CHAPTER 10
FLOATING WHARVES

Both the US Army and Navy have floating equipment suitable for constructing floating wharves. The most promising equipment of each service is discussed below.

Section I. Army Equipment (Current TO&E)

The Army's floating bridge equipment was designed primarily for river-crossing operations. However, its rapid installation and large loading capacities make the equipment useful as floating causeways, rafts, ferries, and ramps used in ship-to-shore cargo transfer.

ALUMINUM PNEUMATIC FLOATING BRIDGE (M4T6)

a. Description. The M4T6 floating bridges and rafts (ferries) consist of aluminum balk decks on pneumatic floats. Figure 10-1 shows the structural assembly of an M4T6 float section. Manpower and equipment requirements for bridge and raft construction are discussed in FM 5-210.

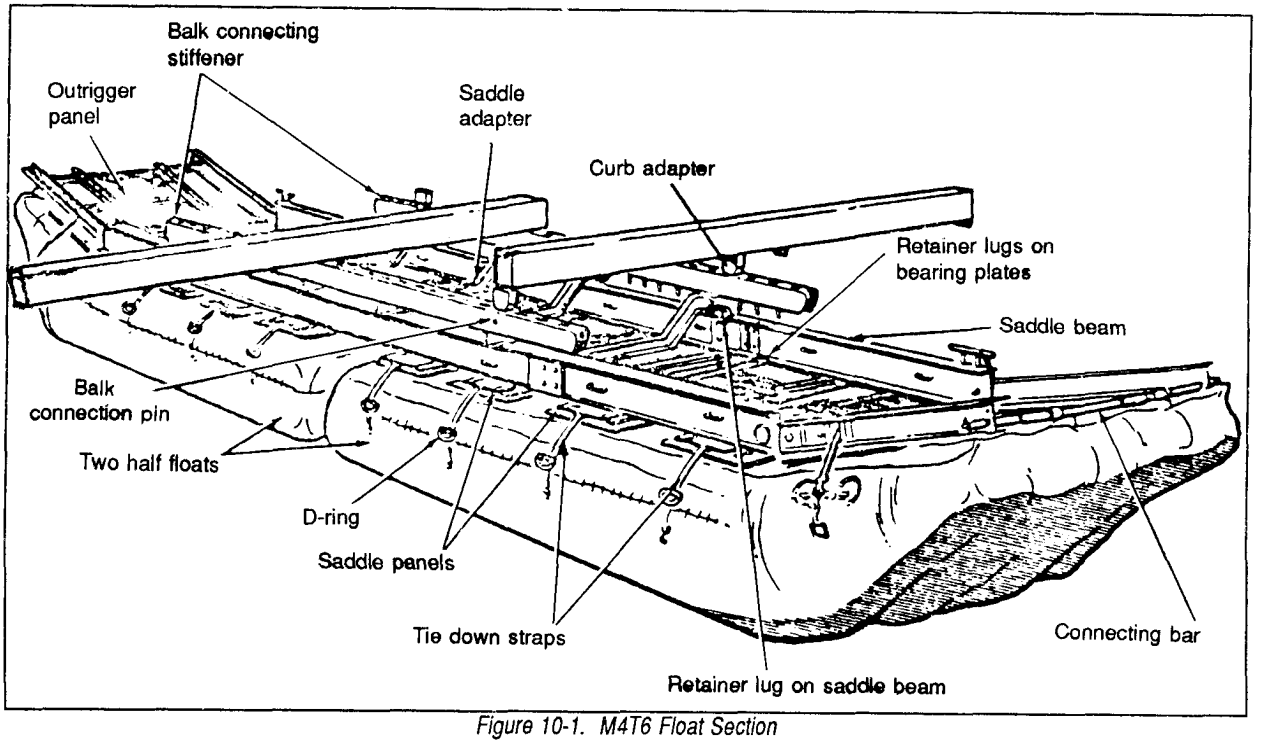


Figure 10-1. M4T6 Float Section

b. Port construction applications. Elements of the M4T6 may be used as causeways, lighters, and floating platforms for pile driving, dredging, and over-water crane operations.

c. Capabilities.

(1) Causeways. The M4T6 provides a one-lane roadway, 13 feet 10 1/2 inches wide. It can carry up to Class 50 wheeled loads in calm water. The loaded 5-ton tractor and 25-ton lowbed trailer combination is a Class 35 load. Rough water or strong currents may reduce the load capacity. Items such as tapered balk, raft ramps, and the 50-ton universal trestle may be used to make connections at the wharf and shore. A suitable anchorage system must be provided for all floating causeways.

(2) Lighters. Rafts from 87 to 103 feet long by 13 feet wide may be constructed to carry loads up to Class 60 in calm water. These rafts are powered by 19- or 27-foot bridge erection boats. For example, the completed four-float normal raft with an overhanging end ramp is 87 feet 1 inch long, and carries a Class 50 load in calm water when powered by one 27-foot bridge erection boat. Other raft capacities are listed in Table 10-1.

TABLE 10-1. Raft Classes, Dimensions, and Propulsion Requirements

Raft Construction	Overall Length	Wheeled Load Class in Calm Water	Propulsion Requirements*
4 float normal	87 ft 1 in	50	1
4 float reinforced	87 ft 1 in	50	1
5 float normal	102 ft 1 in	55	1
5 float reinforced	88 ft 1 in	60	1
6 float reinforced	103 ft 4 in	65	1

** Number of 27-foot bridge erection boats required.*

(3) Floating platforms. Rafts may also serve as floating platforms to support clam-shell or drag-line dredging, pile driving, and water crane and other construction operations. FM 5-210 details raft capacities.

d. Allocation.

(1) The engineer battalion of the armored, infantry, or mechanized division will receive four sets of either the M4T6 or Class 60 floating bridge when not equipped with the ribbon bridge.

(2) The corps engineer float bridge company will be issued five sets of either the M4T6 or Class 60 floating bridge when not equipped with the ribbon bridge.

(3) Bridge sets used in port construction come from depot stocks.

PNEUMATIC FLOATING STEEL (SUPERSTRUCTURE) BRIDGE (CLASS 60)

a. Description. Class-60 floating bridges and rafts (ferries) consist of flush-surfaced, steel-grid decks on the same 24-ton pneumatic floats as the M4T6. The deck panels are pinned together end-to-end to provide rigid connections. The deck can support a Class 65 vehicle load to approximately 10 floats with only minor deflection. See FM 5-210.

b. Port construction applications. Elements of the Class 60 float bridge equipment may serve like the M4T6.

c. Capabilities.

(1) Causeways. The deck width of the Class 60 float bridge is 13 1/2 feet between curbs (Figure 10-2). In calm waters it can carry up to Class 60 loads. As with the M4T6, it requires suitable anchorages and lighter loads in rough water.

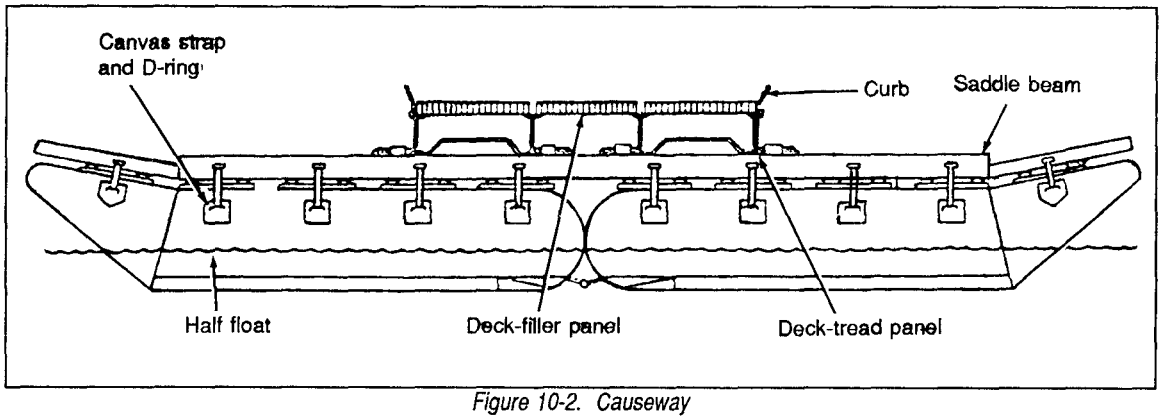


Figure 10-2. Causeway

(2) Lighters. The Class 60 raft is assembled in four- or five-float normal rafts or five- or six-float reinforced rafts. Table 10-2, page 10-4, gives the dimensions, classifications, and propulsion requirements (also see FM 5-210).

(3) Floating platforms. The discussion of the M4T6 used as a floating platform also applies to the Class 60 equipment.

d. Allocation. Same as the M4T6.

FLOATING BRIDGE (M4)

a. Description. The M4 floating bridge consists of aluminum balk decks supported by aluminum pontoons.

b. Port construction applications. As with the other floating bridge equipment, M4 floating bridges may be used in the port environment as causeways, lighters, and floating work platforms. See FM 5-210 and Table 10-2 for specifications.

TABLE 10-2. Class 60 Raft Classes, Dimensions, and Propulsion Requirements

Raft Construction	Overall Length	Length Available for Loading	Wheeled Load Class in Calm Water	Propulsion Requirement*
4 float normal	92 ft 5 in	51 ft	40	1
5 float normal	107 ft 5 in	66 ft	50	1
5 float reinforced	92 ft 5 in	51 ft	55	1
5 float reinforced (with one short deck bay)	83 ft 1 in	43 ft 9 in	60	1
6 float reinforced	92 ft 5 in	54 ft	65	1

** Number of 27-foot bridge erection boats needed to satisfy propulsion requirement.*

c. Capabilities.

(1) Causeways. The roadway width of the M4 float bridge is 13 feet 10 1/2 inches. It can support Class 60 loads when constructed in normal configuration and Class 100 loads using reinforced construction (Figure 10-3). These classes apply to operation in calm water They must be reduced for rough water or strong currents.

