603 PILING

603-1 Description

Piles are rarely used for ADOT bridges and other major structures. Drilled shafts are usually the preferred foundation. The rocky and cemented soils of Arizona are not conducive to deep pile driving. In addition, slender driven piles are not the preferred foundation by many ADOT Bridge Designers because of the severe scouring that occurs in many of our waterways. However driven piles do have a place as a deep foundation for some ADOT structures. When soil and scour conditions are favorable, piles are a very economical alternative to drilled shafts.

This section covers only pile driving and inspection at its basic level. The FHWA has excellent manuals on piling that the Resident Engineer and Inspector should read in advance of any pile driving operation. The *Manual on Design and Construction of Driven Pile Foundations*, referenced at the end of this chapter, is particularly informative and helpful.

What are piles?

A *pile* is a long slender column usually made of steel, reinforced concrete, or wood that is driven into the ground. The pile transmits loads by the frictional resistance developed between the side surface of the pile and the adjacent soil by direct bearing of the pile tip on bedrock (or a very hard soil) or by a combination of the two.

For example, if you drive a stake into the ground deep enough so that it can support your weight when you stand on it, you have a pile. You may only use a 5-pound (2 kg) hammer to drive the stake but the stake can carry much more than the weight of the hammer when a weight (or load) is placed at rest on top of the stake. You may be able to drive the stake further into the ground by jumping up and down on the stake but in reality, the loads placed on piles are static and do not impact the top of the pile (except during earthquakes).

Piles are used when a deep foundation for a structure is needed. Deep foundations are usually required when the soils near the surface are not strong or stable enough to support the weight of and the loads placed on a structure. Piles are also used to support a structure when there is a chance the soil, directly underneath a structure, would become loose or would wash away even though the soil could support the structure. Piles are usually placed in groups. *Piling* simply refers to a group of piles.

It is useful for the Inspector and Resident Engineer to know whether the piles used on the project are friction piles or bearing piles (some piles are a combination of the two) and what soil layers the pile are expected to be driven through. *Friction piles* rely on the residual friction developed between a driven pile and the adjacent soil to transmit loads from the pile to the soil. The friction is developed along the side surface of the pile. *End-bearing piles* are designed to transmit the loads carried by the pile to bedrock or hard soil strata. Although there may be friction developed between the pile and the adjacent soil, this friction is not relied upon. It is the layer of rock or hard soil at the pile tip that is expected to carry the loads.

Problems often occur during pile driving and knowledge of how the piles are intended to function can be very helpful when different solutions are considered. The Project Geotechnical Engineer can provide more information on piling design characteristics and soil conditions intended for the piles.

Test Piling

When test piles are required, the test piles must be driven in the exact location required for piling in the completed structure. The driving must be done in the same manner and utilizing the same equipment as specified for driving the piling for the structure. The test piles must be marked off in 1-foot (300-millimeter) intervals in order that a complete log may be kept on the driving of the test pile. This log should record:

- the date the pile was driven;
- location;
- time required for driving;
- information on hammer blows per foot (300 millimeters) of penetration into the ground; and
- penetration obtained during the last ten blows.

After the test piles are driven, the information should be forwarded to the Geotechnical Engineer for review.

When no test piling is required, the Resident Engineer shall review the driving results of the first two to three piles as to penetration, bearing value, and pile length. Any differences from plan requirements should be reported to the Geotechnical Engineer and the Bridge Designer as soon as possible.

603-2 Materials

Piles can be made of structural steel, pressure treated timber, hollow steel casing, reinforced concrete, or prestressed concrete. The most common type of pile is the steel H-pile. H-piles, like other steel piles, require certificates of analysis showing the test results for yield strength and ultimate strength.

Dimensions for steel H-piles can be found in the Steel Construction Manual referenced at the end of this chapter. In addition to checking the size of the H-pile, the Inspector should ensure that the correct grade and yield strength of steel is used. Some piles, especially those designed for end bearing, are limited in load carrying capacity by the yield strength of the steel. Thus it is imperative that the correct grade of steel is used.

