Construction Methods and Materials: Heavy Construction

PDH Credits:

5 PDH

Course No.:

IHC101

Publication Source:

US Navy
Engineering Aid Basics

"Heavy Construction – Chapter 8"

Pub. # NAVEDTRA 14045A

Chapter 8

Heavy Construction

Topics

1.0.0 Bridge Construction

2.0.0 Types of Modular Bridges

3.0.0 Shoring Excavation

4.0.0 Pile Construction

5.0.0 Waterfront Structures

6.0.0 Timber Fasteners and Connectors

7.0.0 Steel Frame Structures

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Overview

As a Builder, you may perform various construction operations involving heavy structures. Since heavy construction is hazardous work, the use of safe working practices at all times can prevent injuries to personnel and damage to equipment. This chapter describes equipment, terminology, and techniques of heavy construction and explains the methods of constructing heavy timber structures and waterfront structures in terms of contingency operations.

Heavy construction refers to the type of construction in which large bulks of materials (over 5 inches thick) and extra heavy structural members are used, such as steel, timber, concrete, or a combination of these materials. In the Naval Construction Force (NCF), heavy construction includes the construction of bridges, shoring operations, waterfront structures, and steel frame structures.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the procedures for erecting heavy timber bridges.
2. Describe the procedures for erecting shoring.
3. Describe the procedures for pile construction, identify the different types of pile driving equipment and types of piles, and understand the many safety hazards associated with pile driving.
4. Describe the procedures for erecting waterfront structures.
5. Identify the different types of timber fasteners and connectors.
6. Describe the procedures for erecting steel frame structures.

Prerequisites

None

This course map shows all of the chapters in Builder Advanced. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

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Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 BRIDGE CONSTRUCTION

A bridge is a structure used to carry traffic over a depression or an obstacle, generally consisting of two principal parts: the lower part, or substructure, and the upper part, or superstructure. When a bridge is supported only at its two end supports, or abutments, it is called a single span bridge. A bridge with one or more intermediate supports, as shown in *Figure 8-1*, is known as a multi-span bridge.

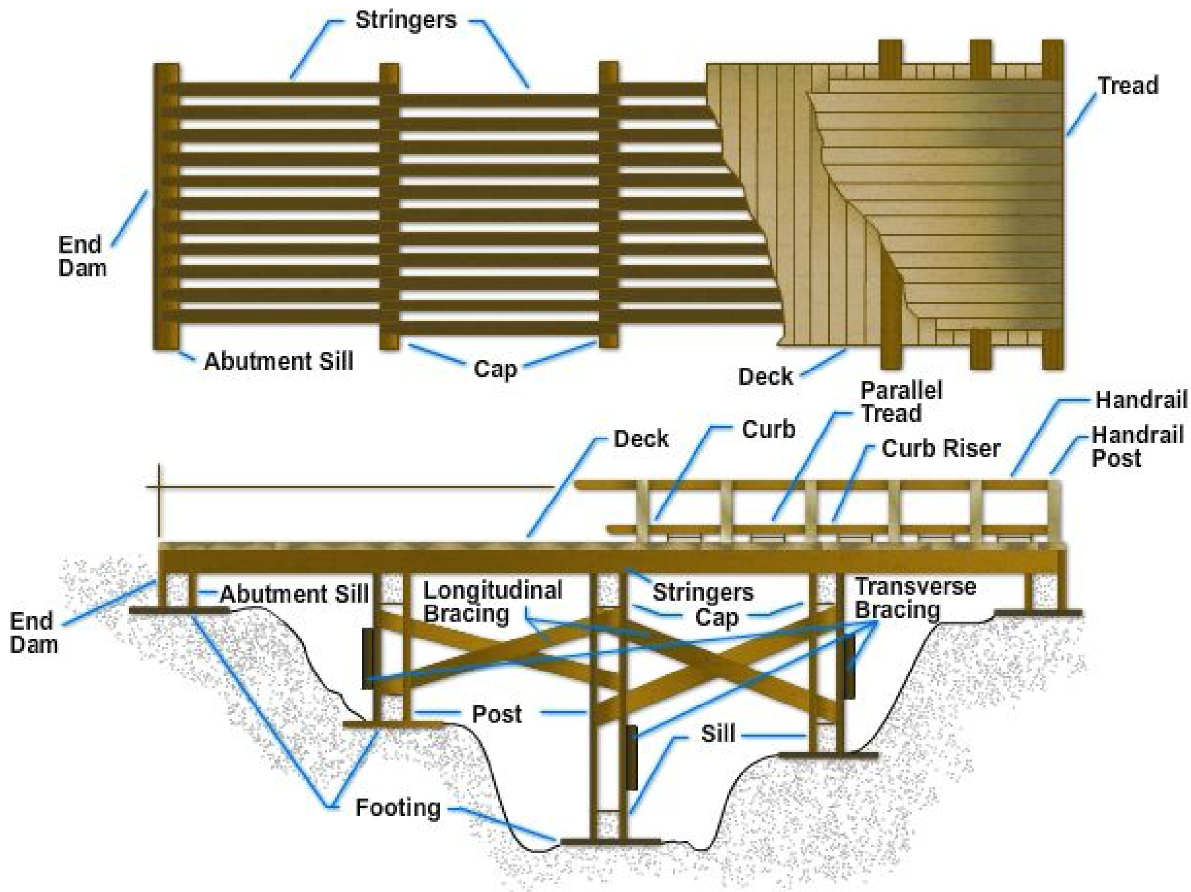


Figure 8-1 – A multi-span (trestle-bent) bridge.

Although bridges may be either fixed or floating, only fixed bridges are covered in this chapter. The following information covers the components of a fixed bridge.

1.1.0 Substructure

The substructure supports the superstructure and consists of abutments, footings, sills, posts, bracing, and caps.

1.1.1 Abutments

There are different types of fixed bridge abutments. First, let's cover the footing type of abutment. In *Figure 8-2*, *Views A* and *C* show two types of footing abutments. *View A* shows a timber-sill abutment, and *View C* shows a timber-bent abutment. By studying both of these views, you will see that three elements are common to a footing type of abutment. Each type has a footing, a sill, and an end dam.

Notice that the timber-sill abutment shown in *Figure 8-2, View A* is the same footing type of abutment shown for the bridge in *Figure 8-1*.

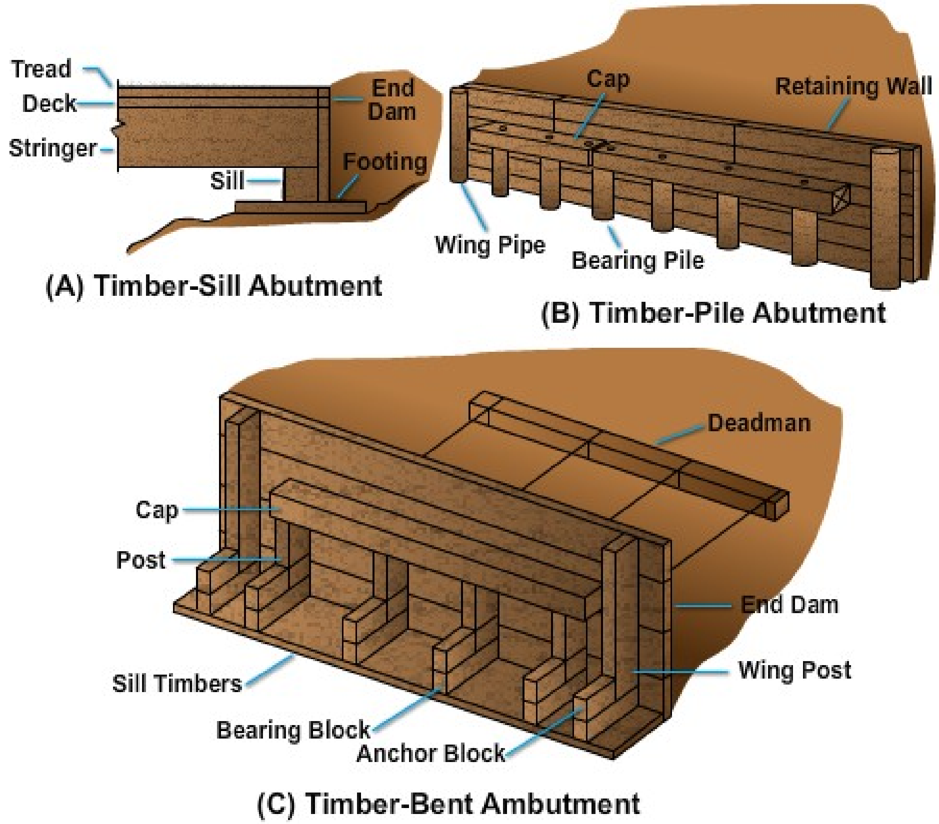


Figure 8-2 – Types of fixed bridge abutments.

In this type of abutment, loads are transmitted from the bridge stringers to the sill, which distributes the load to the footing. The footing then distributes the combined load over a sufficient area to keep the support from sinking into the ground. The end dam is a wall of planks that keeps the approach road backfill from caving in between the stringers. The timber-sill abutment should not be more than 3 feet high. It can be used to support spans up to 25 feet long.

The timber-bent abutment shown in *Figure 8-2,View C* can be used with timber or steel stringers on bridges with spans up to 30 feet. The deadman is used to provide horizontal stability. These abutments do not exceed 6 feet in height.

Other types of fixed bridge abutments are pile abutments and concrete abutments. Timber or steel pile abutments can support spans of any length, can be used with steel or timber stringers, and can reach a maximum height of 10 feet. A timber-pile abutment is shown in *Figure 8-2; View B*. Concrete abutments are the most permanent type and may be:

- Mass or reinforced concrete
- Used with spans of any length
- As high as 20 feet.

These abutments are used with either steel or timber stringers.

1.1.2 Foundations

That part of a building or structure located below the surface of the ground is called the foundation. Its purpose is to distribute the weight of the building or structure and all live loads over an area of subgrade large enough to prevent settlement and collapse.

In general, all foundations consist of the following three essential parts:

- Foundation bed, which consists of the soil or rock upon which the building or structure rests.
- Footing, which is normally widened and rests on the foundation bed.
- Foundation wall, which rises from the foundation to a location somewhere above the ground.

The foundation wall, contrary to its name, may be a column or a pedestal instead of a wall. When it is a wall, it forms what is known as a continuous foundation. *Figure 8-3* shows common types of wall and column foundations.

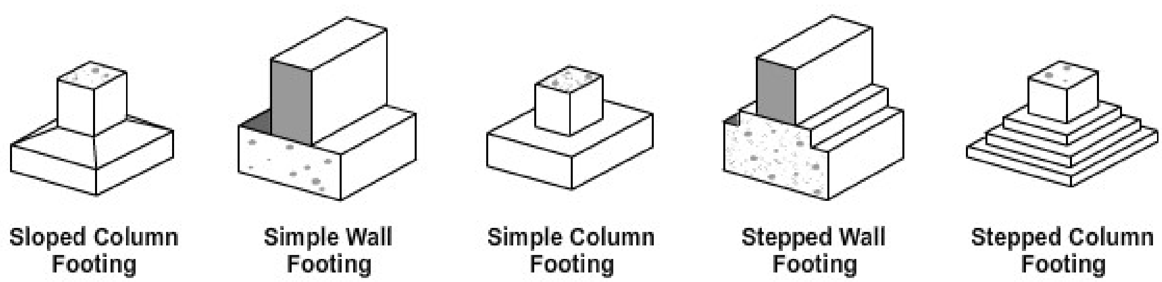


Figure 8-3 – Common wall and column foundations.

The continuous foundation is the type most commonly used for small buildings. The size of the footing and the thickness of the foundation wall are specified based on the type of soil at the site. Most building codes require that the bottom of the footing be horizontal and that any slopes be compensated for by stepping the bottom of the footing.

Another type of foundation is the grade beam foundation. A grade beam is a reinforced concrete beam located at grade level around the entire perimeter of a building, and it is supported by a series of concrete piers extending into undisturbed soil. The building loads are supported by the grade beam, which distributes the load to the piers. The piers then distribute the load to the foundation bed.

A spread foundation, shown in *Figure 8-4*, is often required where heavily concentrated loads from columns, girders, or roof trusses are located. This type of foundation may be located under isolated columns or at intervals along a wall where the concentrated loads occur. Spread footings are generally reinforced with steel. They may be flat, stepped, or sloped, as shown in *Figure 8-3*.

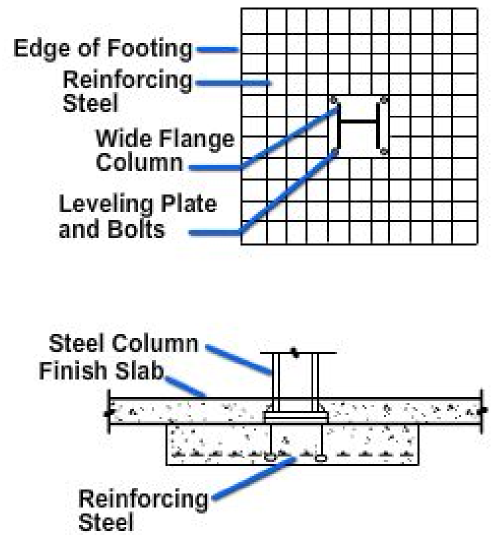
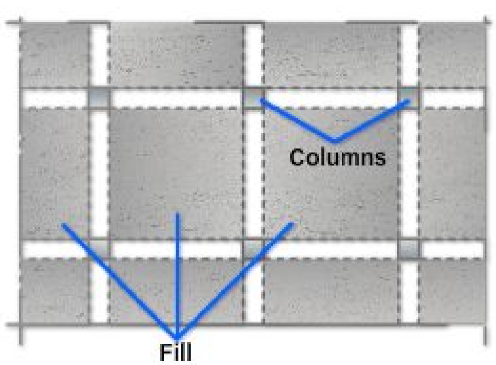


Figure 8-4 – Plan and section of a typical spread footing.

Figure 8-5 shows the plan and section of a typical mat foundation. In this type of foundation, a heavily reinforced concrete slab extends under the entire building and distributes the total building load over the entire site. This minimizes problems created by unequal settlement when the subsoil conditions are uneven.



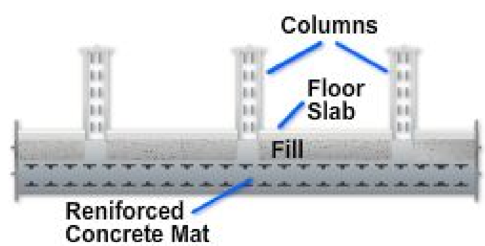


Figure 8-5 – Plan and section of a mat foundation.

1.1.3 Intermediate Supports

Bents and piers provide support for the bridge superstructure at points other than the bank ends. A bent consists of a single row of posts, or piles, while a pier consists of two or more rows of posts, or piles.

The pile bent, shown in *Figure 8-6*, consists of the bent cap, which provides a bearing surface for the bridge stringers, and the piles, which transmit the load to the soil. The support for the loads may be derived either from column action, when the tip of the pile bears on firm stratum, such as rock or hard clay, or from friction between the pile and the soil into which it is driven. In both cases, earth pressure must provide some lateral support, but transverse bracing is often used to brace the bent laterally.

A timber pile bent consists of a single row of piles with a pile cap. It is braced to the next bent or to an abutment to reduce the unbraced length and to provide stability. This bent will support a combined span of 50 feet.

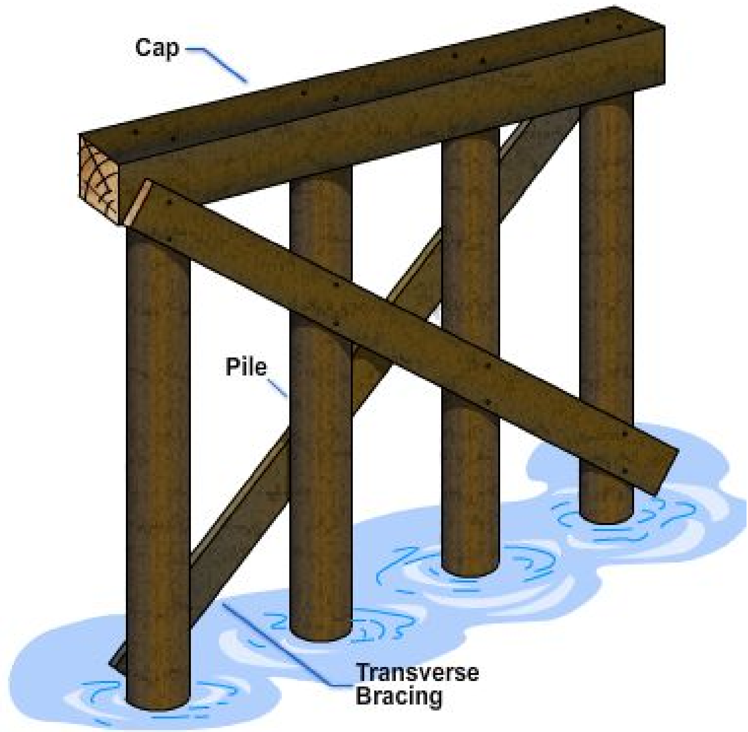


Figure 8-6 – Typical pile bent.

The trestle bent, shown in *Figure 8-7*, is similar to the pile bent, except the post takes the place of the piles and transmits the load from the cap to the sill. The sill transmits the load to the footings, and the footings transmit the load to the soil. Timber trestle bents are normally constructed in dry, shallow gaps where the soil is firm. They are not suitable for use in soft soil or in swift or deep streams. The bent can support a combined span length of up to 30 feet and can be 12 feet high.

A trestle bent pier is the same as the pile bent pier, except it has sills and footings to transmit the load to the soil, as shown in *Figure 8-7*. This bent is designed to carry vertical loads only, and is used to support spans up to a combined 60 feet and ground to grade heights of up to 18 feet.

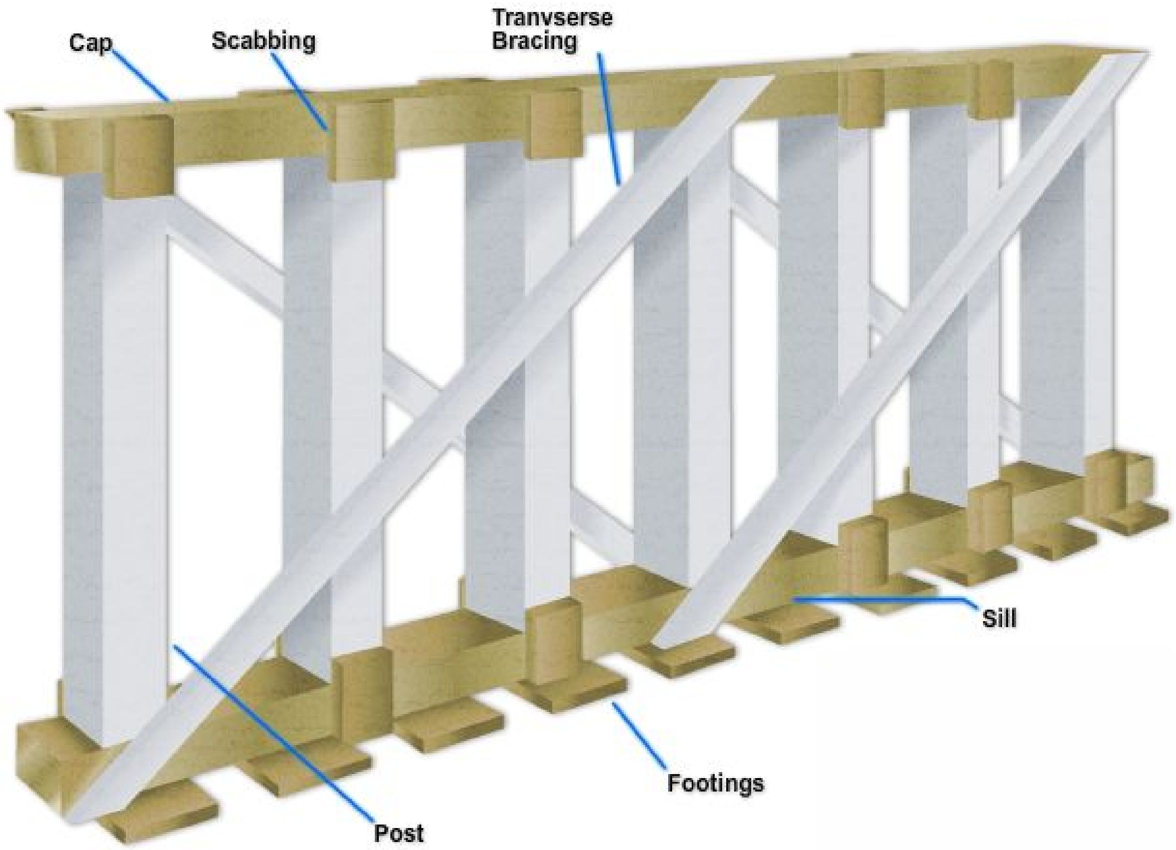


Figure 8-7 – Timber trestle bent.

The pile bent pier, shown in *Figure 8-8*, is composed of two or more pile bents. In this figure, notice the common cap. The cap transmits the bridge load to the corbels which transmits the combined load to the individual bent caps. Piers are usually provided with cross bracing that ties the bents together and provides rigidity in the longitudinal direction.

1.1.4 Bracing

Longitudinal bracing and transverse bracing are the two types commonly used to support the substructure in heavy timber construction, as shown in *Figure 8-8*. Longitudinal bracing is used to provide stability in the direction of the bridge center line. Transverse bracing, sometimes called lateral bracing, provides stability at right angles to the center line.

Sometimes a third type of bracing, called a diaphragm, is used. This bracing is used between the stringers to prevent buckling, which is deflecting laterally under load.

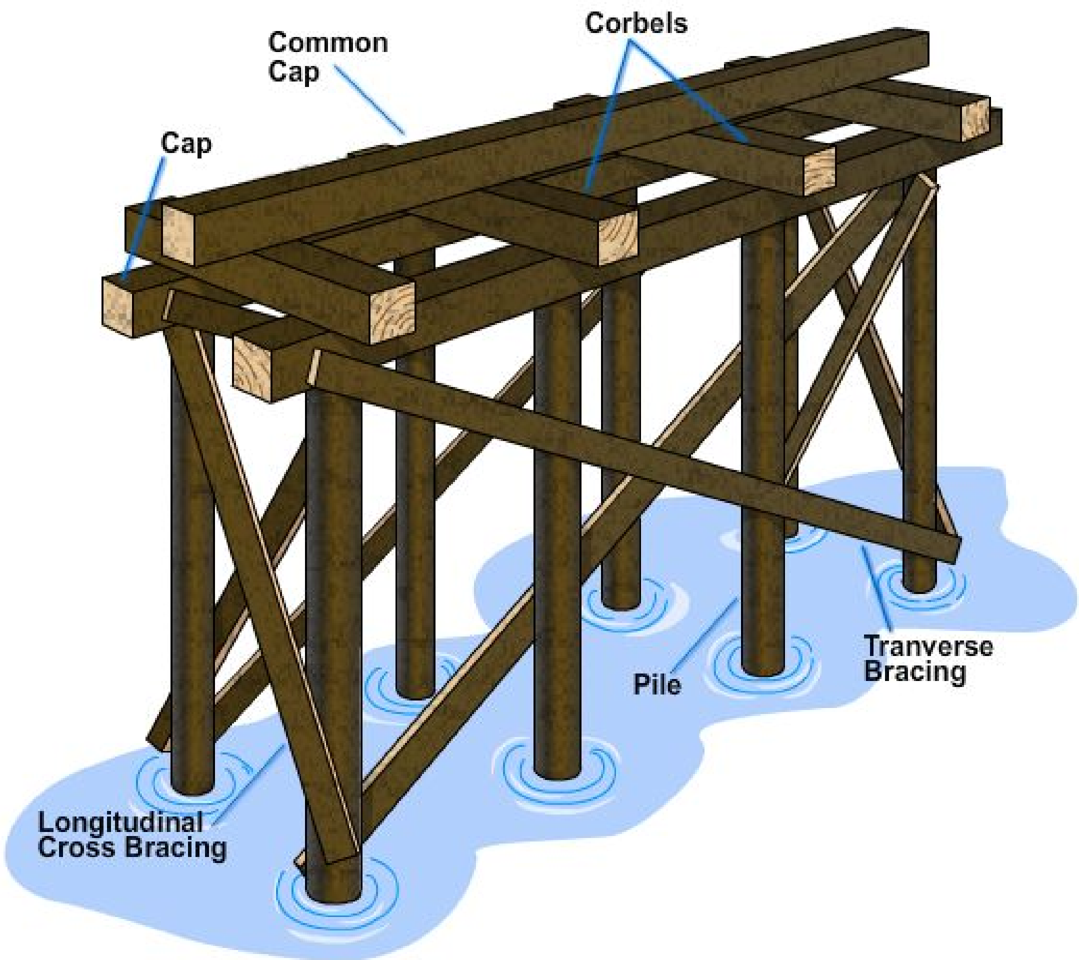


Figure 8-8 – Typical pile pier.