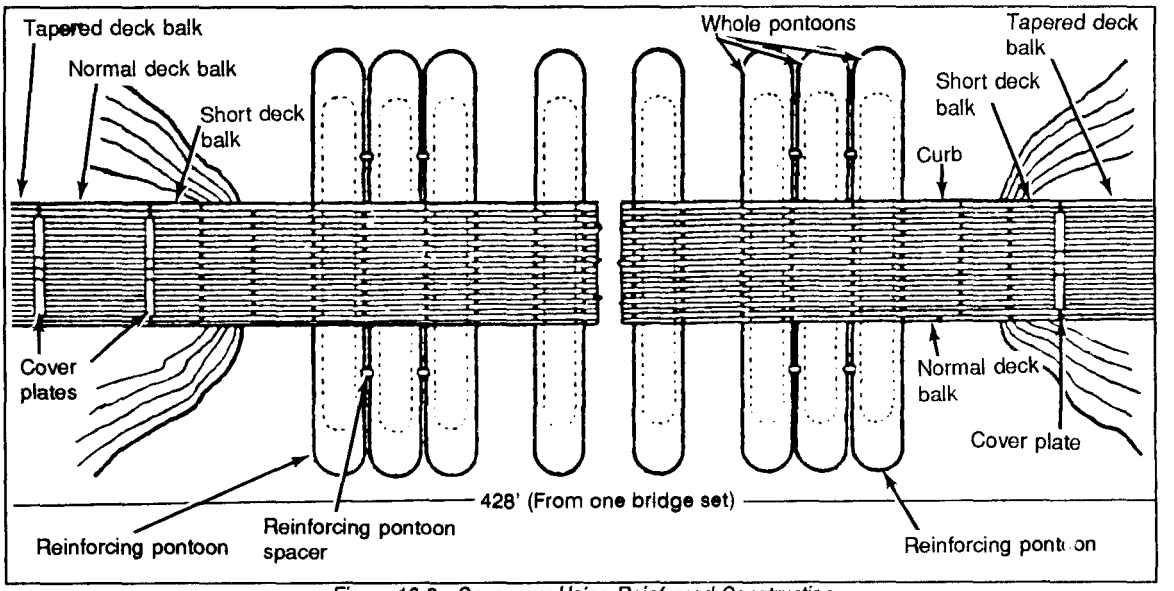


Figure 10-3. Causeway Using Reinforced Construction

(2) Lighters. The M4 may be assembled in 4-, 6-, and 7-pontoon configurations or in shorter rafts of 4 or 5 pontoons. Table 10-3 gives basic M4 characteristics.

TABLE 10-3. M4 Raft Classes, Dimensions, and Propulsion Requirements

Raft Construction	Overall Length	Wheeled Load Class in Calm Water	Propulsion Requirements
4 pontoon	87 ft 3/4 in	50	1
6 pontoon, reinforced	87 ft 3/4 in	70	1
7 pontoon, reinforced	87 ft 3/4 in	85	1
4 pontoon, shortened	73 ft 8-3/4 in	50	1
5 pontoon, shortened	73 ft 8-3/4 in	70	1

* *Number of 27-foot bridge erection boats needed to satisfy propulsion requirement.*

(3) Floating platforms. The earlier discussion concerning use as floating platforms also applies to M4 equipment.

d. Allocation. The M4 bridge is not normally issued to units as organic equipment.

Section II. Navy Equipment

Ruggedness, convenience of assembly, and flexibility make Navy pontoon gear useful as floating wharves, wharf approaches, floating dry docks for small craft, barges, and many other purposes. This gear uses specially designed, internally reinforced, welded steel cubes, officially called Navy lightered (NL) pontoons.

The Navy has used two series of pontoons widely: the T-series, currently being phased out, and the P-series, now in use. The two series are not readily interchangeable due to differences in width and bolt-hole spacing. This manual discusses only P-series pontoons.

P-SERIES PONTOONS

a. General. There are five types of P-series pontoons, designated PI through P5. All withstand an internal pressure of 20 pounds per square inch. All have decks designed for the American Association of State Highway and Transportation Officials (AASHTO) H-20 loadings--32,000 pounds/axle.

b. Uses. Pontoon units are usually configured in one of five ways. They are used as: pontoon barges and tugs, floating drydocks, bridge units, or pontoon wharves. These uses are discussed in more detail in the following section.

a. P1 Pontoon. The PI pontoon (Figure 10-4) has a 5 foot 3/8 inch by 7 foot deck. The sides are 5 feet 3/8 inch high. The side, end, deck, and bottom plating are 3/16 inch thick. The PI is the most common pontoon in the P-series. Every structure of the pontoon system uses it.

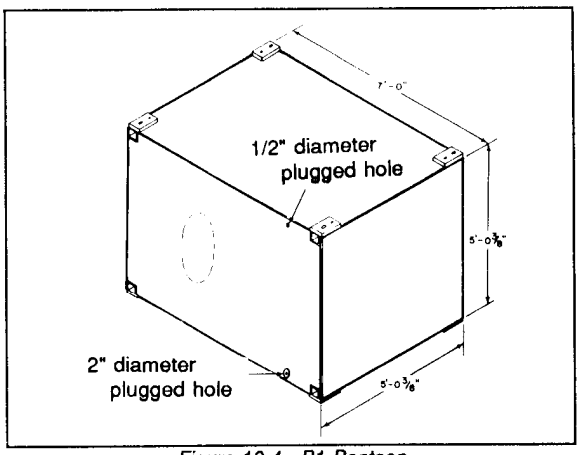


Figure 10-4. P1 Pontoon

b. P2 Pontoon. The P2 pontoon (Figure 10-5) has the same depth as the P1. But it has a 7-foot square deck and a straight-line sloping bow. The side, end, and deck plates are 3/16 inch thick, and the bow plate is 3/8 inch thick. The P2 pontoon is used on the bow and stern of various pontoon structures.

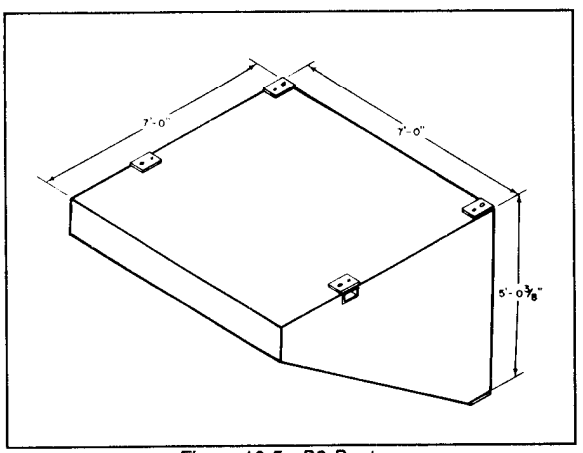


Figure 10-5. P2 Pontoon

c. P3 Pontoon. The P3 pontoon (Figure 10-6) has an inclined deck 5 feet 1 3/4 inches long and 7 feet wide. The deck slopes from 4 feet 11 3/8 inches to 3 feet 8 1/4 inches high. The bottom is horizontal. All plating is 3/16 inch thick. The sloping deck is fitted with five l-inch square ribs 5 feet 5 inches long. They are evenly spaced and secured by welding. A covering of nonskid paint is applied between the cleats. The P3 is used with the P4 to form a sloped ramp for causeway ends and ramp barge bows.

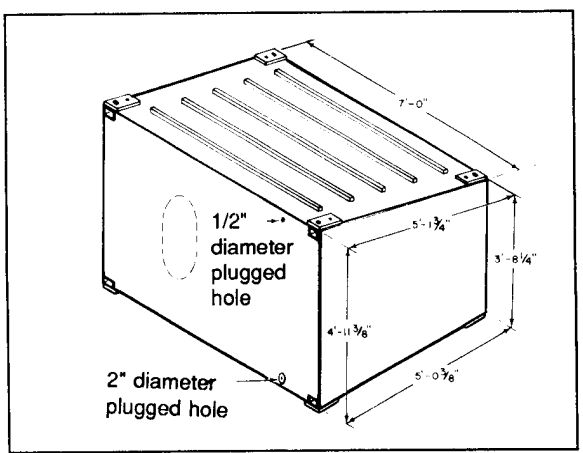


Figure 10-6. P3 Pontoon

d. P4 Pontoon. The P4 pontoon (Figure 10-7) has a deck 5 feet 1 3/4 inches long and 7 feet wide. The slope is the same as the P3 pontoon. The aft end is 3 feet 6 inches high; the forward end, 1 foot. The bottom is horizontal for 8 inches on the aft end, then slopes upward. The deck, side, and back plates are 3/16 inch thick. The bottom or bilge plate is 3/8 inch thick. Five evenly spaced, l-inch square ribs are welded to the sloped deck. A coat of nonskid paint is applied between cleats. Used with the P3, the P4 forms a continuous ramp for causeway ends and ramp barge bows.

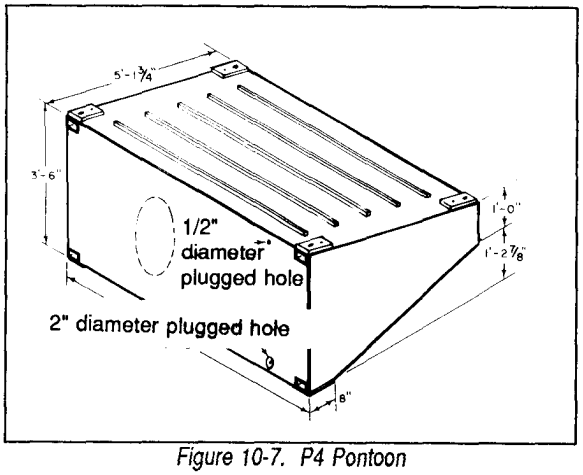
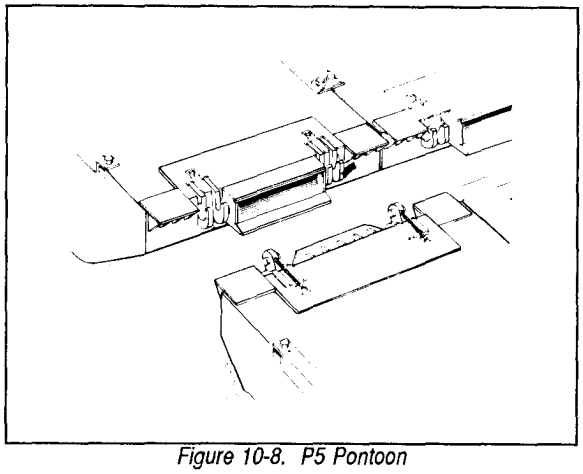


Figure 10-7. P4 Pontoon

e. P5 Pontoon. P-series 3 by 15 pontoon causeways are connected end-to-end by alternate P5M (male) and P5F (female) pontoons (Figure 10-8). As barge sections they serve wharves where end-to-end connection is required. These pontoons are constructed by welding hinge connectors to P2 pontoons. They are then assembled in male and female sequence, forming causeways of any required length. These pontoons may also be used to enlarge or extend wharf structures. The center of the P5F hinge is made from a 8-inch pipe. The center of the P5M hinge is made from a reinforced 6-inch pipe. When jointed, these two parts resist the torsion, compression, and vertical shear forces in the joint.