Excavation and Embankment Materials

Subsection 203-5.03(A) requires that the Contractor excavate down to the top of the piling elevation before driving pile. Driving pile and then excavating around the piles is not an acceptable procedure. The risk of the excavating equipment accidentally hitting a pile and loosening or damaging it must be avoided.

When backfill material is used around metal piles, it must meet the structure backfill requirements of Subsection 203-5.03(B)(1). This specification requires, among other things, a resistivity of at least 2,000 ohm-centimeters to prevent corrosion of the metal pile.

In an embankment situation where metal piles are driven through an existing embankment, Subsection 203-10.02 requires the embankment material within 10 feet (3 meter) of the pile to have resistivity and pH value similar to structure backfill. The avoidance of corrosion is the goal here as well. Most long-term corrosion in metal piles comes from fill materials (like structure backfill and embankment) that do not meet the minimum requirements for pH and resistivity. Rarely do undisturbed natives soils cause corrosion problems with metal piles even when they have pH and resistivity values outside the required limits for backfill and embankment materials.

Embankment materials within 3 feet (1 meter) of the piling should not contain large rocks or debris that might damage the pile tip or prevent the driving of the pile (see Subsection 203-10.03[A]).

603-3 Construction Requirements

Inspection Objectives

There are five basic requirements that the Resident Engineer and Inspector should focus on during pile driving. By keeping the following objectives in mind both before and during piling driving, the Resident Engineer and Inspector will achieve 99 percent of the requirements for a long-lasting, solid foundation.

1. *Pile Location*:

A. Is each pile in the correct location?
B. Are pile groups laid out correctly?
C. Is the pile plumb and has batter been checked?

2. *Pile Material*:

A. Is the pile size correct?
B. Is the material type correct?
C. Is the material grade correct?

3. *Pile Driving Equipment*:

A. Does the Contractor's pile driving equipment meet the specification requirements with the hammer developing the minimum energy needed to properly drive the pile?

4. *Pile Length*

A. Is each pile driven to the correct length?
B. Was the tip elevation or an acceptable bearing value achieved?

5. Pile Bearing Values:

A. Does each pile have the minimum required bearing capacity as calculated in Subsection 603-3.08 or by an approved wave equation analysis?

Pile driving Contractors measure their productivity based on the number of feet (meters) of pile driven each day. Once a pile driving operation begins, these Contractors are reluctant to stop. As a result, it is strongly suggested that the Resident Engineer hold a pre-pile driving meeting with the Contractor so much of the equipment and materials approvals are acquired long before a single pile is driven. Discussions at the meeting should include:

- the Contractor's pile driving procedure;
- safety and hearing protection requirements;
- measurement and payment procedures;
- how bearing values will be determined;
- splicing and welding procedures;
- inspection activities as they impact the Contractor's production;

- potential problem areas during pile driving and possible solutions;
- how the Geotechnical Engineer should be involved in resolving pile driving problems; and
- a streamlined process for resolving piling driving issues as soon as they arise.

The idea is to anticipate any problem areas and resolve them before they become issues at the job site.

Meeting ahead of time to fully discuss the expectations and potential problems associated with pile driving is one of the most important activities a Resident Engineer can do to ensure a successful pile driving operation.

603-3.03 Equipment

Pile driving equipment should be thoroughly checked as soon as the Contractor delivers it to the job. In checking the Contractor's equipment, the Inspector and pile driving foreperson should see that:

1. the equipment proposed for use meets the requirements of the job;
2. the leads are sturdy, smooth, and straight;
3. the hammer falls freely in the leads; and
4. the blocks in the driving head of the hammer are not badly worn.

Inspecting the hammer is very important since it is the most essential piece of equipment of the pile driving operation. The hammer must operate properly so that it delivers its rated energy to the pile. If the hammer does not, then the Inspector's estimation of the pile bearing value will be virtually meaningless.