1.2.0 Superstructure

The superstructure of a bridge consists of the stringers, flooring (decking and treads), curbing, walks, handrails, and other items that form the part of the bridge above the substructure. *Figure 8-9* is an illustration of a superstructure.

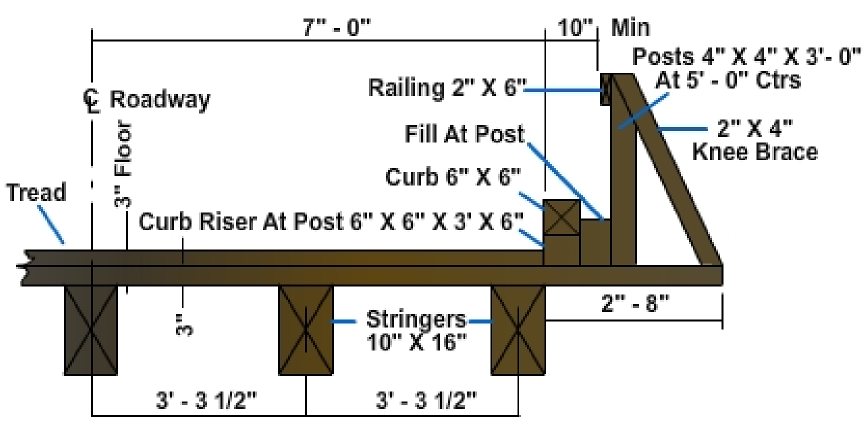


Figure 8-9 – Details of a superstructure of a timber trestle.

As shown in *Figure 8-9*, the structural members that rest on and span the distance between the intermediate supports or abutments are called stringers. The stringers are the main load-carrying members of the superstructure. They receive the load from the flooring and transmit it to the substructure. The flooring system includes these sections:

- Deck
- Wearing surface, or tread, that protects the deck
- Curb and handrail system

The plank deck is the simplest to design and construct, and it provides considerable savings in time compared to other types of decks. Plank decking is normally placed perpendicular to the bridge center line (direction of traffic) for ease and speed of construction. A better arrangement is provided when the decking is placed at about a 30 to 60 degree skew to the center line. Spacing of approximately 1/4 inch between the planks allows for swelling, provides water drainage, and permits air circulation. The minimum thickness of decking is 3 inches in all cases, but when the required thickness of plank decking exceeds 6 inches, a laminated type of decking is used.

2.0.0 TYPES of MODULAR BRIDGES

There are several types of modular bridges available to the Navy. These include the Bailey bridge, shown in *Figure 8-10*, the Mabey bridge, also known as the Mabey Johnson or Johnson bridge, and the medium girder bridge.

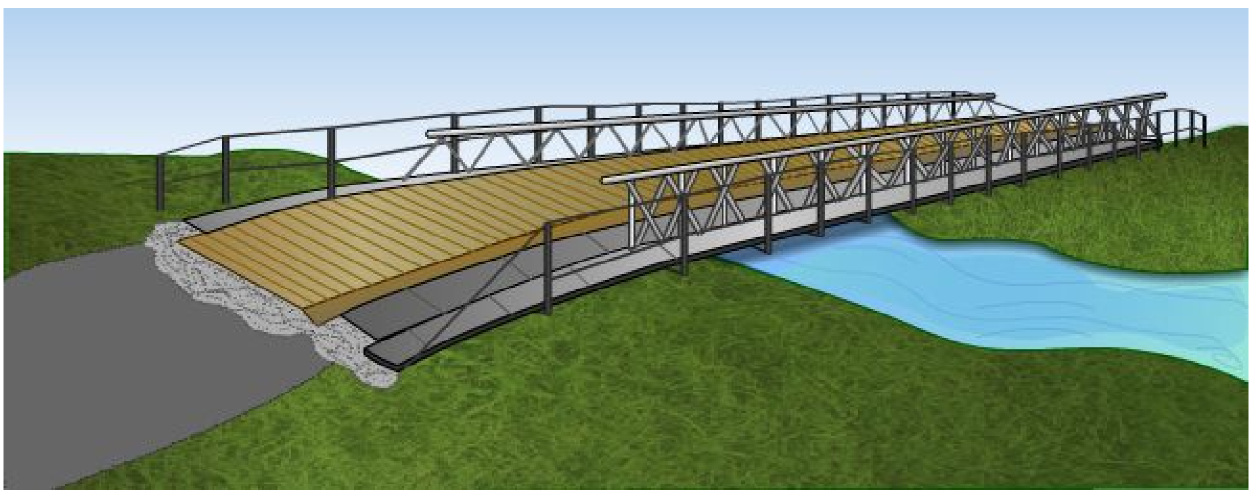


Figure 8-10 – Bailey M2 bridge.

2.1.0 Bailey Bridge

At the outset of World War II, the US Army sought a versatile bridge that could span a variety of gaps and be quickly assembled by manpower alone. We adopted the design for the British prefabricated Bailey bridge, US nomenclature M1. We revised the design to provide a greater roadway width of 12 feet and designated it the panel bridge, Bailey M2, shown in *Figure 8-11*. The Bailey bridge is a through-type truss bridge, with the roadway carried between two main girders. The trusses in each girder are formed by 10- foot panels pinned end to end. In this respect, the Bailey bridge is often referred to as the panel or truss bridge.

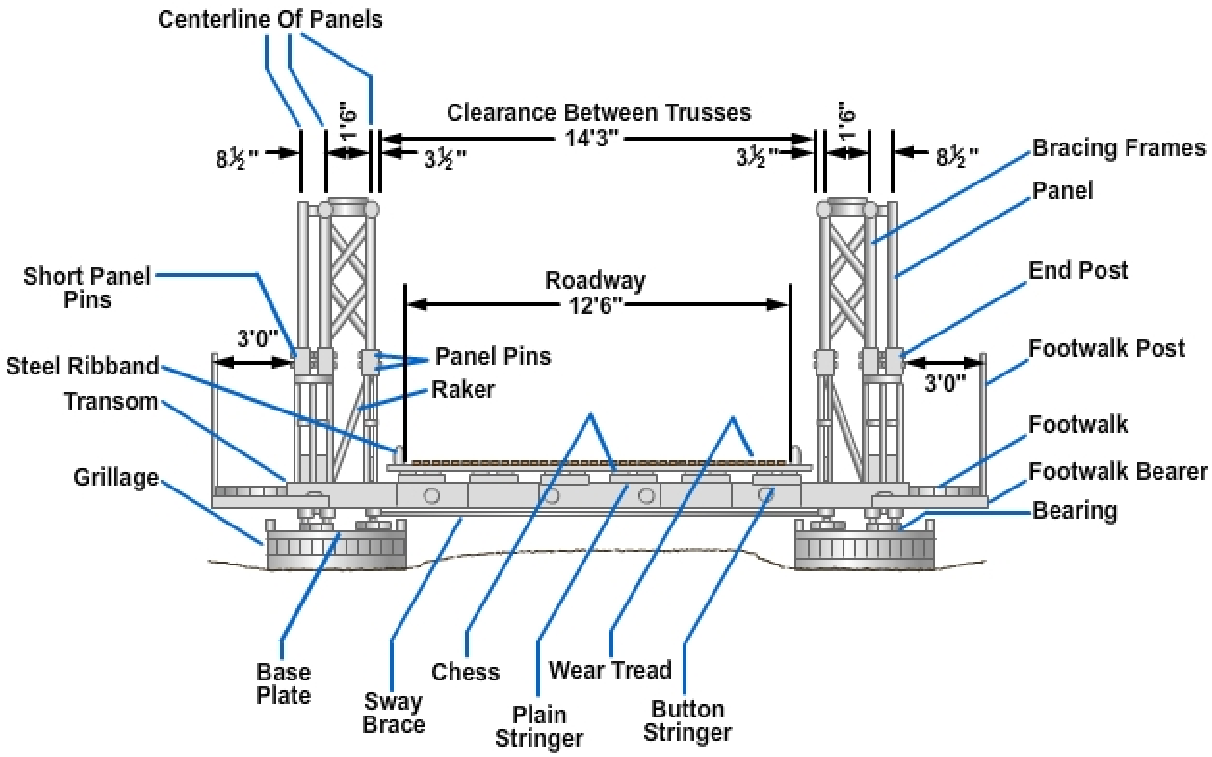


Figure 8-11 – Parts of a Bailey M2 panel bridge.

2.1.1 Advantages

Some of the characteristics that make the Bailey bridge valuable in the field are the following:

- It is easy to install. Each part of the Bailey bridge is a standard machine-made piece and is interchangeable among spans. In most cases, no heavy equipment is required to assemble or launch a Bailey bridge; only basic pioneer skills and equipment are needed.
- It is highly mobile. All parts of the bridge can be transported to and from the bridge site by 5-ton dump trucks and trailers.
- It is versatile. Standard parts are used to assemble seven standard truss designs for efficient single spans up to 210 feet long and to build panel crib piers supporting longer bridges. With minor nonstandard modifications, the expedient uses of bridge parts are limited only by the user's imagination.

2.1.2 Construction

Transverse floor beams, called transoms, are clamped to the bottom chords of the trusses and support stringers and decking. Sway braces between the girders provide horizontal bracing. Rakers between the trusses and transoms keep the trusses upright. Bracing frames and tie plates between the trusses provide lateral bracing within each girder.

2.1.2.1 Main Girders

The main girders on each side of the centerline of the bridge can be assembled from a single truss or from two or three trusses side by side. For greater strength, a second story of panels can be added to the trusses. The upper stories are bolted to the top chord of the lower story. For greatest strength, a third story is added. These three basic types are shown in *Figure 8-12*.

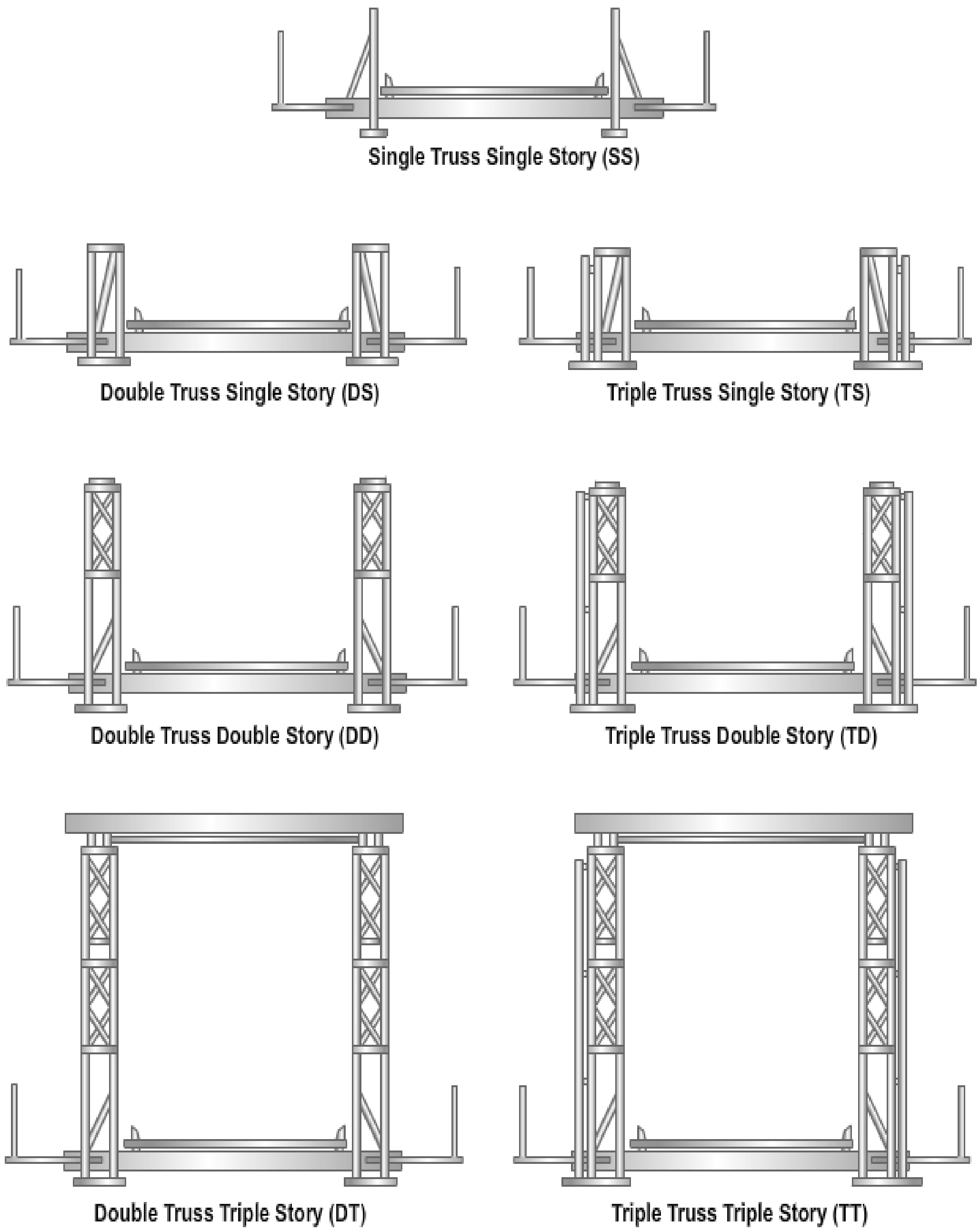


Figure 8-12 – Single, double, and triple truss assemblies.

The types of possible truss assemblies are given in *Table 8-1*. A single truss, double or triple story bridge is never assembled because it would be unstable. All triple story bridges with the deck in the bottom story are braced at the top by transoms and sway braces which are fastened to overhead bracing supports bolted to the top chords.

Table 8-1 – Abbreviations for Bailey Type M2 Single Lane Panel Bridges.

Type		Usual Nomenclature	Abbreviation
Truss	Story		
Single	Single	Single single	SS
Double	Single	Double single	DS
Triple	Single	Triple single	TS
Double	Double	Double double	DD
Triple	Double	Triple double	TD
Double	Triple	Double triple	DT
Triple	Triple	Triple triple	TT

2.1.2.2 Materials

The decking, called chess, is wood. Panels, end posts, transoms, and ramps are a low alloy, high tensile steel. All other parts are carbon structural steel. All joints in the parts are welded.

2.1.2.3 Deck

The clear roadway between curbs, called ribbands, is 12 feet 6 inches wide. The transoms supporting the roadway are normally set on the bottom chords of the bottom story. Footwalks can be carried on the transoms outside of the main trusses on each side of the bridge.

2.1.2.4 Bearings

End posts pinned to the end of each truss sit on cylindrical bearings which rest on a steel base plate. On soft soil, timber grillage is used under the base plates to distribute the load. The bridge can be assembled between banks of different elevations, but the slope should not exceed 30 to 1.

2.1.3 Types of Structures

Panel bridge equipment can be used to assemble fixed bridges and panel crib piers and towers. Other special structures, such as floating bridges, suspension bridges, retractable bridges, and mobile bridges, can be assembled using special parts. Panel bridge equipment is normally used to assemble fixed simple span, through-type bridges from 30 to 210 feet long. The bridge can be assembled to meet varying conditions of span and load. Bridge weight per bay is given in *Table 8-2*.

Table 8-2 – Weight of M2 Panel Bridge in Tons per Bay.

Type of Construction		SS	DS	TS	DD	TD	DT	TT
Bridge Bays		2.76[1]	3.41[1]	4.01[1]	4.66[1]	5.88[1]	6.46[1,2]	8.29[1,2]
Launching-nose Bays		1.00	1.64		2.90			
Decking	Chess and steel ribbands	0.66	0.66	0.66	0.66	0.66	0.66	0.66
	Stringer only	0.79	0.79	0.79	0.79	0.79	0.79	0.79
	Wear treads (four 3" x 12" panels on each side)	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Miscellaneous	Footwalks	0.17	0.17	0.17	0.17	0.17	0.17	0.17
	Overhead bracing (supports, transoms, sway bracing, and chord bolts)	0.54	0.54	0.54	0.54	0.54	0.54	0.54

[1] Footwalks and wear treads not included.

[2] Overhead bracing included.

Information on planning, preparing for, and constructing a Bailey bridge is available in *Field Manual 5-277 Bailey Bridge* from the Department of the Army.

2.2.0 Mabey Bridge

The Mabey Universal panel bridging system, also known as a Johnson bridge, is capable of clear spans up to 266 feet and road widths suitable for single, double, and triple lane traffic. Originally developed in England by Mabey & Johnson Ltd., it was introduced worldwide in 1974. The versatility of the equipment, together with the ease of construction, enables bridges to be built with high load-carrying capacity in a minimum of time. Bridges of varying spans and capacities can be built from a stockpile of standard, interchangeable elements.

- Once the required span and load capacity are known, the necessary construction of the bridge can be automatically calculated or read from tables.
- Bridges can be built quickly with unskilled labor with an engineer supervising.
- With easily transported parts, simple foundations, and minimized on-site time, Mabey Universal bridges can be in service in a very short time.
- Bridges can be launched into position over the gap, and neither temporary supports nor special plants are required.
- With all parts galvanized for minimum maintenance and steel decking which can be coated with an anti-skid surface if required, Mabey Universal bridges are particularly suitable for permanent applications.

2.2.1 Bridge Elements

The panel is the basic unit from which the main girders are formed. Measuring 14' 9" by 7' 9", the Mabey Universal panel is longer and stronger than any other of this type. The panel size has been deliberately designed to permit all the spans normally encountered to be in a single panel height construction.

The effective bending moment capacity of the truss is increased by introducing reinforcement in the form of identical panel chords. Bolted top and bottom to a single panel, the bending moment capacity is doubled. Introducing further panel lines increases both bending and shear capacity. The Mabey Universal is a through-type bridge; the roadway is carried between the main girders, as shown in *Figure 8-13*.

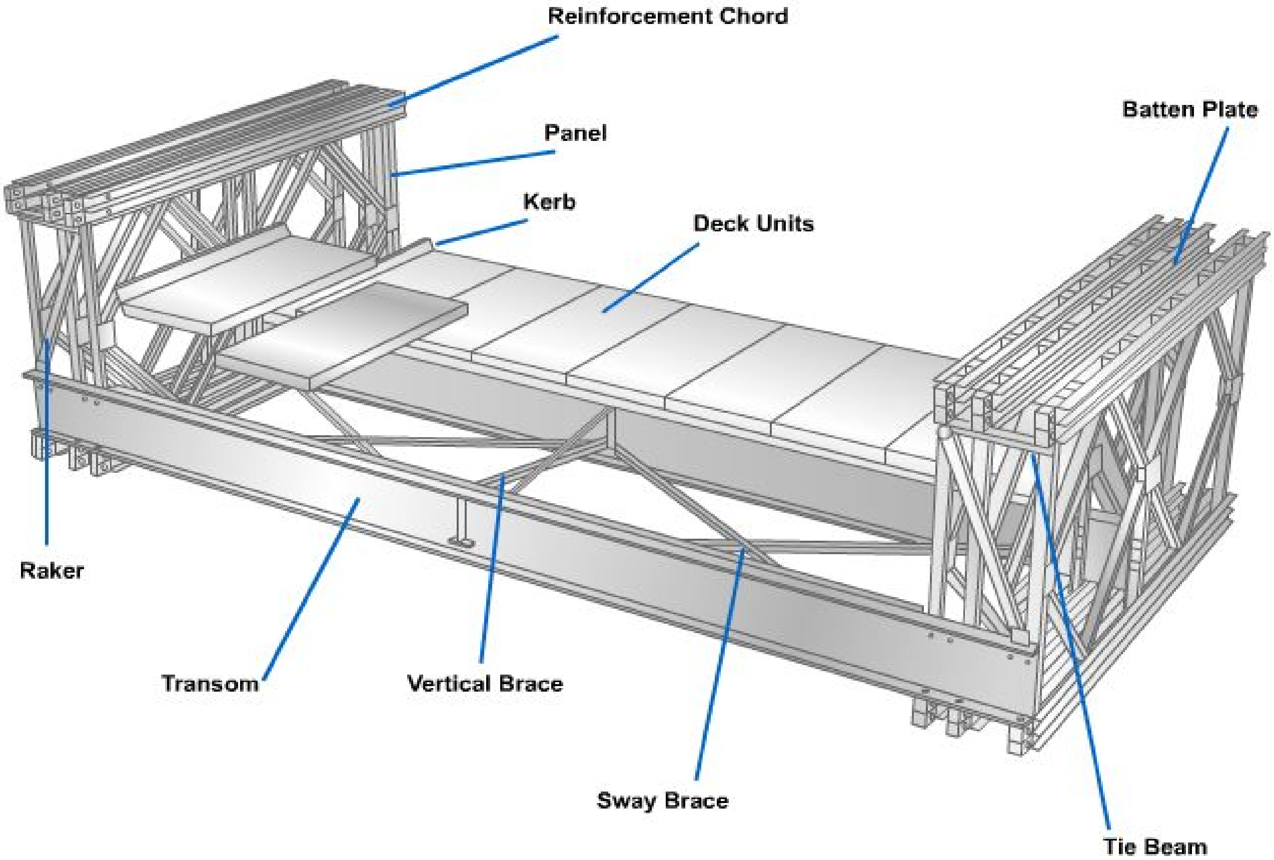


Figure 8-13 – Parts of a Mabey bridge, single bay of two-lane roadway.

The simplest construction is made up of the following parts:

- Panels, which are pinned end to end to form the main girders
- Transoms, the cross beams which connect the main girders and support the roadway
- Rakers, which link transoms and panels, completing the structure and stabilizing the top compression chord of the panel
- Sway braces, which connect diagonally between the transoms, forming a horizontal truss with the transoms and bottom chords of the panels to resist wind and sway forces
- Vertical bracing, which connects diagonally between the top and bottom of the transom webs, acting in tension to stabilize the transoms
- Deck units, which are self-locating on the transoms and provide the running surface of the bridge

2.2.2 Roadway Decking

The deck systems are categorized according to roadway width and load capacity. With the Universal bridge, transoms (cross girders) are fitted at the panel junctions and the mid-panel positions. They vary in depth and length to cater to different roadway widths and loadings.

The configuration is described as two transoms per bay. The transoms support either steel deck units or, on single roadway bridges, stringers which can take timber decking. All the roadways will carry most standard highway loadings. For areas of high traffic density, the steel deck will accept a factory-applied, anti-skid bi-mark wearing course.

The standard ranges of bridge constructions are shown in *Figure 8-14*.