Figure 10-8. P5 Pontoon

USES FOR P-SERIES PONTOONS.

a. Pontoon barges. The standard barge units (3 by 7, 4 by 7, 3 by 12, 4 by 12, 5 by 12, 6 by 18, and 10 by 30) are constructed with P-series pontoons (Table 10-4, page 10-8). Use and limited fabrication details follow for each barge:

(1) 3 by 7 pontoon barge.

(a) Use. This pontoon barge is a general-purpose structure employed in lighters and ferrying. It can also be used as a towed cargo transport. The barge can be self-propelled with the addition of a propulsion unit on the end without fenders. Table 10-5 shows barge capacity and draft.

(b) Construction. Engineers can build 3 x 7 pontoon barges in strings assembled in water. The barge consists of three strings, of five P1 pontoons each with a P2 sloping bow pontoon at each end.

TABLE 10-4. Weights and Volumes of P-Series Pontoons

P-Series Pontoon Type	Weight (lb)	Volume (cu ft)
P1	2,060	175
P2	2,700	160
P3	2,200	138
P4	1,950	103
P5F and P5M	3,200	160

TABLE 10-5. Size, Capacity and Draft of P-Series Pontoons

Type	Approximate Weight* (tons)	Capacity (tons)	Deck Size (feet)	Light Draft (inches)	Loaded Draft (inches)
3 X 7	31.5	50	21 X 43	20	45
3 X 12	54.0	85	21 X 73	20	45
4 X 7	42.0	65	28 X 43	20	48
4 X 12	72.0	100	28 X 72	20	44
5 X 12	90.0	125	35 X 72	20	44
6 X 18	162.0	250	43 X 107	20	48
10 X 30	450.0	800	71 X 177	20	50

* *Used pontoon structures will weigh more because of water accumulated in the pontoons.*

(2) 4 by 7 pontoon barge.

(a) Use. This pontoon barge is similar in all respects to the 3 by 7 barge except it is one string wider. Although it is used chiefly for lighters, it is suitable for other transportation tasks as well (Table 10-5). When equipped with a propulsion unit, the barge can move at speeds of 4 to 6 knots, depending upon the load carried. It can ground and back off the beach in dangerous tides and surf.

(b) Construction. Pontoon string construction details are the same as for the 3 by 7 barge.

(3) 3 by 12 pontoon barge.

(a) Use. This barge, a ramp barge, is used for transporting cargo and equipment in amphibious operations. The sloping bow-end with ramps attached (Figure 10-9) permits beaching the barge under its own power, to unload tractors and equipment to form a causeway pier. Four of the barges can be side-loaded on a landing ship, tank (LST) for side-carry to the assault area, or the barge can be loaded in the well deck of a landing ship, dock (LSD) or deck-loaded on an LST. Table 10-5 shows size, capacity, and draft.

(b) Construction. Engineers can construct 3 by 12 barges by building and assembling the strings in the water. The entire structure can also be assembled and launched as a unit from a dock. The barge has three strings, each consisting of nine P1 pontoons with one P2 pontoon on the stern and one each of the P3 and P4 sloping-deck pontoons on the bow end.

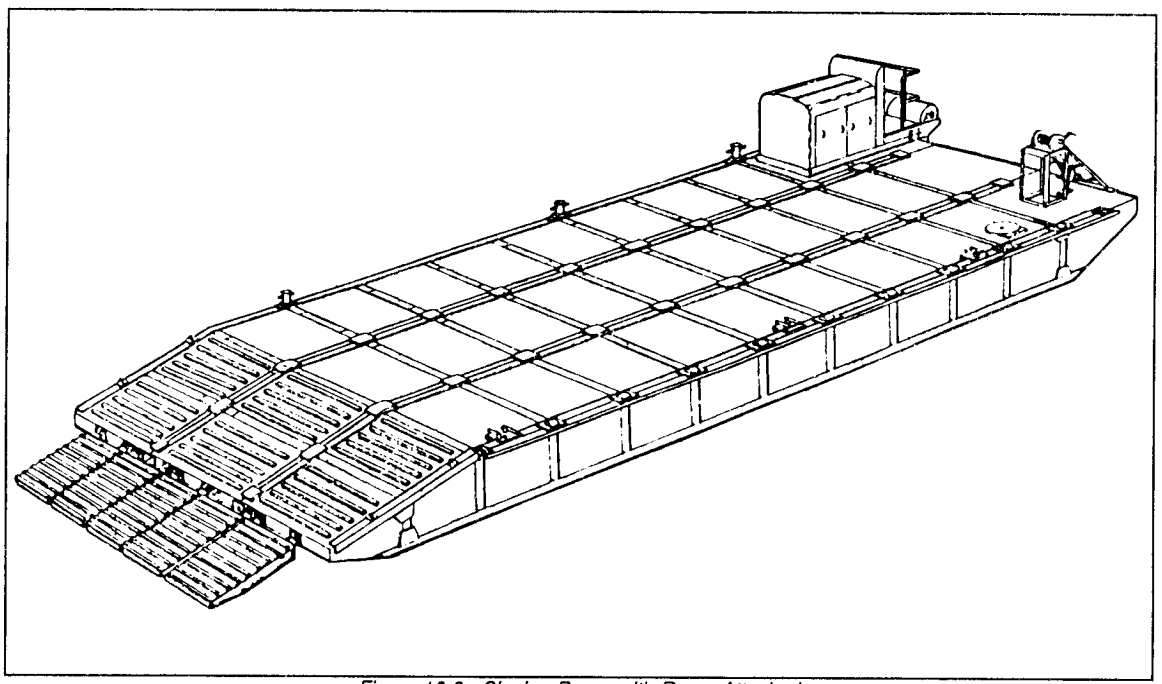


Figure 10-9. Sloping Barge with Ramp Attached

(4) 4 by 12 pontoon barge.

(a) Use. These barges resemble 4 by 7 barges in length and capacity. They also have the same accessories. A general-purpose lighter, the 4 by 12 barge is either towed or self-propelled when propulsion units are added. With accessories it converts to a gate vessel.

(b) Construction. Built and assembled in strings in water, the 4 by 12 barge has four strings of ten P1 pontoons with one P2 pontoon on each end.

(5) 5 by 12 pontoon barge.

(a) Use. This barge is one string wider than the 4 by 12 barge but is similar in all other respects. A crawler crane with a lifting capacity ranging from 20 tons at a 12-foot radius to 7 tons at 55 feet can be mounted to its deck. It can serve as a general-purpose structure or as a self-propelled lighter, after a propulsion unit is added. Figure 10-10 illustrates a typical 5 by 12 pontoon barge.

(b) Construction. Construction of the 5 by 12 barge (Figure 10-10) is the same as for the 4 by 12, except for the additional string.

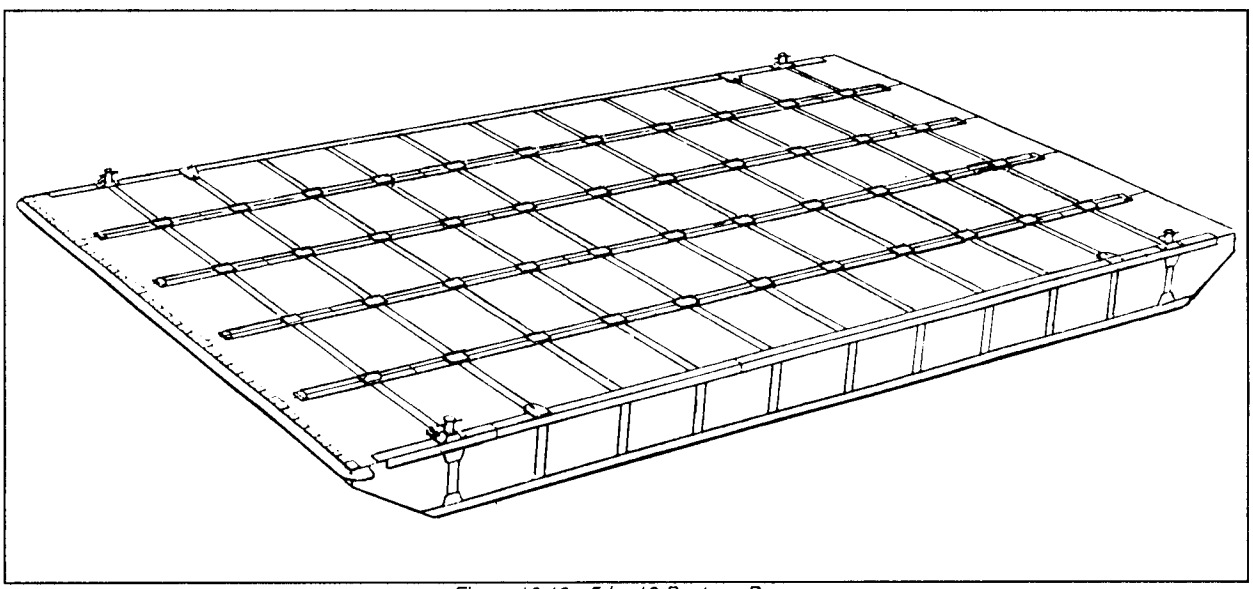


Figure 10-10. 5 by 12 Pontoon Barge

(6) 6 by 18 pontoon barge.