The Performance of Piling Driving Systems: Inspection Manual cited at the end of this chapter contains the forms and lists the procedures necessary for inspecting pile-driving hammers. You will need the Contractor's assistance when inspecting the hammer, so it is advisable to schedule this inspection during equipment set-up procedures.

603-3.04 Driving Piles

Embankments

Subsection 603-3.04(A) requires all embankments to be constructed in the area of piling before the Contractor drives any pile. For example, embankment for a bridge approach should be constructed up to the top of berm (see Standard Drawing B-19.40). The Contractor may have to excavate back down to the top of pile elevation in order to drive the piles.

On some projects the Contractor may propose to build the embankment to some point at or below the top of pile elevation, drive the piles, and then build the rest of the embankment. This is not the correct procedure because building embankment after pile driving will cause surcharge loading and down drag on the piling. Material placed adjacent to and above the piling will induce lateral and vertical loads not accounted for in the design of the piles.

Driving

Piles should be marked in 1-foot (300-millimeter) intervals to track the driving depth before being placed in the leads. Care shall be taken to see that each pile is driven in a vertical position except in cases where battered piles are specified. After the pile is placed in position and plumbed, a few strokes of the hammer should be made to settle the pile. The pile should be checked again to see if it is plumb and blocked firmly in the leads before actual driving starts.

Frequently obstructions are encountered which deflect the pile. If the pile becomes seriously out of line it may have to be pulled and re-driven. As a last resort, the pile location can be moved with the approval of the Bridge Designer.

Piles are either driven to:

- a specified tip elevation, regardless of bearing value;
- a minimum bearing value, regardless of tip elevation; or
- a minimum specified tip elevation with a minimum bearing value.

The Project Plans will specify which of these conditions the piles must meet. Of course the Inspector's job is to determine which of these conditions applies and then ensure that each pile meets the applicable condition.

Another duty of the Inspector is to verify that soil conditions are the same as that shown in the Project Plans or the soils report for the project. This can be done by comparing blow counts shown on the boring logs with actual blow counts for the piles at a given tip elevation. The idea is to compare differences in blow counts as the pile advances to identify the soft and hard soils layers shown on the boring logs. If the Inspector notices significant differences or inconsistencies in the pile blow counts, when compared to the boring log, then the Geotechnical Engineer should be notified. This verification does not need to be done on every pile, but should be done for at least one pile in each pile group.

If the piling cannot be driven to the minimum bearing or tip elevation shown on the Project Plans, the Resident Engineer should immediately notify the Geotechnical Engineer of the condition and must not allow the Contractor to cut off such piling unless authorization to do so is obtained from the Bridge Group. Often a study of all available information may require the Contractor to use jetting, drilling equipment, or other methods in order to reach minimum penetration.

Before a driven pile is cut, the Resident Engineer and Inspector, along with the piling driving foreperson, should verify that the pile would be cut to the correct top of pile elevation. Piling is usually covered with a concrete pile cap with the pile extending part way into the cap. The Inspector should ensure that the pile penetrates into the pile cap for the prescribed length shown in the Project Plans before the pile is cut.

603-3.05 Pile Splices

When piles are to be spliced, the Project Plans will show a splicing detail. Steel H-piles (the most common metal pile) are usually butt spliced with the pile still in the leads. Any welding done on a metal pile must be done by an AWS certified welder.

If a splicing detail is not shown on the Project Plans then Bridge Group should be involved in approving any splicing detail.

Pile driving Contractors should order their pile lengths and plan their pile driving sequence in order to minimize the amount of splicing that needs to be done. It is suggested that the Project Supervisor meet with the pile driving Contractor before piles are ordered to go over lengths and pile driving sequence with the intent of minimizing cut-off waste and unnecessary splicing.