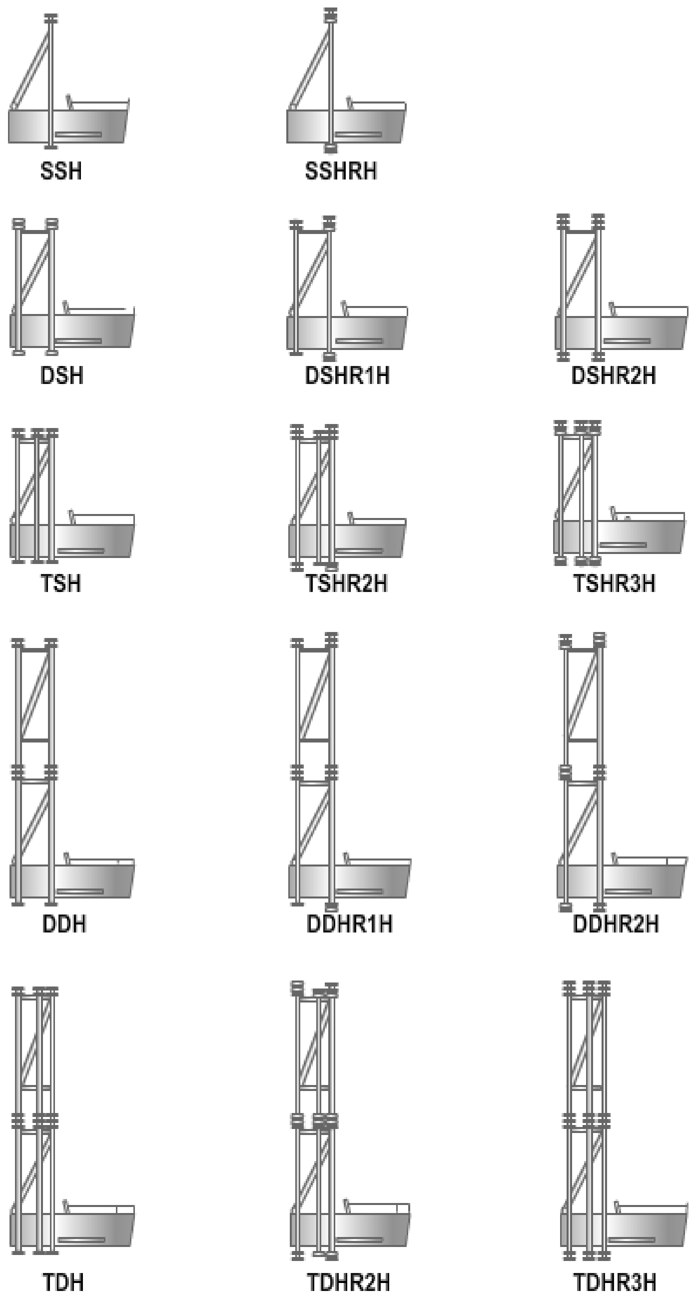


Figure 8-14 – Mabey bridge truss constructions.

Table 8-3 defines the abbreviations.

Table 8-3 – Key to Abbreviations.

Abbreviation	Name	Description
SSH	Single Single	Each truss has a single panel line in a single story format.
SSHRH	Single Single Reinforced	Each truss has a single panel line in a single story format, with a reinforcing chord attached to both the bottom and top of the panel. *
DSH	Double Single	Each truss has two panel lines in a single story format.
DSHR1H	Double Single Reinforced One	Each truss has two panel lines in a single story format with a reinforcing chord attached to both the bottom and the top of the inner panel of each truss only. *
DSHR2H	Double Single Reinforced Two	Each truss has two panel lines in a single story format with a reinforcing chord attached to both the bottom and top of each panel. *
TSH	Triple Single	Each truss has three panel lines in a single story format.
TSHR2H	Triple Single Reinforced Two	Each truss has three panel lines in a single story format with a reinforcing chord attached to both the bottom and the top of the inner and outer panels of each truss only. *
TSHR3H	Triple Single Reinforced Three	Each truss has three panel lines in a single story format with a reinforcing chord attached to both the bottom and the top of all the panels. *
DDH	Double Double	Each truss has two panel lines in a double story format.
DDHR1H	Double Double Reinforced One	Each truss has two panel lines in a double story format with a reinforcing chord attached to both the bottom of the lower inner panel and the top of the upper inner panel of each truss only.
DDHR2H	Double Double Reinforced Two	Each truss has two panel lines in a double story format with a reinforcing chord attached to both the bottom and top of each lower and upper panel. *
TDH	Triple Double	Each truss has three panel lines in a double story format.
TDHR2H	Triple Double Reinforced Two	Each truss has three panel lines in a double story format with a reinforcing chord attached to both the bottom of the lower inner and outer panel and the top of the upper inner and outer panel of each truss only.
TDHR3H	Triple Double Reinforced Three	Each truss has three panel lines in a double story format with a reinforcing chord attached to both the bottom and top of each lower and upper panel. *
H	The letter H is used after either the panel configuration or the chord reinforcement configuration to signify that super panels or super chords are used to form the bridge trusses, instead of standard panels or standard chords. If standard panels are available, they should not be used in conjunction with super panels.	
*	Note that the final bay at each end of the span is always of unreinforced construction.	

2.2.3 Bridge Weights

Table 8-4 shows the weight in metric tons of Mabey bridge bays.

Table 8-4 – Weights per Bay of Bridge Bays (Metric Tons).

Truss Construction	Fully Decked	No Deck
DSH	9.501	5.856
DSHR1H	10.427	6.782
DSHR2H	11.332	7.687
TSH	10.843	7.198
TSHR2H	12.672	9.027
TSHR3H	13.588	9.943
DDH	12.376	8.731
DDHR1H	13.290	6.646
DDHR2H	14.205	10.560
TDH	15.091	11.446
TDHR2H	16.921	13.276
TDHR3H	17.836	14.191

Notes:

1. The weights tabulated above are in tons per 4.500 m long bay and are based upon theoretical component weights with an allowance of 2.5% for galvanizing.
2. The fully decked weights are with all steel deck fitted. The no deck weights are with neither steel deck units nor kerbs fitted.
3. The final bay at each end of a bridge span is always of an unreinforced truss construction, even when the bridge is otherwise of a reinforced construction.

Information on planning, preparing for, and constructing a Mabey bridge is available in the *Mabey Universal Bridge System Bridge Manual* from the manufacturer.

2.3.0 Medium Girder Bridge

The medium girder bridge (MGB) is a two girder deck bridge. The wide upper surfaces of the girders and the deck units laid between them form a roadway 13 feet 2 inches wide. The girders can be constructed to form a shallow single story construction, as shown in *Figure 8-15.* The two girders are constructed from a number of panels pinned together, and are separated by two bankseat beams, one pinned to each of the girders. The roadway is formed by hanging deck units between the girders and connecting ramps to each end. Curbs and guide markers are placed at the outside edges of the girders to mark the edge of the bridge. The single story bridge is used for light loads.

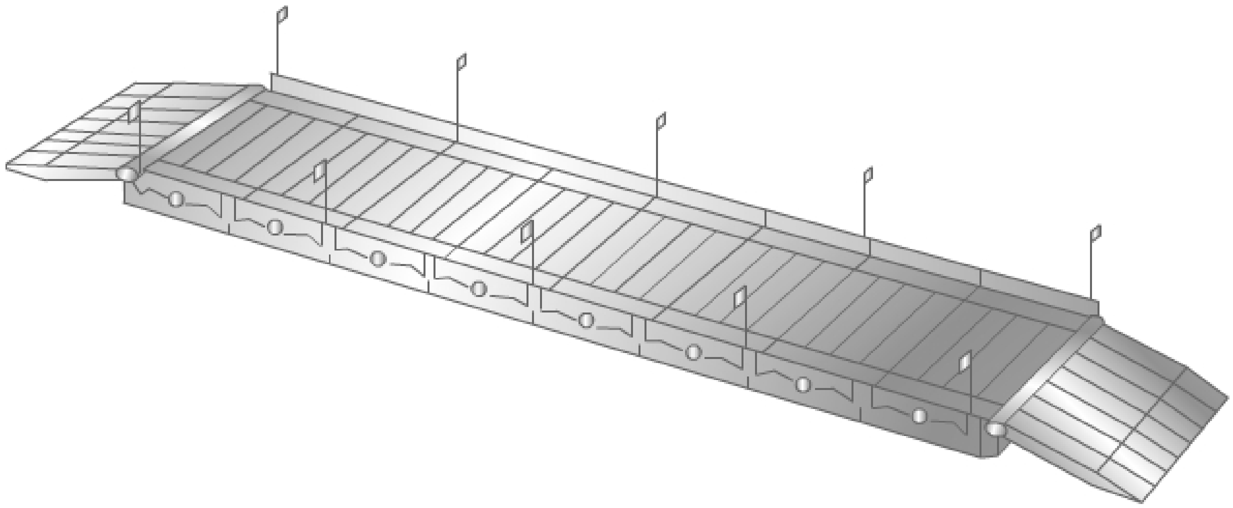


Figure 8-15 – Medium girder bridge - shallow single story.

The girders can also be constructed to form a deeper double story construction, as shown in *Figure 8-16*. A double story bridge (DSB) uses all of the parts of a single story bridge (SSB) which are pinned on top of triangular bottom panels, with junction panels and end taper panels at each end. These parts make the bridge stronger.

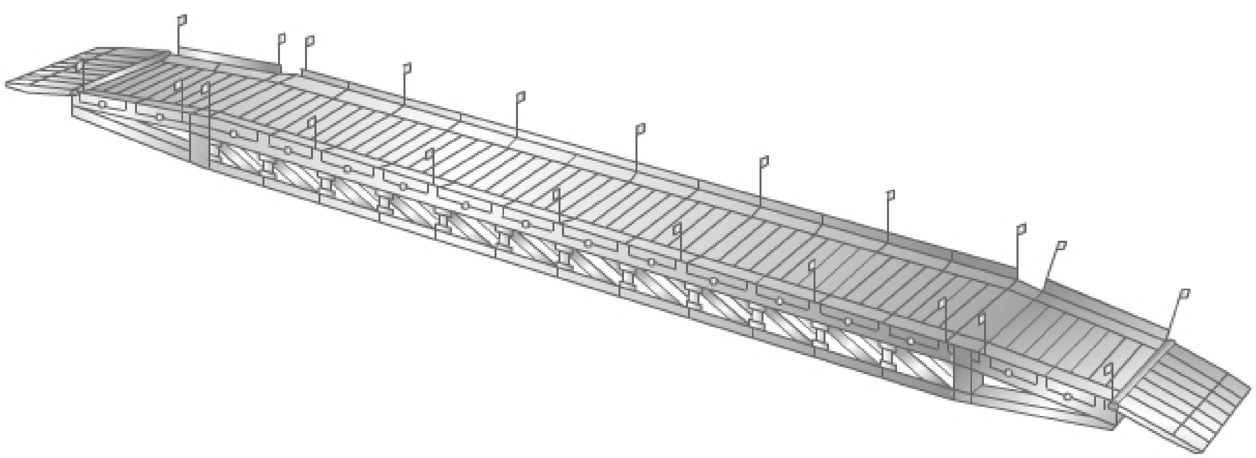


Figure 8-16 – Medium girder bridge – double story.

The double story can be reinforced by adding components of the Link Reinforcement Set (LRS), as shown in *Figure 8-17*; this permits longer Military Load Class (MLC) 70 bridges to be constructed. The Link Reinforcement Set (LRS) extends the single-span capability of the MLC 70 MGB. The set contains all the components needed for use with two bridge sets to construct any length of reinforced MLC 70 (Tracked) MGB up to 150 feet and MLC 60 (Tracked) up to 162 feet (49.4 m). The LRS consists of reinforcing links 12 feet and 6 feet long which are connected to form a pair of link chains, one beneath each bridge girder. The 6-foot links are provided for use in bridges that have an odd number of bays.

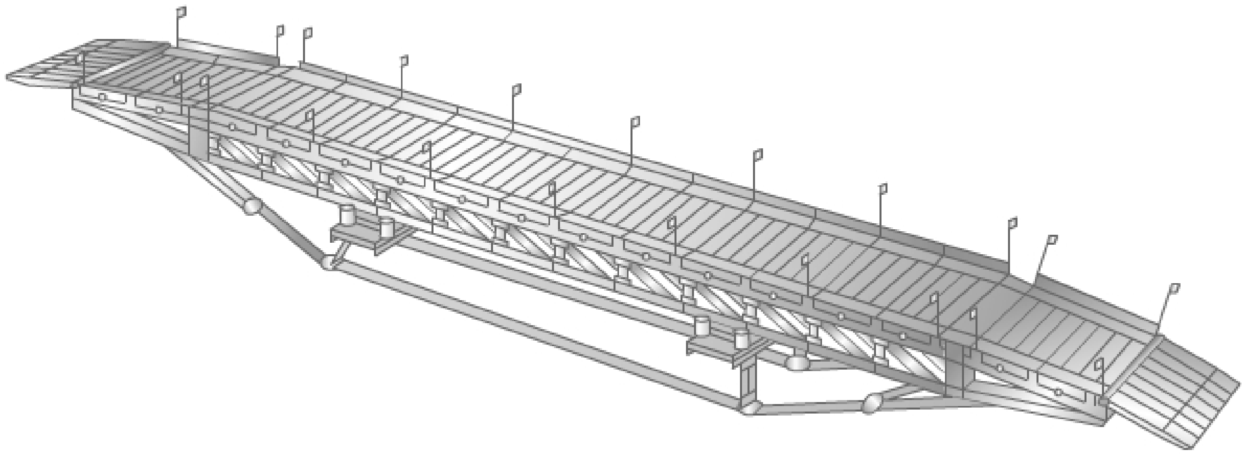


Figure 8-17 – Medium girder bridge - link reinforced.

The maximum load capabilities of single story, double story and link reinforced MGB are given in *Table 8-5*.

Table 8-5 – Bridge Length v Maximum Load Capability.

Bridge	MLC (Note 1)	Bridge Length in Feet (Meters) (Note 2)	Maximum Transverse Slope Unloaded	Maximum Full Load Crossings (Note 2)
Single Story	60	32 (9.8)	1/10	10,000
	70 (Tracked)	32 (9.8)	1/20	5,000
	100 (Wheeled)	32 (9.8)	0	7,500
Double Story	60	102 (31.1)	1/20	10,000
	60 (Tracked)	108 (32.9)	1/20	7,500
	70 (Tracked)	102 (31.1)	1/20	5,000
	100 (Wheeled)	90 (27.4)	0	3,000
Link Reinforced	60	162 (49.4)	1/20	10,000
	70 (Tracked)	150 (45.7)	1/20	10,000
	70 (Tracked)	162 (49.4)	0	5,000
	100 (Wheeled)	102 (31.1)	0	--

NOTES:

1. Deck width is 13 feet 2 inches (4 meters). In MLC 70 (Tracked) and MLC 100 (Wheeled) configurations the bridge width should be indicated by a sign.
2. MLC 100 (Wheeled) span has yet to be confirmed by tests.

Information on planning, preparing for, and constructing a medium girder bridge is available in the *Operator's Manual – Medium Girder Bridge* from the Department of the Army and Headquarters U.S. Marine Corps.

3.0.0 SHORING EXCAVATION

One of the inherently hazardous parts of construction operations is excavating. The main hazards of excavation work are as follows:

1. Collapse or failure of excavation walls, burying workers and equipment
2. Materials, tools, and equipment falling into holes and striking workers below
3. Hazards involving public utilities, such as electricity, water, gas, or natural gases and an oxygen-deficient atmosphere
4. Wet, muddy conditions, causing slips, trips, or falls, complicated by limited spaces in which personnel work

Take precautions to make sure the excavation banks do not collapse and cause injury or death to persons working in the excavation. The method used to protect excavation banks from collapsing depends on these conditions:

- Type of soil in the area
- Depth of the excavation
- Type of foundation being built
- Space around the excavation

Before beginning the excavation, the Builder must secure all possible information regarding any underground installations in the area, including sewer, water, fuel, and electrical lines. As a Builder, you must also take precautions NOT to disturb or damage any utility while digging and to provide adequate protection after any such exposure. Make sure you have a digging permit on the jobsite and that you follow its guidelines.

Many safety codes also require that the excavation be inspected by a qualified person (ROICC or safety officer) after a rainstorm or any other hazardous natural occurrence. Avert earth bank cave-ins or landslides by increasing the amount of shoring and other means of protection.

Provide convenient and safe access to excavated areas for your crew. Such access may consist of stairways, ladders, or securely fastened ramps.

During excavation some soil types pose greater problems than others. Sandy soil is always considered dangerous even when it is allowed to stand for a period of time after a vertical cut. Instability can be caused by moisture changes in the surrounding air or changes in the water table. Vibration from blasting, traffic movement, and material loads near the cut can also cause earth to collapse in sandy soil.

Clay soils present less risk than sand, but soft clay can also be dangerous. You can do a simple test of clay conditions by pushing a 2 by 4 into the soil. If the 2 by 4 is easily pushed into the ground, it indicates that the clay is soft and may collapse. Silty soils, a combination of sand and clay, are also unreliable and require the same precautions as sand.

3.1.0 Sloping

When there is sufficient space around the construction site, slope the earth banks as necessary to prevent collapse. The Occupational Safety and Health Administration (OSHA) code regulations for the construction industry recommend a 45-degree slope for excavations with average soil conditions. Solid rock, shale, or cemented sand and gravel may require less slope. Compacted sharp sand or well rounded loose sand may require more than a 45-degree slope.

3.2.0 Shoring Vertical Walls

Shoring (supporting) the vertical walls of an excavation is required when sloping is considered unsafe or inadequate. Soil types such as clays, silts, loams, or non-homogenous soils usually require shoring. Shoring may also be required where there is insufficient room for sloped banks. This is particularly true in industrial and commercial areas where new construction is right next to existing buildings. In addition to preventing injury from collapse of excavation banks, stability of the foundation walls of adjoining buildings must be protected. A civil engineer supervises shoring for high vertical walls, and qualified personnel supervise the installation. Do not remove the shoring system until the construction in the excavated area is completed and all the necessary steps are taken to safeguard workers. Two methods commonly used to shore high vertical excavation banks are interlocking sheetpiling, shown in *Figure 8-18*, and soldier piles, shown in *Figure 8-19*.

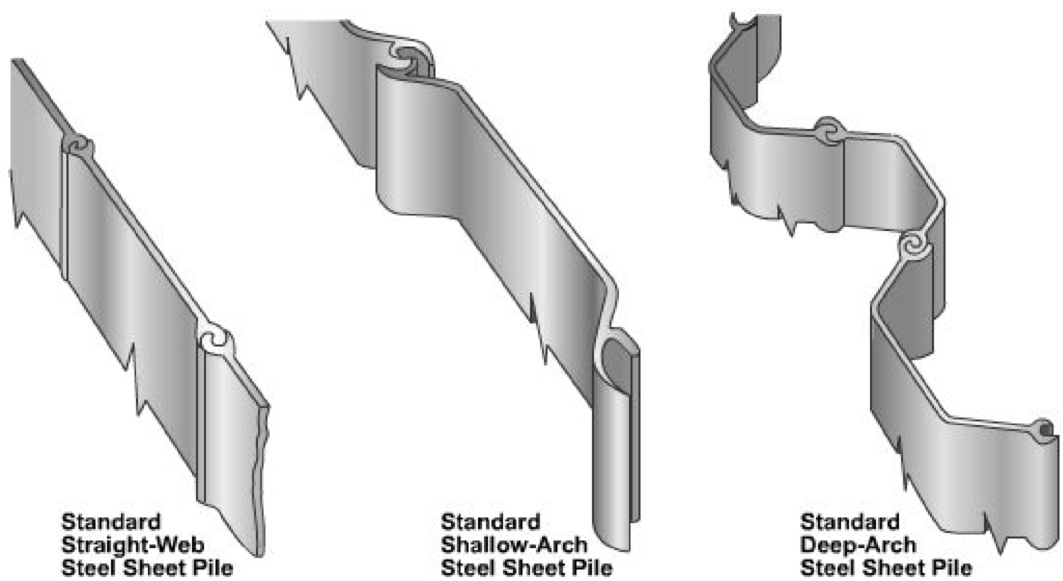


Figure 8-18 – Types of interlocking sheet piles.

3.2.1 Interlocking Sheet Piles

Interlocking sheet piles consist of steel pilings that can be reused many times and offer the additional advantage of being watertight. Each individual sheetpiling is lowered by crane into a template that holds it in position. Then the piling is driven into place with a pile driver. Install braces to help support the metal sheets.

3.2.2 Soldier Pile Systems

Soldier piles are H-shaped piles that are driven into the ground with a pile driver and are spaced between 3 and 10 feet apart. Refer to the plans and specifications for spacing requirements. Three-inch thick wood planks, called lagging, are placed between the flanges or directly against the front of the piles. You may use 2-inch blocks for spacing between each plank or butt the planks together depending on the specifications. Soil conditions and the depth of the excavation may require tie-backs that consist of steel strand cables placed in holes drilled horizontally into the banks of the excavation. The holes are drilled into the banks of the excavation with a power auger and are often 50 feet or more in length. The tie-back cables are inserted through an opening in the pile and are secured in the earth by power grouting the hole. After the grout has set up, a strand-gripping device, consisting of a gripper and gripper casing, is placed over the cables. A hydraulic tensioning jack is used to tighten the cables. When the jack releases the cables, the gripping device holds them and maintains the required tension against the pile. The number of tie-backs required should be determined by an engineer whose decision will be based on soil conditions and the depth of the excavation. Some soldier pile systems may also include a heavy horizontal steel waler held in place with tie-backs. This technique is similar to constructing a single waler system for concrete; it is the same basic principle.

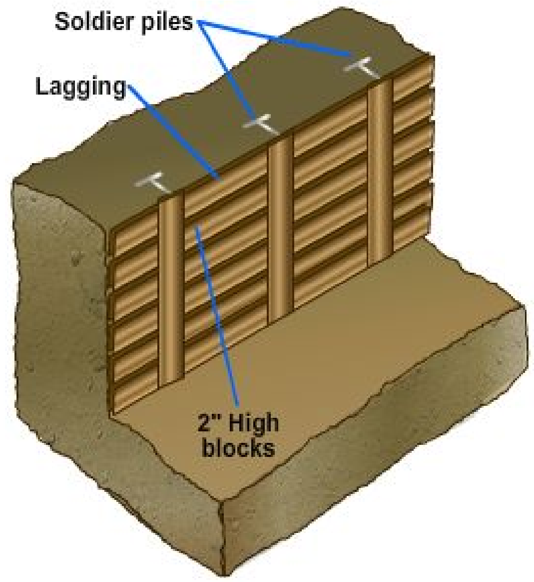


Figure 8-19 – Soldier pile systems.

In many instances, the excavation for a new building must be carried right up to the foundation of an existing one. This presents a problem if the new excavation is to be deeper than the footings of the existing building. Part of the support for those footings will be removed, and it is the BU's responsibility to protect the building against movement caused by settlement during and after construction of the new building. Temporary support may be provided by shoring or needling, while permanent support is provided by underpinning, extending the old foundation to the level of the new one.

A common method of support for adjacent structures is by the use of 12 by 12 timbers, called shores, inclined against the wall to be supported and extending across the excavation to a temporary footing consisting of a framework or mat of timbers laid on the ground. Fit the upper ends of the shores into openings cut in the wall, or butt them against a timber bolted to the wall. Place steel saddles in openings cut in concrete or masonry walls to support lifting or to steady the shores.

As a good practice, set the shores as vertical as possible to reduce lateral thrust against the wall. Whenever possible, locate the heads at floor level to minimize the danger of pushing the wall in.

Make the provision for inducing a lift or thrust in the shores by inserting jacks between the bases of the shores and the footing. Use a standard steel screw jack with the capability to lift as much as 100 tons for the shores. When a single screw jack is used with a shore, bore a hole in the base of the shore to admit the threaded portion of the jack, in an arrangement called a pump. For a larger lifting effect, attach a pair of jacks to a short timber called a crosshead. An advantage of crosshead arrangements is that after the lift has been applied, the crosshead can be blocked and the jacks removed for use elsewhere.