(a) Use. This is the second largest barge in the P-series pontoon system. With propulsion units, it can be used as a lighter, transporting loads up to 250 tons. Other accessories and equipment can convert the barge into a 1,500-barrel fuel storage barge. Installing heavy-duty hinges converts the barge into a wharf. As a barge it can be used for outfitting and repairing smaller structures placed on its deck. The barge comes equipped with a 750-pound mooring anchor, anchor hoist, and winch.

(b) Construction. Each of six strings is made of ten intermediate P1 rectangular pontoons and two sloping bow P2 pontoons (Figure 10-11). They are assembled, launched, and jointed in water. However, heavier angles are used centrally in the strings to compensate for greater forces imposed on larger structures.

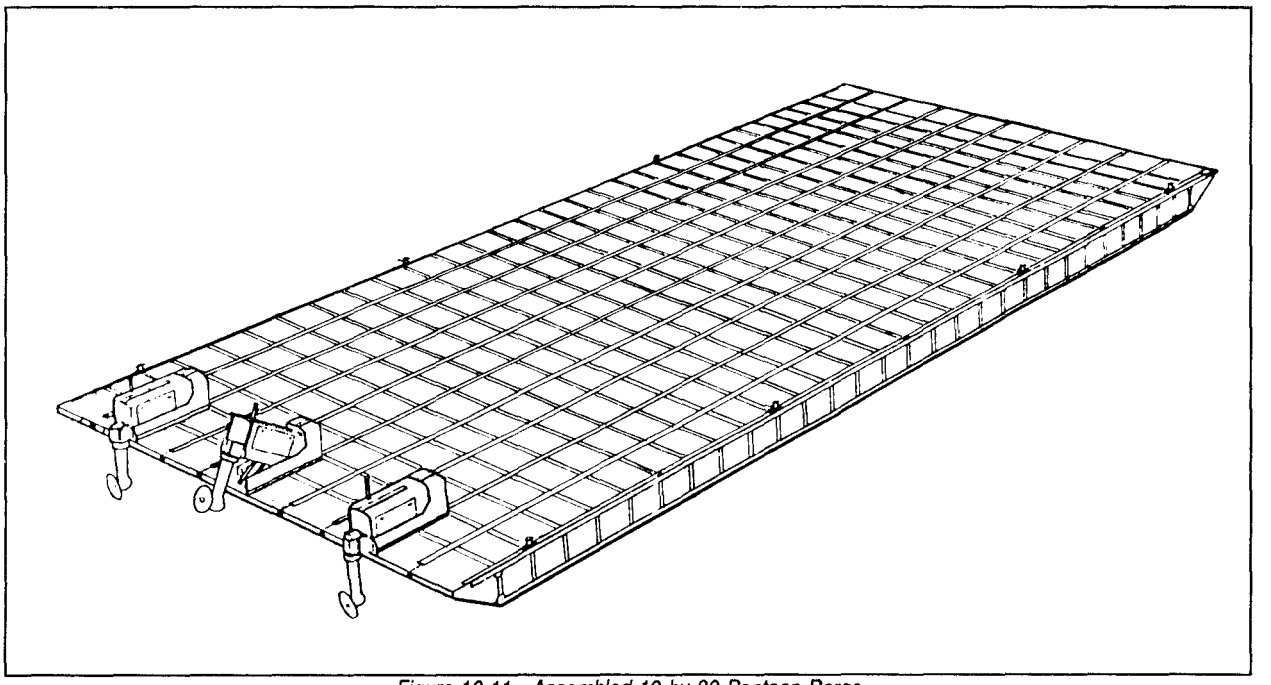


Figure 10-11. Assembled 10 by 30 Pontoon Barge

(7) 10 by 30 pontoon barge.

(a) Use. The largest barge in the pontoon system, it was developed for mounting a 100-ton derrick. The barge has other uses. 'With propulsion units attached, it can serve as a lighter to transport approximately 800 tons of cargo at one time from ship to shore or dock (Table 10-5, page 10-8). The barge can also serve as a pier or wharf. Heavy hinges allow it to act as an extension to an existing pontoon wharf.

(b) Construction. The barge is built from 10 strings, each made of 28 intermediate P1 rectangular pontoons and two sloping bow P2 pontoons. Erection procedures are similar to those used for other pontoon structures. All assembly angles are 8 by 8 by 12 inches.

b. Pontoon tugs. Tugs are barges equipped with outboard propulsion units and other accessories. P-series tugs are widely adaptable for towing, causeway tending, placing and retrieving anchors, salvage, assisting in the installation and recovery of fuel systems, and other services. The 3 by 4 pontoon tug (Figure 10-12) and the 3 by 14 warping tug are the most common.

(1) 3 by 4 pontoon tug.

(a) Use. This pontoon tug has one outboard propulsion unit mounted on the center string. That string is assembled forward of the outboard strings to provide protection at the stern for the propeller of the propulsion unit. The tug has a 150-pound mooring anchor and gear. The tug tows other barge assemblies that are not self-propelled.

(b) Construction. These pontoon tugs consist of three strings. Each string includes two P1 rectangular pontoons with P2 sloping bow pontoons on either end. The tug can be built of strings launched and assembled in the water or can be assembled and launched complete from a deck.

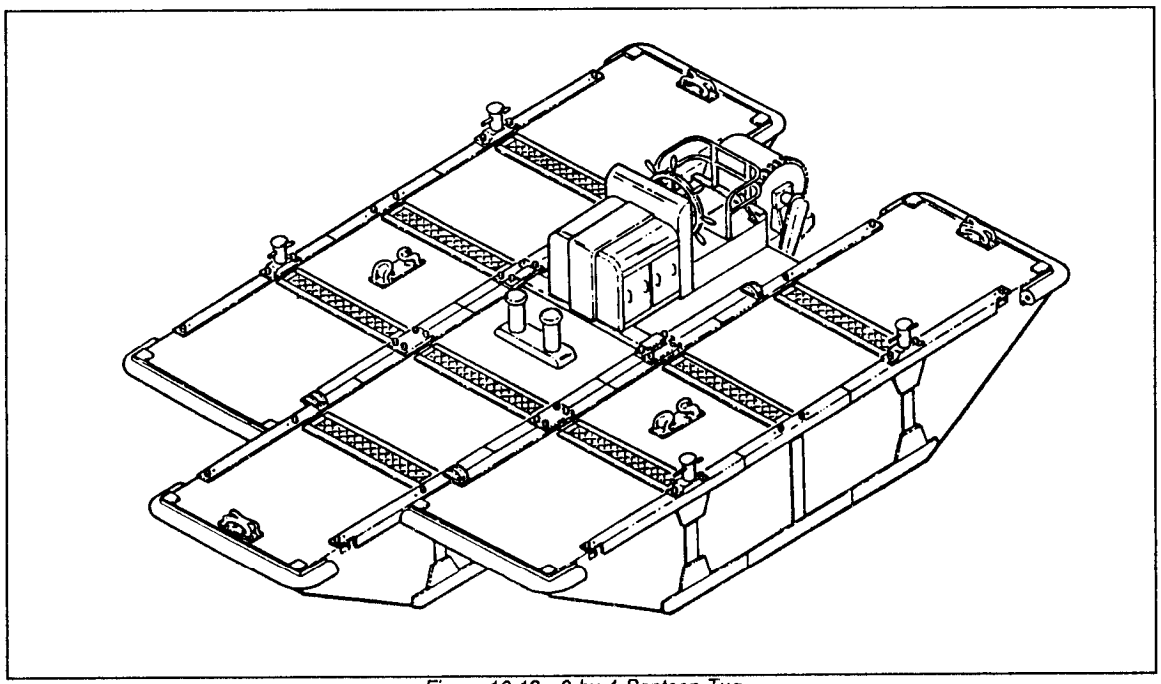


Figure 10-12. 3 by 4 Pontoon Tug

(2) 3 by 14 Warping Tug.

(a) Use. This warping tug is a barge adapted for LST side carry and equipped with two outboard propulsion units. The warping tug can be used to pick up small landing craft sunk in the surf or shallow water, salvage anchors, and install causeways. Other uses include placing and retrieving anchors used when establishing causeway piers, and installing standard tanker moorings for fuel systems (TM 520).

(b) Construction. This warping tug can be built from strings assembled in the water. It has three strings of 14 pontoons each. The port and starboard strings each include 12 rectangular P1 pontoons with one sloping bow P2 pontoon at each end. The center string is made up of 13 P1 pontoons with one P2 pontoon at the bow and an anchor housing attached to the stern pontoon. Figure 10-13 shows an assembled 3 by 14 warping tug with a warping tug A-frame.

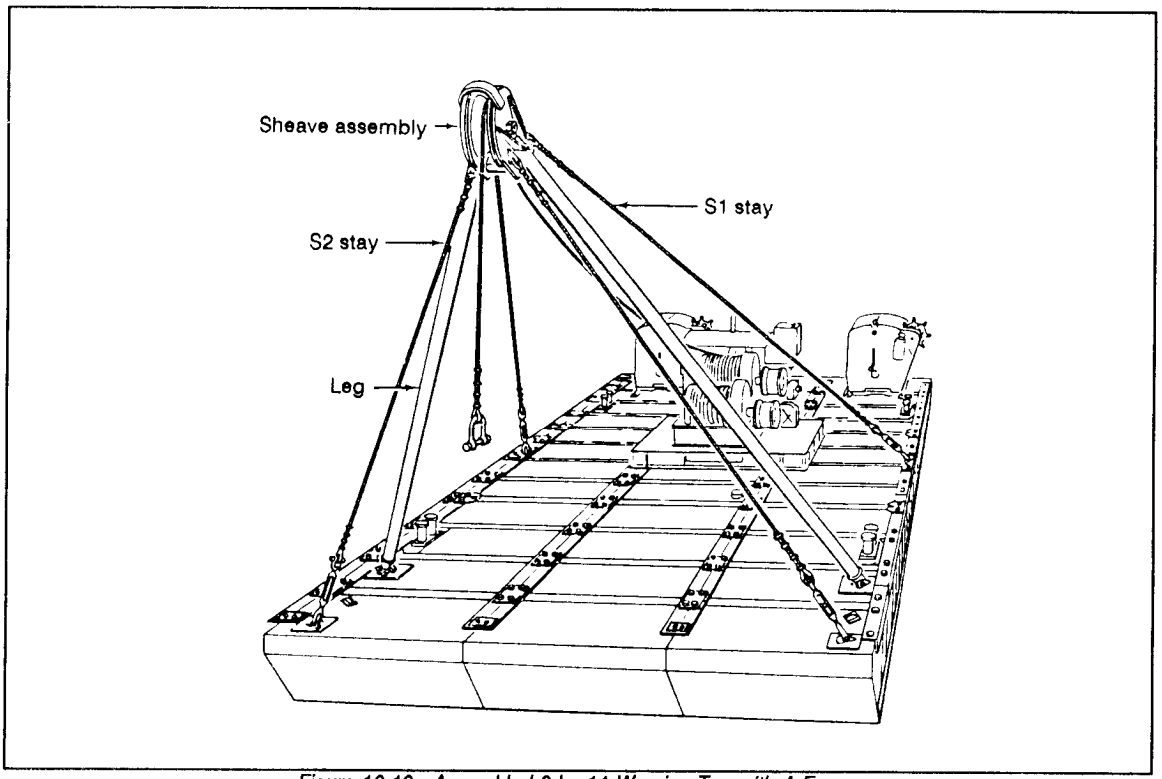


Figure 10-13. Assembled 3 by 14 Warping Tug with A-Frame

c. Floating drydocks.