603-3.06 Pile Cutoff (Waste)

Cut-off waste that remains at the end of a pile driving operation is the property of the Department unless that

quantity is deducted from the furnished pile bid item. The cut-off waste may be incorporated into the project elsewhere or salvaged by a Department of Administration (DOA) authorized salvage Contractor. The DOA Surplus Property Section can be contacted at (602) 542-5701 for further information. The Contractor may purchase the cut-off waste through a supplemental agreement.

603-3.08 Determination of Bearing Values

The Inspector, with the assistance of the Resident Engineer, must determine the bearing value for each pile. This must be done as each pile is driven and before the pile is cut. Bearing values are determined by measuring the pile penetration per blow for the last 1 foot (300 millimeters) of pile driving. Table 603-1, in Subsection 603-3.08 of the Standard Specifications, is used to calculate the bearing value. Penetration readings and blow counts must be carefully recorded in the pile driving records discussed in Subsection 603-4 of this manual.

When a wave equation analysis is used to determine bearing values, the Resident Engineer should consult with the Geotechnical Engineer about acceptable bearing values. The Inspector must monitor the Contractor's dynamic monitoring equipment for acceptable readings when bearing is reached.

603-4 Method of Measurement

Pile Driving Records

Pile driving records consist of the Pile Record Book and Pile Summary Sheet.

The Pile Record Book is a bound field book that contains a pile location plan, hammer data, a pile driving log for each pile, an inventory record of pile cutoff, and any other information gathered or measured in the field related to pile driving. Exhibit 603-4-1 (a through f) illustrates how a piling book should be organized.

Pile Record Books are part of the project as-built plans and should accompany them when forwarded to ADOT's Project Management Section. Bridge Group uses the Pile Record Book to complete a bearing pile record sheet for their Bridge Management Section. This sheet is used for trouble-shooting future bridge foundation problems.

The Pile Record Summary Sheet is a recap of the piling quantities used for each structure for payment purposes (see blank forms). The Inspector prepares the sheet after all pile driving is completed for a structure and should be checked by the Resident Engineer.

EXAMPLE:

PILING RECORD BOOK
COVER AND PAGE 1

EXHIBIT NO. A

PROJECT I-8-3 (71) YUMA-CASA GRANDE HWY.	Project Number Project Name
PILE RECORD BOOK JOHNSON WASH BRIDGE Sta. 1800+	Book Title Name of Structure Location
John Doe ~ Resident Engr. Date: March, 1983	Project Engineer and Title Date piling items were completed.
BOOK 1 OF 2 BOOKS.	Book Number

Exhibit 603-4-1a Piling Record Book

INDEX and INSPECTOR

Example:

INDEX

LOCATION	PAGE
Abutment #1	3 - 10
Pier #1	11 - 20
Pier #2	21 - 30
Abutment #2	31 - 37
Recapitulation	38
Inventory	39

Inspector: J. D. Brown

Transitman: P. O. Blue

Chainman: A. C. Gray

Exhibit 603-4-1b Piling Record Book

PILE LOCATION, TYPE, PLANS LENGTH

a. Batter Pile are indicated by crossed circle. Show cosine of batter to compute elevations.

