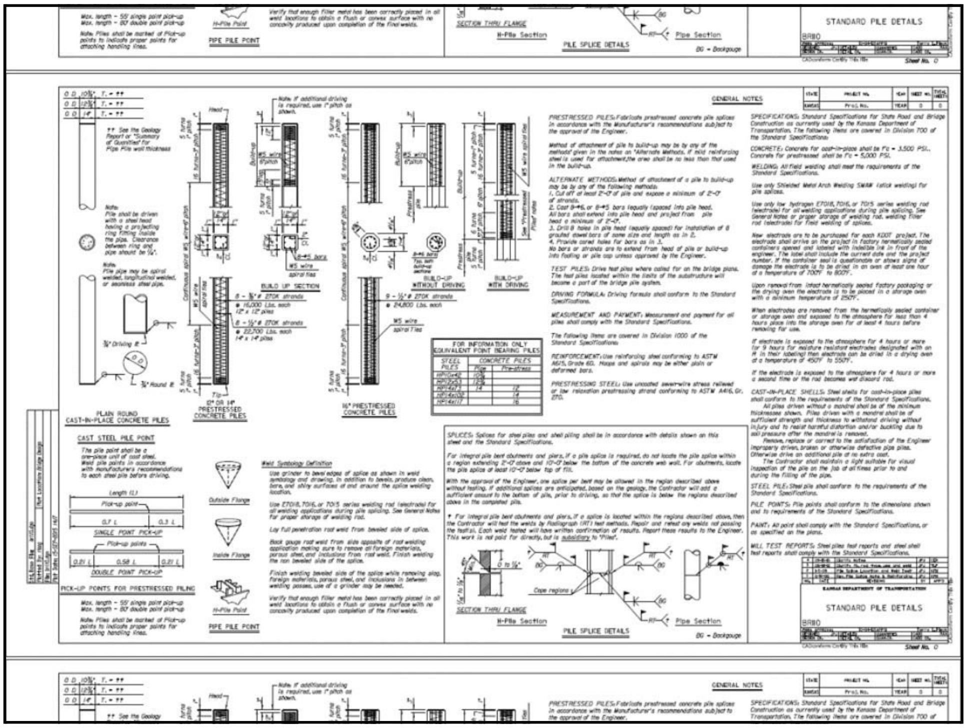


ALIGNMENT METHODS

Short piece of H-pile clamped on

C-CLAMPS AND BOARDS

WHAT NOT TO DO

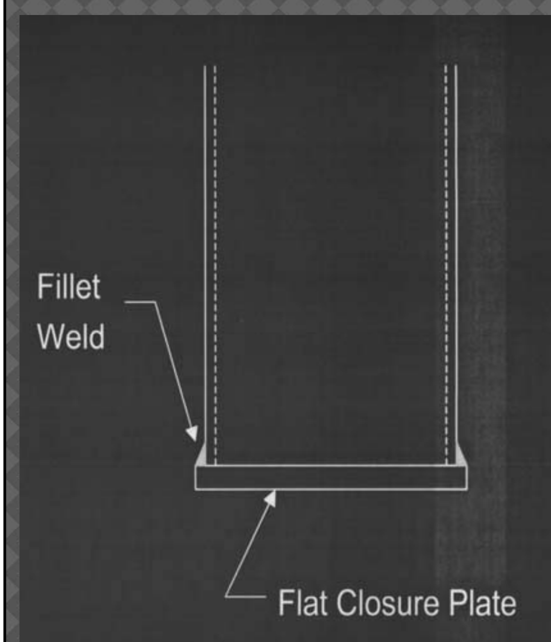


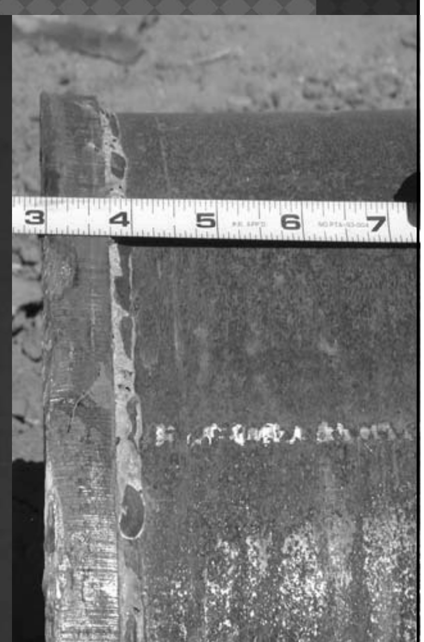
CLOSED END PIPE PILE

CLOSED END PIPE PILE

Using Conical Points

TYPICAL KDOT PIPE PILE PLATE





QUESTIONS?

Test Piles and Test Piles (Special)

1

Test Piles

Driven before main production piles to get an idea of how piles will behave.

2

We use the information to come up with an efficient way of driving the production piles and to plan any splice locations.

3

KDOT pays for piling which becomes "extra" because of test pile information. It is the same as the rate for cutoff.

4

What You Have To Do

Make sure the contractor has a certified welder on site in case a test pile has to be spliced

Keep a continuous log of driving

5

What You Have To Do

Avoid delays once driving has started

Finish driving the test pile in one day unless you need to do a restrike

6

Uh-Oh….

If pile doesn't get resistance within roughly 2 feet of plan elevation, try a restrike

Call the Regional Geology Office for help

7

Pile Restrike Procedure

Wait overnight

Warm up hammer far from test pile

Immediately restrike test pile for 30 blows or until it moves 4 inches, whichever comes first

8

Pile Restrike Procedure

Record penetration for every 5 blows

If pile moves less than ½ inch, stop restrike after 20 blows

Calculate resistance based on average penetration for first 5 blows

9

Pile Restrike Procedure

If calculated resistance is still too low, splice and resume driving

10

Pile Restrike Procedure

If you get enough resistance with the restrike, then we will use that elevation (plan pile tip elevation) for the production piles

11

What You Have To Do

Tell your boss how the test pile went

12

Test Piles (Special)

A fancy name for a test pile that is monitored by the Pile Driving Analyzer

13

Test Piles (Special)

Contact the Topeka Geology Office when the project gets going, just to warn John.

(785) 291-3861

Forward him the hammer data when you get it from the contractor.

14

Test Piles (Special)

You are required to contact the Topeka Geology Office (John) a minimum of 5 working days before the Test Pile Special.

(785) 291-3861

15

Test Piles (Special)

We Will Need Beforehand:

- Hammer type and size
- Pile type, size, and grade
- Test pile locations
- Cut-off elevations
- Plan design pile tip elevations
- If pile bents, the bottom of web wall elevation

16

Remind the contractor that a restrike is required with the PDA.

This may be an overnight restrike.

17

Test Piles (Special)

On the day of the test pile we'll need:

Ground elevation at each test pile location

18

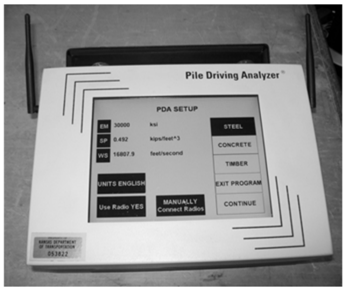
Test Piles (Special)

Keep a continuous log of driving

PDA crew will tell you what elevation to drive to, or what resistance you need using the Pile Drive Formula

19

The Pile Driving Analyzer and Restrike Testing



1

Dynamic Testing at a Glance

- A ram impacts the pile top
- The pile top is compressed at the instant of impact
- A stress wave travels through the pile
- The wave is partially reflected back up the pile due to
  - soil resistance---representing capacity
  - pile property change
  - or at the pile toe
- From the reflected waves PDA calculates capacity

2

Measures

- Evaluation of the Drive System Performance
- Calculation of the Driving Stresses During Installation
- Assessment of Pile Integrity

3

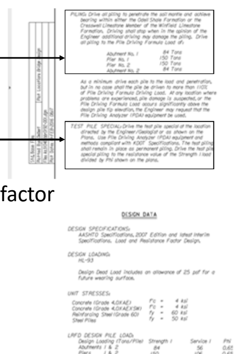
Measurements Cont.

- Assessment of the Pile Capacity and Soil Conditions
- Allows You to Discount any Bearing Capacity in the Scour Zone
- Allows You to See Shaft Versus Toe Capacity on the Pile

4

Before the PDA

- Your target pile load
- PDA target
- PDA target = Strength I load/ Phi factor
- PDA Measures in kips
  - Kip = ½ ton



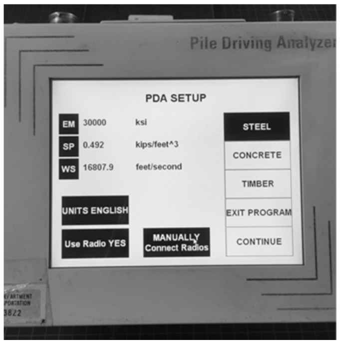
5

Before the PDA

- Determine plan tip depth
- Determine depth to bedrock
- Test pile has been clearly marked by the foot
- Communication between Geology, inspectors, and foreman
  - You keep track of the blows/foot and stroke of hammer
  - Foreman will be marking the pile every 10 blows
    - Marking depth will be determined by testing crew

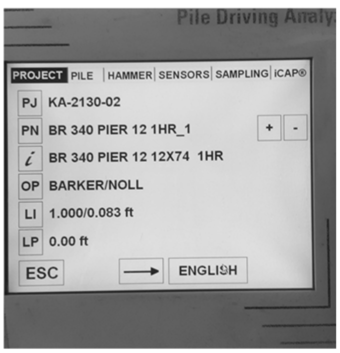
6

Before the PDA



7

Before the PDA



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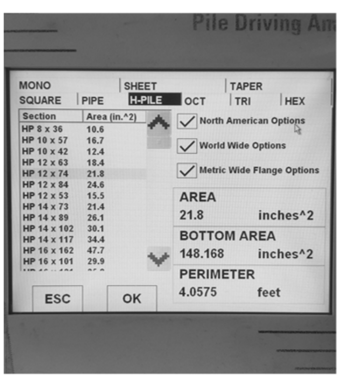
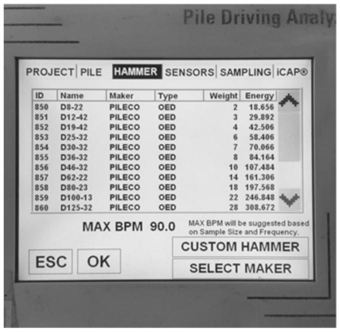
Before the PDA



9

Before the PDA



10

Strain & Acceleration Measurements

Strain Transducers measure force

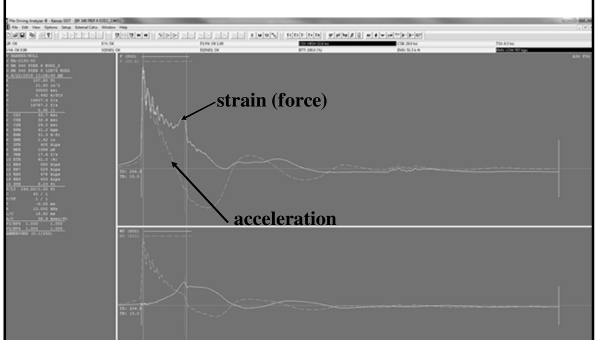
Two Strain Transducers **<u>Required</u>** to Reduce Bending Effects.

Accelerometers measure velocity

Two Accelerometers Used for Redundancy

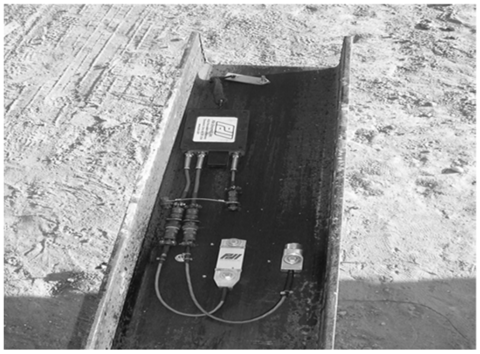
11

Raw PDA Data



12

Typical Gage Arrangement



13

Gage Attachment

14

Gage Attachment

15

Hammer Placement

16

Test Pile Special Length

- 10 ft longer than production
  - Allows for PDA equipment
  - Able to drive deeper if necessary
  - Additional length has a mild effect the ENR calculation

17

PDA Testing Process

- Foreman marks the pile every 10 blows until end of drive
  - Usually beginning above a depth where capacity is expected to change (bedrock)
- The last 20 blows from the initial drive is used for:
  - PDA Analysis
  - ENR Calculation

18

PDA Restrikes

- Standard PDA series of restrikes (15 min, 1 hour, 4 hour, 24 hour)
- Foreman marks every 5 blows

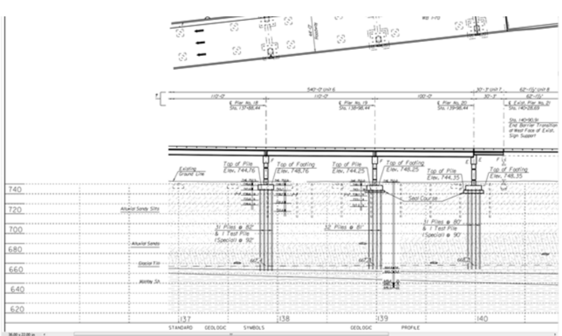
19

Projects with PDA

- Lewis and Clark Viaduct - Pier 18
  - 1 Test Pile Special
  - Results will be applied to 2 pier (Pier 18 and Pier 17)
  - Pile Design Load = 110 tons
  - PDA Target Load (110/.65) = 169 tons (338 kips)
  - Plan length 82 ft
  - 12 x 74 H-Pile
  - Pileco D30-32

20

Lewis and Clark Viaduct Pier 18



21

Lewis and Clark
Pier 18

- **End of drive** – Stop 5 feet above plan tip
  - PDA recording 243.5 tons (we needed 169 tons)
  - Bearing Formula recording 80 tons (needed 110 tons)
    - 80 tons is the new target.
- Good example of typical PDA Test
  - The target load is recognized by the PDA first.
  - New target Bearing Formula Load is less than plan.
- Important to understand
  - We are **NOT** changing the design load of the pile.
  - 80 tons (from the bearing formula) = 243.5 tons (from the PDA)

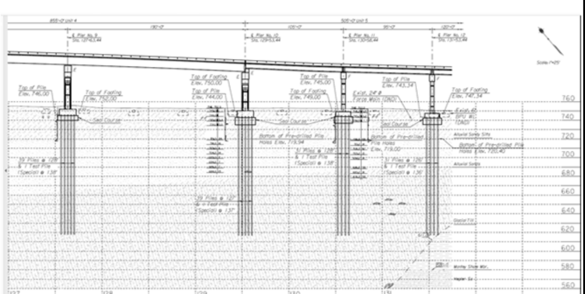
22

Lewis and Clark Viaduct

- Pier 11
  - 1 Test Pile Special
  - Results will be applied to Pier 11 only
  - Pile Design Load = 120 tons
  - PDA Target Load = 184.6 tons (369 kips)
  - Plan Length 128 ft
  - 12 x 74 H-Pile
  - Pileco D36-32

23

Lewis and Clark Viaduct
Pier 11



24

Lewis and Clark
Pier 11

- End of drive – Stopped at plan tip
  - PDA recording 131 tons (we needed 185 tons)
  - Bearing Formula recording 45.2 tons (needed 120 tons)
- 15 minute restrike
  - PDA recording 170 tons
  - Bearing Formula recording 65.9 tons
- 1 hour restrike
  - PDA recording 193 tons
  - Bearing Formula recording 79.6 tons

25

Lewis and Clark
Pier 11

- Results
  - Sufficient capacity achieved after 1 hour.
  - Strictly using the ENR Bearing Formula, driving would have continued well past plan tip elevation.
  - New target Bearing Formula Load is less than plan.
- Important to understand following a PDA with restrikes
  - Follow the initial driving criteria (movement and stroke)
    - 45 tons will be the new target.
  - If capacity is questionable after initial, conduct a 24 hour restrike.
    - Use the ENR values from the PDA restrikes to guide you.

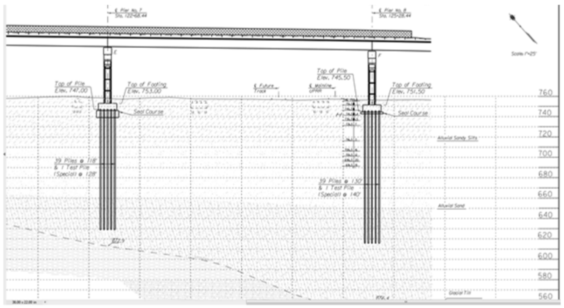
26

Lewis and Clark Viaduct

- Pier 8
  - 1 Test Pile Special
  - Results will be applied to Pier 8 only
  - Pile Design Load = 164 tons
  - PDA Target Load 164/.65 = 252 tons (369 kips)
  - Plan Length 130 ft.
  - 12 x 74 H-Pile
  - Pileco D36-32

27

Lewis and Clark Viaduct
Pier 8



28

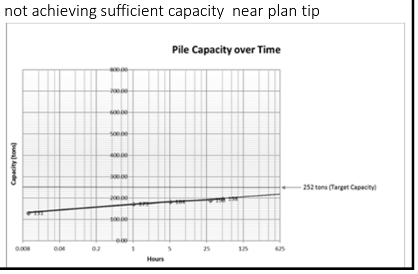
Lewis and Clark
Pier 8

- End of drive – Stopped at plan tip
  - PDA recording 131 tons (we needed 252 tons)
  - Bearing Formula recording 43 tons (needed 165 tons)
- 1 hour restrike
  - PDA recording 173 tons
  - Bearing Formula recording 55.1 tons
- 5 hour restrike
  - PDA recording 184 tons
  - Bearing Formula recording 71 tons
- 29 hour restrike
  - PDA recording 190 tons
  - Bearing Formula recording 85 tons

29

Lewis and Clark
Pier 8

- 50 hour restrike
  - PDA recording 198 tons (we needed 252 tons)
  - Bearing Formula recording 113 tons (needed 164 tons)
- Summary up to this point
  - 26 days, and still not achieving sufficient capacity near plan tip
  - Within a 2 days
  - Keep driving



30

Lewis and Clark
Pier 8

- End of drive # 2
  - Spliced on an additional 25 ft.
  - Drove pile until the PDA started showing capacity was being gained
    - Ended up drove an additional 21.5 ft.
  - Decided to let it set over the weekend, would restrike on Monday
  - PDA recording 207 tons (needed 254)
  - Bearing Formula recording 100 tons (needed 165 tons)
- 66 hour restrike
  - PDA recording 306 tons
  - Bearing Formula recording 167.6 tons

31

Why use the PDA?

32

- **PDA and Restrike Testing Better Quantifies Bearing Capacity**
- **PDA Monitors (**Bearing Formula cannot do these**)**
  - **Driving Stresses**
  - **Checks Hammer Performance**
  - **Evaluates Soil Performance**
  - **Checks Pile Integrity (will see damage)**
  - **Can discount capacity in potential scour areas**
- **In Most Cases by Utilizing the PDA and/or Restrike Testing a Savings Resulting From Fewer Splices or Shorter Pile Lengths**
- **Piles Driven Easier and Faster**

33

- PDA monitors driving stresses
  - may allow piles to be driven harder to reach a minimum pile tip elevation
    - Using bearing formula, driving must stop once 110% of Service is achieved because stresses are not known using the formula
    - Hopefully well before as to not damage the pile, especially in end bearing situations

34

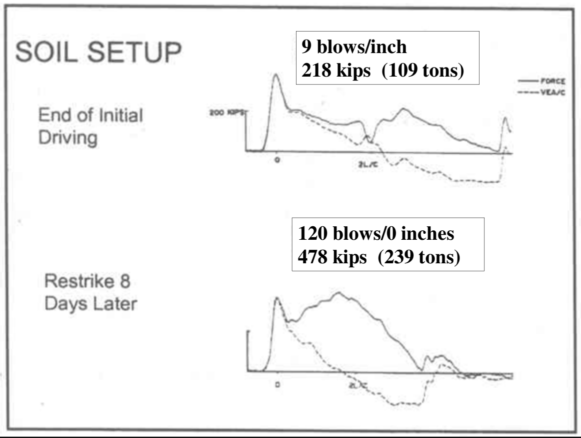
Restrike Testing

35

Restrike Testing

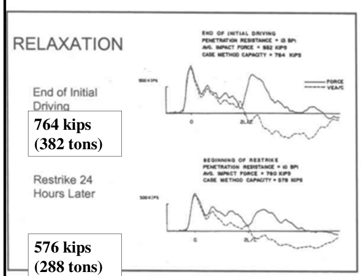
- Long term pile capacity
- Estimating static pile capacity using dynamic method calculations
- Accounts for possible changes in soil conditions
- Restrike testing can record these capacity changes over time
- Only true way to evaluate the pile performance over time

36



37

Soil Relaxation



- Piles driven into weathered shale
- Displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe

Note:
Bearing capacity loss at toe
Some capacity gain on shaft

38

Restrike Testing Procedure

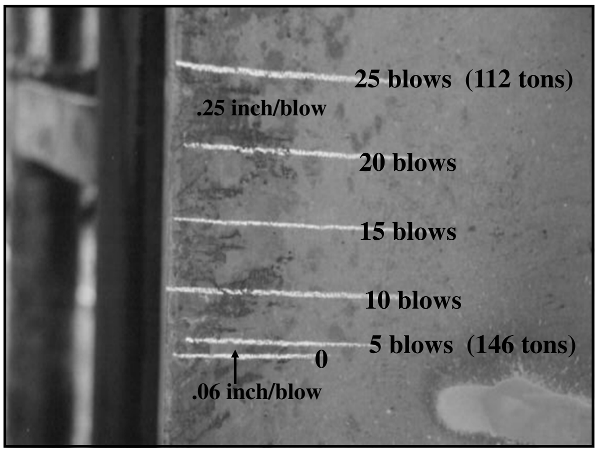
- No driving activity near test site for at least 24 hours prior to testing
- Conduct the restrike a minimum of 24 hours later, unless otherwise specified
- Warm-up hammer—operating correctly
- Hammer should be warmed up at a location as far from the test pile as possible
- Restrike pile for 20 blows or a movement of 4 inches whichever comes first

39

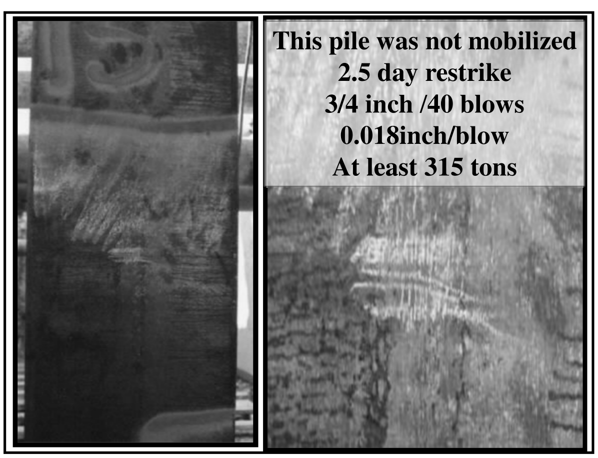
Restrike Testing Procedure

- Record the first blows
- Mark every 5 blows
  - Can compare the first blows of the restrike to the last blows of the restrike.
  - In most cases by doing a restrike you will see an increase in bearing capacity due to soil setup.
  - If pile is mobilized, you should see a difference between beginning and end of restrike in bearing capacity and in set per blow

40



41



42

43

THE INSPECTOR'S ROLE

1

1 Study the Plans

2

Study the Plans

Especially the "General Notes and Quantities" page

and the "Engineering Geology" page

3

2 Read the Bridge Foundation Geology Report

4

3

Read Section 704 of the Standard Specifications and check for new Special Provisions

5

4 Get all of the hammer info from the Contractor

To use the driving equation, you need:

Weight of the hammer piston (ram)

Weight of the pile cap (helmet) and the anvil

6

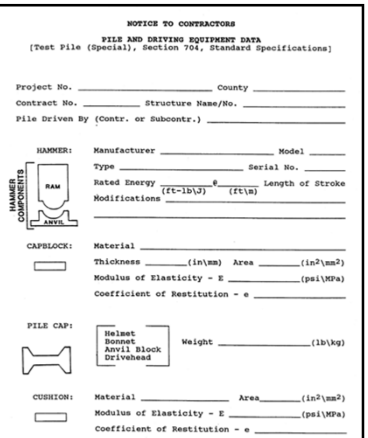
4 Get all of the hammer info from the Contractor

To check the hammer size, you also need:

Maximum stroke of piston

7

This is Form 217 AA, in the Forms Warehouse


NOTICE TO CONTRACTORS

PILE AND DRIVING EQUIPMENT DATA
[Test Pile (Special), Section 704, Standard Specifications]

Project No. ______ County ______
Contract No. ______ Structure Name/No. ______
Pile Driven By (Contr. or Subcontr.) ______

HAMMER: Manufacturer ______ Model ______
Type ______ Serial No. ______
Rated Energy ______ (ft-lb\J) @ ______ (ft\m) Length of Stroke
Modifications ______

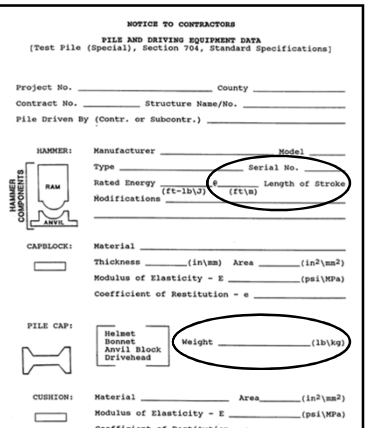
CAPBLOCK: Material ______
Thickness ______ (in\mm) Area ______ (in²\mm²)
Modulus of Elasticity - E ______ (psi\MPa)
Coefficient of Restitution - e ______

PILE CAP: Helmet / Bonnet / Anvil Block / Drivehead Weight ______ (lb\kg)

CUSHION: Material ______ Area ______ (in²\mm²)
Modulus of Elasticity - E ______ (psi\MPa)
Coefficient of Restitution - e ______

8

Here is the maximum stroke and weight of pile cap.


NOTICE TO CONTRACTORS

PILE AND DRIVING EQUIPMENT DATA
[Test Pile (Special), Section 704, Standard Specifications]

Project No. ______ County ______
Contract No. ______ Structure Name/No. ______
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HAMMER: Manufacturer ______ Model ______
Type ______ Serial No. ______
Rated Energy ______ (ft-lb\J) @ ______ (ft\m) Length of Stroke
Modifications ______

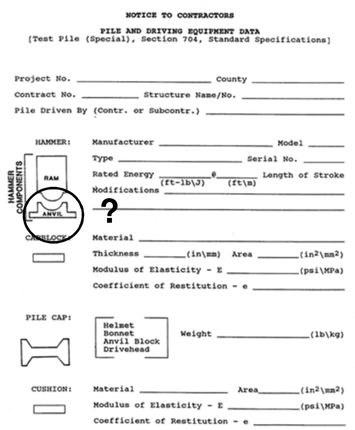
CAPBLOCK: Material ______
Thickness ______ (in\mm) Area ______ (in²\mm²)
Modulus of Elasticity - E ______ (psi\MPa)
Coefficient of Restitution - e ______

PILE CAP: Helmet / Bonnet / Anvil Block / Drivehead Weight ______ (lb\kg)

CUSHION: Material ______ Area ______ (in²\mm²)
Modulus of Elasticity - E ______ (psi\MPa)
Coefficient of Restitution - e ______

9

Notice that the anvil weight is not here.