(1) Floating pontoon drydocks consist principally of a main, wharf-like deck and vertical side towers constructed of P-series pontoon units. They are submerged by admitting a controlling amount of water into the deck pontoon and raised by expelling the water with compressed air. The tower pontoons act as stabilizers to keep the drydock level when the deck is under water. Drydocks require 18 feet of water to submerge the decks 12 feet, the maximum safe depth. They should be moored in sheltered, quiet water 18 to 20 feet deep. The area should have a smooth bottom, without large rocks or other obstacles.

TABLE 10-6. 4 by 15 and 6 by 30 Pontoon Drydock Data

Physical Characteristics	Size by Pontoons	
	4 by 15	6 by 30
Capacity (long tons)	100	400
Nominal length of deck (ft)	86	173
Nominal width of deck (ft)	29	43
Light draft (in)	28	25
Loaded draft (in)	52	52
Draft over deck (ft)	13	13
Approximate submerging time (min)	15	30
Approximate raising time (min)	20	35

(2) The Navy Advanced Base Functional Component Program has two sizes of pontoon drydocks. They are identified as the 4 by 15 (100-ton capacity) drydock and the 6 by 30 (400-ton capacity) drydock. Table 10-6 gives additional data on pontoon drydocks. Figure 10-14 shows a 4 by 15 pontoon drydock.

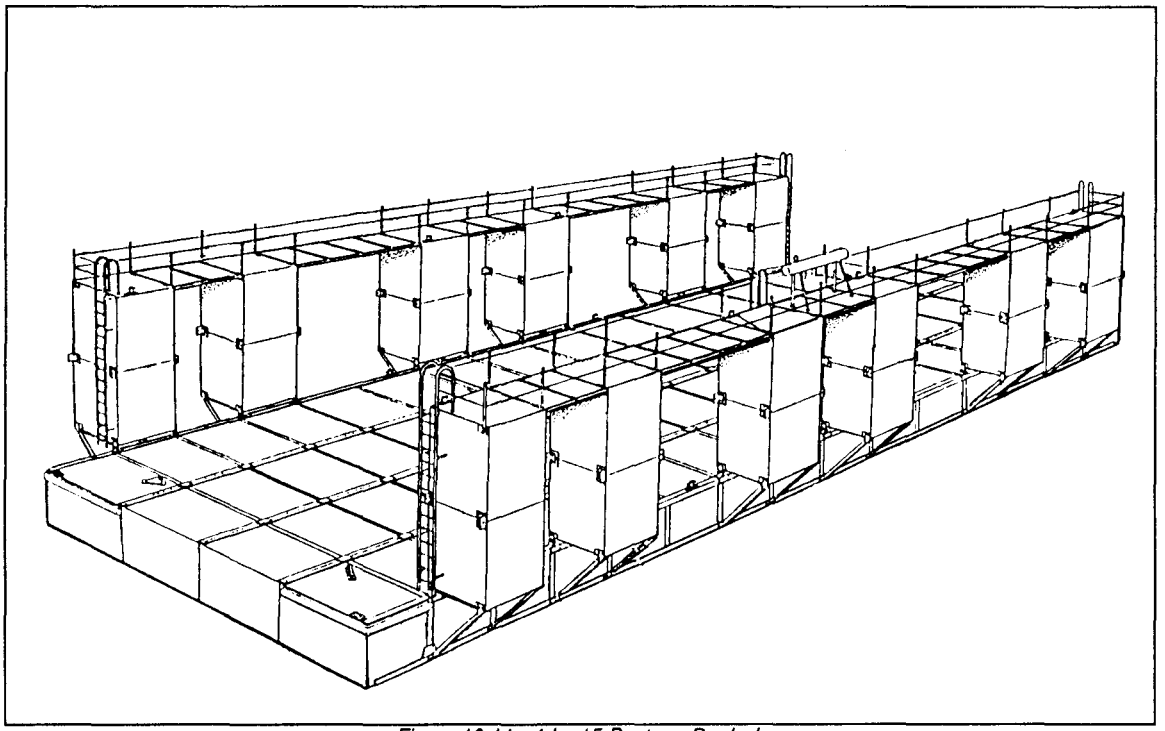


Figure 10-14. 4 by 15 Pontoon Drydock

d. Bridge units. Strings of pontoons may span a waterway or cross a swampy area. More often, bridge units connect pontoon wharves with the shore. Bridge units are unsuitable as unsupported bridges except in emergencies. P-series units classifiable as bridge units are as follows:

(1) 4 by 18 pontoon bridge. This pontoon bridge serves mainly in bridging from the shore to a pontoon wharf. The complete structure weighs 108 tons. The deck area is approximately 107 by 28 feet, with four strings of 16 rectangular P1 pontoons with P2 sloping bow pontoons at each end. Strings are assembled and launched, then joined in the water.

(2) 2 by 6 abutment. Although not actually a bridge unit, the 2 by 6 abutment is used at the shore ends of bridge units. It anchors these ends and serves as a ramp for loading or unloading ships. It has two strings of six P1 rectangular pontoons with a deck area of 35 by 14 feet. It weighs 18 tons and was developed for use as shipping and launch structures at advanced bases.

(3) 3 by 15 causeway (Figure 10-15). These causeway sections can serve as bridge units. They can be connected to other causeway sections or to wharves. They provide room for trucks and cranes. They also serve as piers to unload small craft carrying bulk cargo. Figure 10-15 shows a 3 by 15 causeway section.

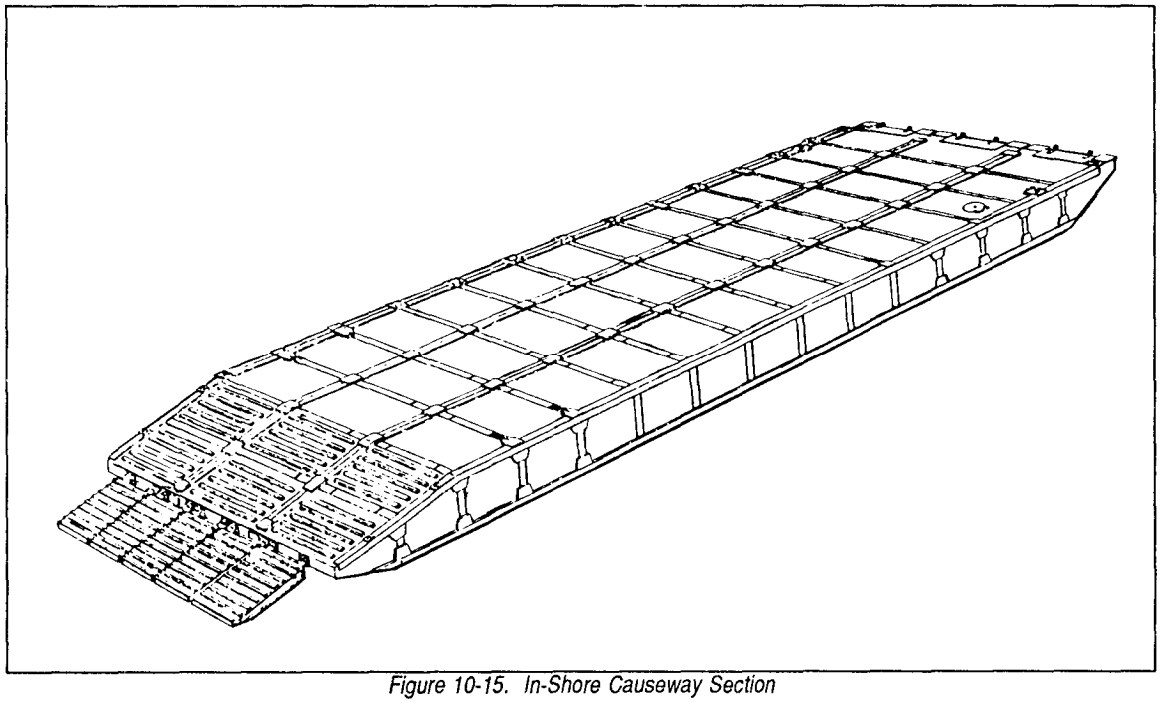
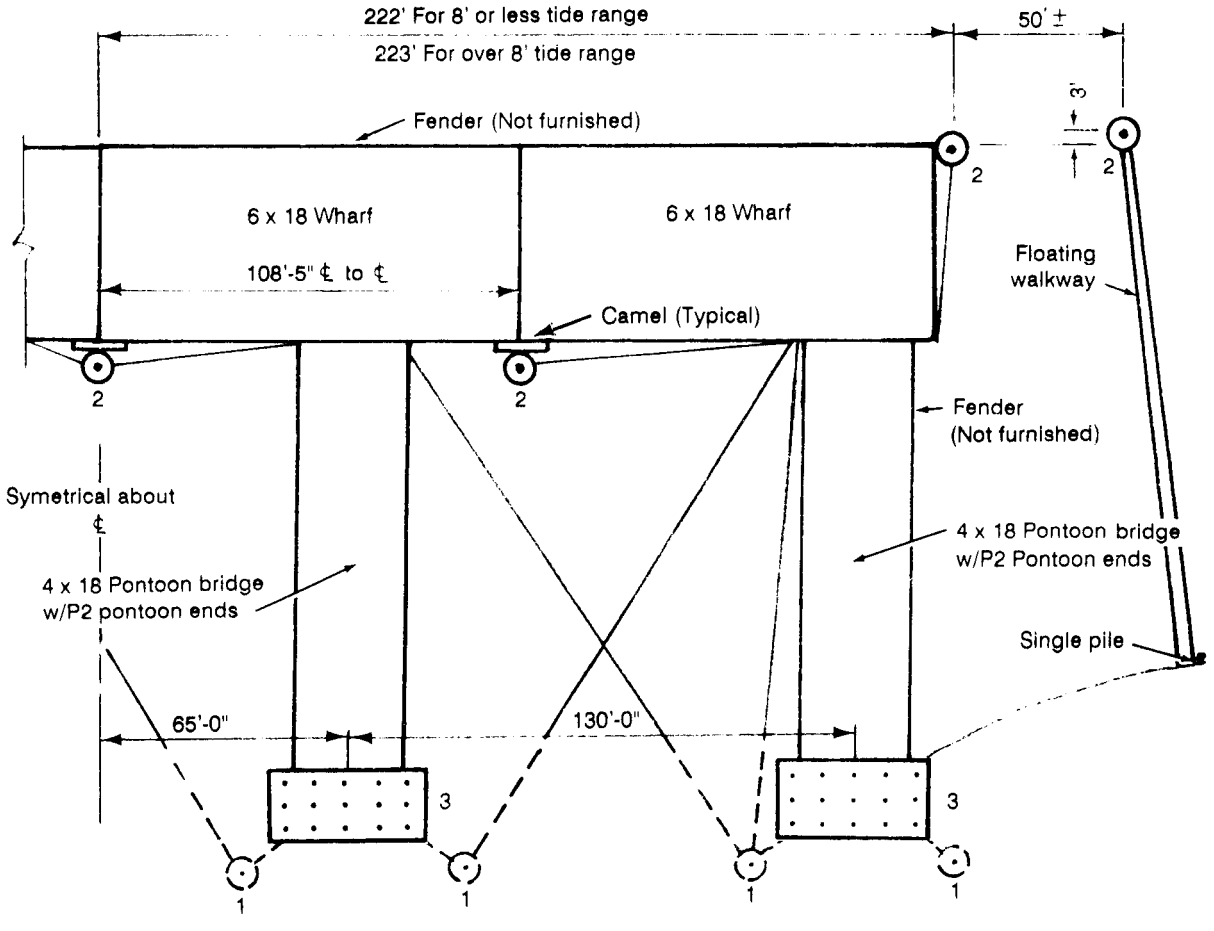