4.0.0 PILE CONSTRUCTION

As a Builder, you will coordinate and direct pile driving operation crews. Piles include many different types and materials. The more common types are covered next.

4.1.0 Bearing Piles

Bearing piles are vertical posts that carry the weight of a foundation. They transmit the load of a structure to the bedrock or subsoil.

4.1.1 Timber Bearing Piles

Timber bearing piles are usually straight tree trunks with the limbs and bark removed; they must be pressure treated. These piles, if kept continuously wet, will last for centuries, but they are used for low design loads because of their vulnerability to damage while they are being driven into the ground. The small end of the pile is called the tip, and the larger end is called the butt. Timber piles range from 16 to 90 feet in length with a tip diameter of at least 6 inches. The butt diameter is seldom less than 12 inches.

4.1.2 Steel Bearing Piles

Steel bearing piles are usually H piles, with an H-shaped cross section. These piles are usually used for driving through bedrock or until refusal. A steel pile can also be a pipe pile with a circular cross section. A pipe pile can be either an open end pile or a closed end pile, depending on whether the bottom end is open or closed.

4.1.3 Concrete Piles

Concrete piles, shown in *Figure 8-20*, may be either precast or cast-in-place. Most precast piles used today are pretensioned and are manufactured in established plants. These piles are made in square, cylindrical, or octagonal shapes. When driven into soft soil or mucky soil, they are usually tapered. Cast-in-place piles are cast on the jobsite and are classified as shell type or shell-less type. The shell type is formed when the hollow steel tube (shell) with a closed end is driven into the ground and filled with concrete. The shell-less type is formed when first a casing and core are driven to the required depth. The core is removed, and the casing is filled with concrete. The casing is then removed, leaving the concrete in contact with the earth.

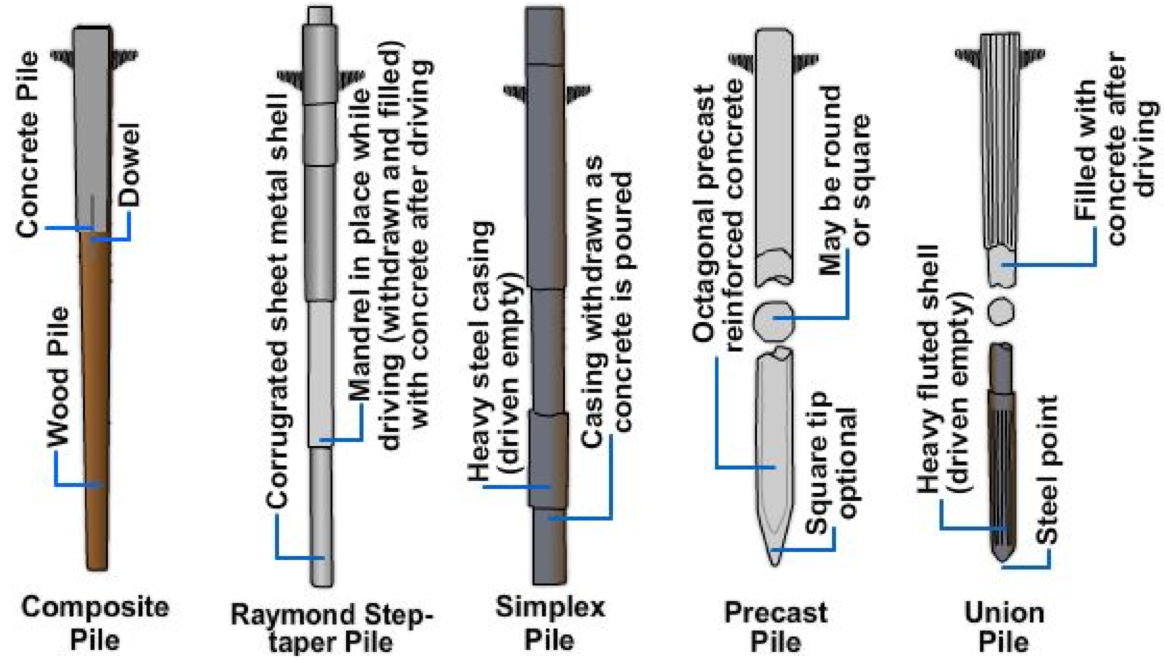


Figure 8-20 – Types of concrete piles.

4.2.0 Sheet Piles

Sheet piles made of wood, steel, or concrete are equipped or constructed for edge joining so they can be driven edge to edge to form a continuous wall or bulkhead. A few common uses of sheet piles are as follows:

1. To resist lateral soil pressure as part of a temporary or permanent structure, such as a retaining wall.
2. To construct cofferdams or structures built to exclude water from a construction area.
3. To prevent slides and cave-ins in trenches or other excavations.

The edges of steel sheetpiling shown in *Figure 8-18* are called interlocks because they are shaped for locking the piles together edge to edge. The part of the pile between the interlocks is called the web.

4.3.0 Pile Driving Operation

Almost all pile driving is done with a crawler or with truck-mounted cranes rigged with pile-driving attachments, as shown in *Figure 8-21*. The main parts of pile-driving attachments are as follows:

- The leads come in 10-, 15-, and 20-foot sections bolted together to form various lengths.
- The catwalks, also called the lead brace or spotters, can be extended or telescoped to various lengths. These can be set to hold the leads vertical for driving bearing piles or to hold them at an angle for driving batter piles.

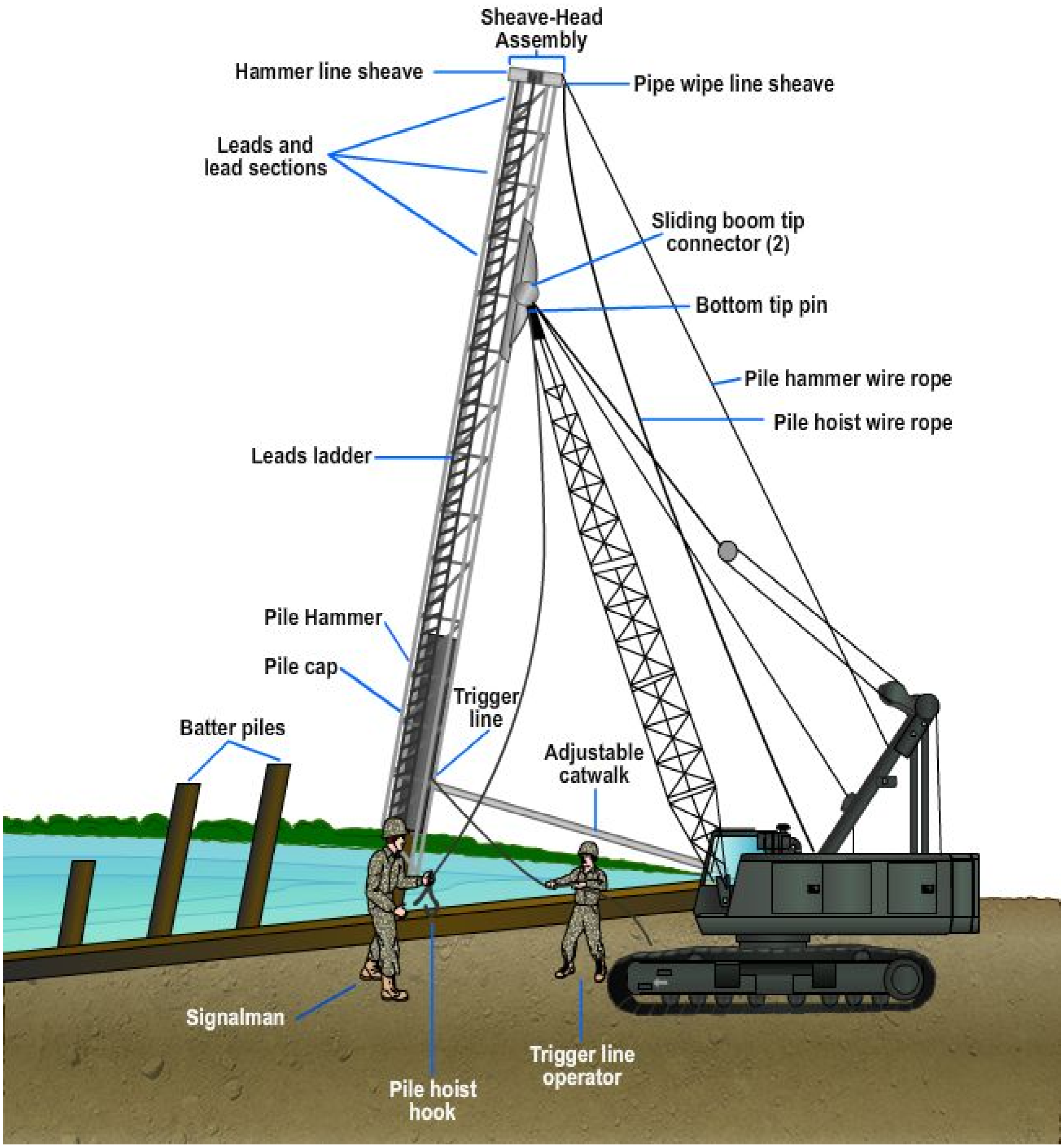
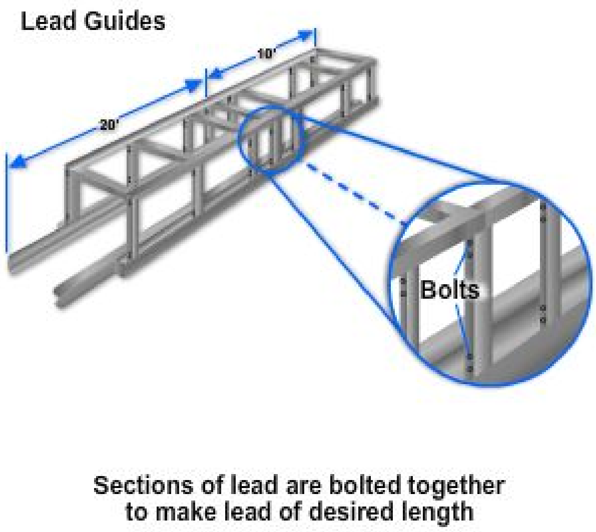


Figure 8-21 – Typical pile-driving operation.

Steps in rigging pile-driving attachments on a crane are as follows:

1. Assemble the lead sections on the ground, as shown in *Figure 8-22*. Line the crane up with the leads, and lower the boom until its head is in line with the tops of the leads, as shown in *Figure 8-22*.
2. Remove the cotter pins on the ends of the boom point pin, install the adapters, and reinstall the cotter pins.
3. Bolt the adapters to the ends of the leads, as shown in *Figure 8-23*. To avoid trouble, bolt on one adapter, and swing the boom enough to align the bolt holes with the adapter and leads. Attach the tops of the leads to the head of the boom.



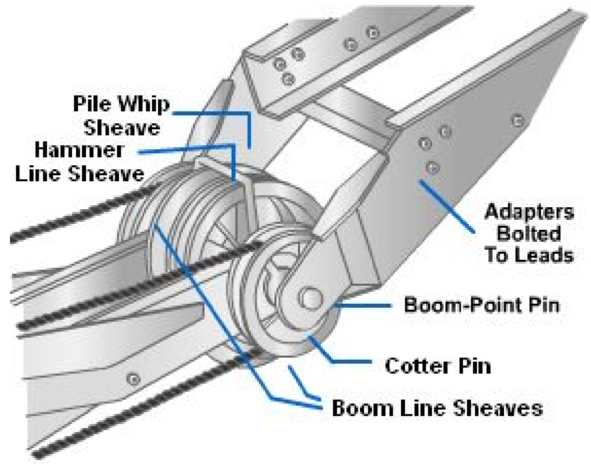
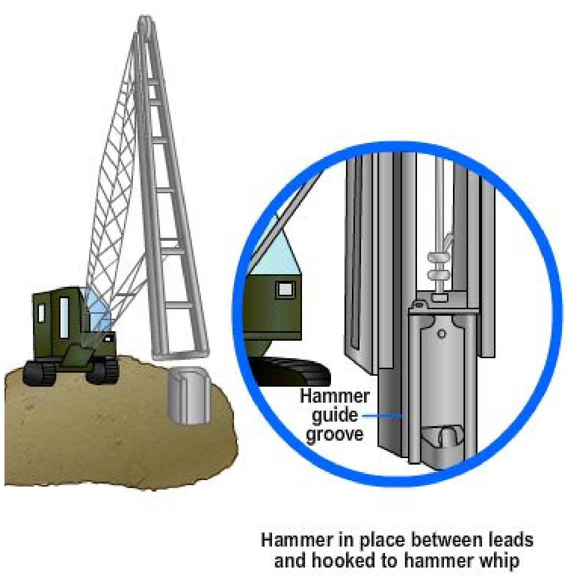


Figure 8-22 – Assembly of 10- and 20-foot sections.

Figure 8-23 – Lead adapters connected to the boom tip.

4. The lines that handle the piles and the hammer are called the pile whip and the hammer whip. Reeve (pass) them over the sheaves at the head of the boom, bring down the ends to the foot of the leads, and lash them. Reeve through enough slack in each whip to ensure that the boom can be topped up to the vertical height of the leads without also straining the sheaves.
5. Raise the leads by topping up the boom.
6. When the leads are raised to the vertical position, attach lead braces or spotters (catwalks).
7. Place the hammer in the leads, as shown in *Figure 8-24*. Raise the leads off the ground by topping the boom, place the hammer under them, lower the leads onto the hammer, and attach the hammer whip line to the pin on top of the hammer.



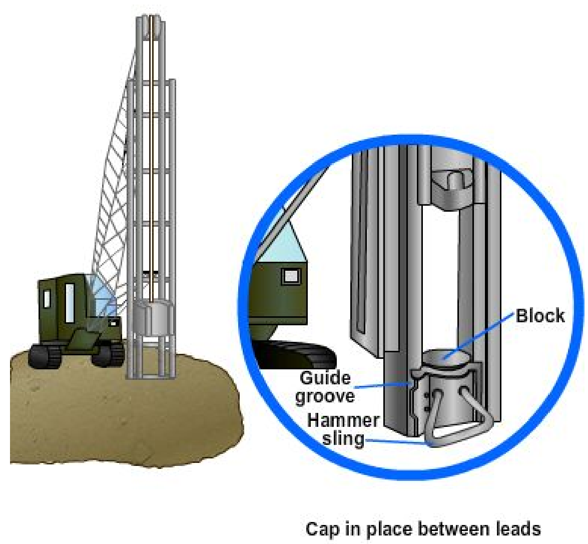


Figure 8-24 – Placing hammer in leads.

Figure 8-25 – Placing pile cap in leads.

8. The driving cap or follower block is a cap that rests on the top of the pile being driven. It slides freely in the leads to steady the pile and to receive and transmit the impact of the hammer. The cap, shown in *Figure 8-25*, has a sling of wire rope, so the cap and the hammer may be drawn to the top of the leads out of the way when a pile is being positioned for driving.

4.3.1 Pile-Driving Hammers

The three main types of pile-driving hammers are the drop hammer, the steam, or pneumatic, hammer, and the diesel hammer.

A drop hammer is a block of metal run up to a specified height and then dropped on a cap placed on the butt or head of the pile. Drop hammers weigh from 1,200 to 3,000 pounds.

The steam, or pneumatic, hammer has basically replaced the drop hammer. This hammer, shown in *Figure 8-26*, consists of a cylinder that contains a steam-driven or air-driven ram. The ram consists of a piston equipped with a striking head. The hammer is rested on the butt or head of the pile for driving.

With a single-action steam, or pneumatic, hammer, the power drive serves only to lift the ram; the downward blow of the ram results from the force of gravity only. In a double-action hammer, the ram is both lifted and driven downward by the power drive. A double-action hammer weighs from 5,000 to 14,000 pounds and a single-action hammer weighs about 10,000 pounds.

The blow of the double-action hammer is lighter but more rapid than that of the single-action hammer. The double-action hammer generally drives lightweight or average weight piles into soils of average density; its rapid blows tend to keep the pile in motion, which reduces the resistance of inertia and friction. For heavy piles in hard or dense soil, the resistance from inertia and friction, together with the rapid, high velocity blows of the double-action hammer, tend to damage the butt or head of the pile.

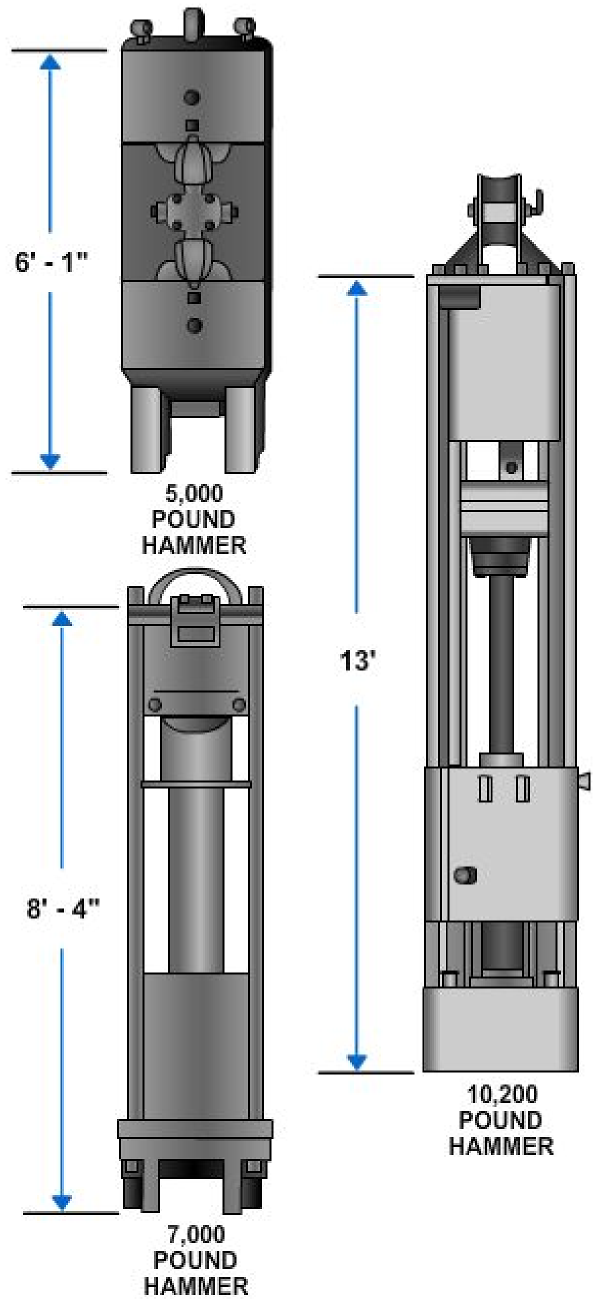


Figure 8-26 – Steam, or pneumatic, pile hammers.

The single-action hammer generally drives heavy piles into hard or dense soil; its heavy ram, striking at lower velocity, allows more energy to be transferred into the motion of the pile, reducing impact and damage to the butt or head of the pile.

The diesel pile hammer, shown in *Figure 8-27*, is the most common hammer used in the NCF. This hammer is made up of a cylinder, a ram piston, a fuel pump, a built-in fuel tank, a lubricant oil tank, and an inertia oil pump that lubricates mechanically during operation.

The diesel pile hammer is about twice as fast as a conventional pneumatic, or steam, hammer of like size and weight. A conventional pneumatic hammer requires a 600 cubic foot per minute compressor to operate, while the diesel is a self-contained unit constructed in sizes that deliver up to 43,000 foot pounds of energy per blow.

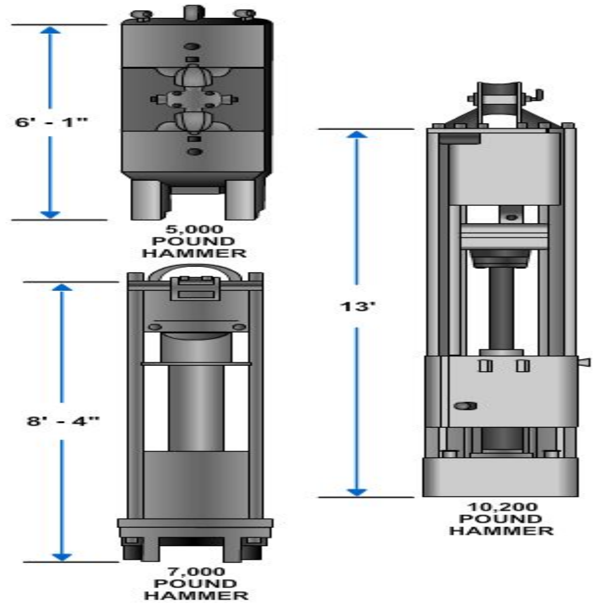


Figure 8-27 – Diesel pile hammer.

4.3.2 Pile-Driving Caps

A pile-driving cap is a block, usually a steel block, that rests on the butt or head of the pile and protects it against damage by receiving and transmitting the blows of the hammer or ram. In the steam, or pneumatic, hammer, the cap is a part of the hammer. The cap with a drop or diesel hammer is a separate casting, with the lower part recessed to fit the head or butt of the pile, and the upper part recessed to contain a hardwood block which receives the blows of the hammer. The cap is fitted with a wire rope sling so that the cap, as well as the hammer, may be raised to the top of the leads when positioning a pile in the leads. Pile caps are available for driving timber, concrete, sheet, and H beam piles. *Figure 8-28* shows an example of a steel H pile and a special cap for driving.

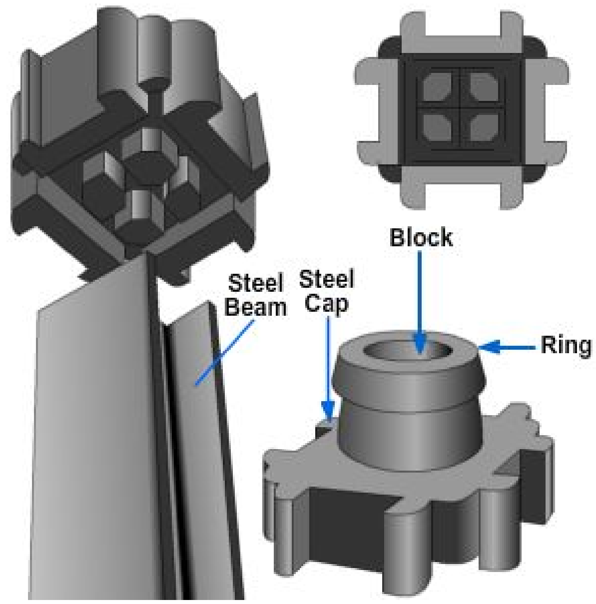


Figure 8-28 – H beam pile-driving cap.

4.3.3 Crane Safety

As the project supervisor of a pile-driving operation, you must be aware of the safety precautions and procedures involved when working with and around cranes.

Statistics on accidents show that a free-moving power crane is one of the most destructive machines used in the Navy, as well as in private industry. Over one-third of the victims of crane accidents are operators, and more than one-fourth are crew members other than operators. Ironically, the people who sustain the most injuries from cranes are the very ones who can do the most to prevent injuries. Most crane accidents are preventable simply because they are caused by situations, conditions, or actions under the control of the operating crew. The term “preventable accident” is illogical; if an accident were preventable, it would not be an accident, but an act of omission or commission by somebody.

Most crane work is, or should be, a coordinated activity of a team of skilled technicians and workers. The lives and well-being of the whole team are in the hands of each member of the team during a continually shifting scene requiring constant judgment and responsibility. The pile-driving crew is usually made up of the following personnel:

- Rig operator
- Signalman
- Loftman
- Hoisting engineer
- Hook-on person

During any pile-driving operation, the signalman is the boss of the rig and is normally the only person giving signals to the operator. The only signal any other person may give that the operator will obey is the emergency stop signal. Refer to the *Equipment Operator Basic NRTC* for more information regarding crane safety.