NOTICE TO CONTRACTORS

PILE AND DRIVING EQUIPMENT DATA
[Test Pile (Special), Section 704, Standard Specifications]

Project No. __________ County __________
Contract No. __________ Structure Name/No. __________
Pile Driven By (Contr. or Subcontr.) __________

HAMMER: Manufacturer __________ Model __________
Type __________ Serial No. __________
Rated Energy __________ (ft-lb\J) @ __________ (ft\m) Length of Stroke
Modifications __________

CAPBLOCK: Material __________
Thickness __________ (in\mm) Area __________ (in²\mm²)
Modulus of Elasticity - E __________ (psi\MPa)
Coefficient of Restitution - e __________

PILE CAP: Helmet / Bonnet / Anvil Block / Drivehead — Weight __________ (lb\kg)

CUSHION: Material __________ Area __________ (in²\mm²)
Modulus of Elasticity - E __________ (psi\MPa)
Coefficient of Restitution - e __________

10

Most of the time, a contractor will send you their company's form and not KDOT's

11

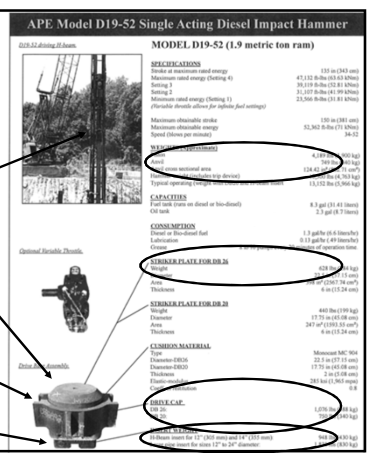
This is off the internet—American Pile Equipment

Anvil: 749 lbs

Striker plate: 628 lbs

Helmet: 1076 lbs

Adapter: 948 lbs



APE Model D19-52 Single Acting Diesel Impact Hammer

MODEL D19-52 (1.9 metric ton ram)

SPECIFICATIONS

Stroke at maximum rated energy	135 in (343 cm)
Maximum rated energy (Setting 4)	47,132 ft-lbs (63.63 kNm)
Setting 3	39,119 ft-lbs (52.81 kNm)
Setting 2	31,107 ft-lbs (41.99 kNm)
Minimum rated energy (Setting 1)	23,566 ft-lbs (31.81 kNm)
(Variable throttle allows for infinite fuel settings)	
Maximum obtainable stroke	150 in (381 cm)
Maximum obtainable energy	52,362 ft-lbs (71 kNm)
Speed (blows per minute)	34-52

WEIGHTS (Approximate)

Piston	4,189 lbs (1,900 kg)
Anvil	749 lbs (340 kg)
Anvil cross sectional area	124.42 in² ([illegible] cm²)
Hammer weight (includes trip device)	10,500 lbs (4,763 kg)
Typical operating (weight with DB26 and H-beam insert	13,152 lbs (5,966 kg)

CAPACITIES

Fuel tank (runs on diesel or bio-diesel)	8.3 gal (31.41 liters)
Oil tank	2.3 gal (8.7 liters)

CONSUMPTION

Diesel or Bio-diesel fuel	1.3 gal/hr (6.6 liters/hr)
Lubrication	0.13 gal/hr (.49 liters/hr)
Grease	[illegible] minutes of operation time.

STRIKER PLATE FOR DB 26

Weight	628 lbs (284 kg)
Diameter	22.5 in (57.15 cm)
Area	398 in² (2567.74 cm²)
Thickness	6 in (15.24 cm)

STRIKER PLATE FOR DB 20

Weight	440 lbs (199 kg)
Diameter	17.75 in (45.08 cm)
Area	247 in² (1593.55 cm²)
Thickness	6 in (15.24 cm)

CUSHION MATERIAL

Type	Monocast MC 904
Diameter-DB26	22.5 in (57.15 cm)
Diameter-DB20	17.75 in (45.08 cm)
Thickness	2 in (5.08 cm)
Elastic-modulus	285 ksi (1,965 mpa)
Coeff. of restitution	0.8

DRIVE CAP

DB 26:	1,076 lbs (488 kg)
DB 20:	750 lbs (340 kg)

INSERT WEIGHT

H-Beam insert for 12" (305 mm) and 14" (355 mm):	948 lbs (430 kg)
Large pipe insert for sizes 12" to 24" diameter:	1,830 lbs (830 kg)

12

Anvil: 749 lbs

Striker plate: 628 lbs

Helmet: 1076 lbs

Adapter: 948 lbs

Total: 3401 lbs

This is the weight of everything below the piston

Add the weight of the pile, and you have "X" for the equation.

13

#5 Make sure that the energy rating of the hammer is high enough to drive the piles

Use the driving equation with 0.1 inch per blow and the maximum stroke for that hammer. Refer to the *Bearing Formula* section in your book.

14

Forward the hammer info to Geology when you get it if:

There is a test pile (special)

You would like one of us on site during the start of driving

15

6 Get the Type-A Certificate from CMS

Go To "Materials"

…then "Materials Report"

…then "Contract Finals"

16

Non Acceptance Tests Report

```
DTMT112                                   KANSAS DEPARTMENT OF TRANSPORTATION              PAGE:   4
RUNDATE: 07 10 06                         NON ACCEPTANCE TESTS REPORT - FINAL
RUNTIME: 10:14 AM
CONTRACT: 503032043 M                      WORK TYPE: BRRPL                      STATUS: FINAL
PROJECT ID: K023 090 K 7333 01             AREA OFFICE: 04                       DISTRICT: 03
CONTRACTOR ID: 00725                       CONTRACTOR NAME: L & M CONTRACTORS, INC.
LINE # ITEM CODE   ITEM NAME                                  UNIT           ORIGINAL QTY  CURRENT QTY
       MATL CODE   MATERIAL NAME              UNIT  SAMPLE ID SI  SAMPLE QTY   RSLT  INSP TYPE  TEST PERFORMED
998    099999      TESTED MATERIALS                               EACH           0.000      0.000
       067010000   STEEL BEARING PILE         LNFT
                                                  00456078  M     609.600    CPLY   CTA     FREE FORM TEXT
                                                  00468576  M   1 524.000    CPLY   CTA     FREE FORM TEXT
                                                  00470725  M     121.920    CPLY   CTA     FREE FORM TEXT
                                                  00471472  M      23.384    CPLY   CTA     FREE FORM TEXT
                                                  00473445  M     259.080    CPLY   CTA     FREE FORM TEXT
           MATERIAL TOTAL : ----------------------------    2 537.984
998    099999      TESTED MATERIALS                               EACH           0.000      0.000
       161060100   CEMENT TY 1/2 BL/BAG       TONS
                                                  00487436  M       0.000    CPLY   VER     FREE FORM TEXT
                                                  00497591  M       0.000    CPLY   VER     FREE FORM TEXT
           MATERIAL TOTAL : ----------------------------        0.000
998    099999      TESTED MATERIALS                               EACH           0.000      0.000
       999900312   CRUSHED GRAVEL (OFQ)       TONS
                                                  00497599  M       0.000    CPLY   VER     AGGREGATE QUALITY TEST
           MATERIAL TOTAL : ----------------------------        0.000
998    099999      TESTED MATERIALS                               EACH           0.000      0.000
       999900319   SAND/SAND GRAVEL(OFQ       TONS
                                                  00497578  M       0.000    CPLY   VER     AGGREGATE QUALITY TEST
           MATERIAL TOTAL : ----------------------------        0.000
```

17

```
DTMT130                      Kansas Department Of Transportation           PAGE - 1
Run Date:     07 10 06         Maintain Sample ID Record
Run Time:     10:03 AM

Sample Id:    00473445     SI:  M
Inspector Id:  000905012   KELLY      MARSHALL    Resp Loc:  MR    Total Samples:  1
Type Insp:  CTA    Date Sampled:  09 29 03     Related Sample Id:
Type Test:  900    FREE FORM TEXT
Proj Id:   K023 090 K 7333 01  Contract #:  503032043  M Line #: 998  Quantity:        259.080
Producer: 00035001  Name:  NUCOR-YAMATO STEEL         Loc: BLYTHEVILLE           St:  AR
Legal Desc:                     Mix Plant:                        Name:
Matrl Cd:  067010000   STEEL BEARING PILE      Desc:  A03-5201               Unit:  m
Qty Represented:              259.080  Nbr of Items:   0    Qty Assigned:          0.000
Sampled From:  PRODUCTION                     Ledge:             Lot/Heat Nbr:
Lab:  SER  Name:  SERVICE              Dates::Shipped:  10 01 03    Received:  10 01 03
Test Start:  10 01 03    Est Compl:                Act Compl:  10 02 03
Test Result:  CPLY      Authorized By:  NAT VELASQUEZ BY KDM
Remarks:
        L&M      1600-11  FINAL DISPOSITION SUBJECT TO CONDITION OF
        MATERIAL WHEN USED AT PROJECT.
        HEAT(QINM), 218107(60.96), 218103(91.44) 219625(106.68)
```

18

7 Make Your Driving Equation Spreadsheet

It's form 217b in Forms Warehouse

19

Delmag McKierman Terry (Diesel Hammer)

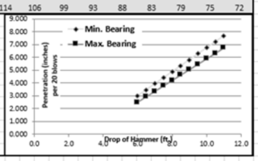
Summary			Formula	Entry Data			
Hammer Wt.	3528	lbs	$$P = \frac{1.6 \cdot W \cdot H}{S + 0.1 \cdot \left(\frac{X^{**}}{W}\right)}$$	Weight per foot of piling (lbs/ft):	53	lbs/ft.	Maximum Hammer Drop: 11 ft.
Cap/Anvil Wt.	2403	lbs		Length of Pile:	43	feet	
Pile Type	HP12x53			X:	4682	lbs	Minimum Hammer Drop: 6 ft.
Min. Res.	60	tons		Minimum "S":	0.100	inches/blow	
Max. Res.	66	tons		Maximum "S":	0.300	inches/blow	

Field Blow count: 20

Penetration per 20 blows (in.)		2.000	2.400	2.800	3.200	3.600	4.000	4.400	4.800	5.200	5.600	6.000
Average Penetration per blow (in.) "S"		0.100	0.120	0.140	0.160	0.180	0.200	0.220	0.240	0.260	0.280	0.300
Drop of Hammer (Stroke) (ft.)		Computed Resistance (tons)										
	6.0	73	67	62	58	54	51	48	45	43	41	39
	6.5	79	73	67	63	59	55	52	49	47	44	42
Calculated Bearing is HIGH	7.0	85	78	72	67	63	59	56	53	50	48	46
	7.5	91	84	78	72	68	64	60	57	54	51	49
	8.0	97	89	83	77	72	68	64	61	57	55	52
Calculated Bearing is GOOD	8.5	103	95	88	82	77	72	68	64	61	58	55
	9.0	109	101	93	87	81	76	72	68	65	62	59
	9.5	115	106	98	92	86	81	76	72	68	65	62
Calculated Bearing is LOW	10.0	121	112	103	96	90	85	80	76	72	68	65
	10.5	127	117	109	101	95	89	84	80	75	72	68
	11.0	133	123	114	106	99	93	88	83	79	75	72

(Drop of Hammer "H" in feet.)

Drop of Hammer "H" in feet.	Penetration required per 20 blows to reach Minimum Resistance (in.)	Penetration required per 20 blows to reach Maximum Resistance (in.)	
6.0	2.991	2.477	->
6.5	3.461	2.905	->
7.0	3.931	3.333	->
7.5	4.402	3.760	->
8.0	4.872	4.188	->
8.5	5.343	4.616	->
9.0	5.813	5.043	->
9.5	6.283	5.471	->
10.0	6.754	5.899	->
10.5	7.224	6.326	->
11.0	7.695	6.754	->



20

Penetration per 20 blows (in.)		2.000	2.400	2.800	3.200	3.600	4.000	4.400	4.800	5.200	5.600	6.000
Average Penetration per blow (in.) "S"		0.100	0.120	0.140	0.160	0.180	0.200	0.220	0.240	0.260	0.280	0.300
Drop of Hammer (Stroke) (ft.)		Computed Resistance (tons)										
	6.0	73	67	62	58	54	51	48	45	43	41	39
	6.5	79	73	67	63	59	55	52	49	47	44	42
Calculated Bearing is HIGH	7.0	85	78	72	67	63	59	56	53	50	48	46
	7.5	91	84	78	72	68	64	60	57	54	51	49
	8.0	97	89	83	77	72	68	64	61	57	55	52
Calculated Bearing is GOOD	8.5	103	95	88	82	77	72	68	64	61	58	55
	9.0	109	101	93	87	81	76	72	68	65	62	59
	9.5	115	106	98	92	86	81	76	72	68	65	62
Calculated Bearing is LOW	10.0	121	112	103	96	90	85	80	76	72	68	65
	10.5	127	117	109	101	95	89	84	80	75	72	68
	11.0	133	123	114	106	99	93	88	83	79	75	72

(Drop of Hammer "H" in feet.)

21

Do a Sample Calculation

Find the appropriate equation such as:

$$P = \frac{1.6 \quad W \quad H}{S + 0.1\ (X / W)}$$

Do a calculation by hand to get comfortable with the different variables and how they change things

22

8 Check Minimum Pile Length

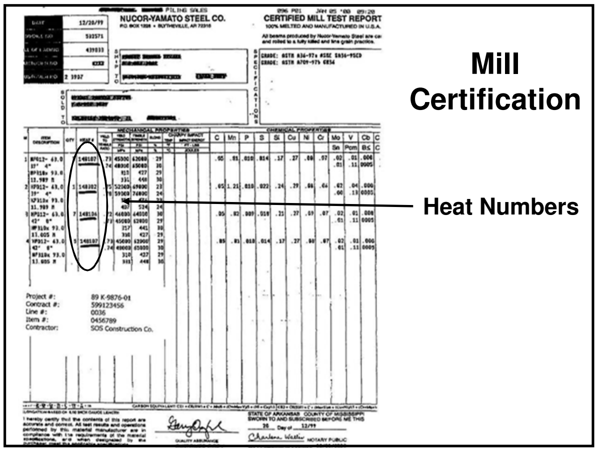
Talk to someone in your office about what to do if you achieve the required resistance before plan length is reached. It will probably be OK, but there may be concerns about scour or minimum pile length.

23

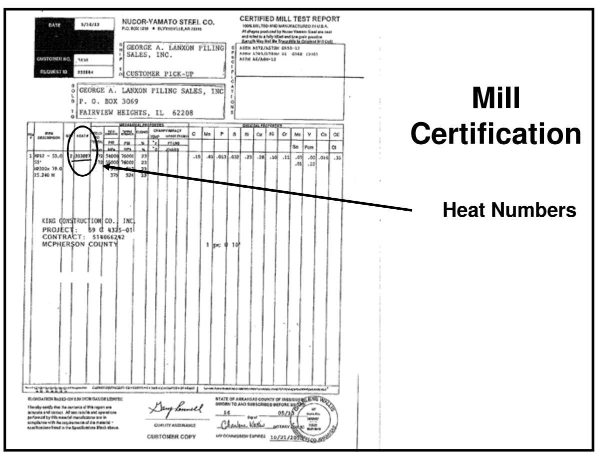
9 Check the Piling Itself

Check that the heat numbers on the certification or bill of lading matches the numbers on the piling

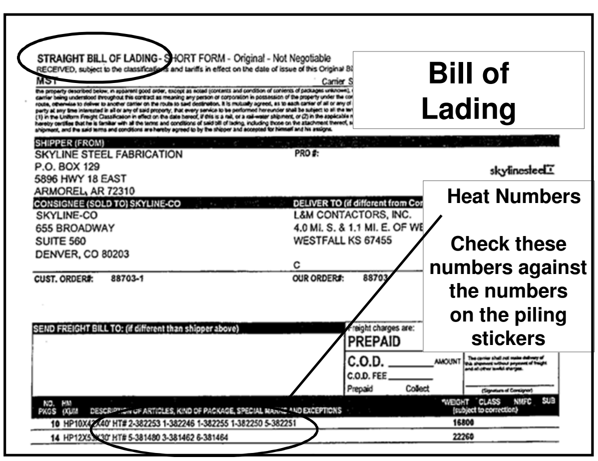
24


NUCOR-YAMATO STEEL CO.
CERTIFIED MILL TEST REPORT
Mill Certification
Heat Numbers
Project #: 89 K-9876-01
Contract #: 599123456
Line #: 0036
Item #: 0456789
Contractor: SOS Construction Co.

25


NUCOR-YAMATO STEEL CO.
CERTIFIED MILL TEST REPORT
GEORGE A. LANXON PILING SALES, INC.
CUSTOMER PICK-UP
P. O. BOX 3069
FAIRVIEW HEIGHTS, IL 62208
Mill Certification
Heat Numbers
KING CONSTRUCTION CO., INC.
MCPHERSON COUNTY
CUSTOMER COPY

26


STRAIGHT BILL OF LADING - SHORT FORM - Original - Not Negotiable
Bill of Lading
SHIPPER (FROM)
SKYLINE STEEL FABRICATION
P.O. BOX 129
5896 HWY 18 EAST
ARMOREL, AR 72310
PRO #:
CONSIGNEE (SOLD TO) SKYLINE-CO
SKYLINE-CO
655 BROADWAY
SUITE 560
DENVER, CO 80203
L&M CONTACTORS, INC.
WESTFALL KS 67455
CUST. ORDER#: 88703-1
Heat Numbers
Check these numbers against the numbers on the piling stickers
SEND FREIGHT BILL TO: (if different than shipper above)
PREPAID
C.O.D.
10 HP10X42X40' HT# 2-382253 1-382246 1-382255 1-382250 5-382251 16800
14 HP12X53X30' HT# 5-381480 3-381462 6-381464 22260

27

Sticker on Pile

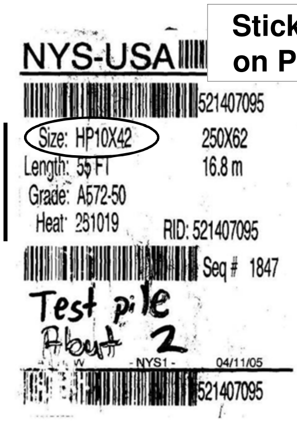
28

Check the Piling Itself

Inspect the piles to make sure they are the type called for in the contract

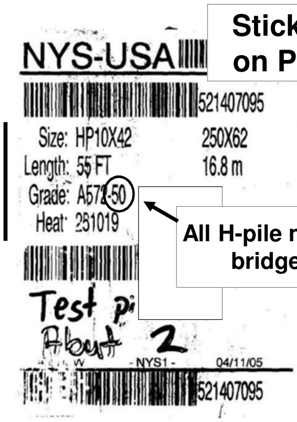
29

Sticker on Pile



30

Sticker on Pile



All H-pile now used in KDOT bridges is Grade 50

31

Check the Piling Itself

Inspect the piles for damage that might have occurred during shipment, or defects that were overlooked earlier

Pipe piles can get bent, concrete piles can get broken

H-piles can have bent flanges

32

10 Measure and Mark the Piling

33

11 Make Sure the Contractor Brought the Hammer He Told Us He Was Bringing

34

12 Check the Hammer Cushion

35

Check the Hammer Cushion

Cushion has to be made of a material approved to use on KDOT projects

What else?

36

Check the Hammer Cushion

Original thickness of cushion should be listed on the hammer data sheet

Ask contractor when cushion was last changed

Check to see if it looks OK

Pry it out of helmet if you think you need to measure its thickness

37

13 Line up some help from the office

38

14 Help the Contractor Verify that Piles are in the Correct Location

39

 # 15 Make Sure the Piles are Plumb

40

 # 16 Keep track of where your pile tip is.

*Know the **depth** you should hit bedrock.*

41

 # 17 Drive Pile to Plan Length or Required Resistance

42

Do any test piles first.

Do a continuous log of the test piles.

43

If you drive to the required resistance before plan length is reached, check with Area Office for scour concerns or minimum pile length

If plan length is reached before the required resistance, call Area Office about a possible restrike

44

18 Mark the Cut-off on the Pile

Help Contractor mark plan cut-off elevation on the pile after driving.

Mark the piece that was cut off, so that you know where it came from. You may need to use it to splice later.

45

Use a number or letter—just some way to keep track of it.

46

 # 19 Have Someone Check Your Calculations

Before the contractor places any concrete around the piling, have a second person go over your resistance calculations.

47

If you see something on site you don't understand, or aren't sure if what the Contractor is doing is acceptable, make him stop and get it resolved.

Yeah, he'll probably get mad.

48

You Aren't Alone!

If you have a question and can't reach your bosses, there are other people in KDOT who will help you:

Your Regional Geologist

the Bridge Designer in Topeka
(Bureau of Structures and Geotech Services)

your District Construction Engineer

49

1

If a problem occurs, what do you do?

2

STOP
DRIVING AND
EVALUATE THE
SITUATION

3

Take a Deep Breath

- Take time to problem solve
  - What is happening
  - Check calculations
  - Check any level runs
  - Check the hammer
  - Check alignment; pile and hammer
  - Review the Geology Bridge Sheet

4

Problem Solving Continued

- Are you using the correct formula
- Correct hammer specifications input
- Using the Strength I load
- Wrong size pile
- Wrong length pile

5

Solution Found!!

- Can you make the decision to correct it?
- Contact
  - Your Boss
  - Construction Engineer
  - Design Engineer
- Adjust and proceed with driving.
- Always document.

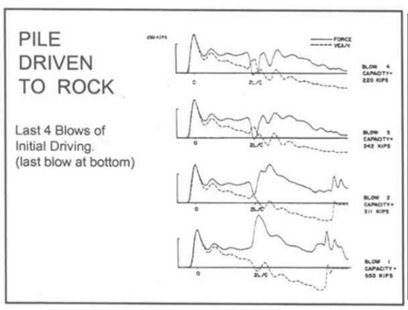
6

Some Problem Scenarios

- Overdriving
- Target bearing not achieved or achieved above
- Misalignment of hammer
- Hammer performance

7

Driving to Hard Bedrock



220 kips (110 tons)

242 kips (121 tons)

311 kips (156 tons)

555 kips (278 tons)

8

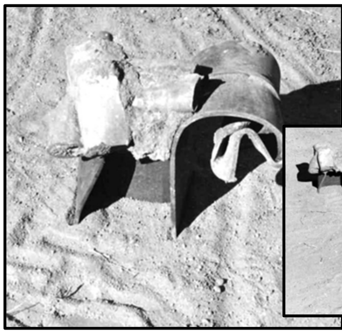
Hamilton County, KS

The lower 7 feet of Pile #5 at Pier 1.

1 mile east, 5.5 miles north of Syracuse

9

Hamilton County, KS



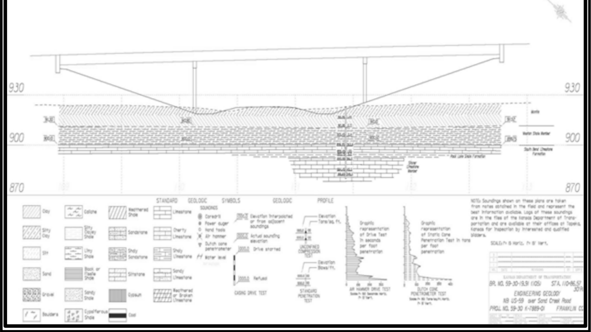
1 mile east, 5.5 miles north of Syracuse

Bottom 2.5 feet rolled
Pile #6, Pier 4

Top of pile damaged too

10

US-59 Franklin County



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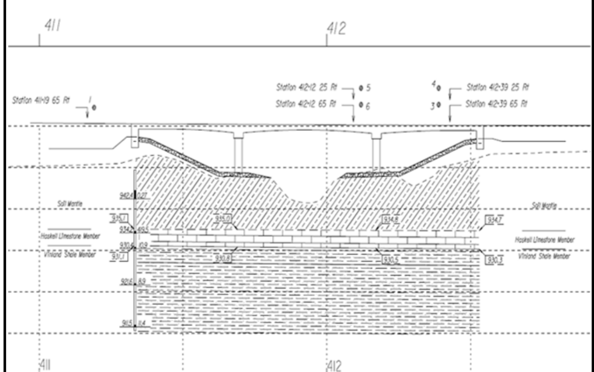

411
412
Station 411+19 65 Rt
Station 412+12 25 Rt
Station 412+12 65 Rt
Station 412+39 25 Rt
Station 412+39 65 Rt
Soil Mantle
Haskell Limestone Member
Vinland Shale Member
Soil Mantle
Haskell Limestone Member
Vinland Shale Member
411
412

14

15

16

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18

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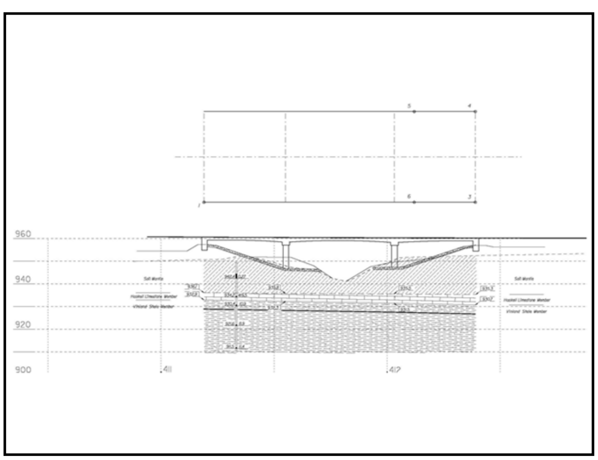

960
940
920
900
Soil Works
Haskell Limestone Member
Vinland Shale Member
411
412

21

22

23

24

25

26

27

Western Kansas

28

Alignment

- Can reduce the transferred energy.
- Can damage pile top
- Can give false blow count
- Pipe pile vulnerable

29

Pile damage suspected

- Is the damage bad enough to be of concern?
- Is the damage far enough down that the remaining good pile will carry the load?
- Can the pile be pulled and a new one driven?
- Do more piles need to be added to compensate for the damaged pile?

30

Barton County

Mushrooming Caused by:
- Misalignment
- Hard driving
- Both?

Could Result in:
- Reduction of transferred energy
- Exaggerated blow count
- Exaggerated bearing capacity

31

Minor Damage to Pile Top

- Target bearing not achieved and above plan tip
  - Stop Driving and cut off the damaged portion of the pile.
  - Check alignment of the hammer on the pile
  - Resume driving.
- Target bearing and minimum plan tip achieved.
  - Stop and cut pile off at cut off elevation
- If a restrike test is to be conducted on this pile, the top should be undamaged.

32

Pile damage suspected cont.

- Contact the Engineer
- Contact the Geology Section to conduct PDA.