Figure 10-15. In-Shore Causeway Section

e. Pontoon wharves. Pontoon wharves are designed to serve general and/or break-bulk cargo requirements in the operational area. Connected to the shore by pontoon bridges, they are moored offshore in water deep enough for cargo vessels. Two sizes of wharves are standard within P-series equipment, 5 by 12 and 6 by 72 wharves. The bridges (causeways) connecting the wharves to the shore are an important part of the installation. Different arrangements are possible. Three such arrangements, each applicable to both 5 by 12 and 6 by 72 wharves, are shown by Figures 10-16 through 10-18. Each installation uses a 4 by 18 pontoon bridge connected to the wharf by heavy-duty hinges at the offshore end and to a 2 by 6 abutment unit filled with sand at the inshore end. Cable moorings anchor both the wharf and its connecting bridges to the shore. Cable is used to anchor any one of the three types of bridge-and-wharf assemblies shown. In each of these arrangements, the wharf is kept fixed by a series of encircling pile dolphins. The offshore location of the wharf depends cm the slope of the sea bottom and the tidal range. If deep water lies a short distance out and the tidal range is small, the wharf may be close to the beach and may require only one section in each connecting bridge. Shallow water for some distance or a great tidal range may require two or more bridge sections between the wharf and the shore.

(1) 5 by 12 pontoon wharf. This pontoon wharf is five strings wide and twelve pontoons long. It has a deck area of 68 by 35 feet. Assembly procedures for the strings and wharf are the same as for other pontoon structures. Moorings to the shore are made with four 150-pound mooring anchors and eight 90-foot lengths of 5/8-inch anchor chain. Heavy-duty hinges connect the wharf to the shore bridges.

(2) 6 by 72 pontoon wharf. The 6 by 72 pontoon wharf is 431 feet long by 42 1/2 feet wide. It has four standard 6 by 18 barges joined (without propulsion units) longitudinally. These are connected to the shore with 4 by 18 pontoon bridges. The 6 by 18 barge units used to make the 6 by 72 wharf are modified by installing alternate P5F and P5M end-connection pontoons on the ends of the barge that connect with other barges.



Legend:

1. Surface mooring anchors
2. 19 pile Dolphin
3. 2 x 6 Pontoon abutment (Note: see April 1969 Edition of Pontoon Gear Handbook For Navy Lightered (N.L.) Equipment, NAVFAC P. 401 for abutment foundation and other construction detaiis.

Figure 10-16. Causeway Arrangement 1 (with Pontoon Wharf)

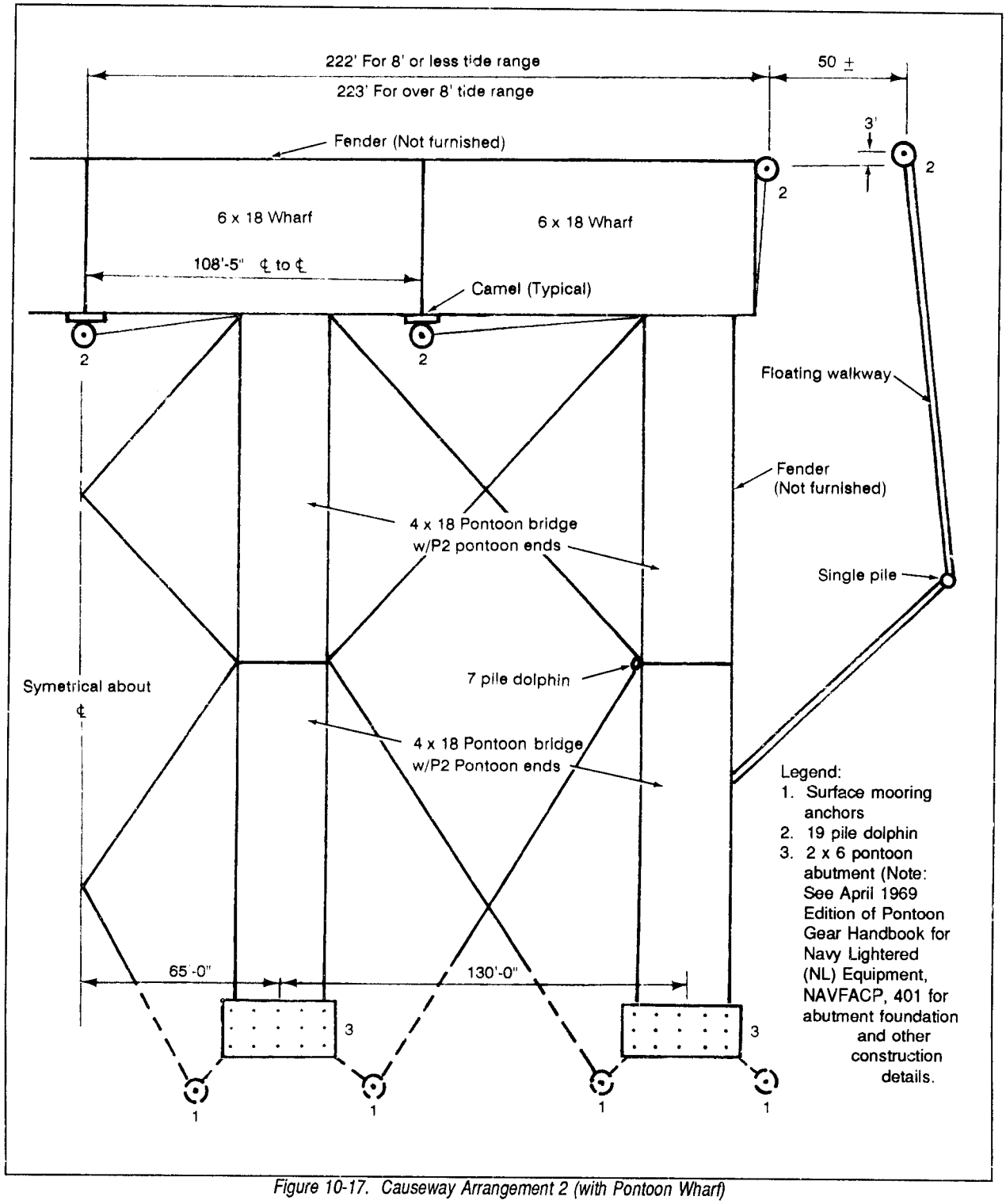


Figure 10-17. Causeway Arrangement 2 (with Pontoon Wharf)