EXAMPLE

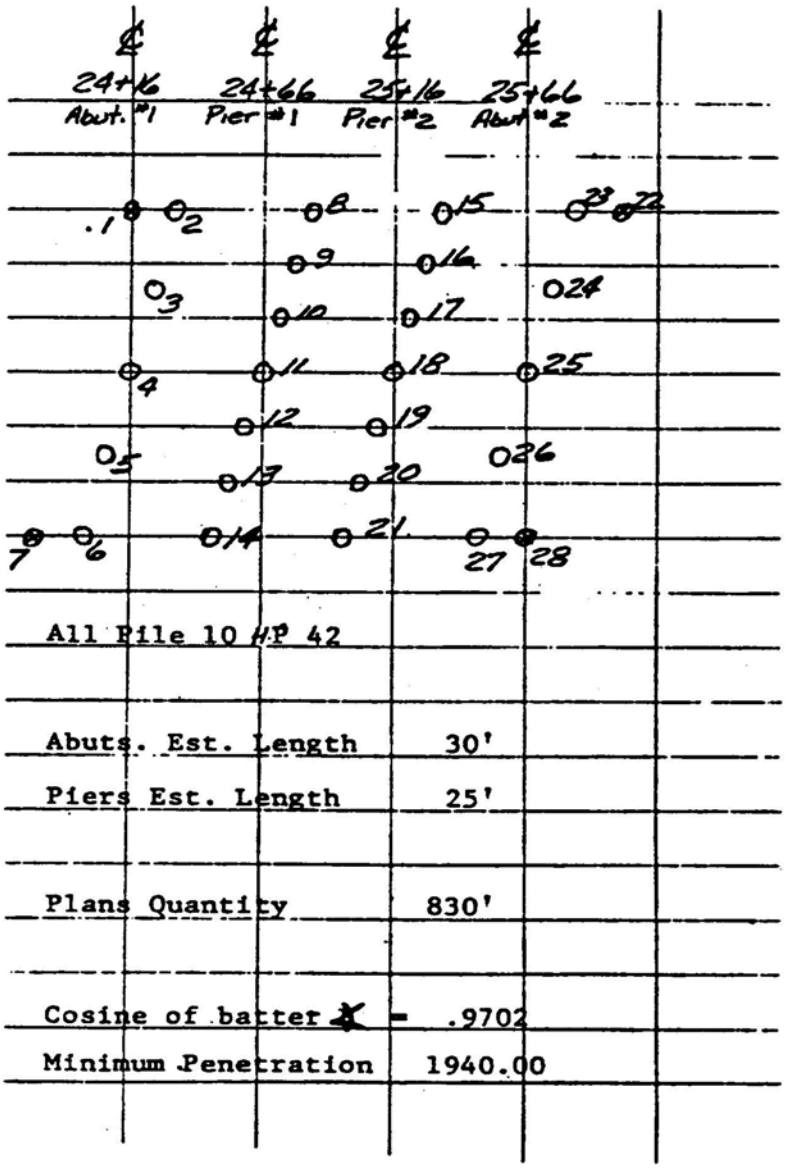

Exhibit 603-4-1c Piling Record Book

HAMMER DATA

a. When loading tests are required, the method of testing shall be as specified in the Special Provisions or Standard Specifications.

b. The Hammer Data to be entered in the field book should be for only the hammer used in driving. Should more than one hammer be used, indicate for which pile each was used.

c. For bearing formulas, see below.

Example

Hammer Data					
Type	-	Single	Action		
Make	-	Vulcan			
Weight	of Ram	- 5000#			
Stroke	-	3'			
	Formula	= P =	$\frac{2\ wh}{S + 0.1}$		
	Bearing	$= \frac{2\ (5000 \times 3)}{S + 0.1}$			
P = safe allowable bearing in pounds					
W = weight of hammer in pounds					
H = fall of hammer in feet					
S = average penetration in inches per blow for the last 10 blows					
A = effective area of piston in square inches					
p = mean effective pressure in psi					
E = manufactures energy rating in foot - lbs. per blow					

Type of File	Type of Hammer	Formula
Timber and Steel	Drop	$P = \frac{2WH}{S+1.0}$
Timber, Steel and Metal Shells for Cast-in-Place Concrete	Single-Acting Steam or Air, or Diesel	$P = \frac{2WH}{S+0.1}$
	Double-Acting Steam or Air	$P = \frac{2H(W+Ap)}{S+0.1}$ $P = \frac{2E}{S+0.1}$
Precast Concrete	Single-Acting Steam or Air, or Diesel	$P = \frac{2WH}{S+0.1}$
	Double-Acting Steam or Air	$P = \frac{2H(W+Ap)}{S+0.1}$ $P = \frac{2E}{S+0.1}$