33

Trouble Achieving Target Bearing

- Check all calculations
- Check input parameters
- Check hammer
- Contact Engineer or supervisor
- Can a restrike test be conducted to evaluate soil set up?
  - If so, restrike pile in at least 24 hours
- May have to splice on more pile and continue the drive

34

K-196 over Whitewater River

35

36

Support Pile

37

38

39

40

Target Bearing Achieved Early

- Check all calculations
- Check input parameters
- Check pile length
- Contact Engineer or supervisor

41

Target Bearing Achieved Early

- If pile tip is close to plan tip elevation and 110% of the Service load (pile driving formula load) has not been reached, the pile can be driven to 110% (if plan tip must be achieved)
- Is pile hitting an obstruction (boulder, hard layer, old footing, another pile)
  - If so, what concerns will it cause.
- Is there enough pile length in place below cut off to satisfy lateral load and scour requirements and, if required, uplift requirements
  - If so pile can be cut off (always consult the Engineer)

42

Hammer Performance

- If the hammer is not performing properly the bearing capacity can not be computed accurately
- Improperly functioning hammer:
  - May exaggerate the blow count
  - May give false set per blow information
  - May reduce pile driving ability
  - May simulate hard driving and high capacity at low capacity conditions

43

Hammer Performance

- Preignition in diesel hammer
  - Fuel starts to combust or fully combust before impact
  - Reduces ram impact velocity
  - Cushions the impact
  - Reduces transfer of energy to the pile, energy returned to the ram causing a high but false stroke
  - Low energy transfer results in high blow counts
- Can simulate hard driving and high capacity condition at a potentially low soil resistance

44

Hammer Performance

- Some things to look for
  - If you are getting a low set per blow yet a very small stroke, could be problems with hammer.
    - A low set per blow should indicate hard driving and you should have a large stroke.
  - Different looking exhaust
    - Fuel could be contaminated (water in fuel)
      - May not get the best fire on each stroke
  - Maybe the hammer just sounds much different than on the previous drive
    - Question the contractor if you feel something is wrong or different

45

Preignition in Diesel Hammer

- Preignition in diesel hammer
  - Caused by overheated hammers
    - Lubrication oils start to burn
    - Fuel vaporizes prematurely due to excess heat
- Signs of Preignition
  - Black smoke while stroke is high
  - Flames in exhaust ports
  - Blistering paint
  - Oils and grease on outside smoking or burning
  - No obvious metal to metal impact ringing sound

46

Preignition in Diesel Hammer

- If preignition is suspected:
  - Stop driving and let hammer cool down for at least 1 hour
  - Recommend the hammer be lubricated to replace any burnt off lubrication
  - Resume driving and monitor stroke and blow count
  - If stroke and blow counts are lower in the first few minutes of driving, preignition was probably occurring

47

Hammer Performance

- Some performance problems and what to look for
  - May be hard to recognize but should be familiar with
- Water or dirt in fuel
  - White exhaust smoke and hollow sounding impacts
- Clogged fuel line (lack of fuel)
  - Little or no exhaust smoke
  - Low strokes
- Malfunctioning fuel pump or fuel injector
  - Inconsistent ram stroke and gray or black exhaust smoke

48

Hammer Performance

- Some performance problems and what to look for
- Low lubricating oil or malfunctioning oil pump
  - Lower than normal blows per minute
  - Reduced stroke
  - A quick check
    - see if ram is wet and shiny during drive when upper ram is visible
- Poor Compression-Worn piston or impact block rings
  - Short strokes even in hard driving
  - Easily checked by way of a "cold blow"

49

Hammer Performance

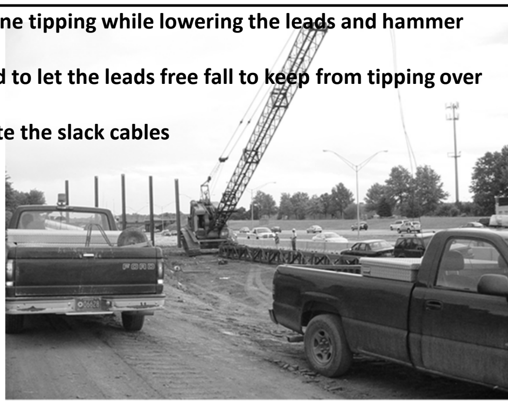
- Some performance problems and what to look for
- "Cold Blow" Procedure
  - Ram is picked up as if to start the hammer but the fuel line rope is kept stretched such that no fuel is pumped.
  - The ram is released and after impact the ram should bounce on the air trapped in the chamber. Each bounce can be heard.
  - Should get 5 to 10 good bounces.

50

Crane tipping while lowering the leads and hammer

Had to let the leads free fall to keep from tipping over

Note the slack cables



51

With all problems you should contact

- Your supervisor
- Engineer in charge
- Design Engineer

If needed you can contact the Geology Section for guidance or to have the PDA brought out

- Neil Croxton Salina Regional Geologist
  - 785-827-3964
- Art Peterson El Dorado Regional Geologist
  - 316-320-1721
- Denny Martin Chanute Regional Geologist
  - 620-431-1000
- John Barker Topeka Regional Geologist
  - 785-291-3861

52

Questions!

53

KDOT Specifications for Piles and Pile Driving

1

Where to find information?

KDOT Standard Specifications Book

2015 Edition

Division 700—Structures

Section 704 Piling

pages 700-15 to 700-21

2

Where to find information?

KDOT Standard Specifications Book

2015 Edition

Division 1600—Ferrous and Non-Ferrous Metals

Section 1609 Steel Piling and Pile Points

page 1600-18

3

How to get to the 2015 Edition from the KDOT Intranet

Go to http://kdotweb

Click on "Documents & Manuals" on the top banner

Scroll down a while and find "Specifications"

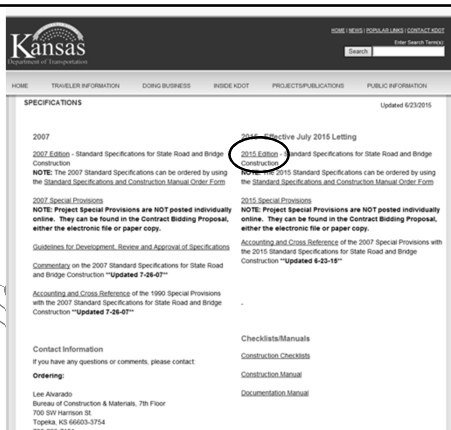
4

How to get to the 2015 Edition

Top right side of screen, click on

"2015 Edition"

5



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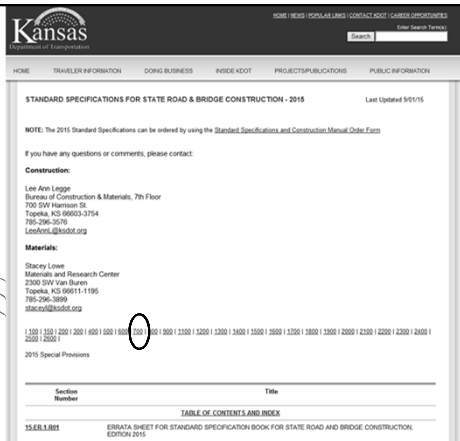


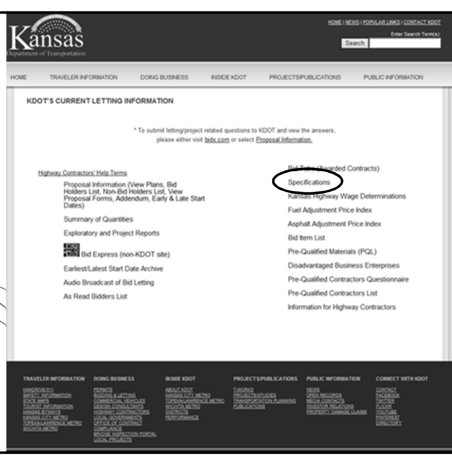
7

How to get to the 2015 Edition from an outside computer

Go to www.ksdot.org

Go to "*Letting Information for Highway Contractors*" (yellow hard hat), then "*Specifications*"

8



9

How to get to the 2015 Edition

Choose *"2015 Edition"* and you're home free.

10

2015 Special Provisions

Below the 2015 Specifications is the link to Special Provisions.

There are currently no piling Special Provisions.

That will change, so check for them.

11

The Bridge Construction Manual

Chapter 5.3 Driven Pile

Contains some practical information about bridge piling construction and inspection.

12

The Bridge Construction Manual

Chapter 5.3 Driven Pile

- General terminology and definitions, pile and hammer types, and the mechanics of pile driving, including formula examples

13

The Bridge Construction Manual

Chapter 5.3 Driven Pile

- We cover all this material in class.

14

The Bridge Construction Manual

Chapter 5.3 Driven Pile

- This section is included in the back of your book

15

The Bridge Design Manual

Bridge Design Manual

Chapter 10.6 Foundation—Piling

Good summary of pile information

16

The Bridge Design Manual

Bridge Design Manual

Chapter 11.5.7 Abutments, Piers and Walls—Pier Details

Has drawings of bridge foundation types

17

To get to these Manuals from the Intranet

http://kdotweb

Click on "Organizational Pages"

Click on "Structures & Geotechnical Services"

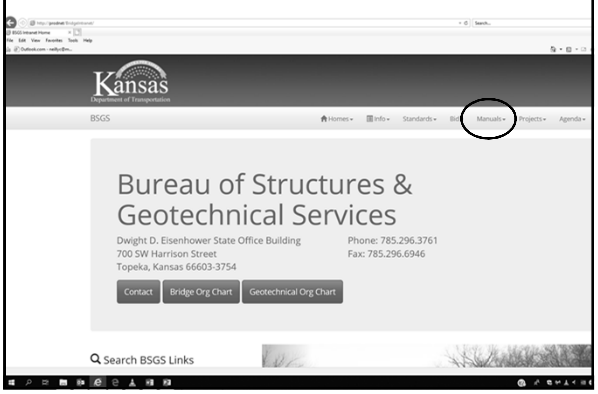
18

To get to these Manuals from the Intranet

At the top is a drop-down menu for "Manuals"

Choose "Bridge Construction Manual", or "Bridge LRFD Design Manual"

19



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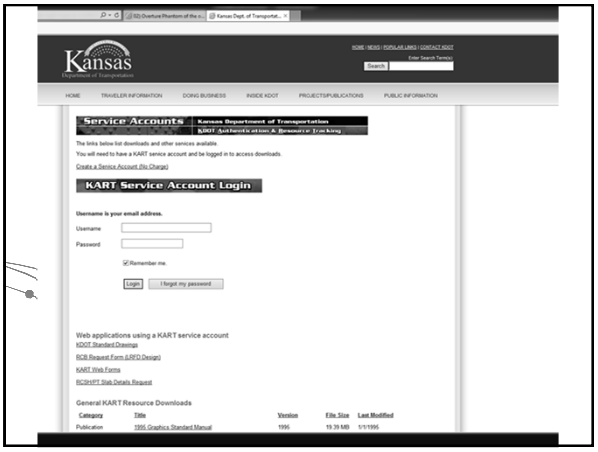
The Direct Links Are:

http://www.ksdot.org/burStructGeotech/constructionmanual/bcm.asp

http://kart.ksdot.org

21



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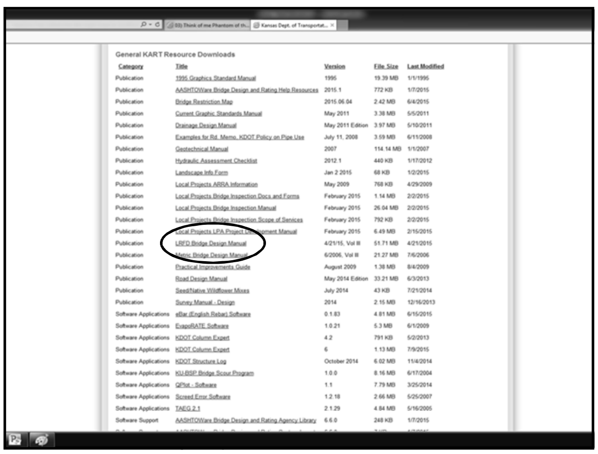


23

Division 700—Structures
Section 704.3 Pile Driving Equipment

(a) General

Size needed to develop the energy necessary to drive piles at least 0.1” per blow at the required resistance on the plans (the Pile Drive Formula Load)

24

Division 700—Structures
Section 704.3 Pile Driving Equipment

(a) General

(1) Open-end Diesel Hammer

Equip with a device extending above ram cylinder to permit visually determining hammer stroke at all times.

25

Division 700—Structures
Section 704.3 Pile Driving Equipment

(a) General

(3) Weight of the striking part of air hammers used shall be a minimum of ⅓ the weight of the pile and drive cap

Minimum weight of striking part is 2,750 pounds

26

Division 700—Structures
Section 704.3 Pile Driving Equipment

b. Hammers for Steel Piles, Steel Sheet Piles and Shells for Cast-in-Place Concrete Piles.

Gravity hammer—minimum weight 3500 pounds

Gravity hammer—maximum drop 12 feet

27

Division 700—Structures
Section 704.3 Pile Driving Equipment

b. Hammers for Steel Piles, Steel Sheet Piles and Shells for Cast-in-Place Concrete Piles.

Diesel or air—maximum fall 90% of the maximum fall recommended by manufacturer

Minimum 6000 foot-pounds energy per blow

28

Division 700—Structures
Section 704.3 Pile Driving Equipment

c. Hammers for prestressed concrete pile

Only driven with diesel or air hammer unless otherwise noted

Hammer must develop 1 foot-pound of energy for each pound of weight driven

Minimum energy of hammer is 6,000 foot-pounds per blow

29

Division 700—Structures
Section 704.3 Pile Driving Equipment

d. Vibratory hammers

Used only when specified in Contract document

If used, 1 of 10 piles must be load tested using an impact hammer (diesel or air) with suitable energy

30

Division 700—Structures
Section 704.3 Pile Driving Equipment

e. Additional Equipment

The plant and equipment provided for air hammers shall have capacity to maintain the pressure at the hammer specified by the manufacturer.

31

Division 700—Structures
Section 704.3 Pile Driving Equipment

e. Additional Equipment

If Contractor cannot drive pile to the required penetration and/or bearing capacity, he must bring a bigger hammer. If the Engineer approves, he may resort to jetting or pre-drilling at his own expense.

32

Division 700—Structures
Section 704.3 Pile Driving Equipment

e. Additional Equipment

Use of the pile driving analyzer may be required when minimum requirements are not met

33

Division 700—Structures
Section 704.3 Pile Driving Equipment

f. Leads

Constructed to allow freedom of movement of the hammer

Except where piles are driven through water, the leads shall be long enough so that followers are not needed

34

Division 700—Structures
Section 704.3 Pile Driving Equipment

f. Leads

Long enough to permit them to be spiked into the ground before driving starts

35

Division 700—Structures
Section 704.3 Pile Driving Equipment

g. Hammer Cushion

Required on all impact pile driving hammers except gravity hammers

Inspect before driving at each bridge or after driving for 100 hours

Replace cushion when thickness is reduced by 25% or it appears to be deteriorating.

36

Division 700—Structures
Section 704.3 Pile Driving Equipment

g. Hammer Cushion

A striking plate is placed on the cushion to insure uniform compression of the cushion material

37

Division 700—Structures
Section 704.3 Pile Driving Equipment

g. Hammer Cushion

Made of “durable manufactured material”

- Micarta (Conbest)—fabric and phenol
- Nylon—2” blocks
- Hamortex- metallized paper reels
- Force 10, Forbon, Fosterlon
- Aluminum

38

Division 700—Structures
Section 704.3 Pile Driving Equipment

(h) Pile Driving Head

Use driving head adequate for distributing the hammer blow to the pile

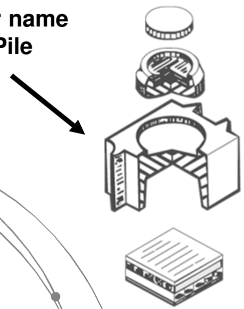
Guided by the leads and not free-swinging

Should fit the pile head adequately

39

Pile Driving Head

Another name for the Pile Helmet



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Division 700—Structures
Section 704.3 Pile Driving Equipment

i. Water Jets

Only used with permission from the Engineer

If used:

- Number of jets and volume and pressure of water sufficient to erode material
- Power enough to deliver at least 100 psi pressure from ¾” jet nozzles

41

Division 700—Structures
Section 704.3 Pile Driving Equipment

i. Water Jets

Jets shall be withdrawn at least 5 feet from the desired final penetration depth and the pile driven the last 5 feet with an approved hammer

42

Section 704.4
Construction Requirements

a. Order Lists, Piles, and Test Piles

- Order list is the same as the estimated quantity (number and length of piles) shown in the Contract Documents.

43

Section 704.4
Construction Requirements

a. Order Lists, Piles, and Test Piles

For piles and test piles, submit the completed "Pile and Driving Equipment Data" sheet a minimum of 3 weeks before the scheduled date of driving piling. The Engineer (that's you) will forward this information for a Test Pile (Special) to the Chief Geologist.

44

Section 704.4
Construction Requirements

a. Order Lists, Piles, and Test Piles

- When Engineer requires a restrike, follow **subsection 704.4e.** for restrike procedures

45

Section 704.4
Construction Requirements

a. Order Lists, Piles, and Test Piles

- Drive test piles at specified locations
- Engineer will use test pile information to determine pile tip elevation

46

Section 704.4
Construction Requirements

a. Order Lists, Piles, and Test Piles

If multiple hammers are used on a project with test piles, drive a test pile with each hammer

47

Section 704.4
Construction Requirements

b. Test Pile (Special)

Pile Driving Analyzer used to monitor test pile

48

Section 704.4
Construction Requirements

b. Test Pile (Special)

Notify Engineer (John) minimum 5 working days prior to test.

Allow 1½ hours for pile to be prepared for test

Allow safe and reasonable access to pile

The Engineer will use the PDA results to provide the Contractor with a blow count for production driving.

49

Section 704.4
Construction Requirements

c. Driving piles

Piles can be driven with a gravity, diesel or air hammer

or

Combination of pre-drilled holes or water jetting and a hammer

Refer to Subsection 704.3 for pile driving equipment

50

Section 704.4
Construction Requirements

c. Driving piles

Drive piles at the locations and to lines shown on plans

Use leads long enough to be spiked into ground

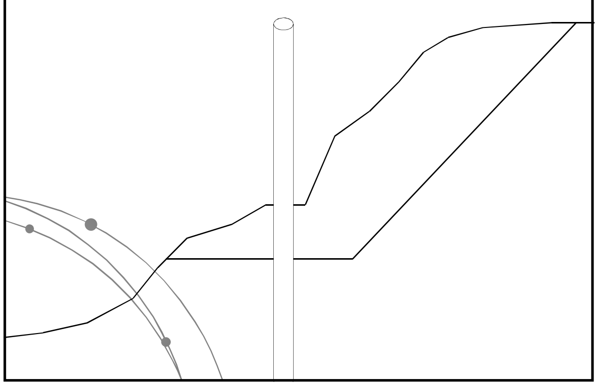
51

Section 704.4
Construction Requirements

c. Driving piles

Do not drive piles until excavation for footing, webwall, or abutment is complete

52



53

Section 704.4
Construction Requirements

Don’t allow a contractor to ignore this spec.

54

Section 704.4
Construction Requirements

c. Driving piles

Drive all piles for a footing or abutment before placing any concrete in the footing or abutment unless pile is over 20 feet from concrete, or unless concrete has cured 24 hours

55

Section 704.4
Construction Requirements

(c) Driving piles

Drill pile holes as shown on the plans

Maximum allowed diameter of predrill holes is 3” greater than pile diameter

If predrilling not specified, Contractor may predrill if Engineer approves

56

Section 704 Piling
704.4 Construction Requirements

(c) Driving piles

After pile is driven, backfill with loose sand or material specified on plans

If concrete is specified for backfill, use adequate slump and vibration to eliminate voids around pile

57

Section 704.4
Construction Requirements

c. Driving piles

Drive all piling perpendicular to long axis of pile

Use pile caps (helmets) on all piles

58

Section 704.4
Construction Requirements

c. Driving piles

For pile caps of concrete piles and prestressed concrete piles, use a suitable cushion next to the pile

Pile helmets for steel piles must have grooves to accommodate the shape of the pile

59

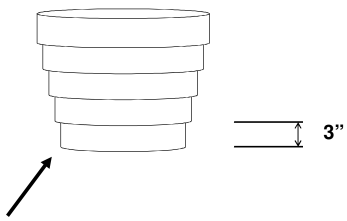
Section 704.4
Construction Requirements

c. Driving piles

On pipe piles, the helmet must have an interior guide (mandrel) that sticks into the pile at least 6 inches.

60

Section 704.4
Construction Requirements



Most of the time, each step on a guide is 3”.
So we need 2 steps inside a pipe pile.

61

Section 704.4
Construction Requirements

c. Driving piles

It is not necessary to have 6 inches of the interior guide up against the pile itself.

Just a total of 6 inches.

62

Section 704.4
Construction Requirements

c. Driving piles

Use full-length pile where practical

Splice steel pile where shown on plans or with permission of Engineer

Provide experienced welder, qualified under Section 713 to make the welded splices for steel pile

(Section 713 is Qualification of Field Welders)

63

Section 704.4
Construction Requirements

c. Driving piles

Contractor must correct any failed splices at his own expense

64

Section 704.4
Construction Requirements

c. Driving piles

Avoid extensions, splices, or build-ups of prestressed concrete piles

Plans will show method for splicing concrete piles

There are no instructions for splicing concrete piles in the Specs

65

Section 704.4
Construction Requirements

c. Driving piles

Replace any damaged pile with new, longer pile

--crushing or spalling of concrete pile

--deformation of steel pile

An additional pile may be driven next to damaged pile, if approved by Engineer

66

Section 704.4 Construction Requirements

c. Driving piles

Do not force misaligned piles into position

Remove and replace any pile not in its proper location with new, longer pile

67

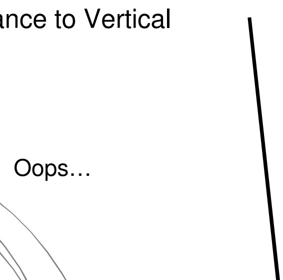
Section 704.4 Construction Requirements

Tolerance to Vertical

68

Section 704.4 Construction Requirements

Tolerance to Vertical



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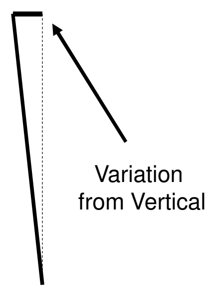
Section 704.4
Construction Requirements

Tolerance to Vertical



70

(c) Driving piles

Tolerance to Vertical

If you have enough pile sticking out of the ground, just measure it directly

71

Section 704.4
Construction Requirements

c. Driving piles

Tolerances to Vertical or Battered Lines

Piles 35 feet or shorter: ¼” per foot of length

Piles longer than 35 feet: 1/8” per foot

72

Driving Tolerances to Vertical—Example

You are driving H-piles into chalky limestone for a 3-pier bridge over Big Possum Creek in southern Gove County. The piers are supported by small pile groups. The order length for piling in Pier 3 is 28 feet. You stop driving when you notice one of the piles seems to be crooked. How can you check to see if it's in spec?

73

Driving Tolerances to Vertical—Example

Pile Length—28 feet

74

Driving Tolerances to Vertical—Example

Pile Length—28 feet

Tolerance for piles shorter than 35 feet is ¼ inch per foot of pile

75

Driving Tolerances to Vertical—Example

Pile Length—28 feet

Tolerance for piles shorter than 35 feet is ¼ inch per foot of pile

You have a 4-foot long level.

4 feet x ¼ inch / foot = ?

76

Driving Tolerances to Vertical—Example

4 feet x ¼ inch / foot = 1 inch

You would measure the distance it is out of plumb, and contact the Bridge Office if it exceeds one inch.

When using a 4-foot level to check, you either have ½" or 1" leeway, depending on the pile length.

77

Section 704.4
Construction Requirements

c. Driving piles

Tolerances to Vertical or Battered Lines

If you don't have enough pile sticking out to measure it directly, have the location surveyed and measure how far off it is. Then back-calculate.

78

Section 704.4
Construction Requirements

c. Driving piles

Tolerances to Position of Pile Head
(Elevation of Top of Pile)

Piles in bents: 2”

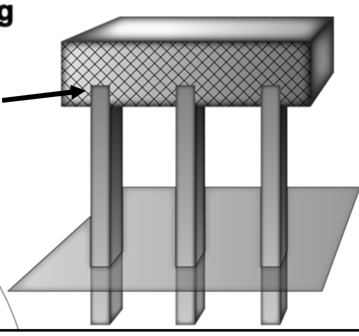
Foundation piles (pile groups): 6”

79

Maximum Variation from Pile Cutoff Elevation at the Top of the Pile After Driving

Piles in Pile Bents

2 inches variation up or down

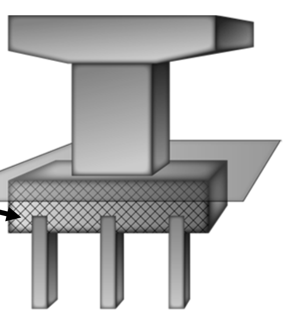


80

Maximum Variation from Pile Cutoff Elevation at the Top of the Pile After Driving

Piles in Pile Groups

6 inches variation up or down



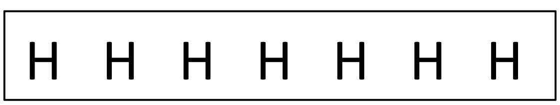
81

Section 704.4
Construction Requirements

c. Driving piles

Drive all piles in the orientation shown on the Plans. If the axial orientation of the pile rotates or twists by more than 10°, the Field Engineer (that's you) will contact the bridge designer in Topeka.

82



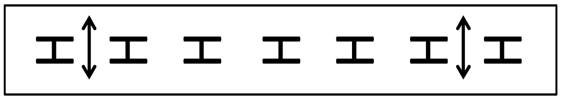
Typical Pile Bent Abutment

83

Weak direction lined up parallel to long axis of bridge.

Abutment can flex with the deck.

84



Weak direction lined up perpendicular to long axis of bridge.

Fixed abutment will resist movement.

85

Section 704.4
Construction Requirements

c. Driving piles

Re-drive all piles pushed up by adjacent pile driving or any other cause

86

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

Drive piling to the specified bearing value, penetration, and pile tip elevation

Stop driving if 1.1 times the minimum resistance (pile drive formula load) is attained

87

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

Stop driving if the pile will be damaged before the minimum requirements are met

88

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

If required bearing can't be obtained, the number of piling may be increased with the approval of the Engineer (bridge engineer in Topeka)

89

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

This would only be done after splicing and restriking have been tried.

Adding piling is rarely needed.

90

Section 704.4
Construction Requirements

TABLE 704-1: PILE FORMULAS

Hammer	Pile Type	Formula
Gravity	Timber	$P = \frac{2\ W\ H}{S + 1.0}$
Gravity	Steel Steel Shell Steel Sheet	$P = \frac{3\ W\ H}{S + 0.35} \left(\frac{W}{(W+X)}\right)$
Air/Steam (Single Acting)	All Types	$P = \frac{2\ W\ H}{S + 0.1}$
Air/Steam (Double Acting)	All Types	$P = \frac{2\ E}{S + 0.1}$
Delmag and McKierman-Terry*	All Types	$P = \frac{1.6\ W\ H}{S + 0.1 \left(\frac{X^{**}}{W}\right)}$
Link-Belt*	All Types	$P = \frac{1.6\ E}{S + 0.1 \left(\frac{X^{**}}{W}\right)}$

*diesel hammers

** For diesel hammers, the quantity X/W shall not be less than 1.

P = safe bearing power in pounds

91

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

Formulas only apply when:

- Hammer falls freely
- Penetration is quick and uniform
- No significant bounce after the strike

92

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

If water jets used, determine bearing capacity after jets have been removed

93

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

If a different brand of **diesel** hammer is used besides the 3 listed in the Formula Table, use 80 % (0.80) of the manufacturer's listed energy rating in the formula to determine bearing capacity.