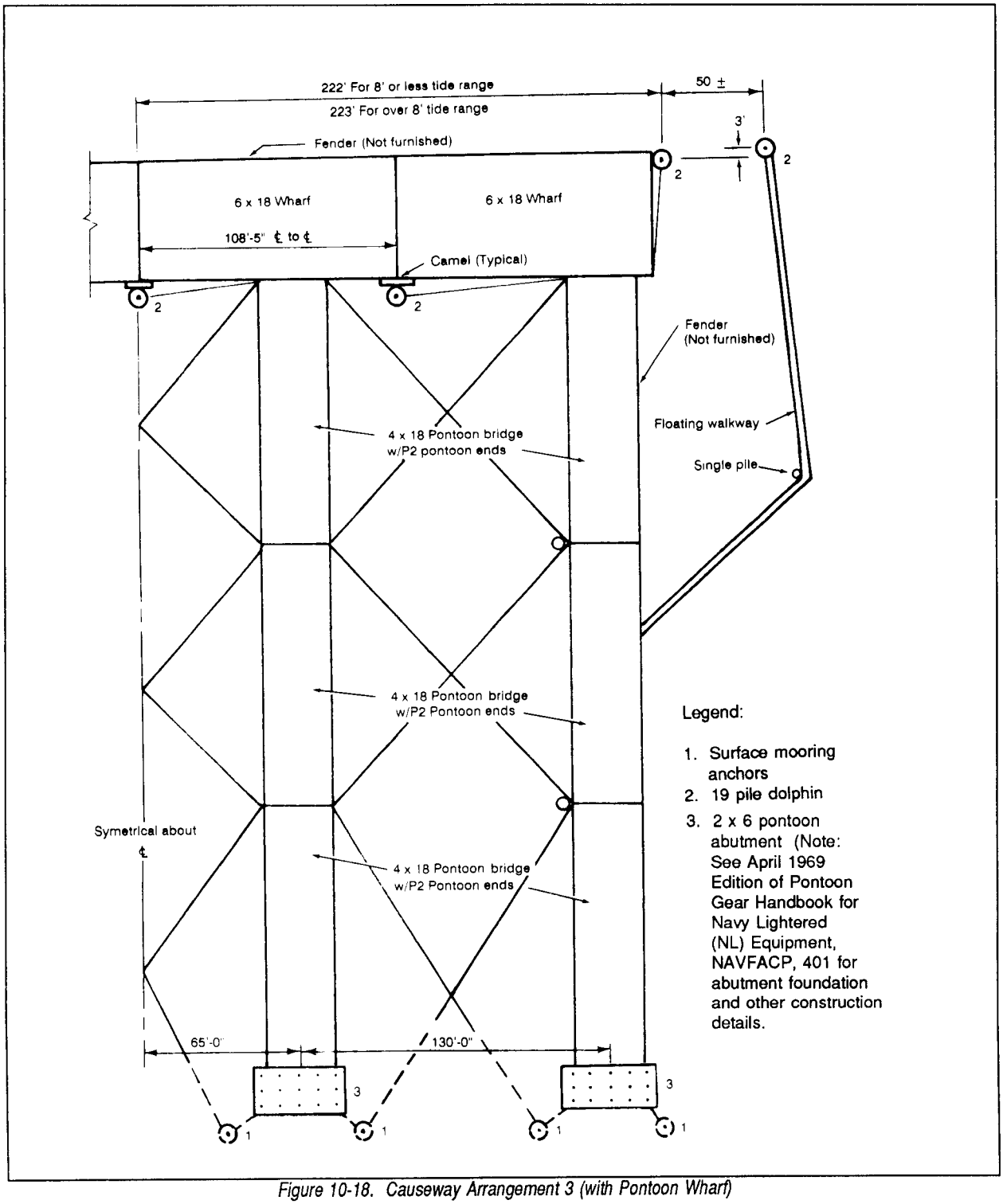


Figure 10-18. Causeway Arrangement 3 (with Pontoon Wharf)

CHAPTER 11
SELF-ELEVATING BARGE PIERS

Section I. DeLong Barges

BACKGROUND

a. The Army has two sizes of self-elevating barges. They are manufactured by the DeLong Corporation and are known as the "A" and "B" units of the DeLong system.

(1) The "A" barge is 300 feet long, 80 feet wide, and 13 feet deep. It is supported by ten 6-foot diameter caissons and ten 500-ton capacity jacks.

(2) The "B" barge is 150 feet long, 60 feet wide, and 10 feet deep. It is supported by six 6-foot diameter caissons and six 500-ton capacity jacks.

(3) In addition, two identical sizes from the Marathon-LeTourneau (M-L) Corporation have been recommended for adoption by the military.

b. Installation and erection procedures for "A" and "B" DeLong barges are outlined in the DeLong jacking systems manual, "Self-Elevating Barge." Therefore, this field manual omits them. It includes all other pertinent information, including fabrication method, design deck loading, supporting systems, operational requirements, past uses and basic considerations in site selection and shore connections.

TYPES

a. Barge. The "A" and "B" DeLong barges are honeycomb-like, welded-steel, box-girder structures consisting of plates and stiffeners. They support a uniform live deck-load of 500 to 600 pounds per square foot. The barges are divided into watertight compartments to maintain safe subdivision in case of towing accidents. Additional watertight compartments provide storage for fresh water and fuel. Each compartment can be entered from the deck through a manhole. The barge has a nonskid deck of 4 by 12 inch wood planking.

b. Caissons. Each caisson is essentially a welded steel pipe 6 feet in diameter and 140 feet long weighing 80 tons. The wall is normally 1 1/2 inches of American Society for Testing and Materials (ASTM) A-131 steel. To ensure lateral stability, a steel diaphragm is positioned 19 feet from the bottom end of each caisson to develop end bearing strength after sufficient penetration. Another diaphragm is fitted 40 inches from the top end. This allows the caisson to float. The load-carrying capacity of the pier and the depth of penetration of the caissons depend on both the foundation soils and the unbraced length of the caissons. Foundation soils of consolidated clays and nonplastic materials are best. Impenetrable, organic, or highly plastic soils are unsuitable.

c. Air jacks and controls.

(1) Air jacks. An air jack is a barrel-shaped steel cylinder approximately 10 1/2 feet high and 10 feet in diameter. It can raise 500 tons at a nominal rate of 12 feet per hour with a stroke of 12 inches. One jack is provided for each caisson well in the barge unit. The top of the jack is guided by four tie-rods anchored to the deck of the barge. The tie-rods are equally spaced around the air jack. Air jacks are secured to the deck using tie-rods during transit to minimize work at the preparation site.

(2) Controls. A master control panel (Figure 11-l) allows controls to operate simultaneously on all caissons. They can be operated individually by smaller control panels (Figure 11-1) connected by flexible hoses to the three-way valves on each jack. The control valves on each panel regulate the functions of the four major jack components as follows:

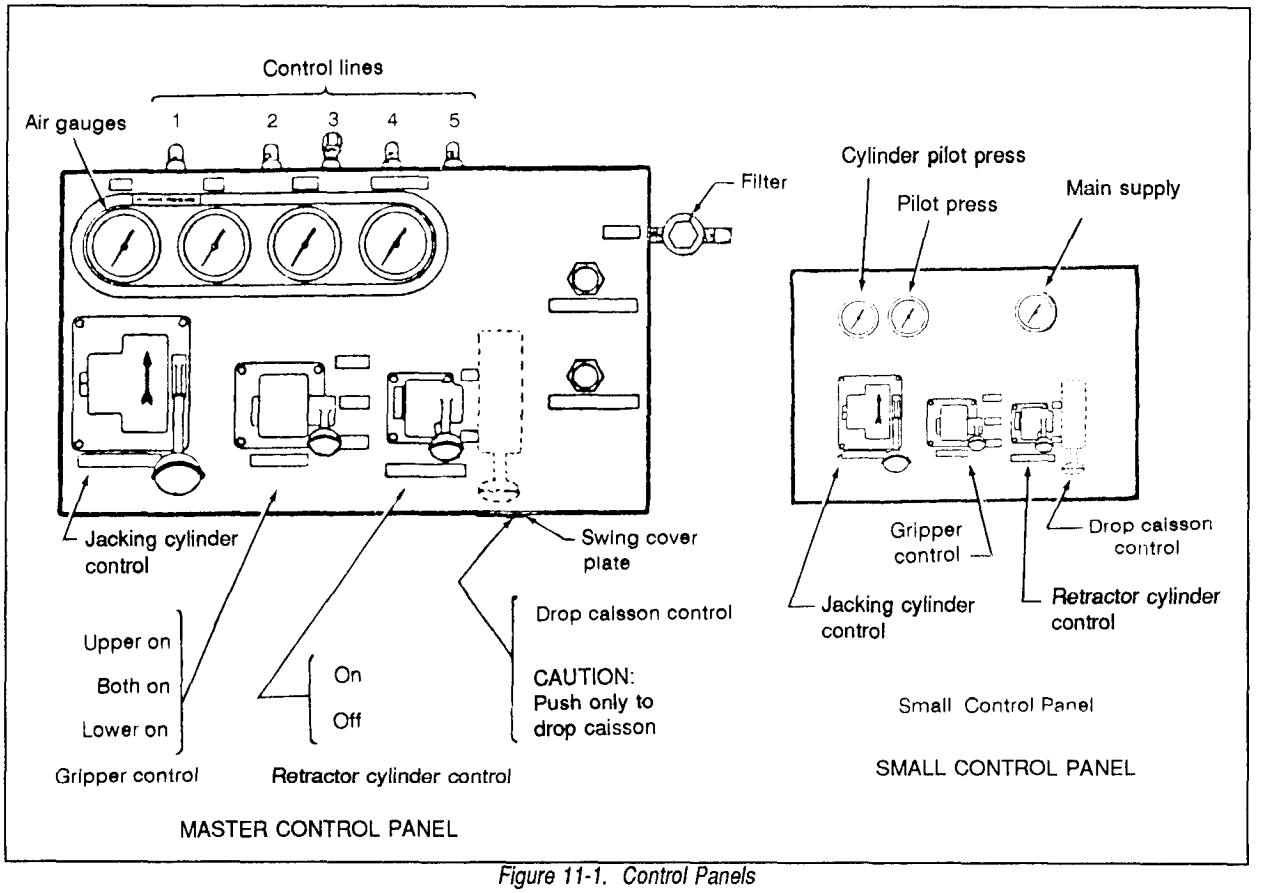


Figure 11-1. Control Panels

(a) The jacking control cylinders govern the jacking cylinders around the jack. When the control valve is "on," compressed air is admitted into the cylinder, causing the jack to lift.

(b) The retractor cylinder control regulates two retractor cylinders, spaced 180 degrees apart on the jack. When "on", this valve allows compressed air to enter the retractor cylinders, causing the jack to close.