Exhibit 603-4-1d Piling Record Book

EXAMPLE

Piling Book Entries

DATE 2-4-83 PILE NO. 21 (BATTER) LAST 10

TIME	NO. BLOWS	PEN. IN FEET	NO. BLOWS	PEN. IN FEET	BLOWS		
						LENGTH OF PILE BEFORE SPLICE	25.2
		0	37	24	4 1/4"	LENGTH OF SPLICE - FROM STOCK	2.2
		(	40	25	S= 4.25/10	TOTAL LENGTH OF PILE AFTER SPLICE	27.4
DRILL		(	40	26	S=.42		
9:25	10	11					
	12	12			Bearing	TOTAL LENGTH OF PILE BEFORE CUTOFF	27.4
	11	13			56.9	LENGTH OF CUTOFF - TO CONTR	0.7
	10	14			Tons	LENGTH OF PILE IN PLACE	26.7
	11	15					
	12	16					
	15	17				ELEVATION OF PILE CUTOFF	1029.35
	14	18				LENGTH OF PILE BELOW CUTOFF	26.34
	16	19				ELEVATION OF PILE POINT	1003.01
	21	20					
	22	21				HEAT No. 13697	
	27	22				26.7 COS 8 .9864 = 26.34	
	30	23					
						INSPECTOR: W. J. K.	

NOTE: Rubber stamps for formats are available from Field Reports Services

Exhibit 603-4-1e Piling Record Book

CUTOFF INVENTORY

Example
(Theoretical)

(OPTIONAL)

38 (page number)

CUTOFF INVENTORY

	From	In Yard	Contr. Use	Waste	Total
Abut #1	Pile #1	2.00	.67		2.67
	2	—	.50		.50
	3	5.50			5.50
	4	4.25			4.25
	5	5.17			5.17
	6	10.00		.33	10.33
	7	1.83			1.83
	8	1.00		.50	1.50
	9	3.17			3.17
	10	6.00	2.80		8.80
	11	3.50		.50	4.00
	12	1.50		.17	1.67
		Total cutoff		-	49.39
		Contr. Use		-	3.97 (not payable)
		Waste	-	-	1.50 (not payable)
		Piling on hand		-	43.92

Exhibit 603-4-1f Piling Record Book

603-4.01 Furnishing Piles

- Measure the quantities delivered to the project site or designated storage area--the quantity should not exceed lengths specified in the Project Plans unless approved by the Resident Engineer.
- Record the lengths in the Pile Record Book.

Cast-in-place pile quantities are equal to the actual driven amount only since any cut-off sections are usually unusable (see Subsection 603-4.01 of the Standard Specifications).

The quantities of furnished pile may be reduced by the Inspector due to:

- pieces wasted through mishandling by the Contractor;
- pieces used by the Contractor for convenience or construction aids (i.e. splice plates);
- pieces used for other structures or for other projects; and
- lengths in excess of those specified unless ordered or approved by the Department.

The length of unused steel piling or metal shells on hand, which are to be purchased by the Department, should be documented in the Pile Record Book and Pile Summary Sheet.

603-4.02 Driving Piles

- Measure the actual length driven in meters and record in the Pile Driving Book.
- Track the number of blows per 1 foot (300 millimeters) and the penetration depth for the last five to twenty blows depending on the hammer type (see Standard Specification Table 603-1).
- Compute bearing values for each pile.
- Record all this information in the Pile Record Book. Include hammer information and any computations.

If pile load testing is performed for the structure, record the results in the Pile Record Book and sign the book.

603-4.03 Splicing Piles

Record the number of splices in the Pile Record Book and pay at the contract unit price. If there is no unit price then refer to Subsection 603-5.04.

The quantity of pile splices may be reduced when splices are made:

- for the Contractor's convenience (i.e. splicing lengths less than those ordered by the Resident Engineer to make a specified length of pile); and
- to correct Contractor errors in cutoff elevation.

The Department will pay for additional splices when they are used to keep the quantity of unused pile down to a minimum.