94

Section 704.4
Construction Requirements

d. Bearing Values and Required Penetration

For an **air** hammer, use 100 % of the manufacturer's listed energy rating in the formula to determine bearing capacity and to check if the hammer is large enough.

95

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

If pile doesn't get resistance within a few feet of plan elevation, a restrike may be used

Call the Regional Geology Office for help

96

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

(1) No test piles called for on bridge and PDA not available

Drive all piles in group to within 2 feet of plan

Leave them alone for at least 24 hours

97

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

Warm up hammer far from piles to restrike

Immediately restrike 20% of piles in group, minimum of 2 piles per group

Restrike piles farthest from each other

When possible, restrike those with lowest resistance during driving

98

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

Strike a pile with warm hammer for 20 blows or until it moves 4 inches, whichever comes first

Record penetration for every 5 blows

If pile moves less than ½ inch, stop restrike after 10 blows

99

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

(1) No test piles called for on bridge and PDA not available

Calculate resistance based on average penetration for first 5 blows

Resistance for all piling in group is the resistance calculated for that one pile. Pretty sweet, huh?

100

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

If calculated resistance is too low, splice and resume driving

Look sad and say "doh"….

101

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

(2) Test pile called for on bridge and PDA not available

Treat the test pile as you would a common restrike, using the above rules.

102

Section 704.4
Construction Requirements

e. Pile Restrike Procedure

(3) Test Pile (Special) called for on bridge or PDA is available

Follow recommendations of the Regional Geologist

103

Section 704.4
Construction Requirements

f. Pile Cut-off and Pile Painting

(1) After piles are driven, cut them off at the designated elevation

If capping is required, make the connection as shown in the Contract

104

Section 704.4
Construction Requirements

f. Pile Cut-off and Pile Painting

Pieces cut off become property of KDOT, if the Engineer wants them.

105

Section 704.4
Construction Requirements

(f) Pile Cut-off and Pile Painting

Some Area Engineers or Area Construction Engineers automatically salvage pieces longer than 5 or 6 feet.

Others try to decide whether their KDOT area will need piling pieces in the near future.

106

Section 704.4
Construction Requirements

f. Pile Cut-off and Pile Painting

(1) Pile pieces not wanted by the Engineer become the property of the Contractor

107

Section 704.4
Construction Requirements

f. Pile Cut-off and Pile Painting

(2) Paint the exposed steel of piling using the same kind of paint and number of coats as used for structural steel of bridge

Paint the piling in the field

108

Section 704.4
Construction Requirements

f. Pile Cut-off and Pile Painting

(2) If no painting specified in plans:

Use prime coat of inorganic zinc

Use acrylic or polyurethane finish coat

See Division 700

109

Section 704.4
Construction Requirements

f. Pile Cut-off and Pile Painting

(2) Paint the piling for a distance of one foot below :

Bottom of channel

Top of embankment

Natural ground

Normal low-water elevation

110

Section 704.4
Construction Requirements

g. Cast-In-Place Concrete Piles

(also called “Shell Piles” and “Closed-end Pipe Piles”)

After steel shells are driven, remove all loose material from inside shells

Fill the shells with Grade 3.5 concrete unless the plans say otherwise

111

Section 704.4
Construction Requirements

g. Cast-In-Place Concrete Piles

Don't place concrete in shells until all driving within 15 feet is finished

or

Until all piles for that bent are driven

112

Section 704.4
Construction Requirements

g. Cast-In-Place Concrete Piles

If that isn't possible, stop driving until concrete in all piles for that bent has cured at least 7 days

Remove water from inside the shells before placing concrete

113

g. Cast-In-Place Concrete Piles

Vibrate the concrete in the upper 15 feet of the shell

114

Section 704 Piling
704.5 Measurement and Payment

The Engineer *(that's you)* will measure:

Length of steel piling left in bridge, by linear foot

Length of concrete pile from the tip to the place where it is cut to connect with the cap or footing

Do not include the length of reinforcing steel at the top of prestressed concrete piles

115

Section 704 Piling
704.5 Measurement and Payment

The Engineer *(that's you)* will measure:

Actual length of ordered and accepted test piles by the linear foot

Each cast steel pile point used

116

Section 704 Piling
704.5 Measurement and Payment

The Engineer *(that's you)* will measure:

Each pile splice needed that wasn't called for in the plans

In other words, when we had to splice because the geology didn't behave

117

Section 704 Piling

704.5 Measurement and Payment

For all types of steel and concrete pile, if a splice is needed and not shown on the plans, the cost of the splice is :

4 times the contract unit price per foot of the pile type

118

Example of Pile Splice Cost

Contract unit cost of steel H-pile = $32.00 per foot

The cost of a splice for this type of pile is 4 times the contract unit price per foot

The splice would cost

$36.00 X 4 = $144.00

119

Section 704 Piling

704.5 Measurement and Payment

Do *not* measure for payment :

Splices shown on the plans

Splices the contractor did for his own convenience

120

Section 704 Piling
704.5 Measurement and Payment

The Engineer *(that's you)* will measure:

Predrilled holes by the linear foot

Measure from bottom of hole to the bottom of footing *(pile cap)* or abutment

121

Section 704 Piling
704.5 Measurement and Payment

If the Contractor drills deeper than the plans call for, do not measure the extra depth

If Contractor uses predrilling for his convenience, do not measure for payment

122

Section 704 Piling
704.5 Measurement and Payment

The Engineer *(that's you)* will measure:

Pile cut-off by the linear foot

Pile cut-off is the difference between the length of pile ordered and accepted and the actual length of pile remaining in the bridge

123

Section 704 Piling
704.5 Measurement and Payment

Length Ordered and Accepted

---- Length left in bridge

= Length of pile cut-off

124

Section 704 Piling
704.5 Measurement and Payment

TABLE 704-2: PILE CUT-OFF PAYMENT	
Pile Type	% of Contract Unit Price Paid
Cast-in-place (Shell)	60
Pre-stressed concrete	75
Steel	75
Steel Sheet	75

125

Section 704 Piling
704.5 Measurement and Payment

Steel Pile = 75% of the Contract unit price for steel piles

Prestressed Concrete Pile = 75% of the Contract unit price for prestressed concrete piles

126

Section 704 Piling
704.5 Measurement and Payment

Cast-in-place concrete piles = 60% of the contract unit price for concrete piles

Steel Sheet Pile = 75% of the contract unit price for steel sheet piles

127

Section 704 Piling
704.5 Measurement and Payment

If Contractor uses a longer pile *(for whatever reason)* than the length ordered and accepted, the excess length is *not* measured as cut-off.

128

Materials Section 1609
Steel Piling and Pile Points

Page 1600-18

Steel Pile:

- Explains type of steel accepted (ASTM)
- Discusses types of welds on pipe pile
- Lists the diameter tolerances on pipe pile

129

Materials Section 1609
Steel Piling and Pile Points

Page 1600-18

Pile Points:

- Fabricated or cast from steel
- References ASTM Standards

130

SECTION 704

PILING

704.1 DESCRIPTION

Drive the specified types of piles to the penetration and bearing values shown in the Contract Documents.

BID ITEMS	UNITS
Piles (*) (**)	Linear Foot
Test Piles (*) (**)	Linear Foot
Test Piles (Special) (*) (**)	Linear Foot
Cast Steel Pile Points	Each
Pre-Drilled Pile Holes	Linear Foot

*Type: Cast-In-Place Concrete, Prestressed Concrete, Steel or Steel Sheet, Corrugated Metal Sheet +
**Size
+Black or Galvanized

704.2 MATERIALS

Provide materials that comply with the applicable requirements.

Concrete	**SECTIONS 401 & 402**
Aggregates for Concrete Not On Grade	**SECTIONS 1102**
Prestressed Concrete Piles	**DIVISION 700**
Steel Bars for Concrete Reinforcement	**DIVISION 1600**
Steel Piling and Steel Pile Points	**DIVISION 1600**
Type B Preformed Expansion Joint Filler	**DIVISION 1500**
Paint Materials	**DIVISION 1800**

704.3 PILE DRIVING EQUIPMENT

a. General. Pile driving hammers other than drop hammers shall be of the size needed to develop the energy required to drive piles at a penetration rate of not less than 0.10 inches per blow at the minimum driving resistance according to the appropriate pile driving formula in **TABLE 704-1**.

In addition to all other requirements, single and double acting diesel hammers and air/steam hammers require the following.

(1) Open-End (Single Acting) Diesel Hammer. Equip open-end (single acting) diesel hammers with a device such as rings on the ram or a scale (jump stick) extending above the ram cylinder, to permit the Engineer to visually determine hammer stroke at all times during pile driving operation. Also, provide the Engineer a chart from the hammer manufacturer equating stroke and blows per minute for the open-end diesel hammer to be used.

(2) Closed-End (Double Acting) Diesel Hammer. Equip closed-end (double acting) diesel hammers with a bounce chamber pressure gauge, mounted near ground level so as to be easily read by the Engineer. Also, provide the Engineer a chart, calibrated to actual hammer performance, equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used.

(3) The weight of the striking part of air/steam hammers used shall be a minimum of ⅓ the weight of the pile and drive cap, and in no case shall the striking part have a weight less than 2,750 pounds.

b. Hammers for Steel Piles, Steel Sheet Piles and Shells for Cast-in-Place Concrete Piles. If a gravity hammer is used for driving steel piles, steel sheet and shells for cast-in-place concrete piles, use one with a minimum weight of 3,500 pounds. In no case may the weight of the gravity hammer be less than the pile being driven plus the weight of the driving cap. In lieu of weighing the hammer, a certification may be provided by the Contractor. Equip all gravity hammers with hammer guides to maintain concentric impact on the drive head or pile cushion. Regulate the fall to avoid injury to the piles. The fall shall be a maximum of 12 feet. If diesel or air/steam hammers are used, the maximum fall shall be 90% of the maximum fall recommended by the hammer manufacturer.

If steam or diesel hammers are used, its rated gross energy in foot-pounds shall be a minimum of 2 ½ times the weight of the pile in pounds. The hammer shall develop a minimum of 6,000 foot-pounds of energy per blow.

c. Hammers for Pre-stressed Concrete Piles. Unless otherwise provided, drive pre-stressed concrete piles with a diesel or air/steam hammer that can develop an energy per blow at each full stroke of the piston of a minimum of 1 foot-pound for each pound of weight driven. The hammer shall develop a minimum of 6,000 foot-pounds of energy per blow.

d. Vibratory Hammers. Vibratory hammers may only be used when specifically allowed by the Contract Documents or in writing by the Engineer. If approved, vibratory hammers shall be used in combination with pile load testing and re-tapping with an impact hammer. In addition, 1 of every 10 piles driven with a vibratory hammer shall be re-tapped with an impact hammer of suitable energy to verify that acceptable load capacity was achieved.

e. Additional Equipment. The plant and equipment provided for air/steam hammers shall have sufficient capacity to maintain, under working conditions, the pressure at the hammer specified by the manufacturer. In case the required penetration or bearing is not obtained by the use of a hammer complying with the above minimum requirements, provide a hammer of greater energy or when permitted, resort to jetting or pre-drilling at Contractor expense. Use of the pile driving analyzer may be required when minimum requirements are not obtained or results are doubtful.

f. Leads. Construct pile-driving leads to afford freedom of movement for the hammer. Hold them in position with guys or stiff braces to support the pile during driving. Except where piles are driven through water, use leads of sufficient length that the use of a follower shall not be necessary. Leads shall be of sufficient length to allow them to be spiked into the ground at the onset of driving.

g. Hammer Cushion. Equip all impact pile driving equipment except gravity hammers with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile and to maintain uniform driving behavior. Use hammer cushions made of durable, manufactured material that shall retain uniform properties during driving. Wire rope and asbestos hammer cushions are prohibited. Place a striking plate on the hammer cushion to maintain uniform compression of the cushion material. Inspect the hammer cushion in the presence of the Engineer when beginning pile driving at each structure or after each 100 hours of pile driving, whichever is more frequent. Replace the hammer cushion whenever there is a reduction of hammer cushion thickness exceeding 25% of the original thickness, or when the cushion begins deteriorating, tearing, etc., before continuing driving.

The following are acceptable types of pile cap material. Other materials may be used with approval of the Bureau of Construction and Materials.

(1) Micarta (Conbest) - This is an electrical insulating material composed of fabric and phenol. Replace when it starts to powderize or when it disintegrates into various layers.

(2) Nylon (2-inch thick blocks) - Occasional vertical cracking is not detrimental. However, replace after the cushion develops horizontal cracks.

(3) Hamortex (metallized paper reels) - Pay attention as it may compress or disintegrate.

(4) Force 10, Forbon, and Fosterlon - These materials are provided by manufacturers of pile driving equipment.

(5) Aluminum - Aluminum is often used to separate layers of softer cushioning material. Replace once the aluminum is deformed or broken.

(6) Wood (plywood or hardwood) should only be used with gravity hammers.

h. Pile Driving Head. Fit piles driven with impact hammers with an adequate driving head to distribute the hammer blow to the pile head. Axially align the driving head with the hammer and the pile. The driving head is guided by the leads and shall not be free swinging. The driving head shall fit around the pile head in a manner that prevents transfer of torsional force during driving while maintaining proper alignment of hammer and pile.

i. Water Jets. When jets are permitted, the number of jets and the volume and pressure of water at the jet nozzle shall be sufficient to freely erode the material adjacent to the pile. Use a plant with sufficient capacity to deliver a minimum of 100 pounds per square inch pressure at ¾-inch jet nozzles at all times. At a minimum of 5 feet before the desired penetration is reached, withdraw the jets and drive the piles to secure the final penetration with an approved hammer.

704.4 CONSTRUCTION REQUIREMENTS

a. Order Lists, Piles and Test Piles. The order list is the same as the estimated quantity (number and length of piles) shown in the Contract Documents.

For piles and test piles, provide the Engineer with the completed "Pile and Driving Equipment Data" sheet a minimum of 3 weeks before the scheduled date of driving piling. The Engineer will forward this information for Test Pile (Special) to the Chief Geologist.

When a restrike is required by the Engineer, follow **subsection 704.4e.** for restrike procedures. Provide piles for the structure according to the order list (number and length of piles) prepared by the Engineer.

Drive the specified test piles at the locations shown in the Contract Documents. The Engineer will use the test pile information to determine the pile tip elevation.

If multiple hammers are used on a project requiring test pile or test pile (special), drive a test pile or test pile (special), whichever is specified, with each hammer.

b. Test Pile (Special). Pile Driving Analyzer (PDA). The Engineer will use the PDA to monitor the driving of the test piles (special). Provide the Engineer with the completed "Pile and Driving Equipment Data" sheet a minimum of 3 weeks before the scheduled date of driving piling. The Engineer will forward this information to the Chief Geologist.

In order to mobilize the PDA, notify the Engineer a minimum of 5 working days before driving the test piles (special). Prior to driving the test pile (special), the Engineer will require approximately 1½ hours to prepare the test piling (special) and install the dynamic measuring equipment. If with prior approval, the piles are to be welded prior to the Engineer attaching the testing equipment, provide the Engineer with safe and reasonable means of access to the pile for preparing the pile and attaching the instruments.

When a restrike is required by the Engineer, follow **subsection 704.4e.(3).** for restrike procedures.

To obtain the estimated ultimate loads, the Engineer will use the PDA to take dynamic measurements as the test pile (special) is driven to the required driving resistance. If non-axial driving is indicated by dynamic test equipment measurements, immediately realign the driving system. The Engineer will use the PDA results to provide the Contractor with a blow count for production driving.

c. Driving Piles. Drive the piles with a gravity hammer, a diesel hammer, an air/steam hammer or a combination of pre-drilled holes or water jetting and a hammer. Use equipment that complies with **subsection 704.3**.

Drive the piles at the locations and to the vertical or battered lines shown in the Contract Documents. Use leads of sufficient length to allow them to be spiked into the ground at the onset of driving the pile.

Do not drive piles until the footing, webwall or abutment excavation is completed. Drive all of the piles required for the footing or abutment before placing any concrete in the footing or abutment, unless the foundation is a minimum of 20 feet away or has cured a minimum of 24 hours.

When specified, drill pile holes before driving the piles. Drill the holes accurately so that the piles are set as shown in the Contract Documents. The maximum size of the pre-drilled holes is equal to the diameter of the pile plus 3 inches. The depth of pre-drilled pile holes is shown in the Contract Documents. If pre-drilled pile holes are not specified, the Contractor may choose to pre-drill pile holes, provided the Engineer approves the Contractor's method and limits. After the piles are driven to their final positions in the pre-drilled holes, fill the holes with loose sand or material specified in the Contract Documents. If concrete is specified, allow sufficient concrete slump and provide vibration to fill all voids around the pile.

Drive all pile heads perpendicular to the longitudinal axis of the piles to prevent eccentric impacts from the drive head of the hammer. Use pile caps on all piles during the pile driving operations. For pile caps of concrete piles and prestressed concrete piles, use a suitable cushion next to the pile head that fits into a casting that supports a timber shock block. On pile caps for steel piles and steel sheet piles, provide grooves in the bottom of the cap to accommodate the shape of the piles to hold the axis of piles in line with the axis of the hammer. On pipe pile, use a helmet with a minimum interior guide of 6 inches.

If specified, use the type of cast steel pile points shown in the Contract Documents. Use pile points that provide full bearing for the piles. Provide an experienced welder to attach the cast steel pile points to the piles.

Use full-length piles where practicable. It is preferred that steel piling is not spliced. Splices may be made with the permission of the Engineer, or when shown in the Contract Documents. Make splices as shown in the Contract Documents. Use an approved welding process as provided in **DIVISION 700** to make the splices. Provide an experienced welder qualified under **SECTION 713** to make the welded splices for structural steel piling and shell piling. Correct or replace any failure in the splice at own expense.

Avoid extensions, splices or build-ups on prestressed concrete piles whenever possible. When splicing is necessary, make them as shown in the Contract Documents.

If the pile driving procedure causes crushing or spalling of the prestressed concrete piles, or deformation of the steel piles, remove and replace the damaged piles with new, longer piles. A second pile may be driven adjacent to the damaged pile, when approved by the Engineer and can be accomplished without detriment to the structure.

Do not force misaligned piles into proper position. Remove and replace piles driven out of their proper location with new, longer piles.

- If the driven pile is 35 feet or less in length, the maximum allowable variation from the vertical or battered lines shown in the Contract Documents is ¼ inch per foot of length.
- If the driven pile is greater than 35 feet in length, the maximum allowable variation from the vertical or battered lines shown in the Contract Documents is ⅛ inch per foot of length.
- The maximum allowable variation on the head of the driven pile from the position shown on the Contract Documents is 2 inches for piles used in bents, and 6 inches for foundation piles.
- Drive all piles in the orientation shown on the Plans. If the axial orientation of the pile rotates or twists by more than 10°, the Field Engineer will contact the Bureau of Structures and Geotechnical Services.

Re-drive all piles pushed up by the driving of adjacent piles, or by any other cause.

d. Bearing Values and Required Penetration. Drive the piling to attain, as a minimum, the specified bearing value, penetration and pile tip elevation. Stop driving the piling (regardless of the penetration) if 1½ times the specified minimum driving resistance is attained. Stop driving the piling if, in the opinion of the Engineer, the specified minimum driving resistance, penetration and pile tip elevation can not be attained without damage to the piling. If the specified minimum driving resistance is not attained with the specified number and length of piling, the Engineer may allow additional piling be driven so that the maximum load on any pile does not exceed its safe carrying capacity.

In the absence of loading tests, determine the safe bearing values of piles by the formulas in **TABLE 704-1**.

TABLE 704-1: PILE FORMULAS		
Hammer	**Pile Type**	**Formula**
Gravity	Timber	$P = \frac{2 \; W \; H}{S + 1.0}$
Gravity	Steel Steel Shell Steel Sheet	$P = \frac{3 \; W \; H}{S + 0.35} \left(\frac{W}{(W + X)} \right)$
Air/Steam (Single Acting)	All Types	$P = \frac{2 \; W \; H}{S + 0.1}$
Air/Steam (Double Acting)	All Types	$P = \frac{2 \; E}{S + 0.1}$
Delmag and McKierman-Terry*	All Types	$P = \frac{1.6 \; W \; H}{S + 0.1 \left(\frac{X^{**}}{W} \right)}$
Link-Belt*	All Types	$P = \frac{1.6 \; E}{S + 0.1 \left(\frac{X^{**}}{W} \right)}$

*diesel hammers
** For diesel hammers, the quantity X/W shall not be less than 1.
P = safe bearing power in pounds
W = weight in pounds, of striking part of hammer
H = height of fall in feet
E = energy of ram in foot-pounds per blow
S = the average penetration in inches per blow for the last 5 blows for gravity hammers and the last 20 blows for air/steam or diesel hammers
X = weight in pounds of the pile plus the weight of any cap and/or anvil used on the pile during driving

The above formulas are applicable only when:

- The hammer has a free fall;
- The penetration is reasonably quick and uniform; and
- There is no appreciable bounce after the blow.

If water jets are used in connection with the driving, determine the bearing capacity by the formulas above from the results of driving after the jets have been withdrawn, or a load test may be applied.

The energy rating used to determine if any type or brand of diesel hammer is of adequate size other than those shown in **TABLE 704-1**, is 80% of the energy rating as listed by the manufacturer.

Use an energy rating of 100% of the energy rating listed by the manufacturer for computing bearing values and to determine if an air/steam is of adequate size. If the number of blows per minute for an air/steam hammer deviates significantly from the number designated by the manufacturer, take corrective action as directed by the manufacturer.

e. Piling Restrike Procedure.

If a pile does not attain the minimum driving resistance within a few feet of the plan elevation, the pile restrike procedure may be used. Contact the Regional Geology Office for guidance before using the restrike procedure. Restrike procedures differ depending on whether a Test Pile, Test Pile (Special) or neither is called for in the Contract Documents. When a PDA is used, the restrike procedure will be as directed by the Regional Geologist.

(1) Use the following procedure when neither a Test Pile nor a Test Pile (Special) is called for in the Contract Documents, and the PDA is not available. The following procedure shall be used.

- Drive all of the piling in a group to within 2 feet of plan elevation;
- A group of piling is defined as all piles contained within a single footing.
- All of the piling in the pile group shall sit undisturbed for a minimum of 24 hours;
- Prior to starting the restrike procedure, warm the hammer up at a location as far away from the pile group as practical, preferably in another substructure member or pile group;

- Using the warmed up hammer, immediately restrike 20% of the piles in a group, with a minimum of 2 in a group restruck. Of these, restrike the piles in a single group with the furthest spacing away from each other. When possible, restrike those with the lowest resistance during driving.
- Restrike for 30 blows or until the pile penetrates an additional 4 inches, whichever comes first. Record the penetration for every 5 blows. In the event the pile movement is less than ½ inch during the restrike, the restrike may be terminated after 20 blows.
- Restrike additional (the 20% or 2 minimum specified above) pile in the group as directed by the Engineer.

The driving resistance of the piling is computed based on the average penetration, if any, for the first 5 blows. The driving resistance of each piling is the driving resistance computed for the pile that was restruck. If the computed driving resistance is less than the design pile load, splice additional length onto each piling in the group and resume driving each piling until the required driving resistance is achieved.

(2) Use the following procedure when a Test Pile is called for in the Contract Documents, and the PDA is not available. The following procedure must be used.

- Drive the Test Pile to within 2 feet of plan elevation;
- The Test Pile shall sit undisturbed for a minimum of 24 hours;
- Prior to starting the restrike procedure, warm the hammer up at a location as far away from the Test Pile as practical, preferably in another substructure member or pile group;
- The Test Pile is then immediately restruck with the warmed-up hammer for 30 blows or until the pile penetrates an additional 4 inches, whichever comes first. Record the penetration for every 5 blows. In the event the pile movement is less than ½ inch during the restrike, the restrike may be terminated after 20 blows.

The driving resistance of the Test Pile is computed based on the average penetration, if any, for the first 5 blows. If the computed driving resistance is less than the design pile load, splice additional length and resume driving until the minimum driving resistance is achieved.

(3) When a Test Pile (Special) is called for on the plans, or a PDA is available, follow the recommendations of the Regional Geologist for the Restrike Procedure.

f. Pile Cut-Off and Pile Painting.

(1) After the piles are driven as specified, cut the piles off at the designated elevation. If capping is required, make the connection as shown in the Contract Documents.

Pile cut-off material becomes the property of KDOT, if the Engineer determines the pile cut-off material is worth salvaging. Store the salvageable material at the site selected by the Engineer. Pile cut-off material determined to not be salvageable becomes the property of the Contractor.

(2) Paint the exposed portion of steel piles, steel sheet piles, or the shells or castings of cast-in-place concrete piles. Unless otherwise noted in the Contract Documents, apply the paint in the field. Use the same kind of paint and total number of coats as specified for the structural steel on the structure. If a paint system is not specified for the structure, use a prime coat of inorganic zinc as required for the shop coat and an acrylic or polyurethane finish coat, as specified in **DIVISION 700** for the final coat. Apply the paint to the pile for a distance of 1 foot below the bottom of the channel, top of the embankment, natural ground or normal low water elevation.

g. Cast-In-Place Concrete Piles. After the steel shells are driven as specified, remove all loose material from inside the steel shell. Unless specified otherwise in the Contract Documents, use Grade 3.5 concrete to fill the steel shells. Do not place concrete in the steel shell until the driving of all steel shells within a radius of 15 feet from the pile is completed, or until all the piles for any one bent are driven. If this can not be done, discontinue all driving within the above limits until the concrete in the last pile cast is a minimum of 7 days old. Remove accumulations of water from inside the steel shells before concrete is placed. Consolidate the concrete in the upper 15 feet of the steel shell by internal vibration.

h. Sheet Pile. Use a fabricated or cast driving head with corrugations to match the top of the sheeting while driving the sheet piling.

704.5 MEASUREMENT AND PAYMENT

The Engineer will measure the length of steel pile, steel sheet pile, cast-in-place concrete pile and prestressed concrete pile remaining in the structure, by the linear foot.

The Engineer will measure the length of prestressed concrete from the tip of the pile to the point that concrete is removed to provide the connection with the cap or footing. This measurement does not include the length of reinforcing steel extending beyond the pile and into the cap or footing.

The Engineer will measure the actual length of ordered and accepted test pile and test pile (special) by the linear foot.

The Engineer will measure each cast steel pile point used.

If after driving the ordered and accepted length of pile, plan bearing is not achieved and additional pile is required, the Engineer will measure for payment each pile splice needed to lengthen the pile to achieve bearing. The Engineer will not measure for payment pile splices shown in the Contract Documents or pile splices approved for the Contractor's convenience.

The Engineer will measure pre-drilled pile holes by the linear foot. The Engineer will measure pre-drilled pile holes from the elevation at the bottom of the hole to the bottom of the footing or abutment elevation shown in the Contract Documents. If the Contractor drills the pile holes to an elevation below that shown in the Contract Documents for bottom of hole, the additional drilling below the elevation shown in the Contract Documents is not measured for payment. Pre-drilled pile holes not specified, but drilled for the Contractor's convenience are not measured for payment.