4.3.4 Pile-Driving Safety

Standard safety and accident prevention procedures developed to govern general construction operations apply also to pile-driving operations. Pile driving is hazardous, and personnel should take adequate care to be protected from injury. Close cooperation between the Equipment Operators and crew members (Builders/Steelworkers) is essential to avoid accidents.

- Apply normal safety precautions to hand power tools used to prepare piles for driving and in cutting off, straightening, and aligning piles after they are driven.
- Wear safety shoes.
- Be sure you and all your crew are wearing hard hats. Mill scale may fly from a steel pile while it is being driven.
- During the first few feet of driving a pile, keep personnel out of the way as much as possible so that if the tip of the pile were to strike an obstacle and slide out of line, no one would be struck by the pile.
- During actual pile driving, protect your ears.
- When working over water, wear a life jacket and make sure crew members do likewise.
- Use safety belts as required.

4.3.5 Characteristics of Different Piles

As a Builder, you will be most concerned with timber piles. Steel piling ranks next in importance, especially where the construction must accommodate heavy loads or the foundation is expected to be used over a long period of time. Steel is best suited for use as bearing piles when piles are longer than 80 feet and column strength exceeds the compressive strength of timber. Steel is also best suited where piles must be driven under the following conditions:

- To reach bedrock for maximum bearing surface through overlying layers of partially decomposed rock.

- To penetrate layers of coarse gravel or soft rock, such as coral.
- To attain greater depth of penetration for stability.

Concrete and composite piles are seldom used because they require material and equipment that is not normally available through military supply channels. They are likely to be used in cases where local materials are readily available, whereas standard military piling would have to be received in large quantities from CONUS. Interlocking steel sheet piling is often used in military construction, but concrete-steel piling can be manufactured in the field when local material is available.

4.3.6 Precautions During Pile Driving

Be careful during driving to avoid damage to the pile, the hammer, or both. If the pile driver shifts position during driving, the blows of the hammer will be out of line with the axis of the pile and both the pile and the hammer may be damaged.

Watch the piles carefully for any sign of a split or break below ground. When you are driving a pile and it suddenly becomes easier to drive or the pile suddenly changes direction, a break or split has probably occurred. When this happens, pull the pile as soon as possible, because further driving is useless.

Springing means that the pile vibrates too much laterally. Springing may occur when a pile is crooked, when the butt has not been squared off properly, or when the pile is not in line with the fall of the hammer. In all pile driving, make sure the fall of the hammer is in line with the pile axis; otherwise the head of the pile and the hammer may be damaged severely and much of the energy of the hammer blow lost.

Excessive bouncing may come from a hammer that is too light. It usually occurs when the butt of the pile has been crushed or broomed, when the pile has met an obstruction, or when it has penetrated to a solid footing. When a double-action hammer is being used, bouncing may result from too much steam or air pressure. With a closed end diesel hammer, if the hammer lifts on the upstroke of the ram piston, the throttle setting is probably too high. Back off on the throttle and control just enough to avoid this lifting. If the butt of the timber pile has been crushed or broomed more than an inch or so, cut it back to sound wood before you drive it any more.

When a pile has reached a level where 6 blows of a drop hammer, 20 blows of a steam or air hammer, or 10 blows of a diesel hammer per inch will not drive it more than an average of one eight inch per blow, the pile has either hit an obstruction or has been driven to refusal. In either case, further driving is likely to break or split the pile. If the lack of penetration seems to be caused by an obstruction, try 10 or 15 blows of less than maximum force; they may cause the pile to displace or penetrate the obstruction. For obstructions which cannot be disposed of in this manner, it is often necessary to pull or extract the pile (see the Extracting Piles section) and blast out the obstruction with an explosive lowered to the bottom of the hole.

A pile is at the point of refusal when it has been driven to a depth where deeper penetration is prevented by friction. A pile supported by skin friction alone is called a friction pile. A pile supported by bedrock or an extra dense layer of soil at the tip is called an end bearing pile. A pile supported partly by skin friction and partly by substratum of extra dense soil at the tip is called a combination end bearing and friction pile.

It is not always necessary for you to drive a friction pile to refusal; such a pile needs to be driven only to the depth where friction develops the required load-bearing capacity.

When bearing piles are driven on land, the position of each pile is usually located by the Engineering Aid and marked with a stake. A common method of locating the positions of a series of pile bents driven in water is by use of a wire rope long enough to stretch between the abutments and marked with pieces of tape, spaced according to the prescribed or calculated distance between bents.

After driving the first bent, use a floating template when driving subsequent bents like the one shown in *Figure 8-29*. Space pairs of battens according to a specified spacing between piles in a bent and nail them across each pair of timbers. Hinge the parts of each batten lying beyond the timbers for raising. Lash the template to the outer piles in the bent already driven by means of a pair of wire ropes equipped with turnbuckles, as shown. After driving the piles in the new bent, raise the hinged parts of the battens, let the wire ropes go, and float the template out from between the bents.

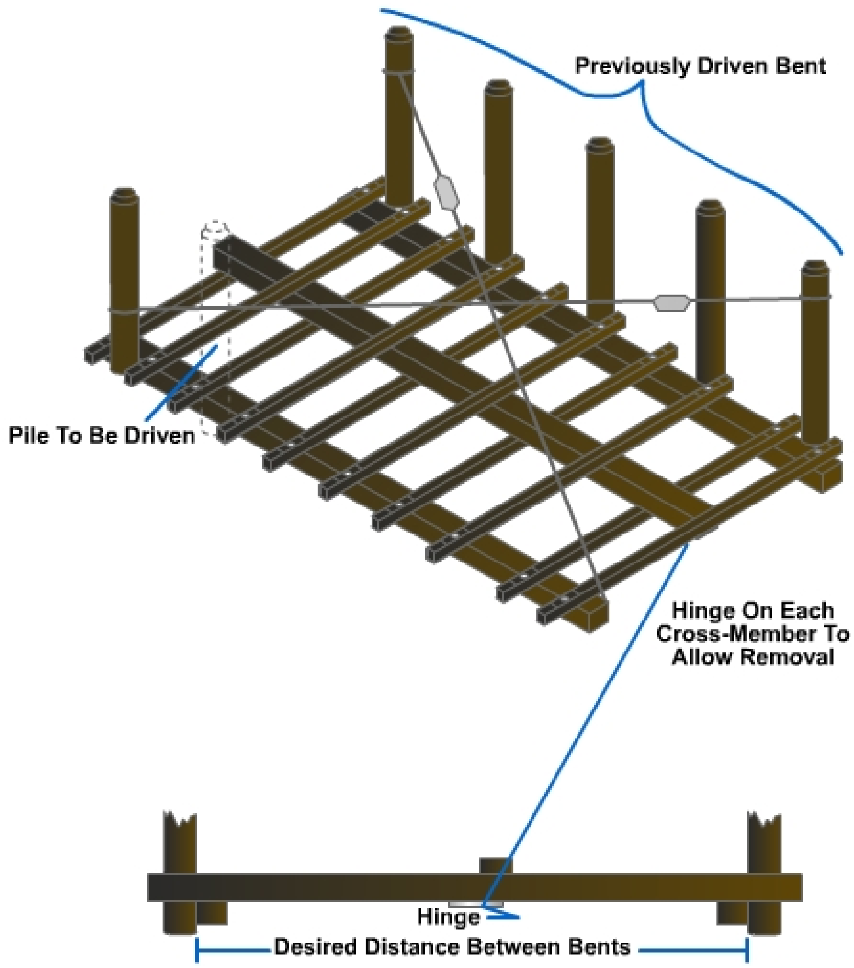


Figure 8-29 – Floating template for positioning piles.

Piles can be driven either tip or butt down; they may be driven butt first if a large bearing area is required or if the pile is to resist an upward force.

4.3.7 Lagging

Lagging is used to increase the resistance of a friction pile. Before driving the pile, lag screw long, narrow strips of wood or steel to the pile, as shown in *Figure 8-30*. Attach these to the lower part of the pile from approximately 12 inches above the tip to the limits of the depth that the pile is expected to penetrate. The extra surface area increases the load-carrying capacity of the pile but tends to make it more difficult to drive.

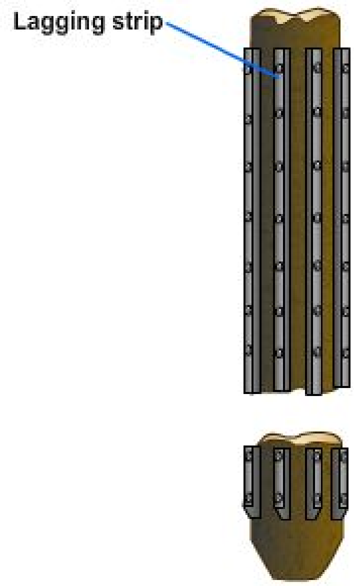


Figure 8-30 – Lagging of a timber friction pile.

4.4.0 Constructing a Pile Bent

After the piles in a pile bent have been driven, the remaining steps in constructing the bent are aligning, cutting, capping, and bracing the piles.

4.4.1 Aligning Piles in a Bent

Straighten the piles in a bent with tackles and bring them into alignment with an aligning frame, as shown in *Figure 8-31*.

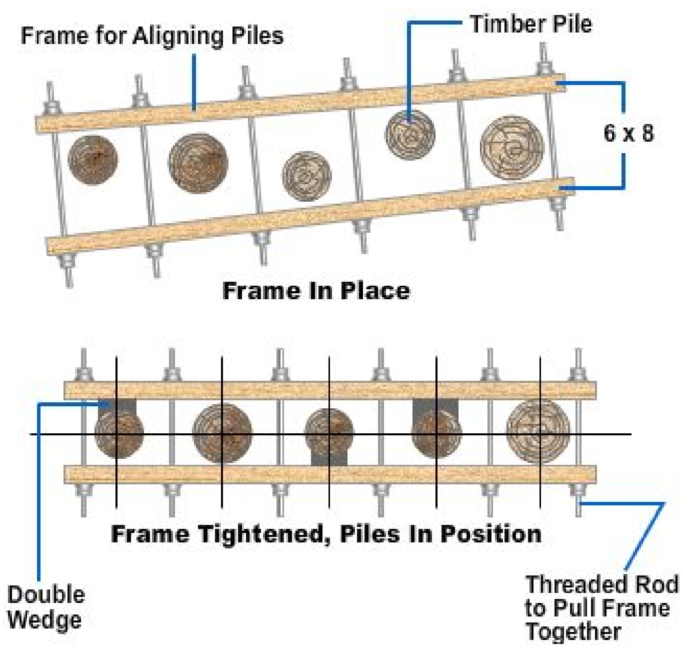


Figure 8-31 – Straightening frame.

After the frame has been put on, a working platform, like the one shown in *Figure 8-32*, is usually erected to support the personnel who will cut, cap, and brace the piles.

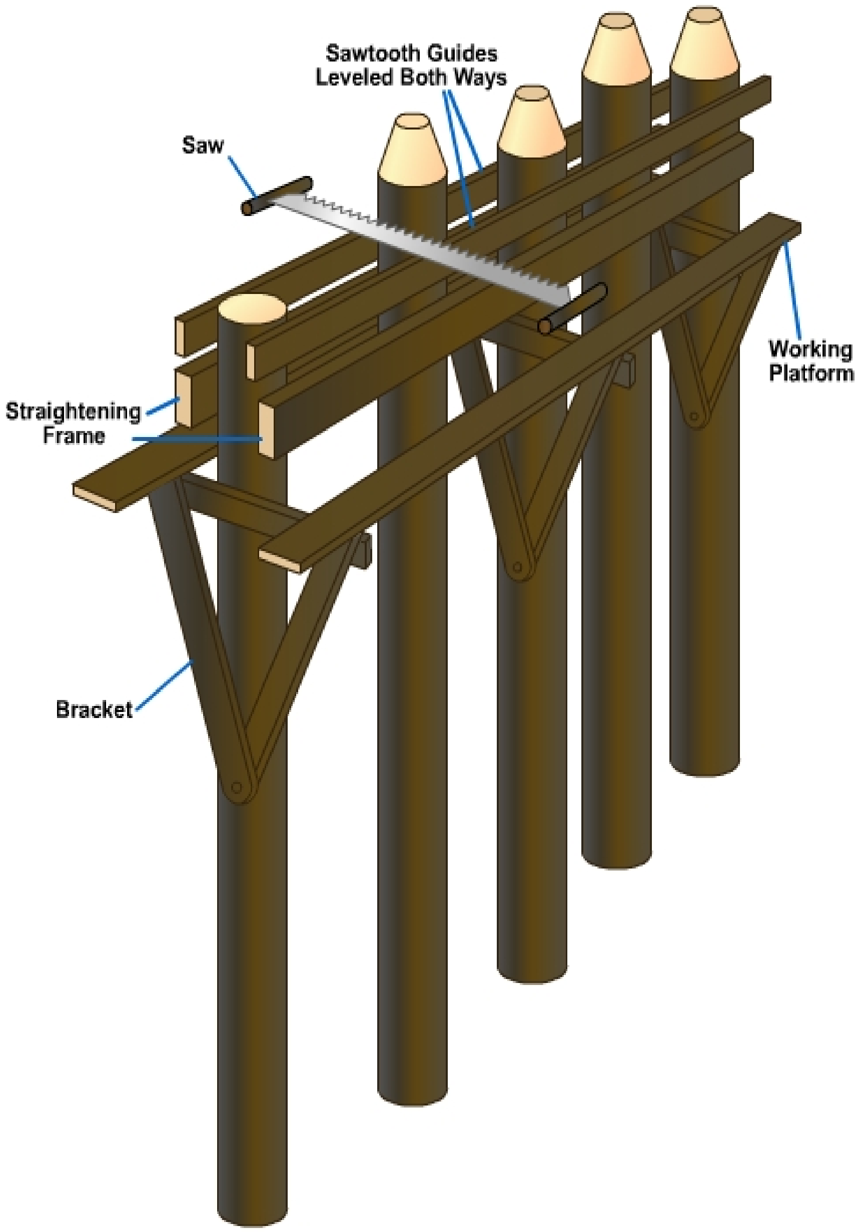


Figure 8-32 – Cutting timber pile bent to final height.

4.4.2 Cutting Piles in a Bent

A timber pile selected for a bent should be long enough to leave 2 or 3 feet extending above the specified elevation of the bottom of the cap after the pile has been driven to the specified penetration. The piles are then cut to the specified elevation with a chain saw or a crosscut saw.

Because the cap must bear evenly on all the piles in the bent, it is important that they all be cut exactly the same elevation. Ensure this by the use of the cutting guide or the sawing guide, as shown in *Figure 8-32*. Determine the position for the cutting guide by locating the correct elevation of the bottom of the cap and using an engineer's level on the two outside piles in the bent.

4.4.3 Capping Piles in a Bent

After the timber piles in a bent are straightened, aligned, and cut, the piles are usually capped. Set the cap in place, bore a hole for a driftbolt through the cap into the top of each pile, and drive the driftbolts. Then put on the transverse and longitudinal bracing. Sometimes the bracing may be installed before the piles are capped.

4.5.0 Placing Piles by Jetting

Jetting often makes pile penetration easier. Jetting is the process of forcing water under pressure around and under the pile to lubricate and/or displace the surrounding soil, as shown in *Figure 8-33*. In soils other than fairly coarse, dense sands, jetting is not necessary or advisable. Jetting equipment consists of a water pump, a length of flexible hose, and a metal jet pipe; jet pipes run from 2 1/2 to 3 inches in diameter.

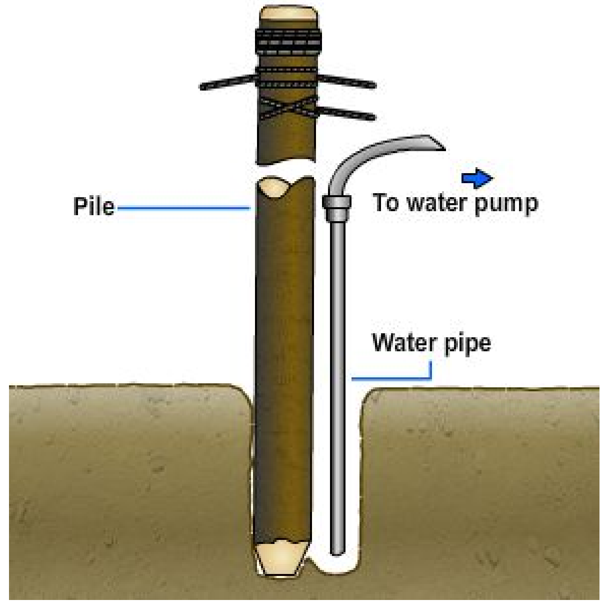


Figure 8-33 – Jetting with a single jet pipe.

Use a single jet pipe as follows. Set the pile in position with the hammer resting on it for extra weight, and manipulate the jet pipe to loosen and wash away the soil from under the tip, as shown in *Figure 8-33*. As the soil is washed away, the pile sinks under its own weight and that of the hammer. Strike a few hammer blows occasionally to keep the pile moving downward. When it is 3 feet above the final tip elevation, withdraw the jet pipe and drive the pile the rest of the way with the hammer.

The action of a single jet pipe on one side of a pile tends to send the pile out of plumb. Whenever possible, use two pipes and lash them to the pile on opposite sides, as shown in *Figure 8-34*.

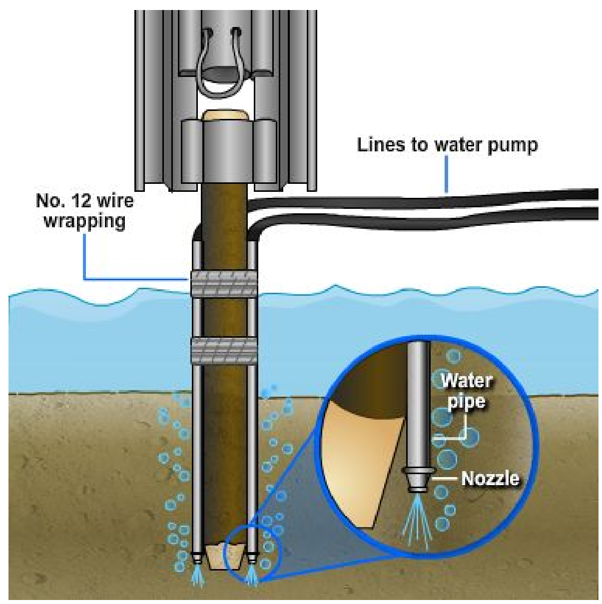


Figure 8-34 – Jetting with two jet pipes.

4.6.0 Extracting Piles

A pile that has met an obstruction, has split or broken in driving, or is to be salvaged (steel sheet piles are frequently salvaged for reuse) is usually pulled (extracted). Pull the pile as soon as possible after driving it; the longer the pile stays in the soil, the more compact the soil becomes, and the greater will be the resistance to pulling. Methods of pulling piles are direct lift and tidal lift.

4.6.1 Direct Lift

In the direct lift method, a crane is used to pull the pile. The crane whip is slung to the pile, and a gradually increased pull is applied up to just a little less than the amount that is expected to start it. Lateral blows from a headache ball, a heavy steel ball swung on a crane whip to demolish walls, or a few light blows on the butt or head with a driving hammer are given to break the skin friction. The crane pull is then increased to maximum capacity. If the pile still will not start, it maybe loosened by jetting or the lift of the crane may be supplemented by the use of hydraulic jacks.

The 5,000-pound double-action hammer may be used in an inverted position to pull piles. Turn the hammer over, pass a wire rope sling over it and attach it to the pile, as shown in *Figure 8-35*. Heave the hammer whip taut; the upward blows of the hammer ram on the sling plus the pull of the hammer whip are usually enough to pull the pile.

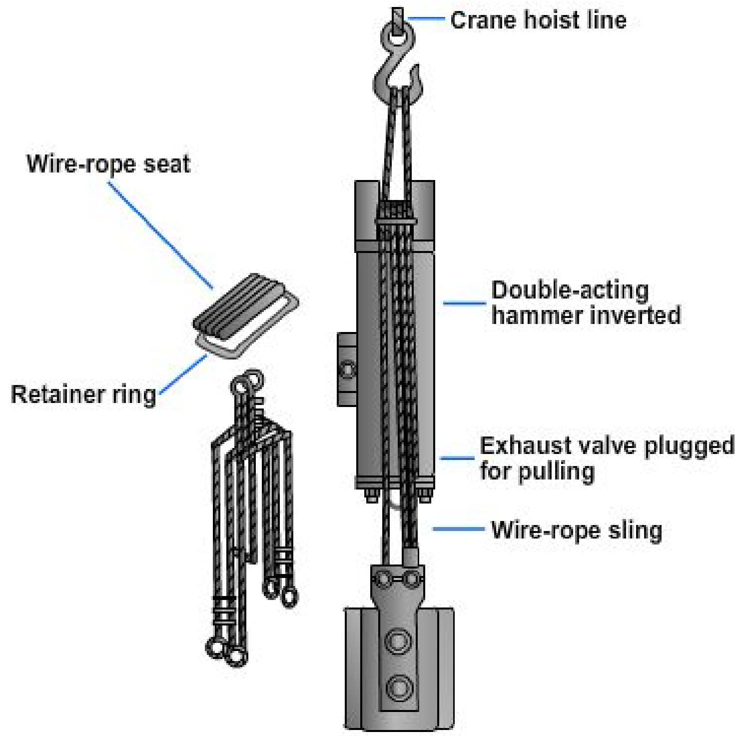


Figure 8-35 – Wire rope sling used with 5,000-pound airstream hammer to pull piles.

4.6.2 Tidal Lift

Tidal lift is used often to pull piles driven in tidewater. Attach slings on the piles to barges or pontoons at low tide; the rising tide pulls the piles as it lifts the barges or pontoons. To avoid the danger of tipping barges over, place a barge on each side of the pile with the lifting force transmitted by girders extending across the full width of both barges.

4.7.0 Planning and Estimating Pile-Driving Operations

So far, you have acquired a thorough understanding of the materials, principles, and capabilities of pile driving. Although preparing estimates, such as for man-days and equipment, is usually left up to the Equipment Operators (EOs), you should have no problem doing so as well.

Manpower estimates for driving piles, shown in *Figure 8-36*, are based on a typical crew consisting of the following members:

- One crew leader
- One crane operator
- Four crew members to place the piles in the leads
- One or two crew members to prepare the piles

This is based on the further assumption that the pile driver can pick up and place the piles in the leads. If this cannot be done because of the location of the undriven piles, you must allow for an additional crane and increase the total man-days required by 15 percent.

Work Element Description	Unit	Man-Hours Per Unit
25 Foot Wood Piling	Each	3.5
50 Foot Wood Piling	Each	6.5
75 Foot Wood Piling	Each	9.6
25 Foot Steel Piling	Each	4.0
50 Foot Steel Piling	Each	7.2
75 Foot Steel Piling	Each	12.0
40 Foot Precast Concrete Piling	Each	13.2
60 Foot Precast Concrete Piling	Each	18.0
80 Foot Precast Concrete Piling	Each	24.0
Steel Sheetpiling	1,000 SF	102.0
Assemble and Rig Leads and Hammer	Each	48.0
Dismantle Leads and Hammer	Each	32.0
Suggested Crew Size: Two EOs, two EAs, six to ten BUs.		
NOTES:	1. Man-hour figures are preliminary estimate only. The many variables of this work require on-site determination for accurate estimates. 2. Factors of importance are: Design, soil, equipment and method used, tides, access to site, currents, materials storage, etc. 3. For concrete filled, fluted hollow steel piling and pipe piling for spudding pontoon small craft finger piers, use the steel bearing pile figures.	

Figure 8-36 – Table from P-405.

The time in man-days required to drive each pile depends on the type of pile and its length. Precast concrete bearing piles drive slower than wood or steel ones, and logically, the use of a longer pile usually means that you plan to drive it deeper, which will take more time. Under average conditions, the following estimates apply:

- 3.0 man-hours to drive a 25-foot wood pile
- 4.0 man-hours to drive a steel pile
- 13.2 man-hours to drive a precast concrete pile

These estimates take into account pile preparation, placing it in the leads, driving, and cutoff, if required.