The Engineer will measure pile cut-off by the linear foot for Pile (*) (**). Pile cut-off is the difference between the length of pile ordered and accepted and the actual length of pile remaining in the structure. If the Contractor (for convenience or method of operation) uses a length of pile that exceeds the length of pile ordered and accepted, the excess length is not measured as pile cut-off.

The Engineer will not measure pile cut-off of Test Pile (*) (**) and Test Pile (Special) (*) (**) for payment. If the pile for these items is cutoff and used/spliced on the project, the pile will not be measured for separate payment. Splices will be paid for according to this subsection.

The Pile Restrike procedure shall not be paid for separately, but shall be subsidiary to the bid item "Piling", "Test Pile" and "Test Pile (Special)".

Payment for the various types of "Piles" and "Test Piles", "Cast Steel Pile Points" and "Pre-Drilled Pile Holes" at the contract unit prices is full compensation for the specified work.

Payment for pile splices at 4 times the contract unit price of the type of pile spliced is full compensation for the specified work.

Payment for pile cut-off per linear foot as shown in **TABLE 704-2** is full compensation for the specified work.

TABLE 704-2: PILE CUT-OFF PAYMENT	
Pile Type	**% of Contract Unit Price Paid**
Cast-in-place (Shell)	60
Pre-stressed concrete	75
Steel	75
Steel Sheet	75

The costs of all load tests ordered by the Engineer will be paid for as Extra Work as shown in **SECTION 104**.

5.3 DRIVEN PILE

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5.3 DRIVEN PILE

5.3.1 General

Driven piles are used as the foundation for almost all abutments in Kansas bridges. Likewise they are used as the foundation for many piers in Kansas bridges. Proper pile driving inspection is critical to a successful bridge project.

What is a driven pile?
There are two types of driven piles: sheet pile and foundation pile. Sheet piles are long, interlocking, rolled steel plates used in retaining structures, such as walls and cofferdams. Foundation piles are long slender columns designed to be driven into the ground. Foundation piles will be discussed here.
Foundation piles are simply columns, designed to transmit surface loads to low lying soil or bedrock. These loads are transmitted by friction between the pile and ground and by point bearing through the end of the pile. The actual amount of frictional resistance or end bearing is dependent on the particular site conditions.
Foundation piles are made of steel, concrete, or timber. Of these materials, steel H-pile and cast-in-place pipe pile are most commonly used in Kansas. The material and size of pile to be used on a particular project are designated in the plans on the General Notes and Summary of Quantities Sheet.

Piles are used when a deep foundation is necessary. This is the case when the soil near the surface is unsuitable to carry the loads imposed by the structure. Piles are also used when the possibility exists that the soil under the foundation may be washed away.

5.3.2 Bid Items

The following is an abbreviated list and brief description of the bid items related to pile foundations. The entire list can be found in the Standard Specifications.

Test Pile:
There are some instances in which the length of pile cannot be determined accurately by means of a soils boring or sounding. This is usually the case when friction pile or bearing pile is used where the geologic formation is weathered. In these instances a test pile will be required. A test pile is a single pile driven to determine the required length of the remaining pile for that foundation element. The test pile location will be shown on the plans. Usually there will be one test pile per bent location. These are ultimately used as production piles so the location tolerance is the same as a production pile. If the production piles are to be pre-drilled then the test pile is pre-drilled to the same depth.

With all the hammer information known, use the appropriate dynamic pile driving equation to compute the blow count (average) for the specified driving load and 110% of this value. The value for over driving the pile was 150% when Allowable Stress Design was used to determine the soil and pile resistance. As the Geology Section has moved into the realm of Load and

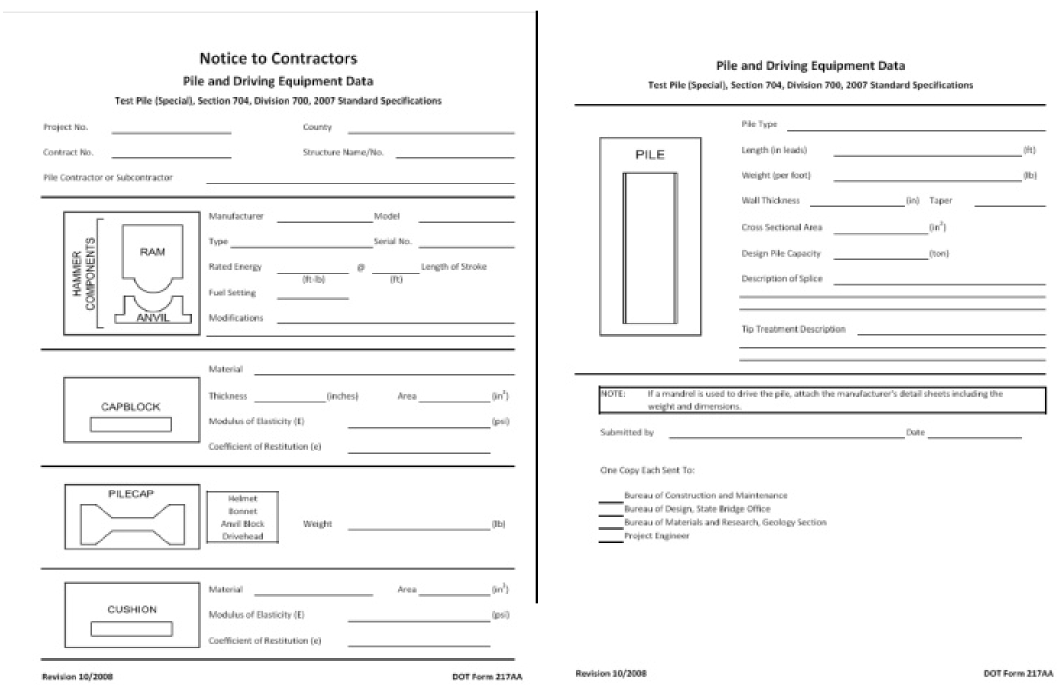
Resistance Factor Design, the limits have been reduced on overdriving the pile. The hammer selected for the particular job should be rated to yield at least this value at the required resistance. Required resistance is 1/4” per 5 blows as the average of the last 20 blows for power driven hammers and the last 5 blows for gravity hammers.

After the pile penetrates the soft upper layers (about 6 feet) the blow count will be taken for each twelve inches of penetration. Mark the pile in twelve inch intervals prior to placing the pile in the leads and count the blows as the marks pass a fixed point. Record the average penetration in decimal inches by dividing twelve inches by the number of blows between the marks.

Test Pile (Special):

The Test Pile (Special) bid item is used when the geology within an area has unpredictable material properties. In such case the plans will direct the Contractor to notify the Engineer five days prior to driving the test piles. The Engineer will contact the regional Geologist and the State Bridge Office. They will mobilize the Pile Driving Analyzer (PDA) to be used on the project. This equipment attaches to the pile as it is driven and measures the energy being supplied by the driving equipment and the stress in the pile. The bearing capacity can be computed from this information.

When the plans show the bid item Test Pile (Special), the information found in Form 217AA (pictured below), located in the Forms Warehouse, must be supplied by the Contractor. The Engineer will use this information in the Wave Equation Analysis Program (WEAP).



Notice to Contractors

Pile and Driving Equipment Data

Test Pile (Special), Section 704, Division 700, 2007 Standard Specifications

Project No. ______ County ______

Contract No. ______ Structure Name/No. ______

Pile Contractor or Subcontractor ______

HAMMER COMPONENTS — RAM / ANVIL

Manufacturer ______ Model ______

Type ______ Serial No. ______

Rated Energy ______ (ft-lb) @ ______ (ft) Length of Stroke

Fuel Setting ______

Modifications ______

CAPBLOCK

Material ______

Thickness ______ (inches) Area ______ (in^2)

Modulus of Elasticity (E) ______ (psi)

Coefficient of Restitution (e) ______

PILECAP — Helmet / Bonnet / Anvil Block / Drivehead

Weight ______ (lb)

CUSHION

Material ______ Area ______ (in^2)

Modulus of Elasticity (E) ______ (psi)

Coefficient of Restitution (e) ______

Revision 10/2008 DOT Form 217AA

Pile and Driving Equipment Data

Test Pile (Special), Section 704, Division 700, 2007 Standard Specifications

PILE

Pile Type ______

Length (in leads) ______ (ft)

Weight (per foot) ______ (lb)

Wall Thickness ______ (in) Taper ______

Cross Sectional Area ______ (in^2)

Design Pile Capacity ______ (ton)

Description of Splice ______

Tip Treatment Description ______

NOTE: If a mandrel is used to drive the pile, attach the manufacturer's detail sheets including the weight and dimensions.

Submitted by ______ Date ______

One Copy Each Sent To:

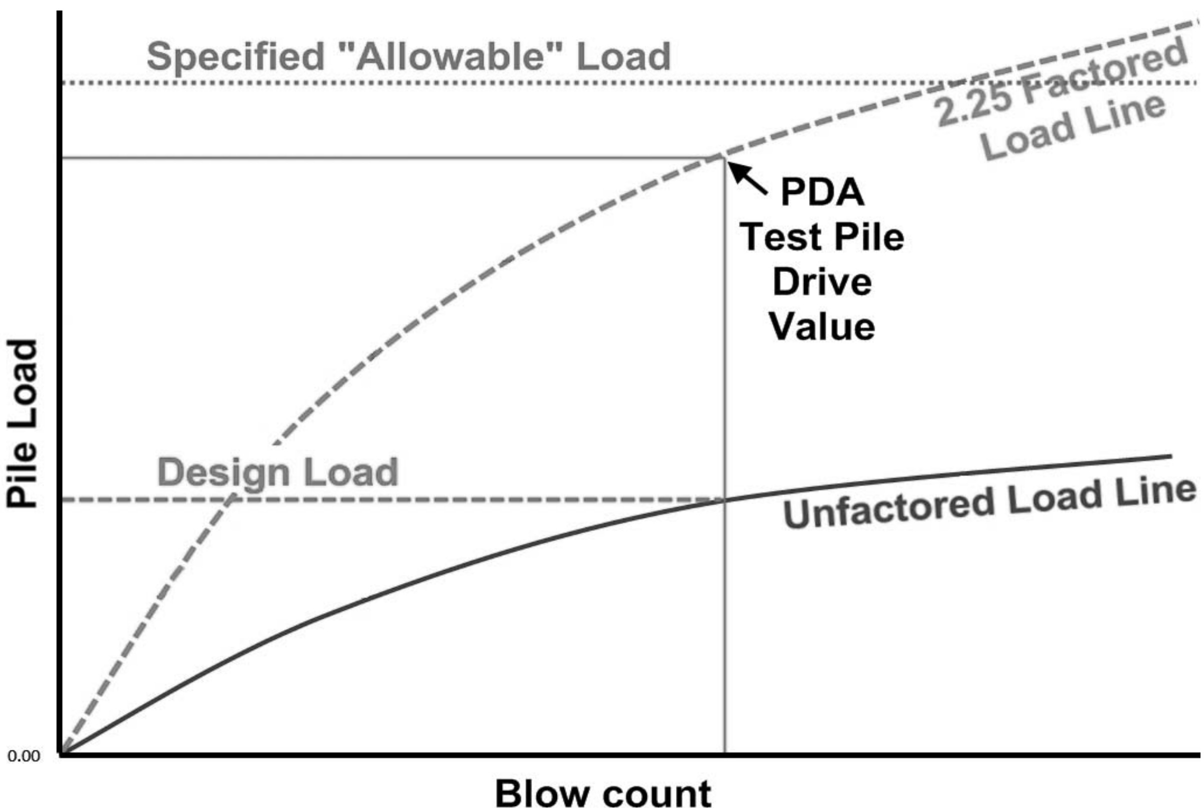
___ Bureau of Construction and Maintenance
___ Bureau of Design, State Bridge Office
___ Bureau of Materials and Research, Geology Section
___ Project Engineer

Revision 10/2008 DOT Form 217AA

Friction Pile PDA Procedures:

Currently plan specified pile driving values include Design Load, Allowable Load, and the General Note that specifies what "allowable" load to drive the pile to at each substructure element. Friction Pile are typically driven in western Kansas since there are no thick bedrock layers to seat a bearing pile into. From a practical standpoint it can be difficult to determine a required pile length with current technology. This is why a PDA is used on these projects to determine the length of pile required, the pile tip elevations, and various other values to allow inspectors to complete the rest of the pile using the equations in the specifications.

The PDA equipment measures the exact value of resistance the pile is building during driving. Current practice gives the geologist running the PDA equipment the authority to modify the values specified in the contract documents to more accurately reflect the subterranean site conditions. The chart below is a representation of what can happen on site during a PDA test pile drive. The values for everything below the green line are only applicable to the geologist running the PDA equipment. The inspector in the field is only given the specified load as stated in the plans. After the PDA test drive is completed, the operator will often have new values for the inspector to achieve for the remaining pile.



The specified load located in the "Piling" General Note the inspector is instructed to drive to can be over-ridden by the geologist running the PDA equipment. The PDA operator will drive to 2.25 times the Design Load stated in the plans. Once the PDA operator achieves that value, the operator will back-calculate the equivalent pile load the inspector will need to calculate using the pile driving equations. Other information the PDA operator will give to the inspector is the approximate pile tip elevation, the blow count, average penetration, and the stroke height of the hammer. The pile driving will proceed using the new values the PDA equipment has determined.**Cut-Off and Splice:**

Pile cut-off and pile splicing are paid for as a function of the bid price for piling per linear foot.

Cut-Off

The Contractor will have enough of the pile sticking out of the ground for the proper cut off leaving a fresh heading and squared end. The penetration of the pile within an abutment or footing is shown on the plans and is critical to the structural continuity. As a minimum, piling will be encased in 2’-0” of concrete.

The cut off elevation (top of pile) will be called out in the plans and is a surveyed elevation. Do not use the top of a piling as a reference elevation for other structural elements in the bridge. Set elevations from a true vertical control element, i.e. a benchmark.

Using the correct pile driving formula, found in Section 704, to calculate the resistance of the pile, and once sufficient resistance is achieved, driving should stop. Continuing to drive the pile to use the ordered length, or the length in the leads may damage the pile. Any excess pile should be cut off at the plan top of pile elevation. It is common to have 3’-0” of cut-off at each pile location.

Pick and Place

If the contractor chooses a method of securing the pile during the pick and place operations which damages the pile, the contractor must remove the damaged portion of the pile at the contractor’s cost before driving. For example, if the contractor burns a hole in the pile as a more secure method to lift the pile into place, the contractor must remove the portion of the pile containing the hole before driving the pile begins. The contractor is required to remove the compromise section of pile to at least one inch below the hole. This cutoff is at the contractor’s cost and is considered to be non-pay cutoff. As such, if the total cutoff made for the contractor’s convenience reduces the supplied pile to less than the Ordered and Accepted pile length and an additional length of pile is needed to achieve cutoff elevation, the necessary splice is a non-pay splice.

Splice

Splicing pile becomes necessary when the founding material is deeper than the designer expected, when the founding material is beyond the reach of a single length of pile, or in the case of friction pile, required resistance is not achieved with the length of pile driven. For long steel bridges with integral abutments or for rigid frame structures (integral pile bent piers), it is desirable to have spliced material at the bottom of the pile rather than have a splice near the bottom of the concrete element supported by the pile. If it becomes apparent that several of the piles in an individual structure (pile cap, abutment, etc.) are going to need to be spliced, it is best if the splices are made before driving begins. The spliced end is then driven first. This way, the strength of the welded section is only tested, axially, by driving and not tested in repeated bending by structure loading, because the splice is located away from the end that will go through the most severe bending. Standard details require locating the splice a minimum of ten feet below the bottom of abutments, integral pile bent piers. Rare special cases may exist for some pile caps which will be determined by the design engineer and designated by a general note in the design plans.

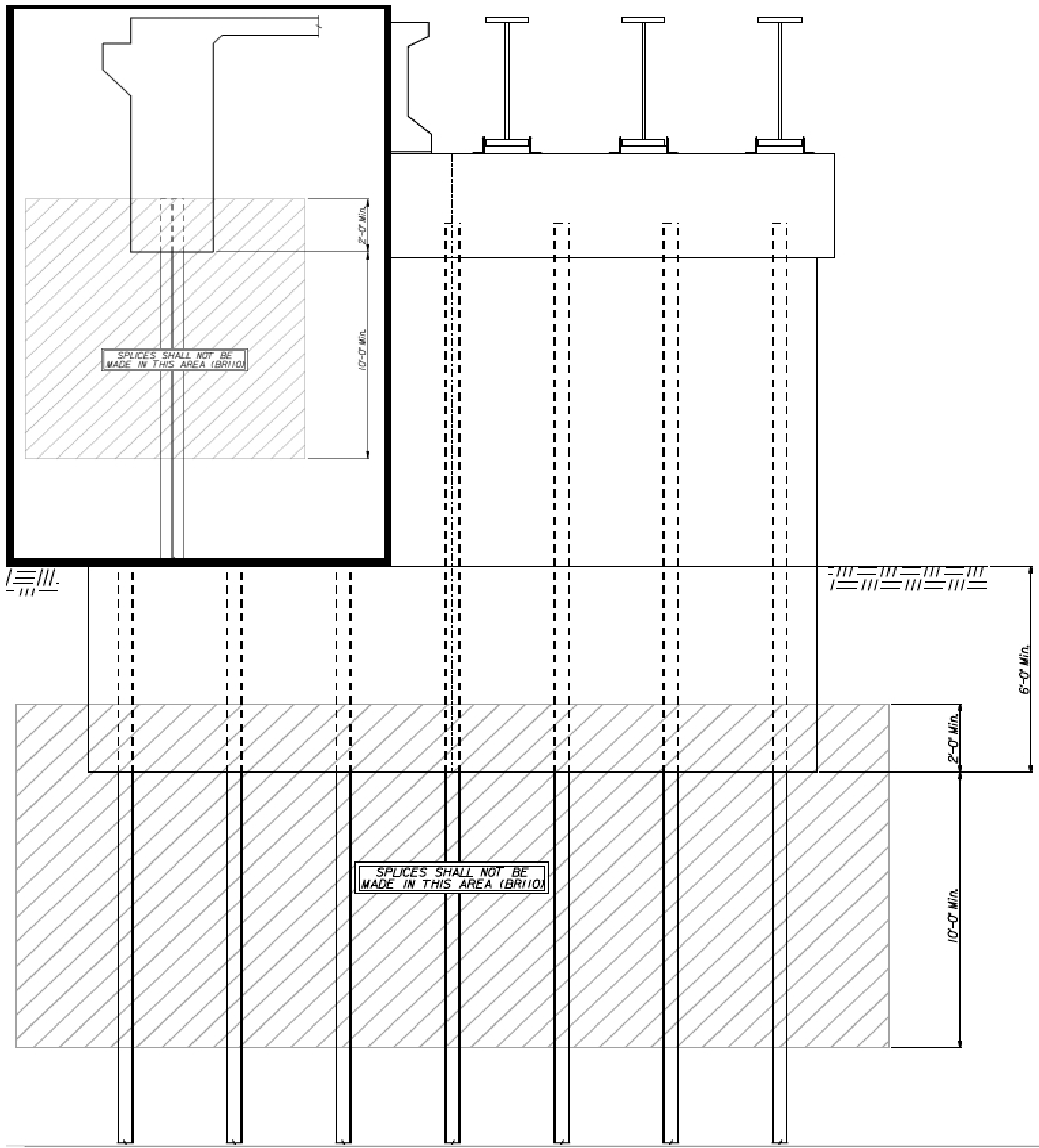


Figure 1 Pile Splice Location Limits

The “Standard Pile Details” (BR110) sheet states splices will be located a minimum of ten feet below the web wall concrete on piling for integral pile substructure elements. This requirement keeps the splice away from the area of maximum bending. In general, the bottom of a concrete web wall will be located two to six feet below the streambed. This note is not meant to exclude splices from being located within the concrete web wall. If the splice is located within the wall, it should be at least two feet above the bottom of concrete, as shown in Figure 1. In general, the above figure shows where the contractor is not allowed to splice piling; the inspector needs to verify this has not been overridden in the plan notes and/or substructure details for each project.

SPLICES: Splices for steel piles and shell piling shall be in accordance with details shown on this sheet and the Standard Specifications.

For integral pile bent abutments and piers, if a pile splice is required, do not locate the pile splice within a region extending 2'-0" above and 10'-0" below the bottom of the concrete web wall. For abutments, locate the pile splice at least 10'-0" below the bottom of concrete.

With the approval of the Engineer, one splice per bent may be allowed in the region described above without testing. If additional splices are anticipated, based on the geology, the Contractor will add a sufficient amount to the bottom of pile, prior to driving, so that the splice is below the regions described above in the completed pile.

† For integral pile bent abutments and piers, if a splice is located within the regions described above, then the Contractor will test the welds by Radiograph (RT) test methods. Repair and retest any welds not passing the test(s). Each weld tested will have written confirmation of results. Report these results to the Engineer. This work is not paid for directly, but is subsidiary to "Piles".

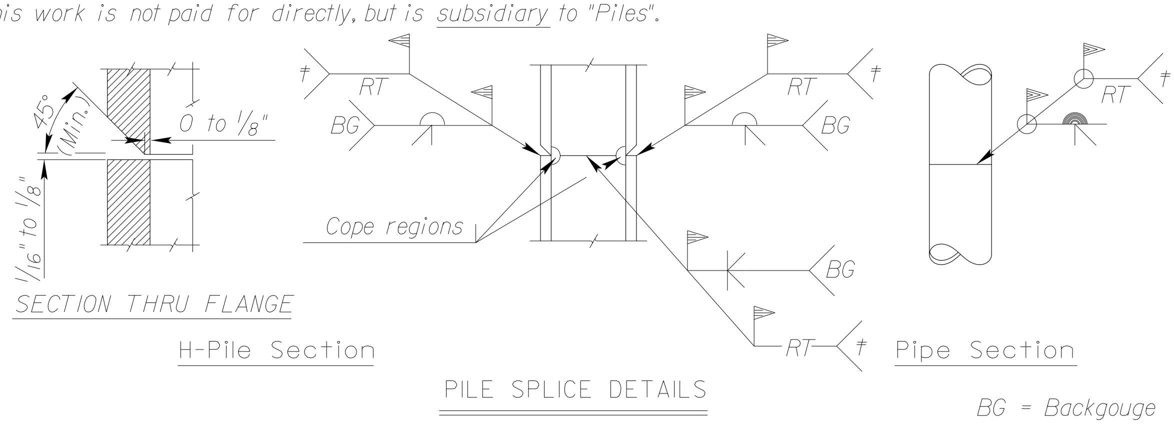
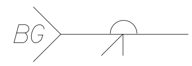


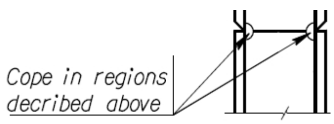
Figure 2 Bridge Standard BR110 Pile Splice Details

The Standard Pile Details (BR110) detail shown in Figure 2 specifies requirements for pile splice welds. One splice is allowed in the restricted region shown in Figure 1, or described in Figure 2, to allow for inconsistencies in the geology across each substructure element. The first splice made within the restricted region should indicate to the contractor the remaining pile should be spliced before they are driven. Standard pile splices that will not fall within the restricted region will only require the standard pile splice weld. However, the second splice, and any additional splices falling within the restricted region in the same substructure element will require more verifiable welding procedures and UT testing. The contractor may elect to excavate below the restricted region, cutoff the pile in order to weld a section below the restricted region that will only require a standard field splice.

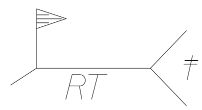
Black Flag: Field operation.



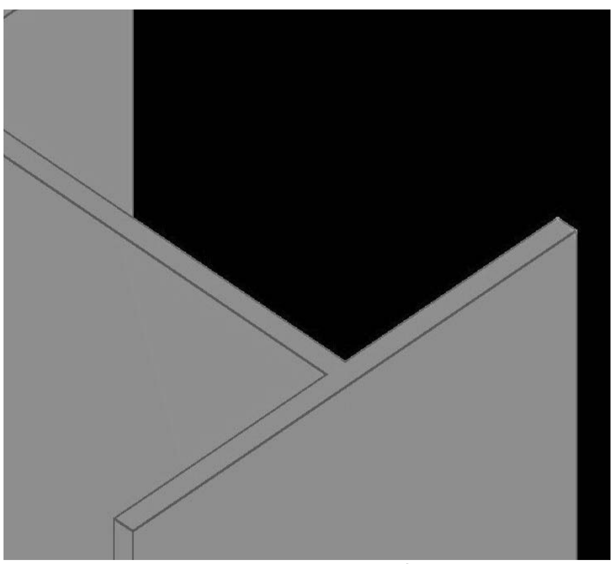
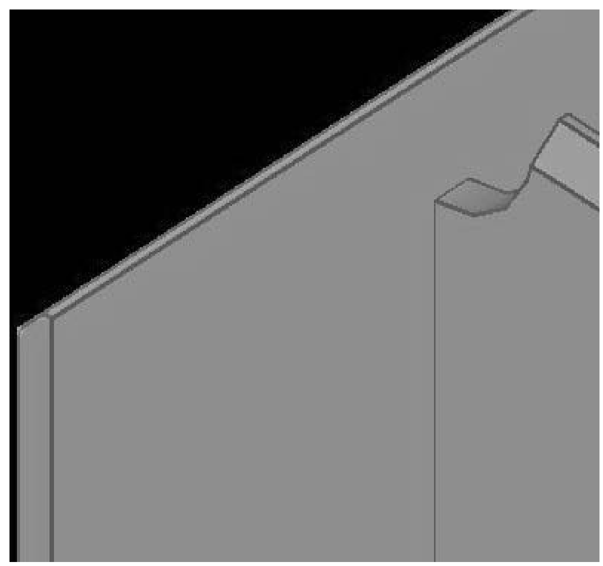
Begin with a backer weld; back gouge (BG) opposite side; finish with groove weld.

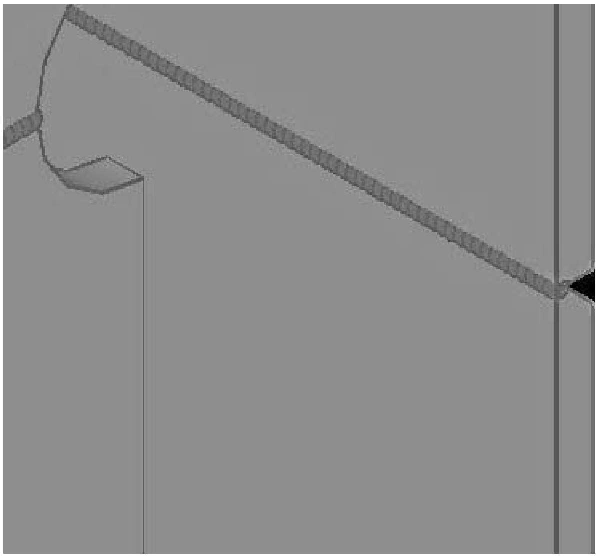
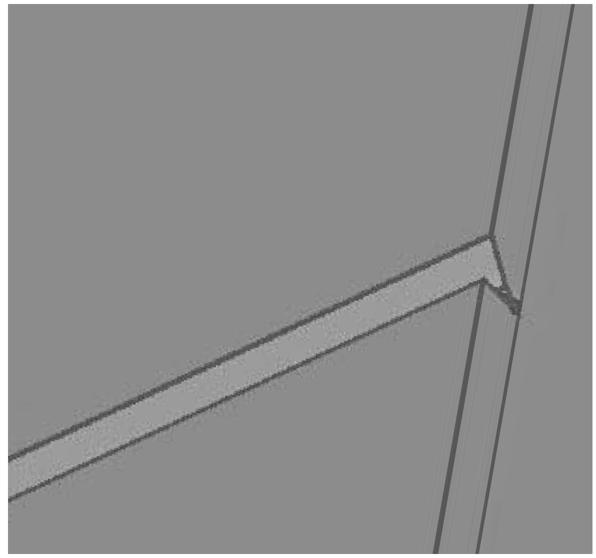
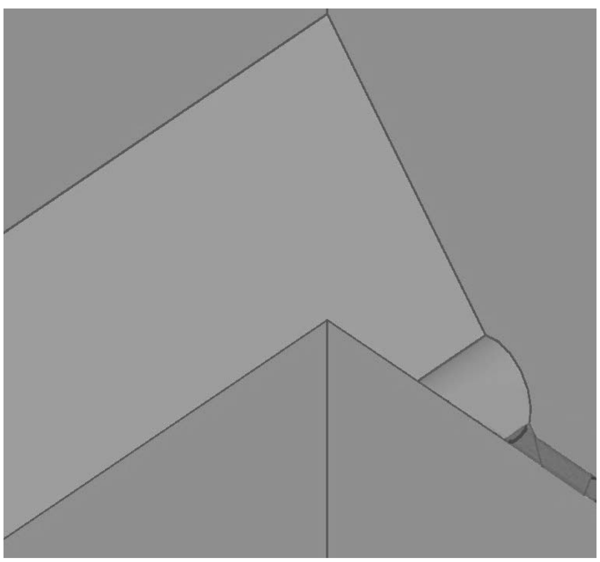
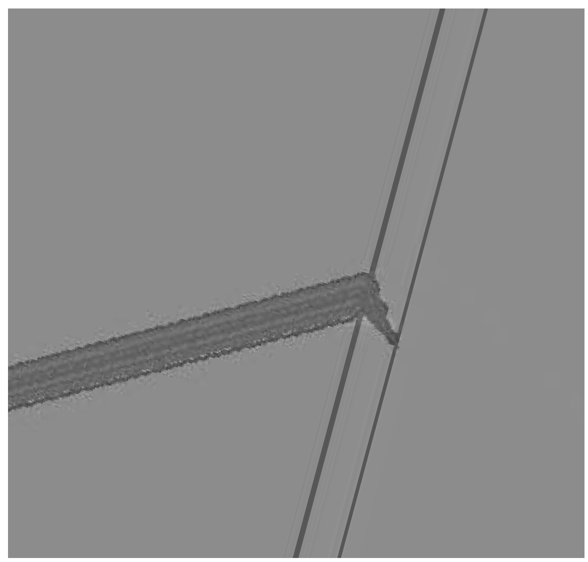


Cope required on additional splices within restricted region for testing purposes.



Radiograph Weld testing required on additional splices within restricted region.

 Step 1: Pile top is squared up after driving.	 Step 2: Pile is prepared for weld procedures. Web cope is prepared, as necessary.

 Step 3: First backer welds are made on each flange and on the web.	 Step 4: Back gouge backer welds to remove weld impurities.
 Close up image of back gouge of backer weld. Also shows plate prep for pile splices.	 Step 5: Place remaining welds (multiple pass) and remove slag/impurities between passes.

5.3.3. Types of Piles

Figure 3 Pile Points

Steel Piles: Steel piles are generally rolled H-pile used in point bearing. H-pile are available in many sizes, and are designated by the depth of the member and the weight per unit length. For example, an HP 12X74 is an H-pile which is 12" deep and weighs 74 pounds per foot. H-piles are well adapted to deep penetration and close spacing due to their relatively small point area and small volume displacement. They can also be driven into dense soils, coarse gravel and soft rock without damage. In some foundation materials, it may be necessary to provide pile points (Figure 2) to avoid damage to the pile. In some instances it may become necessary to increase the length of H-Pile by welding two pieces together. If this is the case, splicing must be done in accordance with KDOT specifications.

KDOT primarily utilizes Steel H-Pile. However, the following types of pile may be used on bridges in Kansas.

Cast-in-place pipe pile: Cast-in-place pipe pile are considered as displacement (friction) type pile. Closed-end pipe piles are formed by welding a watertight plate on the end to close the tip end of the pile. The shell is driven into the foundation material to the required depth and then filled with concrete. Thus both concrete and steel share in supporting the load. After the shell is driven and before filling with concrete, the shell is inspected internally its full length to assure that damage has not occurred during the driving operation. Pipe pile may be either spiral or longitudinally welded or seamless steel. Pipe piles are normally used in foundation footings. Their use for above ground pile bents is not recommended. Pipe pile are considered concrete pile for bidding and on the Standard Pile sheet.

Timber Piles: Timber piles are used for comparatively light axial and lateral loads and where conditions indicate they will not be damaged by driving. Timber piles are rarely used on permanent bridge structures today, but they are used for temporary structures such as falsework construction. Care shall be taken when driving falsework piling to avoid underground utilities. For permanent installations, untreated timber pile is used below water line (pile will be continually wet) and treated timber at all other locations. Untreated pile may be used on temporary structures. Pile points for timber pile are unnecessary unless hard driving is anticipated.

Concrete Piles: Concrete piles come in precast, prestressed, cast-in-place, or composite construction form. Composite concrete piles are very rarely used in KDOT construction and therefore are not discussed in this manual.

- **<u>Precast piles:</u>** Precast piles are cast at a production site and shipped to the project site. The Contractor should take special care when moving these piles as not to create tension cracks. The pickup points on these piles should be as shown on the shop drawings.

- **<u>Prestressed Piles:</u>** Prestressed piles are produced in the same manner as a prestressed concrete beam. The advantage of prestressed piles is their ability to handle large loads while maintaining a relatively small cross section. Also, a prestressed pile is less likely to develop tension cracks during handling.

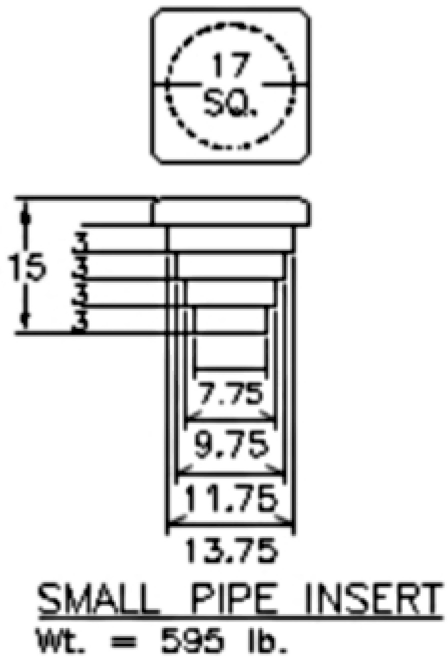


Figure 4 Pipe

- **<u>Cast-In-Place-Piles:</u>** Cast-in-place pressure grouted piles are constructed by drilling with a continuous-flight, hollow-shaft auger to the required depth. A non-shrinking mortar is then injected, under pressure, through the hollow shaft as the rotating auger is slowly withdrawn. A reinforcing steel cage is placed in the shaft immediately after the auger is withdrawn. When a shell or casing is used the contractor must make sure that the inside of the casing is free of soil and debris before placing the concrete. This system is used when hammer noise or vibration could be detrimental to adjacent footings or structures.

5.3.3.1 Basis of Acceptance (Materials)

Material for H–Pile and Steel Shells for Cast-in-Place Concrete Piles are covered by a Type A certification. With approved certification, the field Engineer may accept the piling provided a visual inspection shows that it meets dimensional requirements and that it can be identified with the mill test report by means of heat lot numbers painted or stamped on each piece.

5.3.3.2 Pile Order Lengths

The length and type of pile required by plan is given in a box under the Summary of Quantities on the General Notes and Quantities Sheet. The location and plan length for each pile is given on the elevation view of the geology sheet. The Contractor will most likely provide slightly more pile than required by the plans. This additional length is to account for any pile which is damaged during driving.

KDOT's geology section may require the ideal length of pile to be determined in the field by driving one or more test piles. This will occur when the founding material is fractured, less competent than anticipated or otherwise variable. The Field Engineer may require additional test piles to be driven if sufficient information is not provided from the plan quantity and location for test pile. Typically one test pile per bent is all that is needed. The Contractor will no longer be required to wait to order pile until after the required test pile(s) are driven. The primary use of the test pile is now to verify the subterranean geology (Log of Continuous Pile form), elevations and soil types, which has been provided by the Geology section.

5.3.4 Pile Driving Equipment

This section is governed by **Section 151.30** of the **Standard Specifications**
Pile hammers are unique pieces of equipment. They serve two functions. One, they are tools used by the Contractor to drive pile; two, they are measuring instruments used by the Engineer to determine the bearing provided by the piles.

5.3.4.1 Pile Leads:

Pile leads are required for use with all hammer types except the vibratory and sonic power hammers. The leads serve to contain the pile hammer and to direct its alignment, thus ensuring the pile receives a concentric impact with each blow. They also provide a means for bracing long, slender piles until they have been driven to sufficient penetration to develop their own support. It is essential the leads be well constructed to provide free movement of the hammer. For drop hammers, it is essential the leads be straight and true to prevent restrictions to free fall which would reduce the energy delivered.

There are several types of leads: underhung leads (pinned to the tip of the crane boom): extended 4-way leads (like the underhung lead, but extending vertically above the top of the boom); and swinging. Swinging leads are the most commonly found on Kansas bridge projects. There are usually two stabilization points which provide stability to the bottom of the leads. The leads are then held plumb or to the proper batter by a crane line. The leads are required to be long enough to accommodate, at a minimum, the pile length plus the length of the hammer. It is generally good practice to use a somewhat longer length as a contingency.

5.3.4.2 Pile Cap (Helmet):

Driving different types and shapes of pile requires different types and shapes of pile caps. For standard H-pile or sheet pile, the specifications require grooves, or extended tabs, at the bottom of the cap to hold the pile in alignment with the axis of the hammer. The grooves or tabs for driving H-pile, or sheet pile, must be a minimum dimension of three inches. The cap required for driving pipe pile must have an insert into the top of the pipe a minimum of six inches. The depths are different because pipe pile are only manufactured using 36ksi steel, much weaker than the 50ksi H-pile, and the six inch requirement offers additional alignment accuracy while driving. If a pipe pile were misaligned and struck with the hammer causing damage at the top of the pipe, the Contractor would have a very difficult time squaring the top of the pipe in the field.

Pipe pile inserts typically have several stepped cylinders to allow one cap to be used to drive several sizes of pipe. The Pipe Pile detail in Figure 4, the insert would be acceptable to drive pipe pile varying in size from a 14” diameter down to a 10” diameter pipe. In accordance with the current specifications a minimum of 6" (2 stepped 3" cylinders) must be inside the pipe pile during driving operations.
The weight of the helmet is not included in the weight of the striking part of the hammer (W). The helmet weight <u>is included</u> in the cap or anvil weight calculation (X) in the appropriate pile driving equation.

5.3.4.3 Types of Hammers:

Drop hammer / Gravity hammer – This is the original pile driving hammer. It consists of a steel ram that is guided within a set of leads. The hammer is raised to a certain height and allowed to drop on top of the pile, thus producing the driving reaction. This type of hammer is most often used for driving falsework pile, but sometimes it is used for driving production pile, especially shorter piling. It has the disadvantage of slow operation and ram velocity. If a drop hammer is used for production pile, it is generally necessary to provide a steel cap and shock block over the pile during the driving.

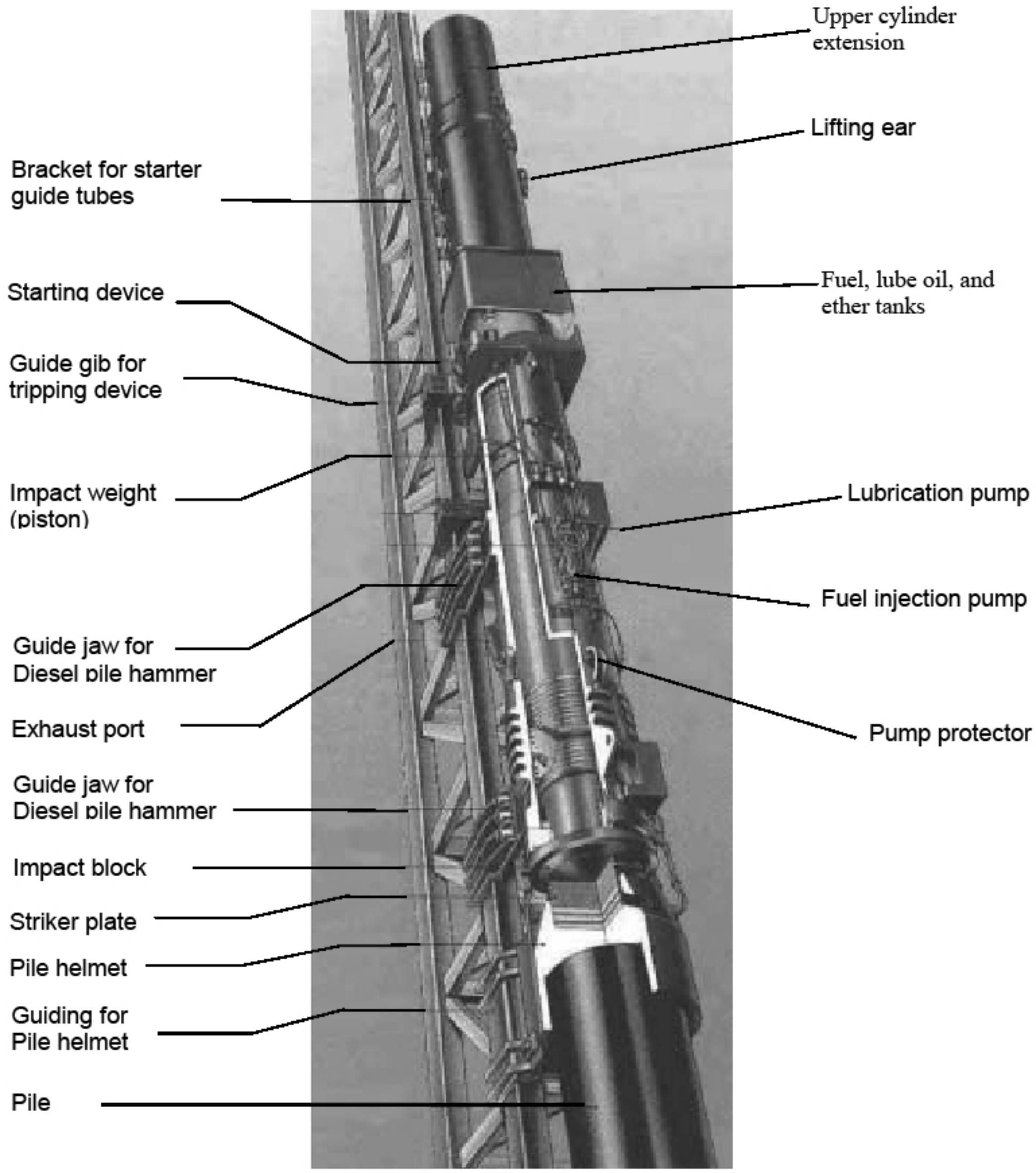
For timber piles the hammer weight shall not be less than 2000 lbs, and preferably not less than 3500 lbs, and the drop will not exceed 12’. When the contractor wants to use a gravity hammer on steel and concrete piling, the hammer must weigh at least 3500 lbs and the drop still must not exceed 12’. In no case will the hammer weigh less than the pile plus the cap. In addition, the falling weight must move within a guide.

The energy provided by a drop hammer is simply calculated by multiplying the weight of the ram by its vertical drop.

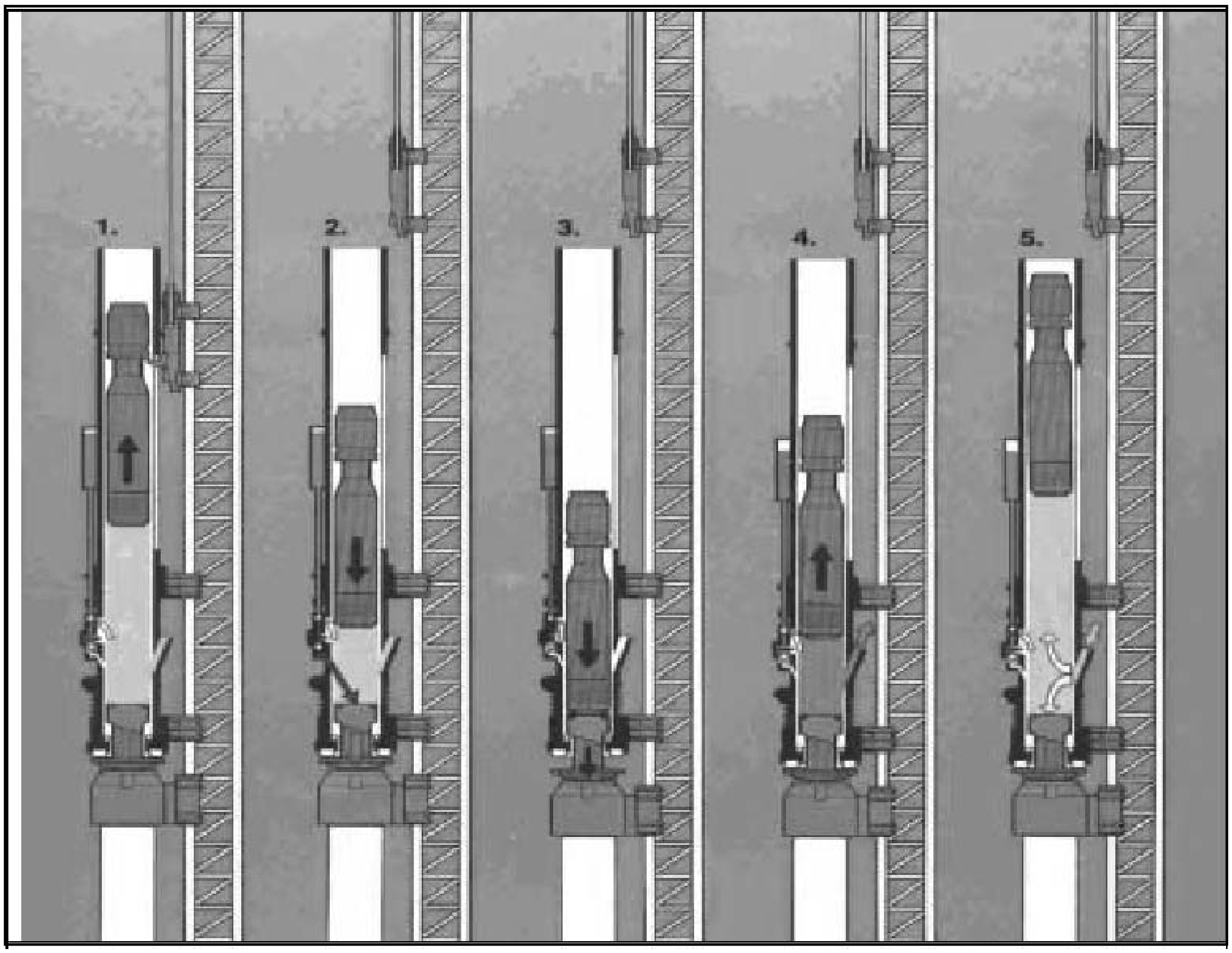
Single acting power driven hammer – Hammers of this type are basically power gravity hammers. The difference between a gravity hammer and a single acting power hammer is that the ram (striking part) is encased in a steel frame work and is raised by steam or compressed air rather than by the crane load lines. The frequency of the blows is also considerably higher than a drop hammer. The ram mass is usually greater than a drop hammer and the vertical travel is usually less than that of a drop hammer. Any type of power hammer is usually more efficient than a drop hammer because there is less time between blows for the soil to set up around the pile. A typical hammer of this type utilizes a ram weight of 5000 lbs with a 3 ft drop. It is adequate for most pile less than 70 feet in length. The energy of this type of hammer is calculated exactly like the drop hammer.

Double Acting Power Driven Hammer – The ram is raised by steam or compressed air, as in the case of the single acting power hammer. When the ram approaches the top of its stroke a valve is opened into a chamber at the top of the cylinder allowing high pressure air or steam into the cylinder forcing the ram downward. Some double acting hammers utilize a light ram, operating at a high frequency, to develop the energy blows comparable to those developed by heavier, slower acting hammers. The advantage of the lighter ram hammer is that there is less time between blows for soil to re-settle against the pile, thus increasing the driving efficiency and decreasing the drive time. The energy is generally related to frequency and is obtained by referring to the manufacturer’s specifications. The manufacturer's rating is a maximum rating and is probably never obtained in the field. Therefore, KDOT specifications require a 20 percent reduction in rated energy for bearing computation.

Diesel Power Driven Hammers – Single acting diesel hammers are probably the most common type found on bridge projects in Kansas. They are simply a one cylinder diesel engine consisting of a steel cylinder containing a ram and an anvil. The ram is raised initially by an outside power source (crane) and dropped. As the ram drops, it activates a fuel pump, which injects fuel into a cup in the top of the anvil. The ram continues down blocking the exhaust ports and compressing the air in the combustion chamber. A ball on the end of the ram, mating closely with the cup in the anvil, forces the fuel into the hot compressed air between the ram and the anvil. The fuel then explodes forcing the ram up and forcing the anvil, and in turn, the pile down. Three common diesel hammers are: Delmag, M.K.T. and Link Belt. The Delmag and M.K.T. are single acting hammers, operating as described above. Link Belt hammers are double acting. Double acting hammers operate in the same way as a single acting hammer except that there is a chamber at the top of the cylinder which provides a cushion of air which is compressed as the ram moves upward. As the ram reaches the top of its stroke the pressure in the chamber provides force in addition to gravity to the ram for the downward stroke. The most noticeable difference between a single acting hammer and a double acting hammer is the frequency of the blows. The double acting hammer will operate at about twice the frequency of the single acting.



Vibratory and Sonic Power Driven Hammers **–** These are the most recent developments in pile hammer technology. They are comparatively heavy, requiring handling equipment of greater capacity than required for conventional pile hammers. The Vibratory Hammer vibrates the pile at frequencies and amplitudes which tend to break the bond between the pile surface and the adjacent soils, thus delivering more of the developed energy to the tip of the pile. The Sonic Hammer operates at a higher frequency than the vibratory hammer, usually 80 to 150 cycles per second. At this frequency, the pile changes minutely in cross sectional dimension and length with each cycle, thus enlarging the cavity then elongating the pile. The matter of determining the pile bearing values for these hammers is a problem. Often the vibratory hammer is used to position the pile to plan tip elevation, then a diesel hammer is used to drive the pile to plan bearing.



1. Raising the piston (starting). For starting the diesel hammer, the piston (ram) is raised by means of a mechanical tripping device and is automatically released at a given height.

2. Injection of diesel fuel and compression. As the piston falls through the cylinders, it activates a lever on the back of the fuel pump, which injects a measured amount of diesel fuel on to the top of the impact block. Shortly after this, the exhaust ports are closed.

3. Impact and atomization. Compressing all the air /fuel between the exhaust ports and the top of the impact block, the piston continues falling until it strikes the top of the impact block. The heat generated by the compression of air, in the presence of atomized fuel, causes the explosion of the fuel, throwing the piston upward and forcing the impact block downward against the pile.

4. Exhaust. While moving upwards, the piston will pass and open the exhaust ports. Exhaust gases will escape and the pressure in the cylinder will equalize.

5. Scavenging. The piston continues its upward momentum, which draws in fresh air for the next cycle, cools the cylinders, and releases the pump lever. The pump lever returns to its starting position, so that the pump will again be charged with fuel. Gravity stops the upward motion of the piston and it starts falling through the cylinders once again.

5.3.4.4 Power for Hammers:

Except for self-contained power source hammers, such as diesels, vibratory and sonic hammers, an outside power source is required for power-driven hammers. Years ago, steam was the primary outside power source, but currently air compressors are the most common source of power. Regardless of source, adequate power must be supplied if hammers are to function properly. Insufficient power will result in a hammer that operates at something less than specified stroke or frequency.

5.3.4.5 Diesel Hammer Terminology:

Energy Range:
The potential energy for single acting hammer is the product of ram weight and stroke; whereas, for double acting hammers, the force resulting from "bounce chamber pressure” is added to the gravitational component. Some manufacturers may include the effects of the explosive force to the hammer potential energy.
For inclined pile driving, only the vertical component of the stroke should be used in computing hammer potential energy.

Example: Energy is 75,230 ft-lbs, batter is 3:12.

Energy Vertical Component = 75,230 * = 70,073

Model:
This is the model name designation given by the manufacturer to each hammer. Usually, it provides some description of the hammer (e.g., Delmag D30 hammer has a ram weight of 6600 lbs).

Manufacturer:
The name of the manufacturing company.

Type:
Single acting hammers are open ended at the top while double acting hammers are closed ended. Single acting hammers allow the ram to travel outside the cylinder which makes it visible for inspection of the stroke. Double acting hammers utilize a bounce chamber for increasing the hammer rate of operation. The ram is not visible in a double acting hammer.

Blows per Minute:
Number of strokes per minute. For single acting hammers, the rate can be empirically correlated to the stroke. The hammer rate depends on many factors including but not limited to, the hammer, the type and length of pile, as well as soil conditions. The height of the stroke of a **single acting** diesel hammer can be computed from the following equation: $H = 0.04 * t^2$. Where H is the height of the stroke in ft., and t is the length of time in seconds to record 10 strokes.

Weight of Striking Part:
This is the weight of the part of the hammer that actually impacts the pile. This is commonly known as the "ram or piston". Hammer rated energy and general effectiveness is a direct function of the weight of its striking part. In some cases, this weight is indicated as part of the hammer model designation.

Total Weight:
This is the total weight of the hammer. This value is important in sizing the crane, transportation requirements and other aspects involving the hammer.

Hammer Length:
This is the total length of the hammer in its normal operating configuration. This excludes any accessories which may be present between the hammer and the pile head.

Maximum Stroke:
Maximum attainable stroke. Values obtained under favorable controlled conditions. Strokes under common field conditions vary depending on hammer mechanical condition, cushion and pile elastic effects, soil resistance and general hammer-cushion-pile-soil dynamic compatibility.

Jaw Dimensions:
Dimensions of the hammer guides which interface with the leads. All diesel hammers have "female" type jaws and most have provisions for changeable guides.

Fuel Consumption:
This is the amount of fuel (diesel) per hour that a hammer might consume. Actual amount is subject to operating variations. For proper hammer function, the appropriate type of fuel must be used.

Ram (Piston):
This is the internal mass that moves up and down in the cylinder. The ram masses for different hammers are given in the appendix at the end of this chapter.

Helmets (driving caps or anvil blocks) for steel piling:
These are provided for use with standard bases when driving sheet pile or H-pile. The upper ring is filled with a cushion material.

Cushion Material:
Cushions soften the sharp blow of the hammer and distribute the load evenly.

Follower:
Followers are placed between the top of the pile and the hammer when it is necessary to drive the head of pile below the reach of the hammer. Using followers introduces an additional uncertainty to the dynamic pile equations. Followers should not be used without permission from the District Engineer.