When estimating the man-days required to complete a pile-driving operation, you cannot forget to include time for assembling the leads and hammer, preparing the equipment for driving, cutting holes in steel piling to facilitate handling, and disassembling the equipment upon completion, if required. You must also allow time for pile extraction if it is a required part of the project.

5.0.0 WATERFRONT STRUCTURES

Waterfront structures may be broadly divided into three types:

1. Harbor shelter structures
2. Stable shoreline structures
3. Wharfage structures

5.1.0 Harbor Shelter Structures

Harbor shelter structures are offshore structures designed to create a sheltered harbor. Various types of these structures are covered next.

5.1.1 Breakwater and Jetty

A breakwater is an offshore barrier erected to break the action of the waves and thereby maintain an area of calm water inside the breakwater. A jetty is a similar structure, except its main purpose is to direct the current or tidal flow along the line of a selected channel.

The simplest type of breakwater or jetty is the rubble mound (also called rock mound) type, shown in *Figure 8-37*.

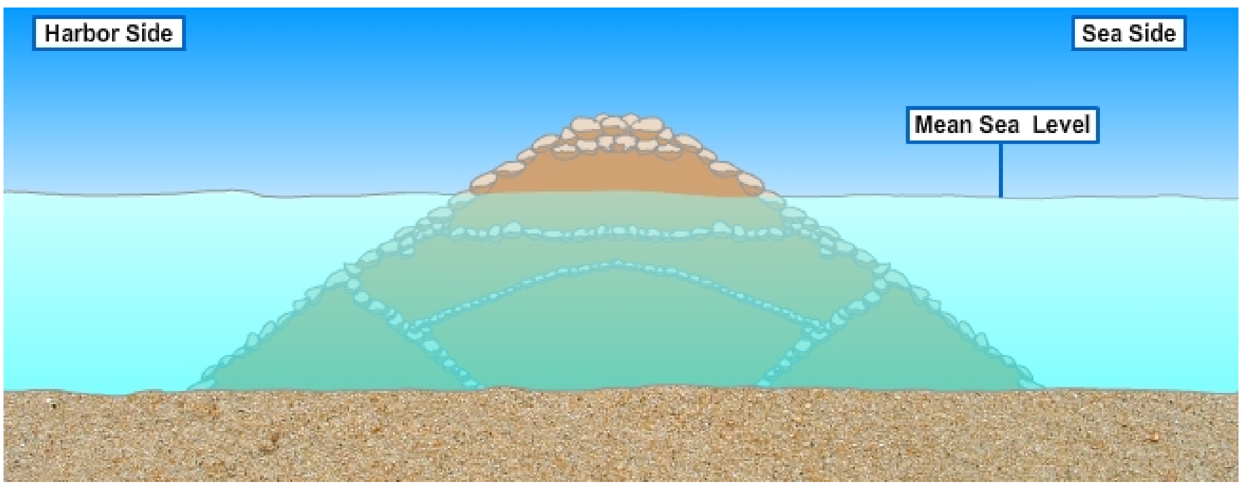


Figure 8-37 – Rubble mound breakwater or jetty.

The width of its cap may vary from 15 to 70 feet. The width of its base depends on the width of the cap, the height of the structure, and the slopes of the inner and outer faces.

For a deepwater site or for one with an extra high tide range, a rubble mound breakwater may be topped with a concrete cap structure, as shown in *Figure 8-38*. A structure of this type is called a composite breakwater or jetty. In *Figure 8-38*, the cap structure is made of a series of precast concrete boxes called caissons, each of which is floated over its place of location and then sunk into position. A monolithic (single piece) concrete cap is then cast along the tops of the caissons.

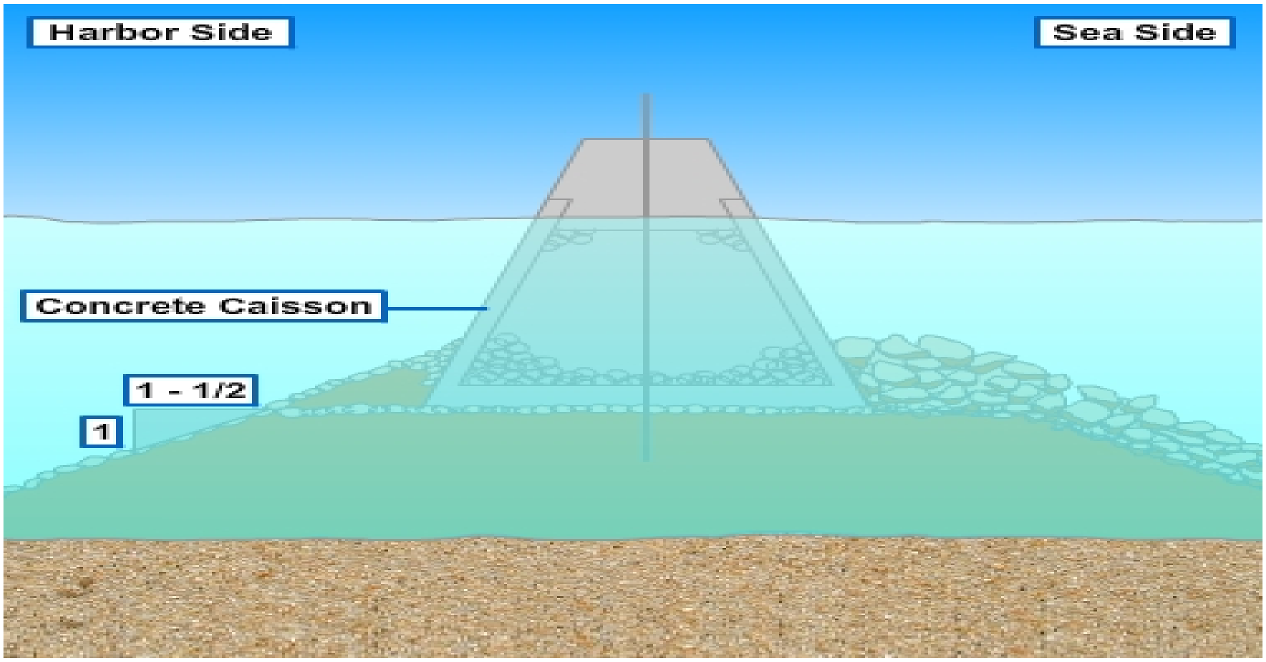


Figure 8-38 – Composite breakwater or jetty.

Sometimes breakwaters and jetties are built entirely of caissons, as shown in *Figure 8-39*.

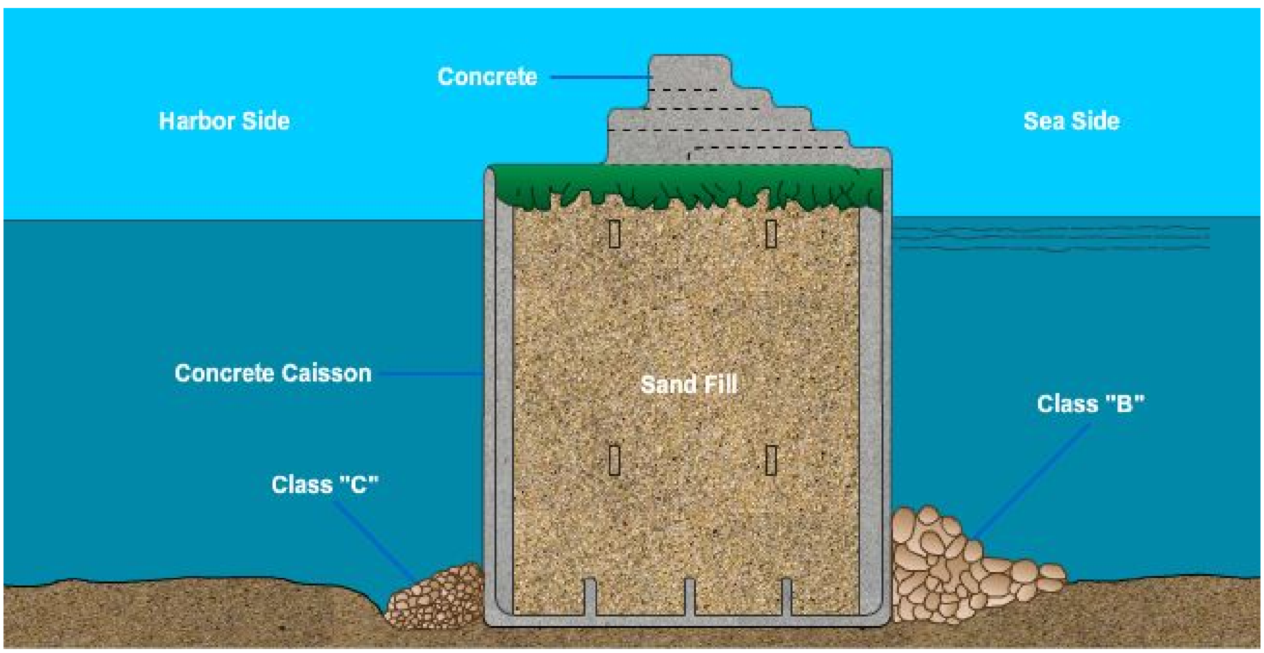


Figure 8-39 – Caisson breakwater or jetty.

5.1.2 Groin

A groin is a structure similar to a breakwater or jetty, but it serves a third purpose. It is used in a situation where a shoreline is subject to along-shore erosion caused by wave or current action parallel or oblique to the shoreline. The groin is run out from the shoreline (usually there is a succession of groins at intervals) to check the along-shore wave action or deflect it away from the shore.

5.1.3 Mole

A mole is a breakwater that is paved on the top for use as a wharfage structure. To serve this purpose, it must have a vertical face on the inner side, or harborside. A jetty may be similarly constructed and used, but it is still called a jetty.

5.2.0 Stable Shoreline Structures

These structures are constructed parallel with the shoreline to protect it from erosion or other wave damage. They are covered next.

5.2.1 Seawall

A seawall is a vertical or sloping wall that offers protection to a section of the shoreline against erosion and slippage caused by tide and wave action. A seawall is usually a self-sufficient type of structure, such as a gravity type retaining wall. Seawalls are classified according to the types of construction and may be made of riprap or solid concrete. Several types of seawall structures are shown in *Figure 8-40*.

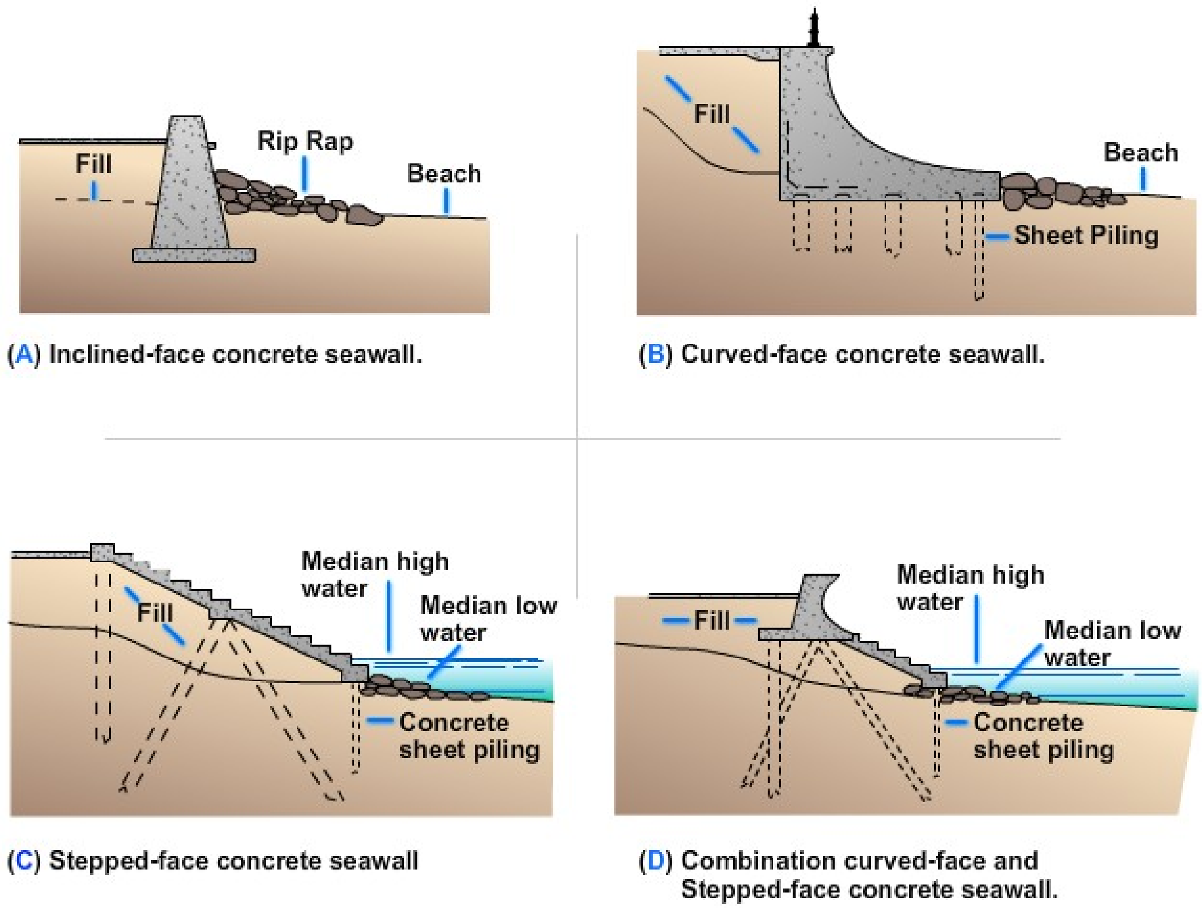


Figure 8-40 – Various types of seawalls.

5.2.2 Bulkhead

A bulkhead serves the same general purpose as a seawall, namely, to establish and maintain a stable shoreline. However, while a seawall is self-contained, relatively thick, and supported by its own weight, the bulkhead is a relatively thin wall. Bulkheads are classified according to types of construction, such as the following:

- Pile and sheathing bulkhead
- Wood sheet pile bulkhead
- Steel sheet pile bulkhead
- Concrete sheet pile bulkhead

Most bulkheads are made of steel sheet piles, as shown in *Figure 8-41*, and are supported by a series of tie wires or tie rods that are run back to a buried anchorage (or deadman). The outer ends of the tie rods are anchored to a steel wale that runs horizontally along the outer or inner face of the bulkhead. The wale is usually made up of pairs of structural steel channels that are bolted together back to back.

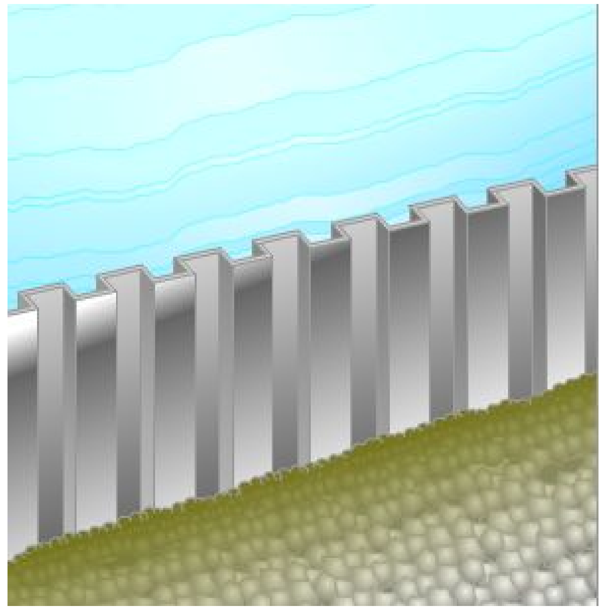


Figure 8-41 – Steel sheet pile bulkhead.

In stable soil above the groundwater level, the anchorage for a bulkhead may consist simply of a buried timber, a concrete deadman, or a row of driven and buried sheet piles. A more substantial anchorage for each tie rod is used below the groundwater level. Two common types of anchorages are shown in *Figure 8-42*. In *View A*, the anchorage for each tie rod consists of a timber cap supported by a batter pile, which is bolted to a bearing pile. In *View B*, the anchorage consists of a reinforced concrete cap supported by a pair of batter piles. As shown in the figure, tie rods are supported by piles located midway between the anchorage and the bulkhead.

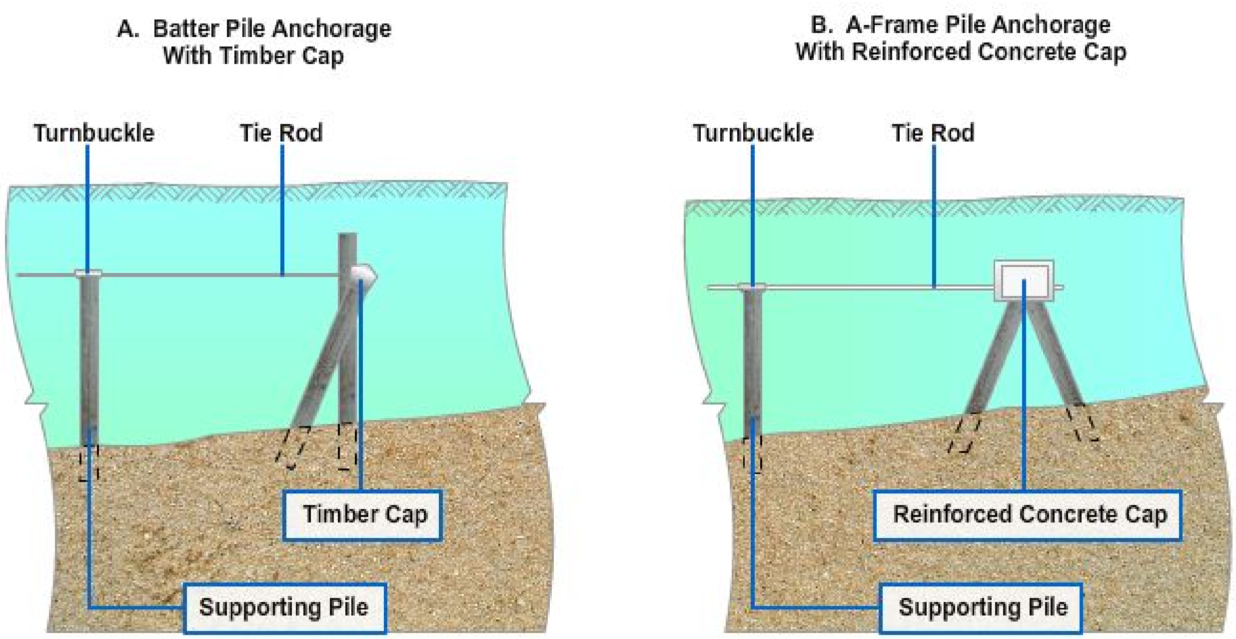
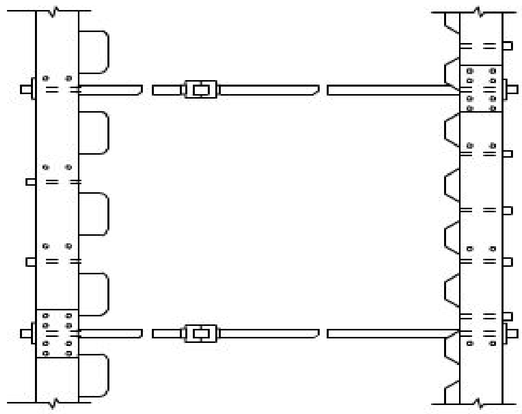


Figure 8-42 – Two types of tie-rod anchorages for bulkheads.

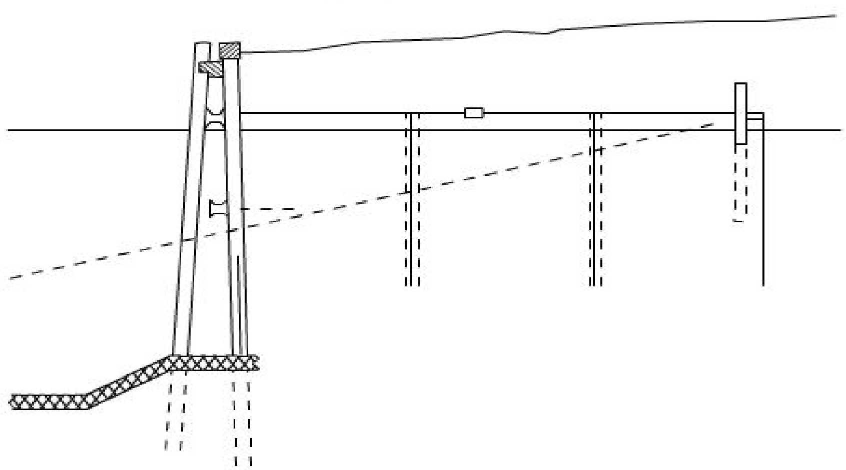
Bulkheads are constructed from working drawings like those shown in *Figure 8-43*. The detail plan for the bulkhead shows that the anchorage consists of a row of sheet piles to which the inner ends of the tie rods are anchored by means of a channel wale.

The section view shows that the anchorage will lie 58 feet behind the bulkhead. This view also suggests the order of construction sequence. First, excavate the shore and bottom to the level of the long, sloping dotted line. Then drive the sheet piles for the bulkhead and anchorage. Drive the intervening supporting piles at intervals of 19 feet 4 inches to hold up the tie rods. Drive the piles next, and then set the tie rods in place. Bolt on the wales, and tighten the tie rods moderately with turnbuckles.

Begin backfilling to the bulkhead. The first backfilling operation consists of filling over the anchorage out to the sloping dotted line. Then set up the turnbuckles on the tie rods to bring the bulkhead plumb. Then put in the remaining fill out to the bulkhead. Finally, outside the bulkhead, dredge the bottom to a depth of 30 feet.



Detail Plan of Bulkhead



Section Thru Bulkhead

Figure 8-43 – Working drawings for steel sheet pile bulkhead.

Fit the fender piles with a timber cap, as shown in *Figure 8-44*, to make it possible for ships to come alongside the bulkhead. These piles, installed at proper intervals, provide protection against the impact of ships and protect the hulls of ships from undue abrasion.

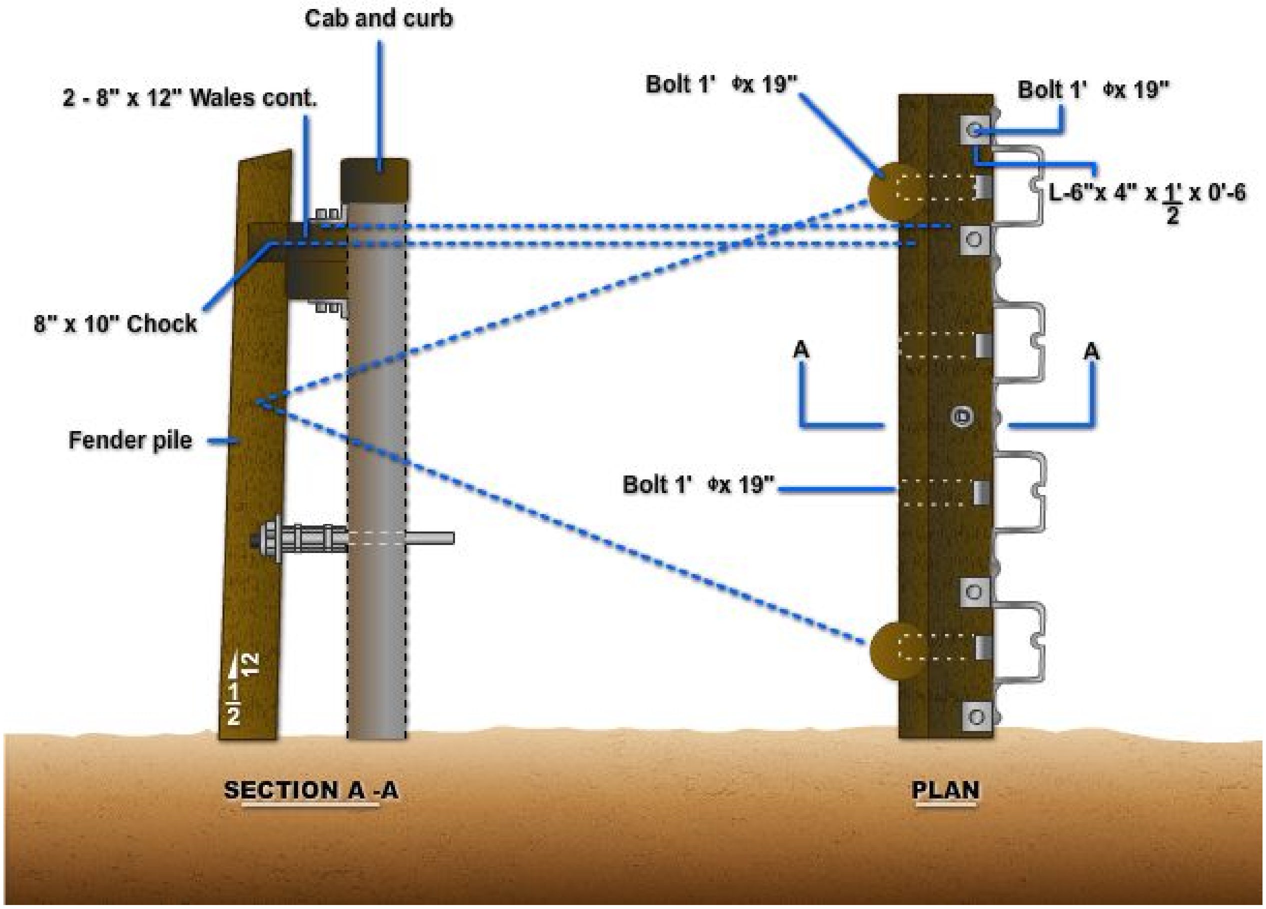


Figure 8-44 – Cap and fender pile for bulkhead.

5.3.0 Wharfage Structures

Wharfage structures are designed to allow ships to dock alongside them for loading and discharge. *Figure 8-45* shows various plan views of wharfage structures. Any of these may be constructed of fill material, supported by bulkheads.

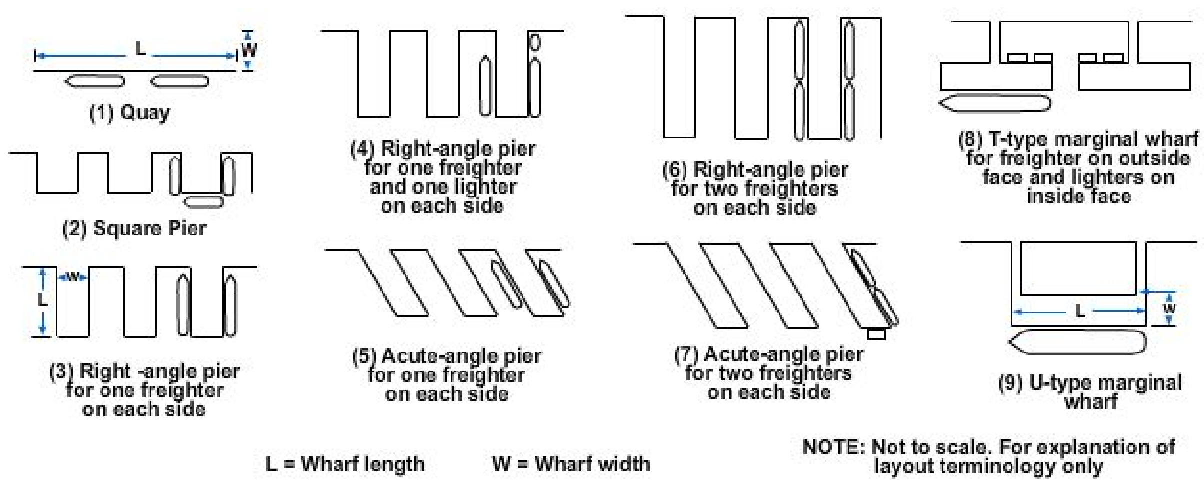


Figure 8-45 – Types of wharfage structures.

5.3.1 Pier

A pier or marginal wharf usually consists of a timber, steel, or concrete superstructure supported on a substructure of timber, steel or concrete pile bents.

Working drawings for advanced base piers are found in the ABFC system. You access them by clicking on the P437 Diagrams button. *Figures 8-46*, *8-47*, and *8-48* are portions of the advanced base drawing for a 40-foot timber pier. The Advanced Base Functional Components chapter provides further information on the advanced base functional components (ABFC).

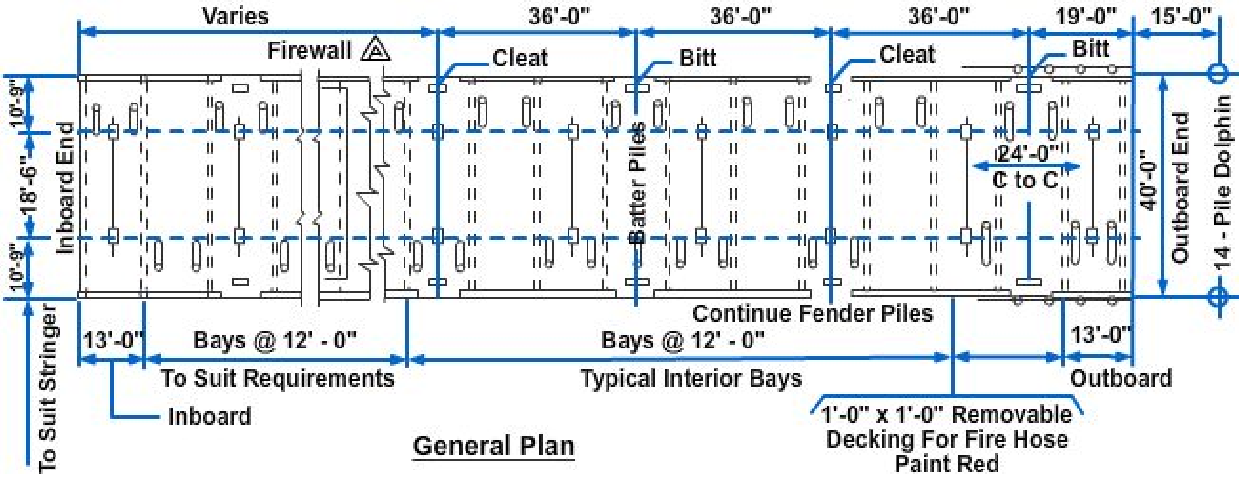
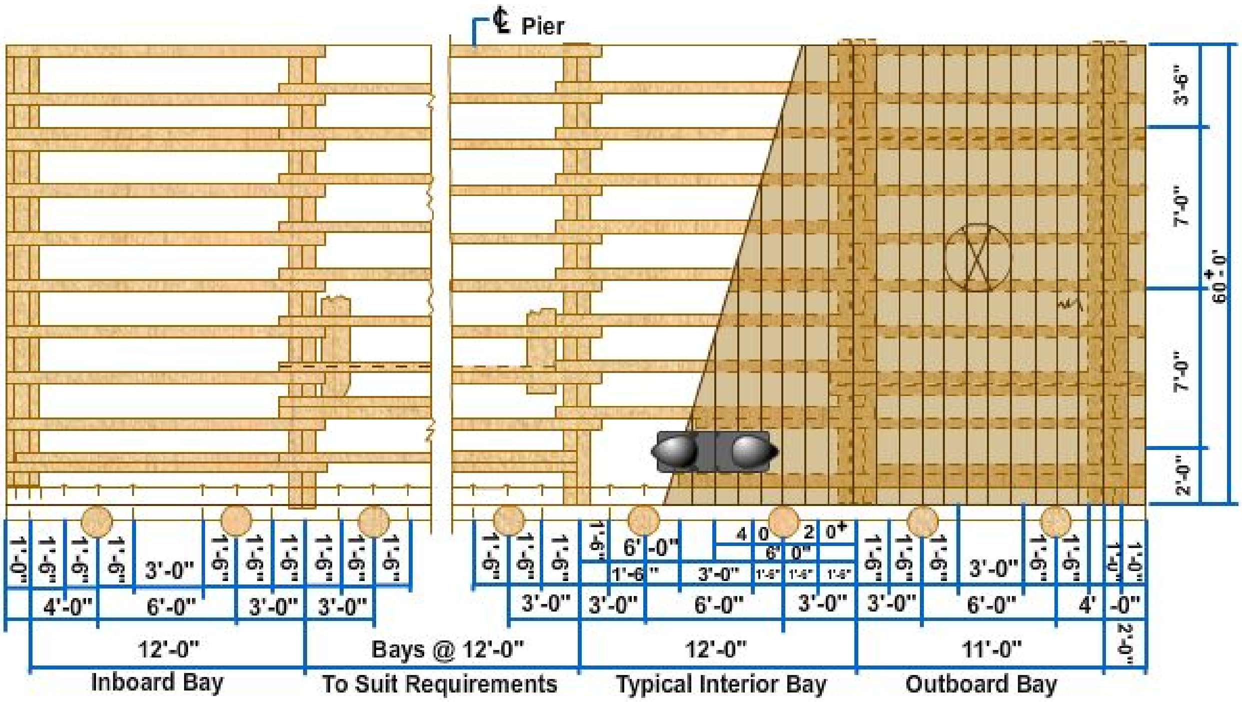


Figure 8-46 – General plan of an advanced base 40-foot timber pier.

Each part of a pier lying between adjacent pile bents is called a bay, and the length of a single bay is equal to the on-center spacing of the bents. In the general plan shown in *Figure 8-47*, the 40-foot pier consists of one 13-foot outboard bay, one 13-foot inboard bay, and 12-foot interior bays as needed to meet the length requirements for the pier.



Part Plan

Figure 8-47 – Part plan of an advanced base timber pier.

The cross section shown in *Figure 8-48* shows that each bent consists of six bearing piles. The bearing piles are braced transversely by diagonal braces. Additional transverse bracing for each bent is provided by a pair of batter piles. The batter angle is specified as 5 in 12. One pile of each pair is driven on either side of the bent, as shown in the general plan. The butts of the batter piles are joined to 12 by 12-inch by 14- foot longitudinal batter pile caps, each of which is bolted to the undersides of two adjacent bearing pile caps in the positions shown in the part plan. The batter pile caps are placed 3 feet inboard of the center lines of the outside bearing piles in the bent. They are backed by 6 by 14-inch batter pile cap blocks, each of which is bolted to a bearing pile cap. Longitudinal bracing between bents consists of 14-foot lengths of 3 by 10-inch planks bolted to the bearing piles.

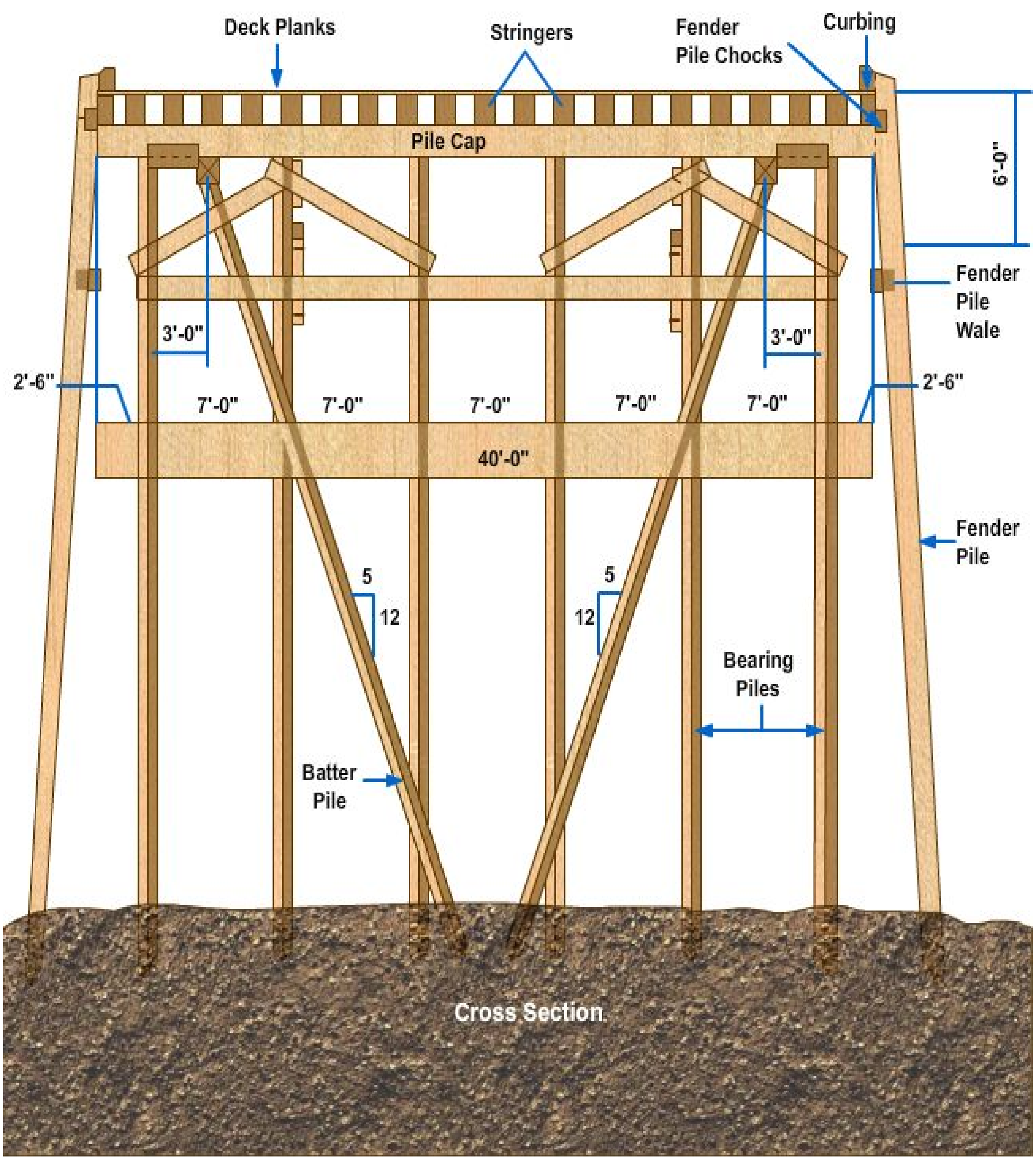


Figure 8-48 – Cross section of an advanced base timber pier.

The superstructure shown in *Figure 8-48* consists of a single layer of 4 by 12 planks laid on 19 inside stringers measuring 6 inches by 14 inches by 14 feet. The inside stringers are fastened to the pile caps with driftbolts. The outside stringers are fastened to the pile caps with bolts. The deck planks are fastened to the stringers with 3/8 by 8-inch spikes. After the deck is laid, 12-foot lengths of 8 by 10 are laid over the outside stringers to form the curbing. The lengths of curbing are distributed as shown in the general plan. The curbing is bolted to the outside stringers.

The pier is equipped with a fender system to protect it against shock caused by contact with vessels coming or docked alongside of it. Fender piles, spaced as shown in the part plan, are driven along both sides of the pier and bolted to the outside stringers. The heads of these bolts are countersunk below the surfaces of the piles. An 8 by 10 fender wale is bolted to the backs of the fender piles. Lengths of 8 by 10 fender pile chocks are cut to fit between the piles and bolted to the outside stringers and the fender wales. The spacing for these bolts is shown in the part plan. As shown in the general plan, the fender system also includes two 14 pile dolphins, located 15 feet beyond the end of the pier.

5.3.2 Dolphin

A dolphin, shown in *Figure 8-49*, is an isolated cluster of piles.

6.0.0 TIMBER FASTENERS and CONNECTORS

As a Builder, be aware that it is usually unnecessary in working drawings to call out the types of fasteners used for light frame construction. However, this is not the case for heavy timber construction. To prepare drawings or estimate materials for timber structures, you need a working knowledge of timber fasteners and connectors and the manner in which they are used. The following discussion covers the more common types.

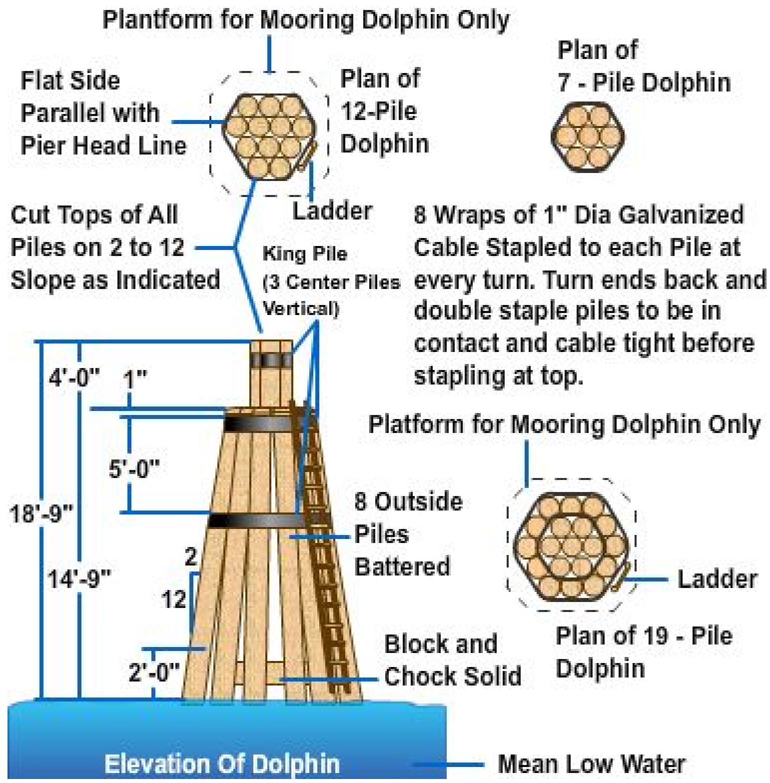


Figure 8-49 – Typical dolphin plan.

6.1.0 Timber Fasteners

Bolts used to fasten heavy timbers usually come in 1/2-, 3/4-, and 1-inch diameters and have square heads and nuts. In use, the bolts are fitted with round steel washers under both the bolt head and the nut. The bolts are then tightened until the washers bite well into the wood to compensate for future shrinkage. Bolts should be spaced a minimum of 9 inches on center and should be no closer than 2 1/2 inches to the edge or 7 inches to the end of the timber.

6.1.1 Driftbolts

Driftbolts, also called driftpins, are used primarily to prevent timbers from moving laterally in relation to each other, rather than to resist pulling apart. They are used more in dock and trestle work than in trusses and building frames. A driftbolt is a long threadless rod that is driven through a hole bored through the member and into the abutting member. The hole is bored slightly smaller than the bolt diameter and about 3 inches shorter than the bolt length. Driftbolts are from 1/2 to 1 inch in diameter and 18 to 26 inches long.

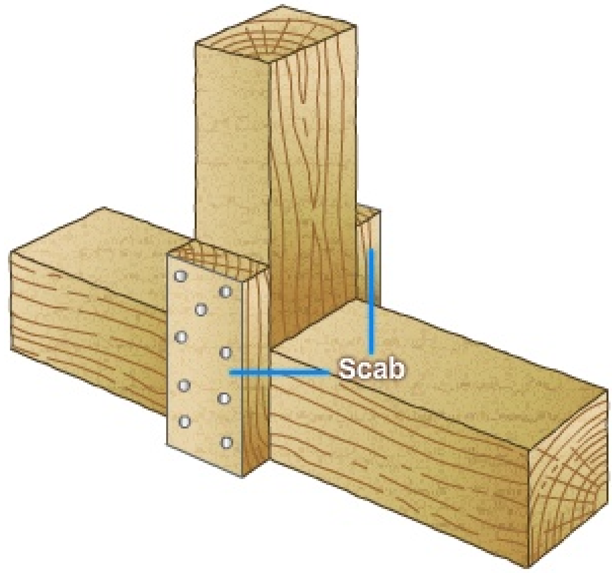


Figure 8-50 – Scabs.

6.1.2 Scabs

Butt joints are customarily connected using driftbolts; however, another method of making butt joint connections is to use a scab. A scab is a short length of timber that is spiked or bolted to the adjoining members, as shown in *Figure 8-50*.

6.2.0 Timber Connectors

A timber connector is any device used to increase the strength and rigidity of bolted lap joints between heavy timbers.

6.2.1 Split Ring

For example, the split ring shown in *Figure 8-51* is embedded in a circular groove. These grooves are cut with a special bit in the faces of the timbers that are to be joined. Split rings come in diameters of 2 1/2 and 4 inches. The 2 1/2-inch ring requires a 1/2-inch bolt, and the 4-inch ring uses a 3/4-inch bolt.

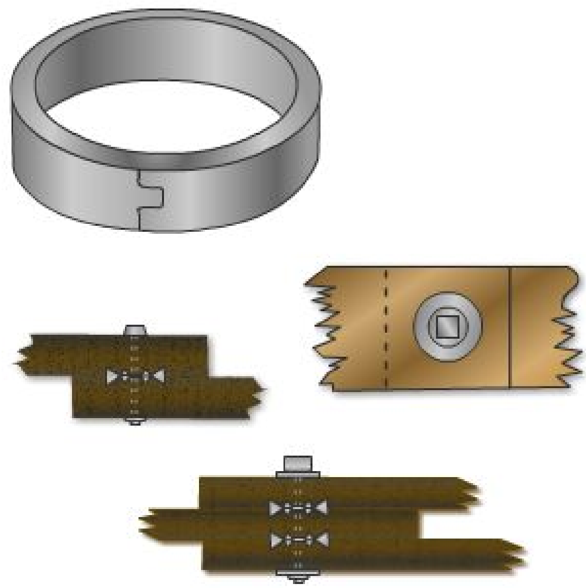


Figure 8-51 – Split ring and split ring joints.

6.2.2 Shear Plates

Shear plates are shown in *Figure 8-52*. These connectors are intended for wood to steel connections, as shown in *View B*. But when used in pairs, they may be used for wood to wood connections, as shown in *View C*. When making a wood to wood connection, the fabricator first cuts a depression into the face of each of the wood members. These depressions are cut to the same depth as the shear plates. Then a shear plate is set into each of the depressions so that the back face of the shear plate is flush with the face of the wood members.

Finally, the wood members are slid into place and bolted together. Because the faces are flush, the members easily slide into position, which reduces the labor necessary to make the connection. Shear plates are available in 2 5/8- and 4-inch diameters.

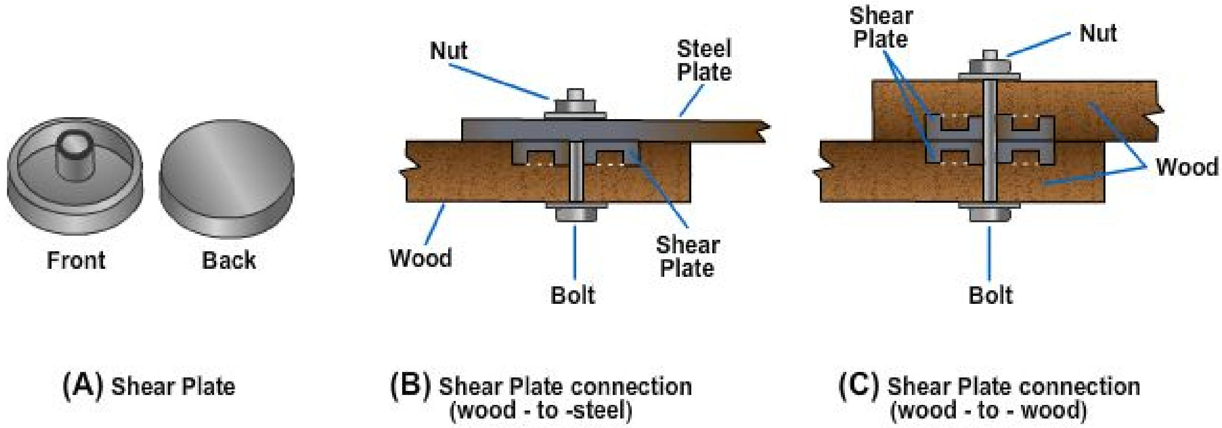


Figure 8-52 – Shear plate and shear plate joints.