5.3.5 KDOT Specifications for Hammer Sizes:

Section 151.30

(a) Hammers for Timber Piles.
Gravity hammers for driving timber piles shall have a mass not less than 2,000 lbs and preferably not less than 3,500 lbs. The fall shall be so regulated as to avoid injury to the piles, and in no case shall exceed 12 feet. When a steam or diesel hammer is used the total energy developed by the hammer shall be not less than 6,000 foot-pounds per blow.

(b) Hammers for Steel Piles, Steel Sheet Piles, and Shells for Cast-in-Place Concrete Piles.
Gravity hammers for driving steel piles, steel sheet piles and shell piles shall have a mass not less than 3,500 lbs. In no case shall the gravity hammer weigh less than the pile being driven plus the weight of the driving cap. All gravity hammers shall be equipped with hammer guides to ensure concentric impact on the drive head or pile cushion. The fall shall be so regulated as to avoid injury to the piles and in no case shall exceed 12 feet. Steam hammers or diesel hammers for driving steel piles, steel sheet piles, and shells for cast-in-place concrete piles shall be of such size that the rated gross energy of the hammer in foot-pounds shall be not less than 2½ times the weight of the pile in pounds. In no case shall the hammer develop less than 6,000 foot-pounds per blow.

Contractor certified weights may be used for the weight of gravity hammers.

(c) Hammers for Prestressed Concrete Piles.
Unless otherwise provided, prestressed concrete piles shall be driven with a diesel, steam or air hammer which shall develop an energy per blow at each full stroke of the piston of not less than one foot-pound for each pound of weight driven. In no case shall the energy developed by the hammer be less than 6,000 foot-pounds per blow.

(d) Vibratory Hammers.
Vibratory hammers may be used only when specifically allowed by the Contract documents or in writing by the Engineer. Vibratory hammers, if permitted, should preferably be used in combination with pile load testing and re-tapping with an impact hammer. In addition, one of every ten piles driven with a vibratory hammer shall be re-tapped with an impact hammer of suitable energy to verify that acceptable load capacity was achieved.

(e) Hammer Cushion.
All impact pile driving equipment except gravity hammers shall be equipped with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile and to insure uniform driving behavior. Hammer cushions shall be made of durable, manufactured material, which will retain uniform properties during driving. ***Except for use with a gravity hammer, all***

wood, wire rope, and asbestos hammer cushions are specifically disallowed and shall not be used. A striking plate shall be placed on the hammer cushion to insure uniform compression of the cushion material. The hammer cushion shall be inspected in the presence of the Engineer when beginning pile driving at each substructure element or after each 100 hours of pile driving, whichever is less. Whenever there is a reduction of hammer cushion thickness exceeding 25 percent of the original thickness, the hammer cushion shall be replaced by the Contractor before driving is permitted to continue.

The following are acceptable types of hammer cushion material. If the contractor proposes a material type that is not included in this list, contact the Bureau of Materials and Research.

Micarta (Conbest) – This is an electrical insulating material composed of fabric and phenol. It must be replaced when it begins to disintegrate or when it delaminates into various layers.

Nylon (Blue or other colors) – This material comes in 2" thick blocks. Occasional vertical cracking is not detrimental. However, after the cushion develops horizontal cracks, it should be replaced.

Hamortex – This material consists of metallized paper reels. It has good engineering properties but needs attention as it may compress or disintegrate.

Force 10, Forbon, and Fosterlon – These materials are provided by manufacturers of pile driving equipment.

Aluminum – Aluminum is often used to separate layers of softer cushioning material. The aluminum does no cushioning itself; however, it is thought to extract the heat from the cushion stack. Once the aluminum is deformed or broken, it should be replaced.

NOTE: Wood (plywood or hardwood) will probably remain the most common type of material used as a pile cushion for gravity hammers.

5.3.6 Pile Driving Mechanics:

The length of stroke or fall of the hammer ram is a factor that influences the energy delivered by the hammer. As mentioned above, for a single-acting hammer,

Energy = (weight of ram) X (height of fall)

The weight of the ram is an important factor, since a heavy-ram impact hammer working on a short stroke is more effective in driving a pile than a light-ram long-stroke hammer. The weight of the ram, the length and speed of the stroke, and their relation to the weight of the pile is important to the proper driving of the pile. In theory, a pile can be of such a length that all the energy, which it receives from a hammer blow, is absorbed into its mass. Under these circumstances, a blow of the hammer will not advance the point of the pile. To appreciate this statement, it is necessary to understand what happens when the hammer hits the pile.

A hammer blow causes the pile to compress and rebound. This compression and rebound travels through the pile from the head down to the tip in the form of a wave, thus driving the pile into the ground. As the wave travels through the pile, energy is lost. In a short pile, this effect is negligible and can be disregarded. In a long pile, the energy losses due to the temporary compression of the pile can be considerable. Using an undersized hammer results in a driving resistance which is higher than the actual resistance, and thus a lower bearing capacity. For this reason, it is absolutely necessary that heavy-ram hammers be used in the driving of long piles.

The size of the ram should be gauged for the work that has to be done. A heavy-ram slow-acting hammer is more effective than a light-ram fast-acting hammer in driving a pile of a given weight, even though the two hammers may have the same rated energy per blow. The heavier-ram hammer will drive the pile deeper with each blow and will produce a more accurate bearing value than the equally rated lighter-ram hammer. As a general rule, pile driving should employ the heaviest-ram hammer that will not damage the pile. If the ram weight exceeds twice the pile weight, the pile material should be checked for resistance to impact.

5.3.6.1 Reviewing the Information on the Plans:

Type of pile: Called out on the General Notes Sheet in a box under the Summary of Quantities (example: Use only HP10x42). This designation identifies the pile to be used as an H-Pile, with 10 indicating the long dimension of the web is 10 inches, and the pile has a weight of 42 pounds per linear foot.

Pile Length: Called out on the General Notes Sheet, Construction Layout and Geology Sheet (example: 9 @ 40’-0”). This notifies the inspector there should be 9 pile at least 40 feet long used in the substructure element.

Pile Location: Geology Sheet Plan View

Pile Orientation: This locates the direction of the web (example: strong axis or weak axis)

Pile Batter: This is the slope of the pile as driven (example: 3/12 = 3” horizontal per 12” vertical.). Unless shown otherwise on the plans, pile shall be driven plumb.

Design Pile Load: This is the load the bridge designer and checker agreed upon based on all combination of live load, dead load, wind, water etc.

Allowable Pile Load: Found in the general notes, this is the minimum required driving resistance to be accepted by the Engineer. The maximum driving resistance allowed will also be shown within this note.

Depth of Pile: The General Notes Sheet will include a note directing the Contractor to drive the pile to penetrate or bear upon a specified formation. Or, the note will direct the contractor to drive to a specified depth and resistance. The Geology sheets will show the formations and their approximate elevations
The tip elevation is not called out explicitly, but may be estimated from the top of pile elevation and the length of pile specified on the geology sheet.

Pre-Drill: The bid item **"**Pre-Drilled Pile Holes**"** will appear in the Summary of Quantities and the depth of pre-drill will be in the general notes.

Cut-off elevation (top of pile): This elevation is shown on the Construction Layout in the profile view. This locates the top of the pile within the pile cap, abutment or pile bent. Usually, the embedment is between 2 feet to 3 feet in an abutment; one foot (1'-0") in a footing.

5.3.6.2 Preparing to Drive Pile

The inspector should check to see if the Contractor's choice of hammer will provide enough energy to drive the pile to bearing. To do this the inspector needs the hammer specifications. For steel pile to achieve bearing, assume required resistance to be reached at 10 blows per inch. Use this number when checking the adequacy of the hammer. Here is an example of checking the Contractor's hammer.

Example:

Given: **Diesel Hammer Delmag D12**
1 inch per 10 blows, therefore S = 0.1 in./blow
(Assumption based on previous experience)
From Pile Hammer Specifications:
Piston weight = W = 2750 lbs
Max Height of fall = H = 8.17 ft
Weight of pile cap and/or anvil = 2690 Lbs.
(Contractor provides this information)

Weight of Pile (HP10x42, length=40 ft.) = (42 lbs/ft.)(40 ft.) = 1680 lbs.
X = Weight of Pile + Weight of pile cap and/or anvil = 4370 lbs.
P = bearing load = 112,000 lbs (according to general notes in plans)

Analysis: $P = \frac{1.6\ W\ H}{\left(S + 0.1\left(\frac{X}{W}\right)\right)}$ **Delmag hammer equation, Division 700, Section 704**

Note: the quantity (X/W) shall not be taken less than 1.0.
X/W = 4370/2750 = 1.589
P must be at least 112,000 lbs. and not greater than 110% (2009 General Notes Revision) of 112,000 lbs.

P = (1.6(2750)(8.17))/(0.1+0.1(1.589)) = 138,849 lbs.
112,000 < 123200 < 138,849 Hammer is O.K.
Use caution as the hammer is capable of overdriving the pile.

The Contractor's hammer has been checked. The Engineer should now calculate the actual average penetration per blow for the last 20 blows of the hammer. Below is an example.

Given: **Solve the equation for S given the previous information.**

Analysis: $$P = \frac{1.6\ W\ H}{\left(S + 0.1\left(\frac{X}{W}\right)\right)}$$

Rearrange and solve the equation for S: $S = \left(\frac{1.6\ W\ H}{P}\right) - 0.1\left(\frac{X}{W}\right)$

Note: the quantity (X/W) shall not be taken less than 1.0.
X/W = 4370/2750 = 1.589

S = (1.6(2750)(8.17))/112,000) - 0.1(1.589))
S = 0.16 in/blow
So, for the last 20 blows the pile should move (0.16/blow)(20 blows) = 3.2 in.
If the pile is driven further than 3.2 inches for the last 20 blows then the pile is NOT to bearing yet, and driving must continue.

An important note to remember, the Contractor is not allowed to modify his hammer in the field by making the fall height greater in order to achieve more energy. If the Engineer finds the hammer is inadequate the Contractor must use a **heavier** hammer.

The Engineer should mark the pile which is to be continuously logged every 12 inches. Continuous logging will be discussed later in this section.

5.3.6.3 During the Drive

Figure 5 Plumbing an H-Pile

After the Contractor has the pile “stabbed” and is preparing to drive the pile, make sure the pile is plumb, or battered as shown on the plans (see the photo above). The Standard Specifications require that piles be driven within 1/4 inch per foot of length to the vertical or battered lines indicated on the plans, except that foundation piles more than 3.5 feet long or any piles used in bents shall be driven to within 1/8 inch per foot of length to the vertical or battered lines indicated on the plans. Orient the pile as shown in the plan sheets. Effective for letting from July 2013, a maximum rotation of 10 degrees from plan orientation of the pile is allowed by specifications. The maximum variation on the head of the pile after driving from the position shown on the plans shall be 2" for piles used in bents and 6" for other foundation piles. Bents are rows of pile, for instance in a pier, or an abutment. Misaligned piles shall not be forced into position. It is for this reason that it is so important to position the pile and leads correctly at the beginning of driving operations.

The rotation of a pile can be measured easily by use of a string line. The string line should be placed over the center line or offset parallel to the center line of the foundation being built. Measure the distance from the string line to the two flange tips of each individual pile; for each individual pile subtract the smaller measured distance from the larger measured distance of the flange tips to the string line. The subtraction of the smaller from the larger distance of the flange tip to string line measurement establishes the difference. Once the difference has been calculated for each pile acceptance or rejection of the pile maybe established by looking in the table below. If the difference you have calculated for any pile in the foundation is greater than the maximum allowable difference in the table, that pile is not acceptable and can be rejected. The contractor will then have to propose a solution that is acceptable to the field engineer and the State Bridge Office. (Figure 6 demonstrates the use of a string line for making measurements in the field.)

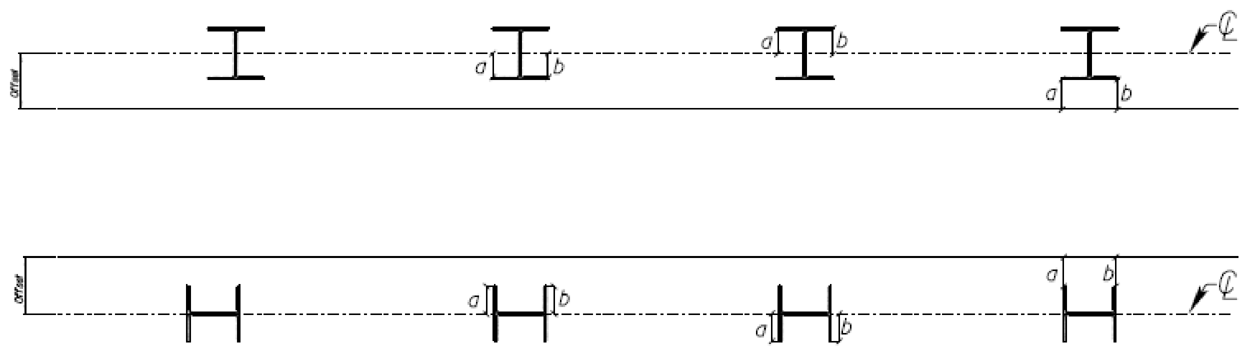
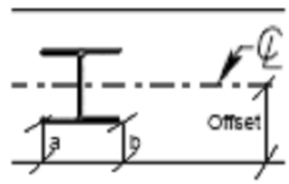


Figure 6 Measuring Rotation of a Pile

Weak Axis Orientation		
Pile Size	Depth (inches)	Maximum Allowable Difference (a-b) (inches)
HP 14x117	14.2	2 7/16
HP 14x102	14	2 7/16
HP 14x89	13.8	2 3/8
HP 14x73	13.6	2 3/8
HP 12x84	12.3	2 1/8
HP 12x74	12.1	2 1/8
HP 12x63	11.9	2 1/16
HP 12x53	11.8	2 1/16
HP 10x57	9.99	1 3/4
HP 10x42	9.7	1 11/16
HP 8x36	8.02	1 3/8

Table 1 for Rotated Pile

Strong Axis Orientation



Pile Size	Flange Width (inches)	Maximum Allowable Difference (a-b) (inches)
HP 14x117	14.9	2 9/16
HP 14x102	14.8	2 9/16
HP 14x89	14.7	2 9/16
HP 14x73	14.6	2 9/16
HP 12x84	12.3	2 1/8
HP 12x74	12.2	2 1/8
HP 12x63	12.1	2 1/8
HP 12x53	12	2 1/16
HP 10x57	10.2	1 3/4
HP 10x42	10.1	1 3/4
HP 8x36	8.15	1 7/16

Table 2 for Rotated Pile

Plumbing the leads prior to driving:

If the pile is to be continuously logged the Engineer must log the number of blows per 1 foot of penetration. There are two ways to keep track of the continuous log of driving. The Engineer can observe the 1 foot marks painted on the pile as they are driven below ground, and count how many blows are required to drive the pile from one mark to the next. It is important that the Engineer stand in the same place during the entire drive as to keep the same perspective on the pile marks as they enter the ground.

The second way of keeping track of continuous log of driving is to use a theodolite. The Engineer should set the cross-hairs of the instrument close to the ground level. The Engineer observes through the instrument as driving proceeds and counts the number of blows between the marks on the pile as described above. As the pile nears the plan formation or plan length, the Engineer must monitor the items required to calculate bearing; namely, the average penetration “S” for the last 20 blows (5 for gravity hammers), the length of stroke for single acting hammers and bounce chamber pressure for double acting hammers.

"S" is calculated as follows: A four foot level or straight edge is leaned against the pile during driving, and the pile is marked at the top of the level or straight edge. Then the level is moved away while keeping the bottom end in position. After 20 blows the level is leaned back against the pile and the pile is marked again. The distance between the marks is measured and then divided by the number of blows to give the average penetration per blow.

Figure 7 Mark pile as Driving Continues

Figure 8 Mark After Specified Blows

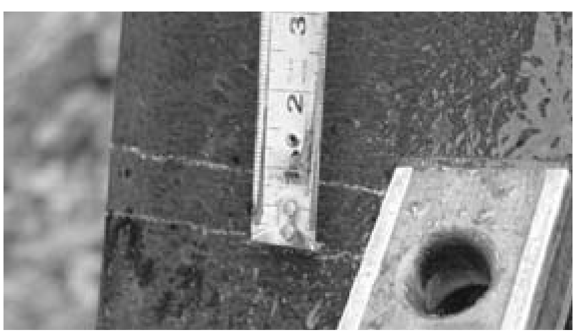


Figure 9 Measure Displacement

Figure 10 Continue Driving Until Bearing

The length of stroke for a single acting hammer can be monitored two different ways. The simplest way is to visually note the top of the hammer at the top of the stroke in relation to some premeasured reference. The reference is usually a 2x4 attached to the hammer and marked in relation to the top of the hammer at rest. Another way is to compute the theoretical stroke length based on the time required for a number of blows. This will only work on a warmed up hammer hitting with a consistent rhythm. The length of stroke can be calculated from the following equation:

H = 0.04 x t^2 Where H is in feet and t is the length of time in seconds to record 10 blows

When the length of stroke / height of fall is known and an average penetration is known, these values are used to compute a bearing resistance as in the example above.
Some time can be saved by programming a calculator so the average penetration and stroke length are input and the bearing resistance is calculated. Once the required bearing is achieved, the Engineer approves the pile and the Contractor may move on to the next pile in the group.

5.3.7 Pile Restrike

Drive end-bearing pile, such as HP10x42, until they reach the penetration and bearing value shown on the plans. During driving, the pile will essentially stop penetrating. Driving will stop when the resistance calculated by the pile driving formula is between 100% and 110% of the allowable pile load shown on the plans. If 110% of the resistance calculated using the correct pile driving formula is reached before the plan penetration occurs by two feet or more, contact the regional geologist

Drive friction piles, such as concrete-filled pipe piles and sometimes H-pile, until they attain the resistance shown on the plans. Resistance is built up gradually as the pile is driven, and the additional depth that each hammer blow drives the pile is fairly uniform. For example, over 10 hammer blows, the pile may be driven 3 inches per blow, 30 inches for those 10 blows. If 110% (2009 General Notes Revision) of the resistance calculated using the correct pile driving formula is reached before the plan tip elevation occurs by two feet or more contact the regional geologist.

There are cases where friction piling will not achieve adequate resistance near the formation or driven length specified in the plans, and splicing would be needed to meet the capacity requirements. Rather than splicing additional pile length in these cases, it is possible to let the soil set-up for at least 24 hours. Striking the piling with a warmed up hammer after this 24 hour period may show improved driving resistance. This procedure is called “restrike”. Using a “restrike” test may save considerable pile length. When planning a restrike procedure, contact the regional geology office to see if a PDA is necessary to monitor the pile during driving.

The restrike procedure cannot be used in all pile driving situations. Depending on soil conditions, performing the restrike procedure may not lead to enough of a gain in driving resistance to prevent the need for splicing and further driving. In some soils, relaxation can occur, which would lead to a loss in driving resistance, although this is rare in Kansas. Using restrike on friction piling in a potential scour area requires weighing many factors. Do not use restrike to reach penetration before the plan length has been driven. The length of pile below a scour line must be sufficient to support the structure if the material above the scour line is lost. Contact the regional geology office and State Bridge Office before using restrike.

The term “test pile” in the following procedure may refer to a production pile or the “Test Pile” and “Test Pile (Special)” bid items discussed in Section 5.3.2. The restrike procedure is as follows:

- All but the test pile are driven to within two feet of the plan elevation. It is recommended that the test pile be an exterior pile. All pile driving on the test pile bent should cease a minimum of 24 hours prior to the test or as directed by the regional geologist.

- If a PDA is used, drive the test pile to within 6’ to 7’ of the plan elevation in order to allow room for the PDA attachments.
- All of the piling should be allowed to sit undisturbed for at least 24 hours.

- Prior to starting the restrike procedure, warm the hammer up to operating temperature at a location as far away from the pile group as practical, such as on a dummy block, a different pile bent, or an opposing exterior pile. Do not warm-up the hammer on a pile in the bent to be tested, without the approval of the regional geologist.

- The test pile is then immediately restruck with the warmed-up hammer for 30 blows or until the piles penetrate an additional 4”, whichever comes first.

The bearing capacity is computed based on the penetration of the first 5 to 10 blows. The penetration used in the bearing formula is the penetration for 5 blows multiplied by 4, or the penetration for 10 blows multiplied by 2. It is important that the first 5 to 10 blows are used to calculate the bearing capacity; because, by the time 20-30 blows are reached, the soil has been disturbed and set-up is negated. The resistance is then essentially the same as before the restrike.

If the first 5 to 10 blows indicate that the bearing resistance has been reached, no further driving is necessary for the test pile and the remaining pile in the bent can be driven to the pile tip elevation determined from the test results or as directed by the regional geologist. If the bearing resistance has not been reached, driving should resume, which may require additional pile length. If the calculated bearing capacity is within 5% of the required bearing capacity, the piling must again be left undisturbed for an additional 24 hours before the restrike procedure can be performed again.

It is important that all pile restrikes be performed with a hammer that is warmed-up and operating efficiently before being used to restrike the test pile. Equally important is that no driving is done near the test pile during the set-up period, which would disturb the surrounding soil and negate the test results.

Payment for the piling installed will depend on the bid items. The restrike procedure may be initiated by the Contractor or by the Engineer. The regional geology office’s recommendation to proceed is required. The restrike procedure is an option to meet the design intent and no additional payment is made for the procedure. Payment is for in-place piling as per specification.

If the “Test Pile (Special)” item is on the plans, the piling recommendations must come from the PDA results.

<u>Hammer Performance</u>

Hammer performance is important in determining bearing resistance in that, if the hammer is not performing properly the bearing resistance can not be computed accurately. Following are some possible problems and indicators of those problems.

Pre-ignition means that the fuel combusts before impact occurs. Thus, pre-ignition reduces the ram impact velocity and cushions the impact. When a hammer pre-ignites, the full ram energy is not transmitted to the pile, but rather returned to the ram, causing the stroke to be very high. The low energy in the pile results in a high blow count. Pre-ignition, therefore, has all the symptoms of a hard driving condition at a potentially low soil resistance. Overheated hammers often pre-ignites after long periods of hard driving when lubrication oil starts to burn or fuel vaporizes prematurely due to heat.

The following are signs of pre-ignition in hard driving:

- Black smoke while strokes are high.
- Flames in exhaust ports.
- Blistering paint (due to excessive heat).
- No obvious metal to metal impact sound.

If pre-ignition is suspected, then the hammer should be stopped, allowed to cool down for an hour, and then restarted. Stroke and blow count should then be accurately monitored. If both stroke and blow counts are lower during the first two minutes after the resumption of driving, then proof exists of a pre-ignition condition before the cooling period was established.

Most atomized fuel injection hammers have some design pre-ignition. The fuel usually starts to burn when the ram is a small distance above the impact block. If the ram descends slowly, the pressure has more time to act on the ram than in the case of a high stroke, when the ram reaches the impact block within a short time. Thus, in hard driving, with high strokes and, therefore, high ram velocities, "design pre-ignition" is of little consequence.

Water in the fuel will cause the exhaust to be white and the impact of the hammer will sound hollow.

Clogged fuel lines will cause little or no exhaust smoke.

A malfunctioning fuel pump is indicated by inconsistent ram strokes and gray or black exhaust smoke.

A malfunctioning fuel injector is indicated by inconsistent ram strokes and gray or black exhaust smoke.

Low lubricating oil is indicated by lower than normal blows per minute.

A malfunctioning oil pump is indicated by lower than normal blows per minute.

Water in the combustion chamber is indicated by white exhaust smoke and hollow sounding impacts.

Worn piston rings are indicated by short strokes. When the pile is near the required resistance the hammer stroke should be near the maximum published height.

Overheating is indicated as above in the pre-ignition section.

5.3.8 Log of Pile Driving

Log of Continuous Pile Driving:

A Continuous Pile Driving Record should be recorded for a representative pile on each abutment and pier footing on a structure. The record should be inclusive from the beginning of the drive to the final bearing of the pile. For structures under 755 feet in length, the above information will be required on two footings only. One of the piles should be in an abutment footing and the other in a pier footing near the opposite end of the structure. If the structure has no piling in the pier footings, then the record should be made for a pile in each abutment footing.

For structures over 755 feet in length, the continuous record stipulated above will be required on three footings, one on an abutment and two on pier footings. If the piers have no piling then the information will be recorded on one pile from each abutment.

The log of Continuous Pile Driving records are the same as records obtained for structures that have the bid item of test piles, and will, therefore, not need to be recorded in cases where structures include the bid item of test piles.

The State bridge Office plots the pile driving log on the Geology Sheet of the as-built plans for historical purposes.

FORM 217 – LOG OF PILE DRIVING
The form shown below can be found in the KDOT forms warehouse:
(English Version): http://www.ksdot.org/burdesign/bridge/constructionmanual/217us.xls

1. FORM POLICY: Complete and submit this report as soon as all piling is driven in an abutment or pier. Also, complete and submit this report for all test piling immediately after driving each test pile.

2. PREPARING REPORT:

A. General Information:

1. "Type of Hammer" – Enter the brand and model of the hammer used.
2. "Hammer Weight" – Enter the weight of the striking part of the hammer (i.e. piston or ram) as denoted on the specification plate on the hammer or in Figure IV-1 of the Construction Manual (4.03.08).

3. "Cap and/or Anvil Weight" - Enter the weight of any cap and/or anvil to be used while driving pile.
4. "Energy Rating (ft-lbs)" - Enter the energy rating as denoted on the specifications plate on the hammer, or in Figure IV-1 of the Construction Manual (4.03.08). Also, note the 80% factor in the Standard Specifications (704.04(e)).
5. "County" and "Project" – Enter the name of the county. Enter the project number, if available.
6. "Br. No. and/or Sta." - Enter the bridge number of the structure for which the piling was driven. Also, enter the station for the structure, **not** the station for the pier or abutment where the pile was driven. For city or county structures that don't have a bridge number, the station of the structure is sufficient.
7. "Type of Pile" – Enter the entire bid item name for the type of piling used. Examples: PILE (STEEL) (HP10X42), TEST PILE (STEEL) (HP12X57), PILE (PRESTRESSED CONCRETE) (12 in.) or TEST PILE (SPECIAL) (HP10X42).
8. "Plan Note Overdrive %" – A drop down menu will allow the user to select 110 or 150 to determine the maximum resistance allowed based upon the "Piling" note within the General Notes for the project.
9. "Min. Resistance Required" - Enter minimum required bearing as specified under the "Piling" note on the plans. This is **not** to be confused with the bearings listed under the Design Data.
10. "Max. Resistance Allowed" - The maximum bearing is now calculated based upon the value listed under the "Piling" note on the plans. This value is now based upon This is **no**t to be confused with the bearings listed under the Design Data.

After filling out the General Information sheet, select the tab associated with the hammer to be used to drive the pile. "Gravity (Steel)," "Air-Steam (Single)," "Air-Steam (Double)," "Delmag & McKierman – Terry," "Link-Belt" tabs are the hammer types available. Many comments are available all across the new form, and can be read by placing the cursor over the cell with the red triangle in the upper right corner of the cell.

1. "Abutment" **or** "Pier" - Enter the number, taken directly from the design plans, for the abutment or pier where the pile will be driven.
2. "Number, Individual Length, and Total Length of Pile" – Enter the total number of pile in the substructure unit (abutment beam, pier footing, pier bent, etc.), then enter an "@" symbol, the total length of one pile, and the sum of all pile in the unit. (8 @ 45 = 360 ft.)
3. "Plan Cutoff Elev. (ft.)" – Enter the Top of Pile elevation given on the plans for the substructure unit.
4. "Wt. per foot piling (lbs/ft)" – This data can be found in different locations for different types of pile.
    a. For H-pile, physical properties are in the name. Such as with HP12X53, the 12 represents the long dimension of the web in inches, and the 53 represents the weight per linear foot.
    b. For steel shell pile, the weight per meter can be found on mill test/lading ticket from the supplier. If that information is not available, some physical properties for steel shell pile are shown in Table 1 at the back of this document.

c. For pre-stressed concrete pile, if the weight per foot is not given on the test report, the inspector can use a density of **150lbs/ft^3** to calculate a theoretical weight per foot:

i. 12 inches square – 150 lbs/ft^3

ii. 14 inches square – 204 lbs/ft^3

iii. 16 inches octagonal – 220 lbs/ft^3

5. “Type of Cushion Mat’l” – Plywood, oak, whatever material will be used to protect the top of the pile.
6. “Footing Sketch” – Draw a sketch of the footing with piles numbered to represent the numbers listed in the “Pile No.” column of this form. The north arrow must be shown.

B. **Driving Information**: Measure and report piling length to the nearest one-hundredth of a foot (i.e. 0.01 ft.). Report all elevations to the nearest one-hundredth of a foot (i.e. 0.01 ft.).

1. “Pile No.” – Represents the as labeled in the footing sketch.

1. “Varied Plan Cutoff Elev.” is used if the substructure element is super-elevated and each pile has a distinct pile cutoff elevation. Enter the elevation listed on the plans for each pile so the “Pile Tip Elev.” field calculates correctly.

2. “Actual Length in Leads” – This is the length of pile the Contractor opts to use. This length is used to calculate the weight of the pile for use in the bearing formula, and the length can change as driving operations progress:
   - When driving operations first start, the “Actual Length Placed in Leads” is equal to length of pile placed in the leads. If bearing is not achieved and a splice is required, the **new** value for “Actual Length Placed in Leads” is equal to the original length placed in the leads, **plus** the length of pile spliced on to it.
   - If bearing is achieved prior to splicing the pile and the splice is made solely to achieve plan cutoff elevation, the “Length Placed in Leads” will increase by the amount spliced onto the pile to achieve plan cutoff elevation, and “Ordered and Accepted” will equal the “Length Placed in Leads.” In no case should the “Actual Length in Leads” be less than the “Length Left in Footing” cell.

3. “Ordered and Accepted” – Typically this is the length of pile the Engineer instructs the Contractor to use (i.e. the length of pile indicated on the plans). However, situations do arise where the “Ordered and Accepted” length will differ from the plans:

   - If the length indicated on the plans is too short and additional length is needed to achieve bearing and “Plan Cutoff Elevation”, the Engineer instructs the Contractor how much additional length is to be spliced onto the pile. In which case, the “Ordered and Accepted” length is now equal to the original length on the plans, plus the additional length that the Engineer authorized being spliced.
   - If the Contractor opts to use a longer pile than the Engineer authorized and the additional length, in part or in whole, is needed to achieve bearing and “Plan Cutoff Elevation”, the “Ordered and Accepted” length is equal to the length of pile

left in place. Thus, the "Ordered and Accepted" length and "Length Left in Foundation" are equal.

- If the contract has test piling, the Engineer will determine the "Ordered and Accepted" length from the test pile data.

4. "Spliced after Drive" is used when the contractor drives a length of pile, then splices a section to the top, but does not drive the additional length. The accurate bearing is calculated on the length placed in leads, so do not change this number. If the length spliced onto the pile brings the total to more than the Ordered and Accepted length, the Ordered and Accepted length will be changed accordingly. Cutoff should not be an issue in this situation. The contractor will likely splice on the exact length needed to bring the pile up to cutoff elevation.

5. "Actual Cutoff" – The actual length of pile cutoff after achieving bearing and "Plan Cutoff Elevation."
   - The "Actual Cutoff" is not necessarily equal to "Pay Cutoff."
     - i. If the Contractor elects to use a longer pile than was specified by the Engineer ("Ordered and Accepted"), the length in excess of the length specified by the Engineer is considered "Non Pay Cutoff." (Example: The pile are supposed to be 20 foot sticks, but the Contractor uses a 40 foot stick on the first pile. Actual Cutoff is measured at 23 feet. This would equal 3 feet of "Pay Cutoff" and 20 feet of "Non Pay Cutoff" if this was the only pile to be driven.)
     - ii. The "Actual Cutoff" from one pile may be spliced in part, or in whole, to other pile. In which case, it will become part of the "Ordered and Accepted Length" on the pile receiving the splice. This depends on the length of pile the Engineer directs the Contractor to use. (Example: From above, the Contractor turns around and uses the 23 foot cutoff pile for the next pile. It is driven to bearing and Actual Cutoff is 8 feet, so Pay Cutoff for this pile is 5 feet, and the Non Pay Cutoff is equal to 3 feet. In total, for both pile, the Pay Cutoff sum is 8 feet and the Non Pay Cutoff sum is only equal to 3 feet, since all of the Non Pay Cutoff from the first pile has been used for the second pile. This prevents the State from paying for Cutoff for lengths of pile eventually used in the structure.)

5. "Length Left in Footing" is the **PAY LENGTH**, and is the length of pile left after Actual Cutoff is removed.
   - If no splice is made, or a splice is made to extend the pile to achieve bearing, the "Length Left in Foundation" equals the "Actual Length Placed in Leads", minus the "Actual Cutoff."
   - If a splice is made solely to achieve "Plan Cutoff Elevation" (i.e. bearing is achieved prior to splice), the "Length Left in Foundation" equals the "Ordered and Accepted" length equals the "Actual Length in Leads."

6. “Pay Splices” – Enter the number of Pay Splices occurring for the individual pile. This does not include splices made for the Contractor’s convenience.

7. Length Left in Footing” is the **PAY LENGTH**, and is the length of pile left after Actual Cutoff is removed.

8. “Pile Tip Elev.” **typically** is the “Plan Cutoff Elev.” minus the “Length Left in Footing.” However, if the pile is battered, the batter needs to be taken into account to determine the tip elevation.
9. “Stroke (Drop of Hammer)” is observed by the inspector, and recorded in the appropriate column.

10. “Average Penetration” is equal to the penetration in inches for 20 blows divided by 20 blows.

11. “Computed Bearing Power” – Computed by the inspector immediately upon reaching a predetermined point to establish the actual bearing relationship with plan bearing. Even though laptops are routinely used in the field, an inspector should **thoroughly** understand the bearing formula and how to manually calculate the bearing, before a laptop is used.

12. “Range” – This will indicate where the driving process is for the entered data by displaying “Low,” “OK,” or “High” based on the Min and Max bearing numbers.

13. “Totals” – Automatic totals for each column for “Actual Length Placed in Leads”, “Ordered and Accepted Length”, “Actual Measured Cutoff” and “Length Left in Foundation.”

14. “Accepted Length” – Equals the total from the “Ordered and Accepted” column.

15. “Non Pay Cutoff” – Represents the length of pile in excess of the length specified by the Engineer, and was cutoff. It equals the “Actual Cutoff” column minus “Pay Cutoff” minus the “Non Pay Cutoff used for Splice (Reg)” cell.

16. “Non Pay Cutoff used for Splice” - Is the length of pile that was originally considered as part of the “Non Pay Cutoff”, but was spliced to another pile to achieve “Plan Cutoff Elevation” and/or bearing. A column exists for Reg, for production pile, and Test, for Non Pay Cutoff from a Test Pile. It is important for the inspector to keep track of the amount of Non Pay, or Pay Cutoff used in the structure. KDOT does not want to pay 75% of the contract price for Pay Cutoff, only to have the same pile spliced on and used in the structure to be paid at full contract price.

17. “Pay Cutoff used for Splice” – Is the length of pile that was originally considered as part of the “Pay Cutoff” from one pile, but was spliced to another pile to achieve “Plan Cutoff

Elev." and/or bearing. Since the cutoff was previously considered "Pay Cutoff", deduct it from the "Pay Cutoff" total, so it is **not** paid for as "Pay Length" **and** "Pay Cutoff." Show the deduction on the report for the footing where the cutoff came from. If this report has already been submitted, submit an amended report showing the deduction. (Example: A 6 foot stick of Pay Cutoff pile from Abutment 1 is spliced onto a pile in Pier 2. Go back to the report for Abutment 1 and enter 6 into the "Pay Cutoff used for Splice" cell so the pile does not get paid for as Pay Cutoff on the Abutment 1 report, but all, of a portion of it will get paid for as Pay Length and/or Pay Cutoff on the Pier 2 report.)

18. "Total Cutoff used for Splice" – Equals the "Non Pay Cutoff used for Splice" plus "Pay Cutoff used for Splice."

19. "No. of Pay Splices" – Equals the total number of splices, ordered by the Engineer, to extend the pile beyond the original "Ordered and Accepted Length". Splices made for the Contractor's convenience are not considered pay splices.

20. "Pay Length" – Equals the total from the "Length Left in Footing" column.

21. "Pay Cutoff" – Equals the "Accepted Length" minus the total from the "Length Left in Foundation" column, minus "Pay Cutoff Used for Splice."

22. "Remarks" – Provide a recap of **<u>all</u>** splicing information, and unique information about the pile driving operations:
    a. Indicate if a splice was a pay or non-pay splice (i.e. instructed by the Engineer or the contractor's option.)
    b. Which pile a splice pile came from.
    c. Which pile a splice pile was spliced to.
    d. The length of each splice pile.
    e. Indicate if a splice was made after bearing was achieved.

22. "LOG OF CONTINUOUS PILE DRIVING AND/OR TEST PILE" – Record a continuous pile driving record for a representative pile on each abutment and pier footing on a structure. The record should be inclusive from the beginning of the drive to the final bearing of the pile. Refer to the example below.

    a. "Total Pile Length"- Report the length of pile to be driven into the ground. Once the pile has developed enough resistance to require **at least** 1 blow per foot, begin recording in 1.0 foot increments. In the first "To" cell, if the pile drops 6.75 feet with the first three blows, enter 6.75 in the "To" cell, and enter "3" in the "Number of Blows" cell. If the pile drops 1.5 feet in the next two blows, enter "8.25" in the next "To" cell, and "2" in the next "Number of Blows" cell. At the point the pile requires at least 1 blow per foot, record the one foot increment in the "To" column and record the appropriate number of blows. Also, record the fractional increment just prior to achieving final bearing (i.e. 16.25 – 16.6).

b. "Number of Blows" is the number of blows that were counted while driving the pile each foot (after it has developed the resistance mentioned in (a.) above).

c. "Drop of Hammer" is observed by the inspector, and recorded in this column.

d. "Average Penetration" is the one foot increment divided by the "Number of Blows" for that increment.

e. "Computed Resistance" is the computed bearing after driving each one foot increment.

f. Under the last entry (i.e. fractional increment), record the penetration for the last 20 blows and associated bearing.

Pile No.	Total Pile Length	Length Driven		Number of Blows (Blow Count)	Drop of Hammer (Stroke) (ft.)	Average Penetration (in.)	Computed Resistance (tons)	Computed vs. Specified
		From	To					
A1	18.6	0.00	6.75	3	4.00	27.00	0.4	Low
A1	18.6	6.75	8.25	2	5.00	9.00	1.3	Low
A1	18.6	8.25	9.25	1	6.00	12.00	1.2	Low
A1	18.6	9.25	10.25	2	6.00	6.00	2.4	Low
A1	18.6	10.25	11.25	4	8.00	3.00	6.2	Low
A1	18.6	11.25	12.25	7	8.50	1.71	11.2	Low
A1	18.6	12.25	13.25	21	9.50	0.57	34.0	Low
A1	18.6	13.25	14.25	28	10.00	0.43	45.4	Low
A1	18.6	14.25	15.25	32	10.00	0.38	50.5	Low
A1	18.6	15.25	16.25	39	10.00	0.31	58.9	Low
A1	18.6	16.25	16.60	20	10.00	0.21	77.4	Ok
A1	18.6	16.60						

Figure 11 Continuous Log Example

For structures under 750 feet in length a continuous pile driving record is required on two footings; create one record for a pile in an abutment footing and the second record for a pile in a pier footing near the opposite end of the structure. If the pier footings have no piling, then create the second record for a pile in the opposite abutment.

For structures over 750 feet in length a continuous pile driving record is required on three footings. Create one record for a pile in an abutment footing and the second and third record for piling in two pier footings. If the pier footings have no piling, then create a second record for a piling in the opposite abutment, and disregard the third record.

23. DISTRIBUTION LIST: Unless extenuating circumstances exist, requiring additional distribution, submit one copy of this form to the District Office and three copies to the Bureau of Construction and Maintenance – Change Order Section. Once all "Log of Pile Driving" forms for a structure have been submitted, the Bureau of Construction and Maintenance – Change Order Section will distribute copies to the Bureau of Materials and Research – Geology Section, Bureau of Design – State Bridge Office and Bureau of Local Projects.

24. SIGNATURES: **Always** include the names of the individuals that inspected the pile driving operations, checked the computations and submitted the form.

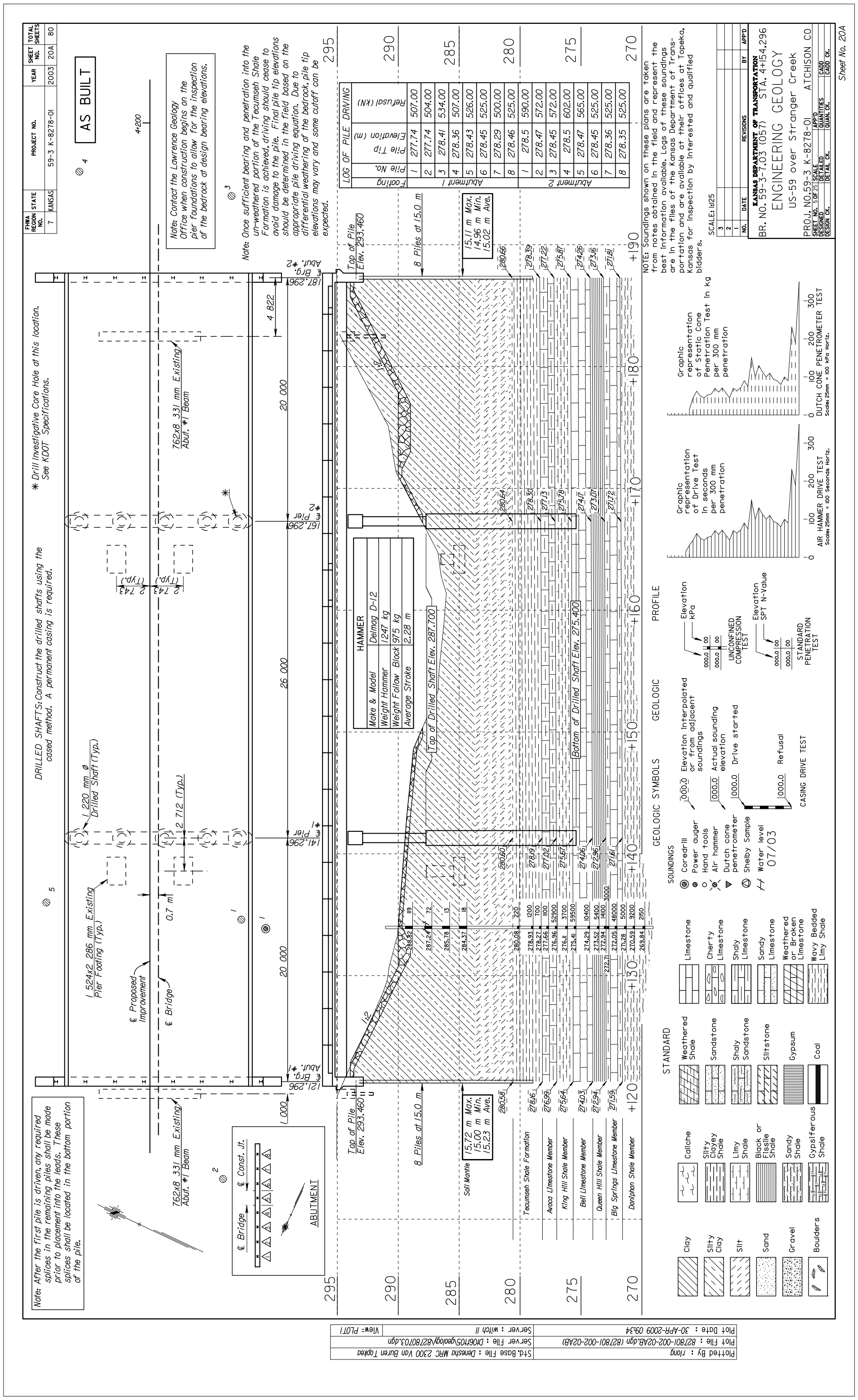
25. The following is a completed example of "Remarks" in a "Log of Pile Driving." Note the "Plan Length" for each pile is 16.7 ft.

    ·**Pile #1** - Driven to bearing with 0.2 ft. (non-pay cutoff) trimmed off to reach "Plan Cutoff Elevation."
    ·**Pile #2 –** Driven to bearing with 1.90 ft trimmed off to reach "Plan Cutoff Elevation" - 1.7 ft (pay cutoff) and 0.2 ft (non-pay cutoff).
    ·**Pile #3 –** After driving 16.9 ft of piling bearing wasn't achieved. To provide a fresh head 0.2 ft (non-pay cutoff) was trimmed off and 1.9 ft from #2 was spliced (pay splice) on (1.7 ft of pay cutoff, 0.2 ft of non-pay). The pile was then driven to bearing and 0.7 ft (pay cutoff) and 0.2 ft (non-pay) was cutoff.
    ·**Pile #4 –** Bearing was achieved after driving the 16.9 ft pile, but it was below cut off elevation. Thus, 0.2 ft (non-pay cutoff) was trimmed off to provide a fresh head, and 0.5 ft was spliced (pay splice) on to reach plan cutoff elevation.
    ·**Pile #5 –** The Contractor used a longer pile than was specified by the Engineer. Thus, the pile was driven to bearing with 0.5 ft (non-pay cutoff) and 0.20 ft (pay cutoff) cutoff.
    ·**Pile #6** - Contractor elected to splice (non-pay splice) together two pieces of cutoff from Pier 1. After the pile was driven to bearing the resultant cutoff was 0.75 ft (non-pay cutoff) and 0.3 ft (pay cutoff). Appropriate amounts of Cutoff used for Splice have been deducted from Pier 1 sheet.

5.3.8.1 As-Built Geology

Occasionally the as-built pile lengths, and even pile locations, may vary from those shown on the plans. It is important for any deviation in foundation elements from the plans to be recorded on the as-built geology sheet and submitted to the District Engineer. The District Engineer will in turn submit these sheets the Bridge Office. Someone from the Bridge office will then incorporate those changes into the original geology sheet. This is done so that there is a permanent record for use in the future. An example of an as-built geology sheet is shown below.

As **Built Geology**



PU-80

5.3.8.2 Pile Driving Formulas

Hammer Type	Pile Type	U.S. Customary
Gravity	Steel, Shell, Steel Sheet	$P = \frac{3 \cdot W \cdot H}{S+0.35} \cdot \left(\frac{W}{(W+X)}\right)$
Steam (Single Acting)	All Types	$P = \frac{2 \cdot W \cdot H}{S+0.1}$
Steam (Double Acting)	All Types	$P = \frac{2 \cdot E}{S+0.1}$
Delmag/McKierman-Terry*	All Types	$P = \frac{1.6 \cdot W \cdot H}{S+0.1 \cdot \left(\frac{X^{**}}{W}\right)}$
Link-Belt* All Types	All Types	$P = \frac{1.6 \cdot E}{S+0.1 \cdot \left(\frac{X^{**}}{W}\right)}$

* Diesel Hammers
** For Diesel Hammers if the quantity (X/W) is less than one, (X/W) is set equal to one.

<u>ENGLISH</u>
P in Pounds
W in Pounds
X in Pounds
S in Inches
E in Foot-Pounds
H in Feet

5.3.8.3 Field Pile Driving Guide

Many methods can be used to calculate resistance in the field. The inspector can program a calculator to compute resistance at the appropriate number of strokes, but this can be difficult because the height of the stroke and the penetration are both changing as the pile advances. The PDA calculates resistance as the pile is driven, but it is not currently specified on all projects. The field may request the PDA through the regional geology office. The State Bridge Office created the "Field Pile Driving Guide" to help the inspector calculate resistance as stroke and penetration change. This form will be available on the Forms Warehouse, or through contacting the Bridge Construction Manual Engineer.

First, the inspector needs to have all the appropriate information from the Contractor. If Form 217AA has been filled out, all of this information can be found there. Next, fill out the project information on the "General Information" sheet 217B. The plans will show the designer's specified load for each substructure pile and the pile type, which will give the inspector the pile weight in units of pounds per foot. Additional sheets included in the form are related to the hammer that the contractor will use for the project. The inspector will go to the correct hammer sheet and enter data into the light green shaded cells. Enter the Length of Pile near to the length that will be left in the ground. This will provide the inspector with the calculations near the end of the drive as the pile reaches the specified load stated in the "Piling" note on the "General Notes" sheet of the plans. The Hammer, Cap, and Anvil weights will come from the contractor. It is important to make sure that the contractor's hammer data is within the limits set in Sections 157 and 704 in the Standard Specification. The minimum and maximum penetration, "S", will depend on the energy of the hammer and the piling that is being driven. Values of $^1/_8$" and $^1/_4$" per blow are appropriate for most cases; however, a blue "band" of acceptable values is the goal of Form 217B in order to give the inspector an achievable range in the field. The minimum and maximum hammer fall, "H", will depend on the energy of the hammer and the piling that is being driven. For gravity hammers, the maximum fall may go up to 15'.

After the data is entered, the spreadsheet highlights the band of acceptable bearing values, and provides a graph based on Drop of Hammer vs. Penetration in 20 blows. The top line on the graph is the Minimum Bearing line; for a given hammer drop, the penetration in 20 blows must be less than the value given at this line. The bottom line on the graph is the Maximum Bearing line; for a given hammer drop, the penetration in 20 blows must be more than the value given by this line. For a small hammer drop, with a large penetration in 20 blows (above and left of the two lines), the pile has not achieved minimum bearing. For a large hammer drop, with a small penetration in 20 blows (below and right of the two lines), the pile has gone beyond the maximum bearing. The highlighted portion of "Computed Resistance" and the "Acceptable Range" in the graph can be adjusted by changing the range of hammer fall and the range of average penetration. While the contractor drives the piling, the inspector regularly checks the value of resistance for the observed fall of the hammer and pile penetration. Instructions are included on the "General Information" sheet within the form, and the Bridge Construction Manual Engineer should be contacted for further guidance.

Field Pile Driving Guide

Enter known data in all available cells.

General Information

If you can not see colored tabs for different hammers at the bottom of the window, go to "View" tab, "Arrange All", and hit "OK" in the window that pops up.

(This information is common to all sheets in the Workbook)

Hammer Information			**PROJECT INFORMATION**		
Type of Hammer			**County**		
			Project		
Hammer Weight		lbs	**(Br. No.) and/or Sta**		
Cap and/or Anvil Weight		lbs	Type of Pile		
Energy Rating		ft-lbs	Plan Note Overdrive %		%
			Min. Resistance Required		tons
			Max. Resistance Allowed		tons

Figure 12Form 217B General Information Sheet

Delmag McKierman Terry (Diesel Hammer) Example

Summary			Formula	Entry Data				
Hammer Wt.	4200	lbs	$$P = \frac{1.6 \cdot W \cdot H}{S + 0.1 \cdot \left(\frac{X^{**}}{W}\right)}$$	Weight per foot of piling (lbs/ft):	42	lbs/ft.	Minimum Hammer Drop	
Cap/Anvil Wt.	980	lbs		Length of Pile:	52.3	feet	4	ft.
Pile Type				X:	3177	lbs	Maximum Hammer Drop	
Min. Res.	60	tons		Minimum "S":	0.000	inches/blow		
Max. Res.	90	tons		Maximum "S":	0.500	inches/blow	10	ft.

PROJECT SCOPE: HP10x42 pile, 52.3 ft long...Observed approximately 4 to 4.25 inches in 20 blows with about 6 feet hammer drop.

Penetration per 20 blows (in.)	0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000
Average Penetration per blow (in.) "S"	0.000	0.050	0.100	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500
Drop of Hammer (Stroke) (ft.) — Drop of Hammer "H" in feet.	**Computed Resistance (tons)**										
4.0	134	**90**	**67**	54	45	38	34	30	27	24	22
4.6	155	103	**77**	**62**	52	44	39	34	31	28	26
5.2	175	116	**87**	**70**	5[illegible]						
5.8	195	130	97	**78**	**65**						
6.4	215	143	108	**86**	**72**						
7.0	235	157	118	94	**78**						
7.6	255	170	128	102	**85**						
8.2	276	184	138	110	92	**79**	**69**	**61**	55	50	46
8.8	296	197	148	118	99	**84**	**74**	**66**	59	54	49
9.4	316	211	158	126	105	90	**79**	**70**	**63**	57	53
10.0	336	224	168	134	112	96	**84**	**75**	**67**	**61**	56

Text Indicates Bearing is within acceptable range.

Text Indicates Bearing is outside of acceptable range.

Based on a hammer drop of around 6.0 ft.
Based on around 4 inches of penetration in the last 20 blows.
Bearing is within acceptable range: it is between 65 ton and 72 ton.

Drop of Hammer "H" in feet.	...ed per 20 blows Resistance (in.)		...ed per 20 blows Resistance (in.)	
4.0	2.480		0.987	->
4.6	3.152		1.435	->
5.2	3.824		1.883	->
5.8	4.496		2.331	->
6.4	5.168		2.779	->

Minimum Bearing is achieved if penetration is LESS than a number between 4.496" and 5.168". 4" is less, so OK.
Maximum Bearing is not exceeded if penetration is MORE than a number between 2.331" and 2.779". 4" is more, so OK.
Graphically, to the right, the penetration per 20 blows of about 4" with a hammer drop of 6 feet is in the acceptable range.

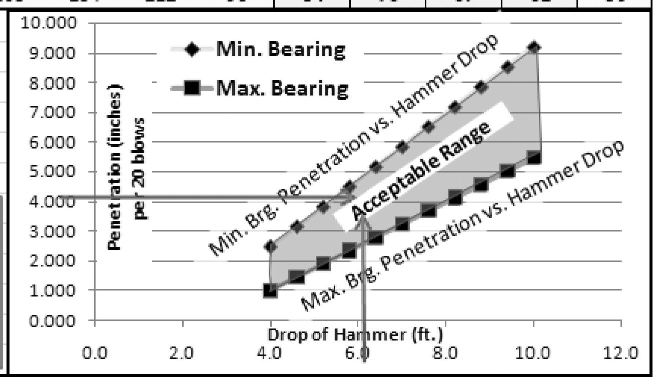


Figure 13Form 217B Delmag Sheet Example

5.3.9 Hammer Data

More information is available online than is included here:
http://www.conmaco.com/html/new_equip.html
http://www.apevibro.com/asp/manuals-MKT.asp M-K and APE data