6.2.3 Toothed Rings

For special applications, toothed rings and spike grids are sometimes used. The toothed ring connector, shown in *Figure 8-53*, functions in much the same manner as the split ring but can be embedded without the necessity of cutting grooves in the members. The toothed ring is embedded by the pressure provided from tightening a high tensile strength bolt, as shown in *Figure 8-54*. The hole for this bolt is drilled slightly larger than the bolt diameter so that the bolt may be extracted after the toothed ring is embedded.

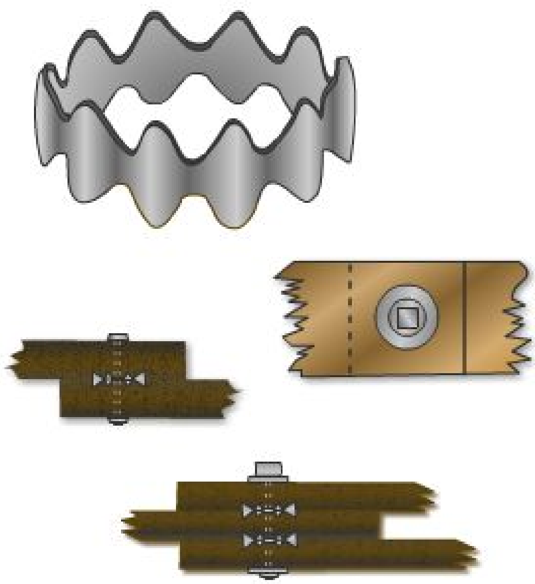


Figure 8-53 – Toothed ring and toothed ring joints.

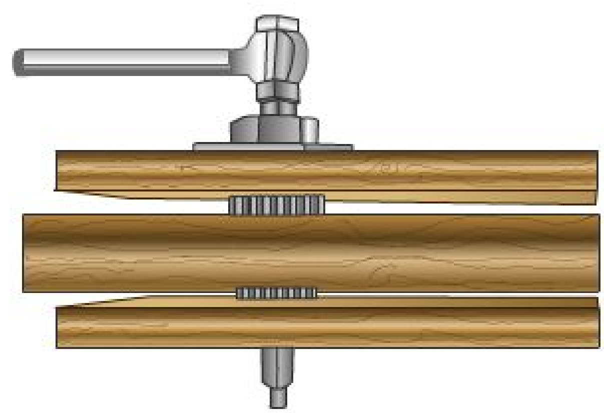


Figure 8-54 – Embedding toothed rings.

A spike grid is used as shown in *Figure 8-55*. A spike grid may be flat for joining flat surfaces, single curved for joining a flat and a curved surface, or double curved for joining two curved surfaces. A spike grid is embedded in the same manner as a toothed ring.

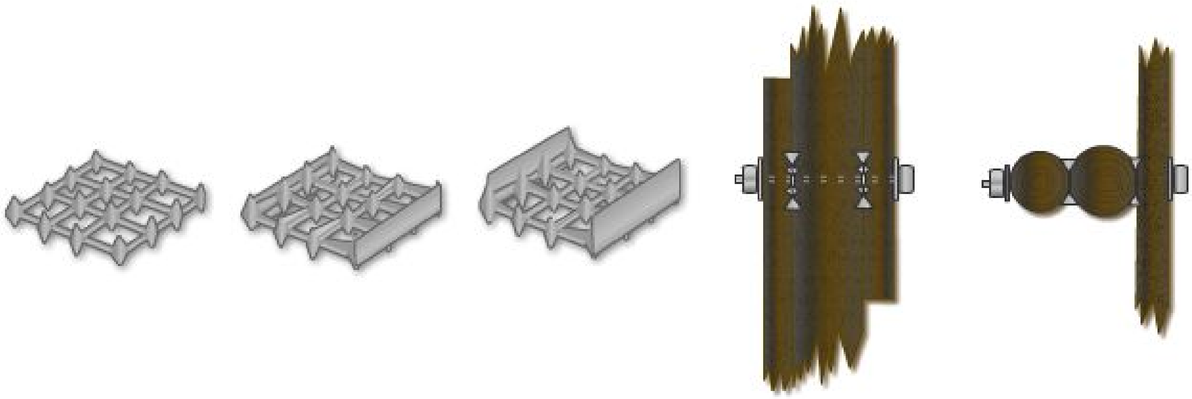
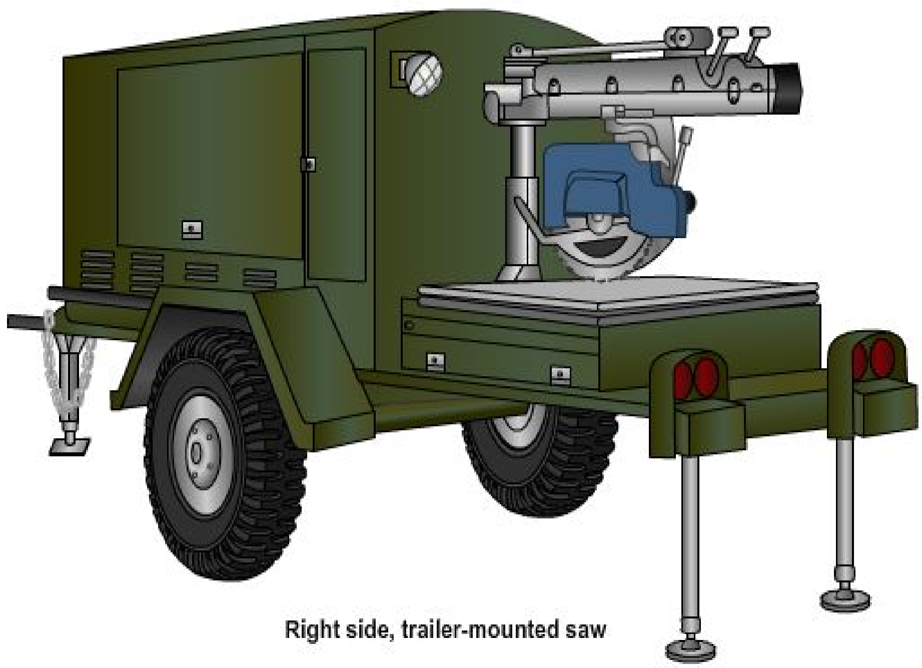


Figure 8-55 – Spike grids and spike grid joints.



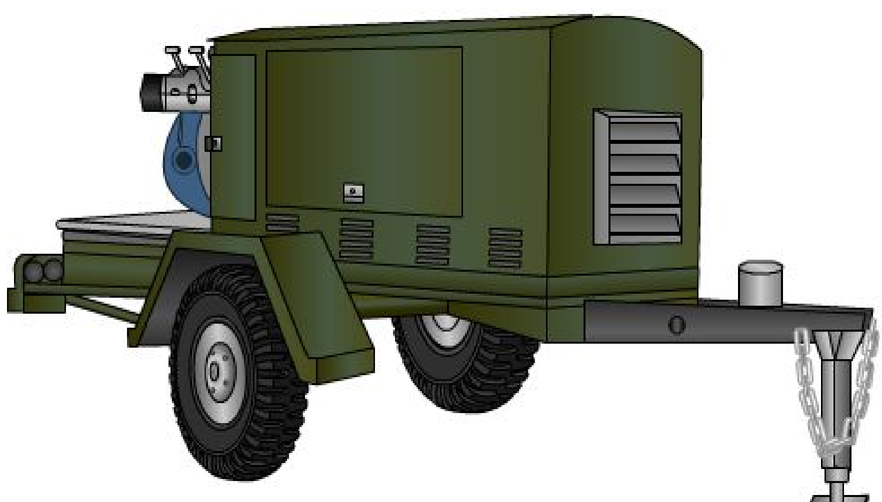


Figure 8-56 – Trailer-mounted radial overarm field saw (front view and side view).

Tools used in heavy construction are covered in the Use *and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085. In the Table of Allowance (TOA), you will find certain kits that can be used, such as the following:

- Kit assembly 80041 – Heavy Construction Tools F/4
- Kit assembly 82072 – Saw, Radial Arm (Field), shown in *Figure 8-56*
- Kit assembly 85025 – Saw, Chain 36N, GEN, 2 man
- Kit assembly 80019 – Carpenters Tools F/4

These are just a few of the kits that can be used from the TOA. Refer to *NAVFAC P-405* for a list of the assemblies by number.

7.0.0 STEEL FRAME STRUCTURES

The construction of a framework of structural steel involves two principal operations: fabrication and erection. Fabrication involves the processing of raw materials to form the finished members of the structure. Erection includes all rigging, hoisting, or lifting of members to their proper places in the structure, and making the finished connections between members.

A wide variety of structures are erected using structural steel. Basically, they can be listed as buildings, such as PEBs, bridges, and towers; most other structures are modifications of these three.

7.1.0 Steel Buildings

Three basic types of steel construction are used today, designated as follows:

- Wall-bearing construction
- Skeleton construction
- Long span construction

7.1.1 Wall-Bearing Construction

In wall-bearing construction, exterior and interior masonry walls are used to support structural members, such as steel beams and joists, which carry the floors and roof. Note that while this section of your manual covers steel structures, wall-bearing construction is applicable to non-steel structures as well. Wall-bearing construction is one of the oldest and most common methods in use. Although modem developments in reinforced concrete masonry make the use of this method feasible for high rise structures, wall-bearing construction is normally restricted to relatively low structures, such as residences and light industrial buildings.

7.1.2 Skeleton Construction

A tall building with a steel frame, as shown in *Figure 8-57*, is an example of skeleton construction.

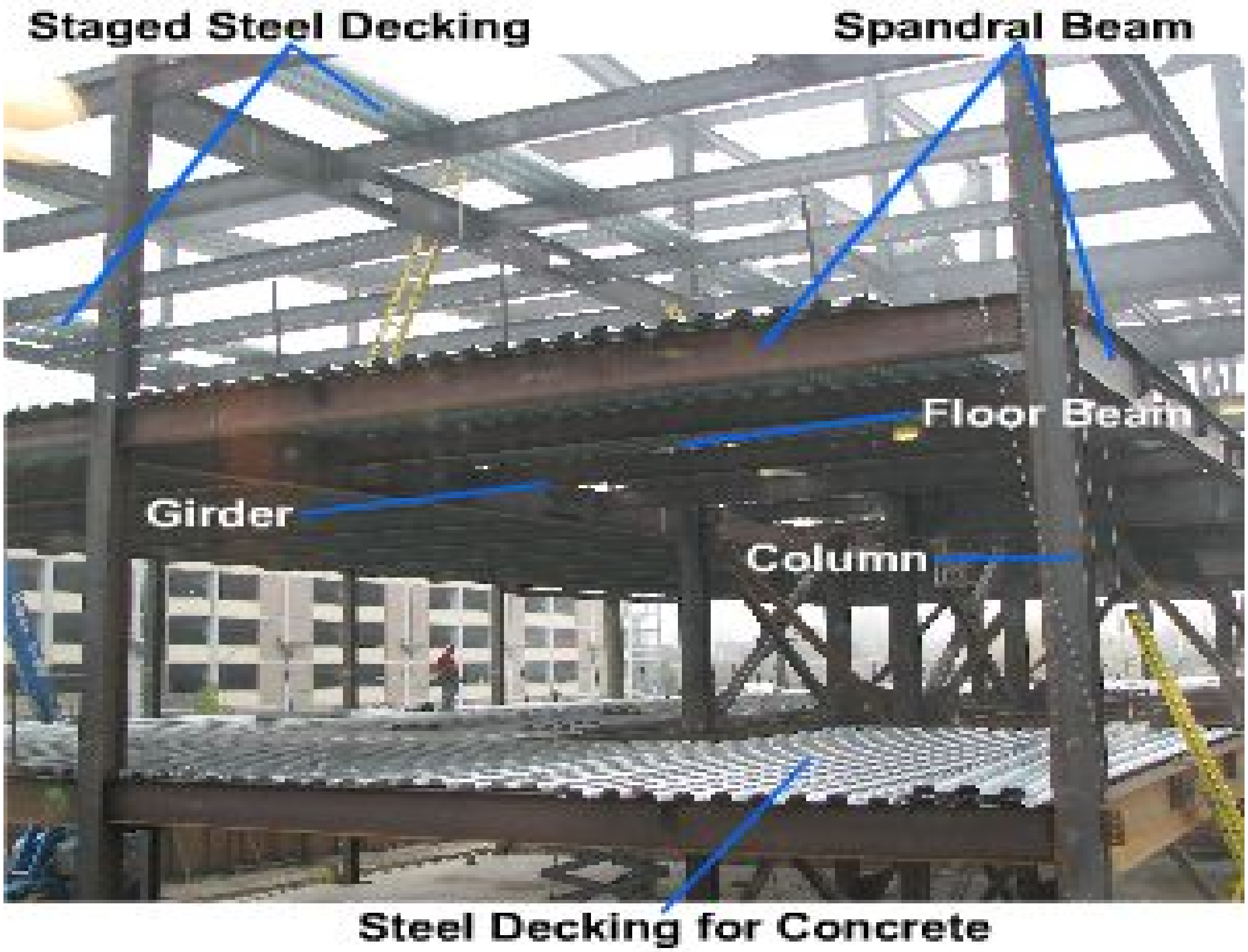


Figure 8-57 – Structural and skeleton construction.

In this type of construction, all live and dead loads are carried by the structural frame skeleton. For this reason, the exterior walls are nonbearing curtain walls. Roof and floor loads are transmitted to beams and girders, which are, in turn, supported by columns. The horizontal members or beams that connect the exterior columns are called spandrel beams. If you add additional rows of columns and beams, there is no limitation to the area of floor and roof that can be supported using skeleton construction. One limitation of using skeleton construction, however, is the distance between columns.

7.1.3 Long Span Construction

Often large structures, such as aircraft hangars, may require greater distances between supports than can be spanned by the standard structural steel shapes. In this case, one of several methods of long span steel construction is used. One method uses built-up girders to span the distances between supports.

Two types of built-up girders are shown in *Figure 8-58*. As shown in the figure, the built-up girder consists of steel plates and shapes that are combined to meet the necessary strength. The individual parts of these girders are connected by welding or riveting.

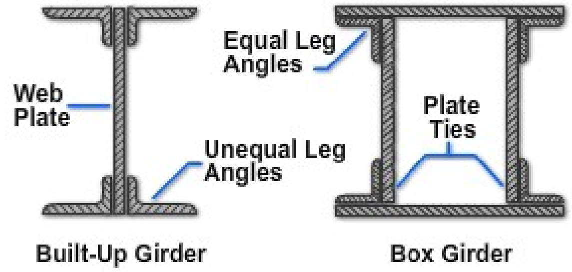


Figure 8-58 – Typical built-up girders.

Another method, usually more economical, is the use of a truss to span large distances. A truss is the framework of a structural member consisting of a top chord, a bottom chord, and diagonal web members that are usually placed in a triangular arrangement. *Figure 8-59* shows many different types of trusses that can be fabricated to conform to the shape of nearly any roof system.

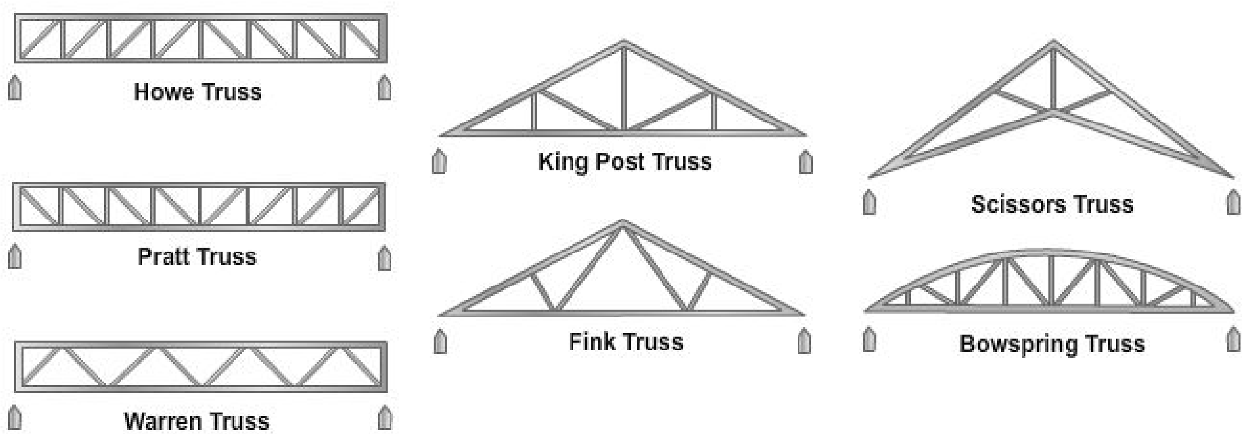


Figure 8-59 – Typical steel trusses.

A third long span method, although not as versatile as trusses, is the use of bar joists. Bar joists are much lighter than trusses and are fabricated in several different types. One type is shown in *Figure 8-60*. Prefabricated bar joists, designed to conform to specific load requirements, are obtainable from commercial companies. Other long span construction methods involve several different types of framing systems, which include steel arches, cable-hung frames, and other types of systems. These methods, however, are beyond the scope of this manual.

Figure 8-60 – Clear span bar joists.

7.2.0 Pre-Engineered Metal Structures

Pre-engineered metal structures are commonly used in military construction. These structures are usually designed and fabricated by civilian industry to conform to specifications set forth by the military. Rigid-frame buildings, steel towers, communications antennas, and steel tanks are some of the most commonly used structures, particularly at overseas advanced bases. Pre-engineered structures offer an advantage in that they are factory-built and designed to be erected in the shortest amount of time possible. Each structure is shipped as a complete kit, including all the materials and instructions needed to erect it.

Of the pre-engineered metal structures available, the one that is perhaps most familiar to the Seabees is the pre-engineered metal building (PEB), shown in *Figures 8-61* and *8-62*. *Figure 8-62* shows the nomenclature of the various parts of the PEB. For definition of this nomenclature, erection details, and other important information regarding the PEB, you should refer to the Steelworker Basic rate training manual.

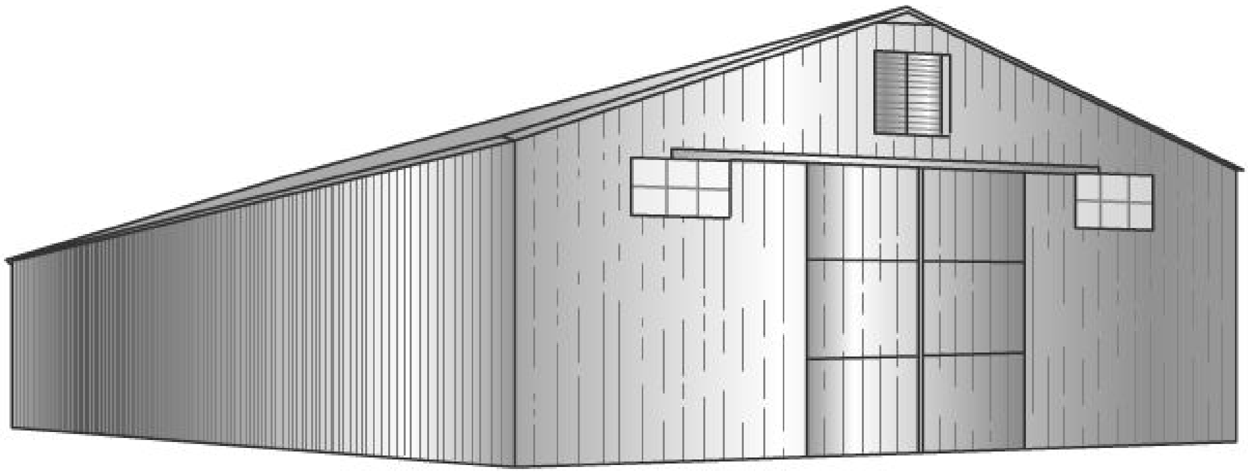


Figure 8-61 – Completed 40' x 100' x 14' pre-engineered metal building.

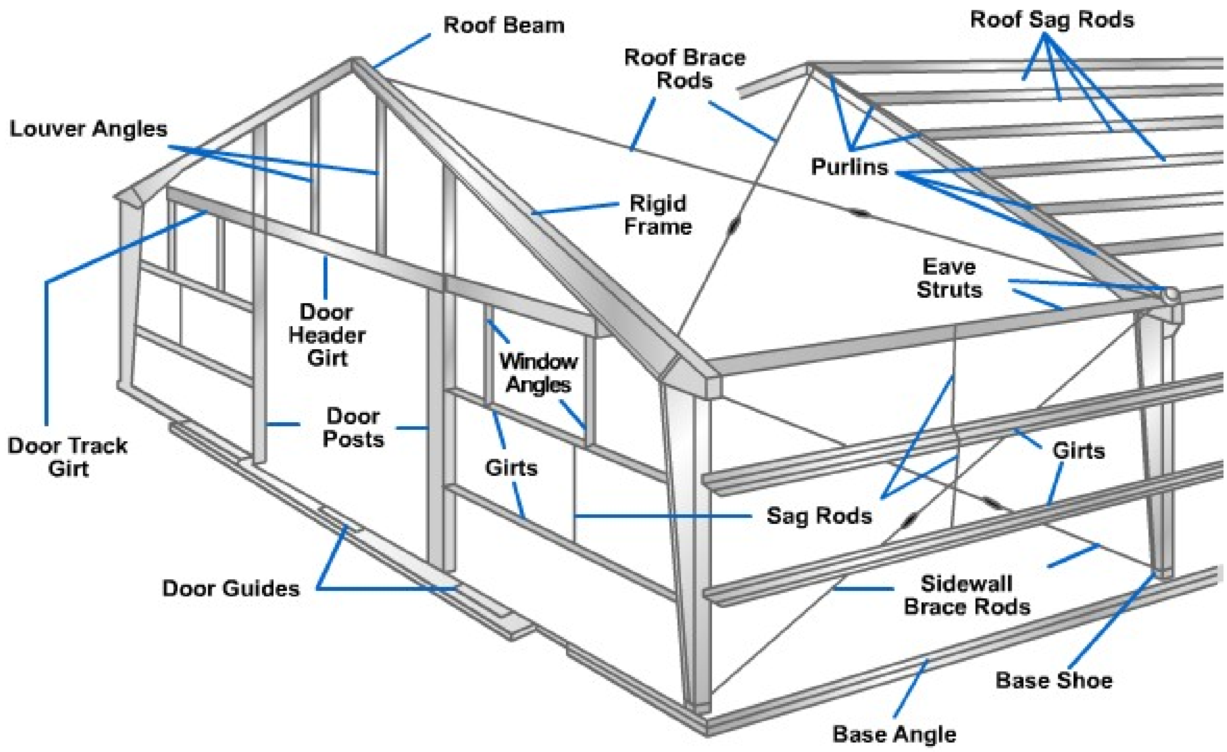


Figure 8-62 – Structural members of a pre-engineered metal building.

Summary

This chapter presented information on various construction operations involving heavy structures, and the importance of safe working practices to prevent injuries to personnel and damage to equipment. You learned about the equipment, terminology, methods, and techniques of heavy construction and the methods of constructing heavy timber structures and waterfront structures in terms of contingency operations.

You now understand how large bulks of materials (over 5 inches thick) and extra heavy structural members are used, including steel, timber, concrete, and a combination of these materials. You discovered that heavy construction in the Naval Construction Force includes the construction of bridges, shoring operations, waterfront structures, and steel frame structures.