(c) The upper and lower grippers are in the upper and lower portions of the jack. Each set of grippers has six rubber tubes inside the jack. Two controls regulate their function: the gripper control and the drop caisson control. The gripper control has three positions. In the "lower on" position, the lower grippers inflate and secure the lower portion of the jack to the caisson. The "both on" position secures the entire jack to the caisson. The "upper on" position secures the jack's upper half to the caisson. The "drop caisson" control overrides the gripper control and deflates both upper and lower grippers, allowing the caisson to drop through the jack.

d. Miscellaneous equipment.

(1) Shore connection span. Shore connection spans (Figure 11-2) are transported to the erection site by the barge units required for the pier or wharf. Each span is 79 feet long by 30 feet wide by 4 1/2 feet high. The span is of girder construction with four 4 l/4-foot girders supporting a 3/8-inch sheet steel deck. It is shipped split lengthwise into 15-foot sections.

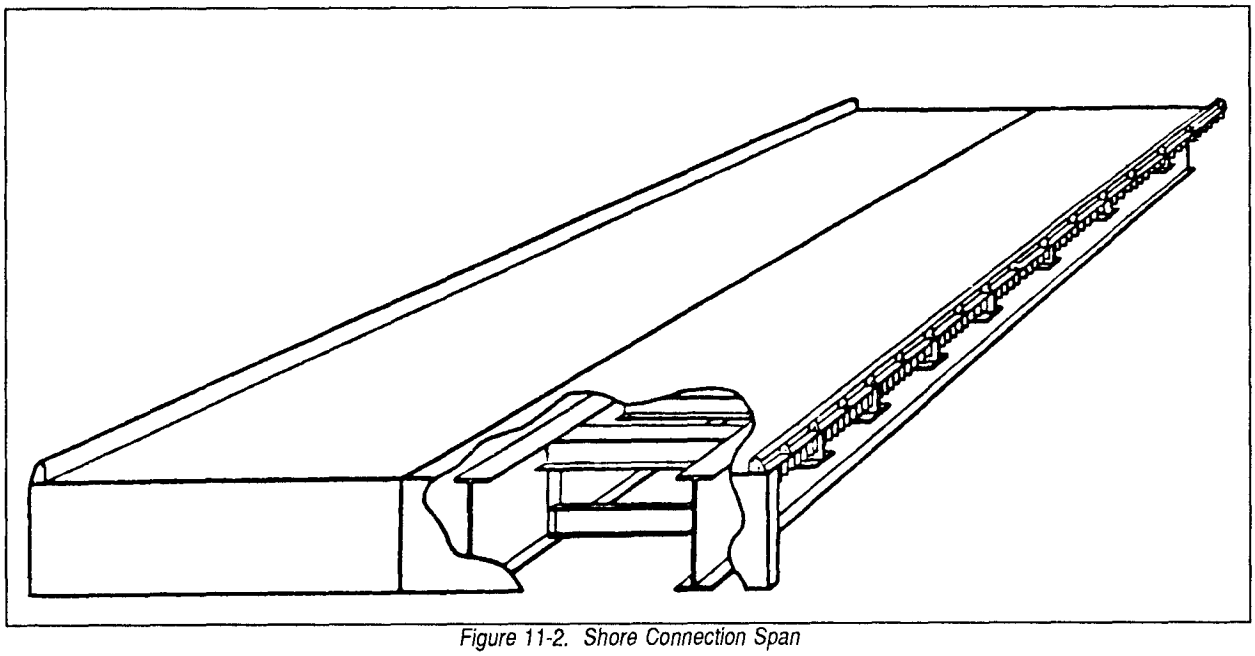


Figure 11-2. Shore Connection Span

(2) Compressors. Two 350-pound per square inch (psi), 400 cubic foot per minute (cfm) air compressors supply sufficient air pressure to operate and control the pneumatic jacks. The compressors should be secured as shown in Figure 11-3. They should be connected by flexible hose to a receiver tank inlet.

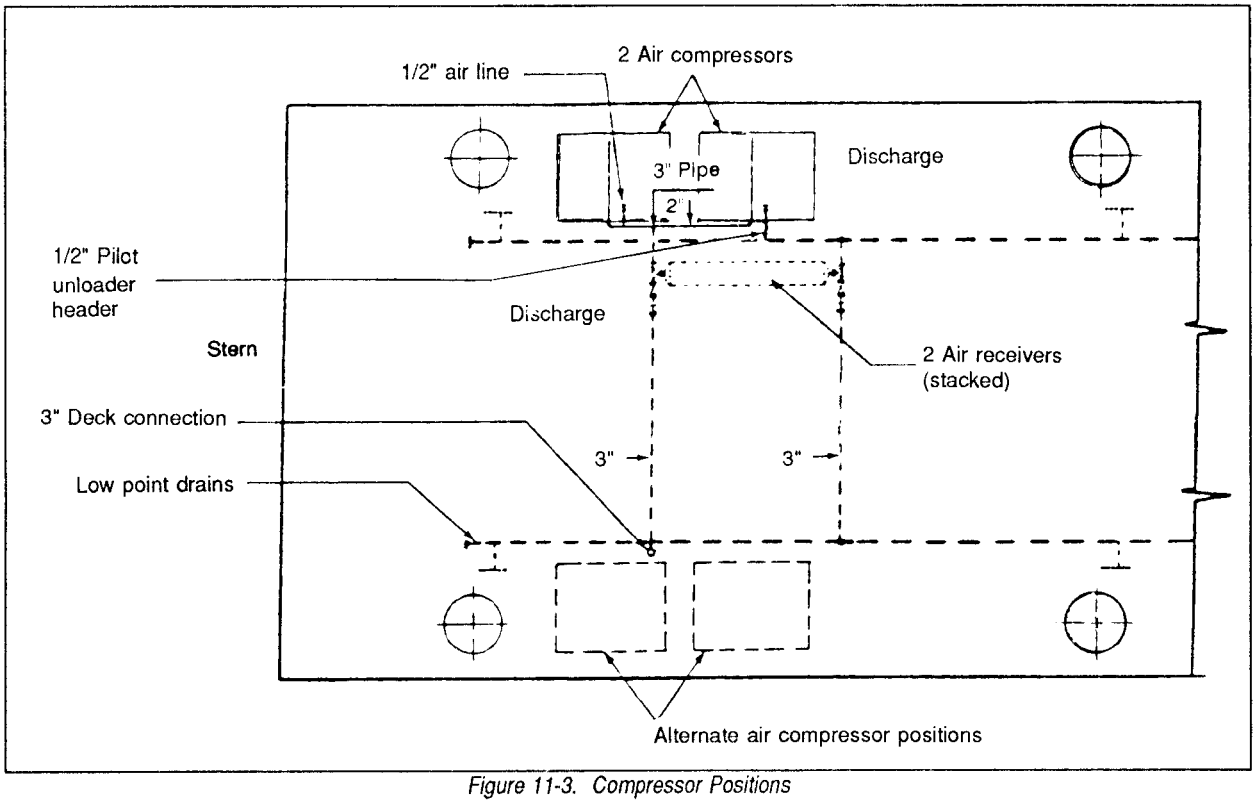


Figure 11-3. Compressor Positions

(3) Weld-off rings. Weld-off rings are pieces of steel tubing with a 10 3/4-inch outside diameter, a 1-inch wall thickness, and a 3-inch length. Eight weld-off rings per caisson are provided for semipermanent installations.

(4) Caisson covers. One steel caisson cover protects the cutoff caisson in a semipermanent installation and provides for each caisson-well in the barge unit.

(5) Fenders. The fenders for the "A" and "B" barges are made of 12 by 12 inch timbers and of 6 foot diameter steel hoops. One is provided per caisson.

e. Accessory equipment. Several items of useful equipment not provided with the barge unit include--

(1) Lifting cranes. The cranes listed below are necessary for erecting self-elevating DeLong barges.

(a) The self-elevating barge may be erected with one large barge-mounted crane. The crane should have a boom at least 200 feet long and a 75 percent tipping load rating exceeding 80 tons. The crane should also be capable of handling a boatswain's chair during lift. In addition, a smaller, at least 40-ton, barge-mounted crane may be used to hasten elevation.

(b) The above crane is not a military adopted item of material. Therefore, it may not be available at the site during construction. In this case, it becomes necessary to use at least two smaller barge-mounted cranes. They should each have a 100-ton capacity and 80-foot booms. Such cranes are available for issue from the Naval Ship Systems Command.

(c) Crawler-mounted cranes are useful in small lifting tasks, such as installing fenders and moving compressors and welding machines.

(2) Welding apparatus. If a large barge-mounted crane is not available, or a semipermanent installation is desired, welding equipment is necessary. Both oxyacetylene and electric-arc welding can be used in barge erection.

(a) Oxyacetylene welding equipment may be used. Only fusion welding with a low-carbon or high-strength steel rod is acceptable. A 300° Fahrenheit (F) to 500° F preheat is required with oxyacetylene apparatus.

(b) Electric-arc welding is preferable. It must be metal arc, using reverse polarity and 25-20 or modified 18-8 stainless steel shielded arc rods. No preheat is necessary.

(3) Pile hammer specifications.

(a) Able to work without shore connection.

(b) Six-foot diameter pile capacity.

(c) Rated striking energy of 120,000 foot-pound.

(d) Capable of sixty blows per minute.

(4) Other floating equipment.

(a) A 600-horsepower, 65-foot harbor tug must tow and position the self-elevating barge, especially if crossing open sea. In calm water, a 200-horsepower, 45-foot tug will suffice.

(b) An LCM is useful in positioning and hauling personnel and material between barge and shore.

(c) Various expedient floats, such as small rafts made from 55-gallon drums and small outboard motors, help speed elevation. They help particularly after the barge is jacked clear of the water.

SITE SELECTION FOR DELONG BARGE UNITS

a. Tides. Pier or wharf decks are usually positioned about 5 to 6 feet above mean high water. The mean tide range is the difference in height between mean high and mean low water. It is very important in selecting sites for piers or wharves.

b. Soil (foundation) conditions. Table 11-1 contains guidance in planning and site selection. If the erection site is in CONUS, data on offshore subsurface soil conditions is available through the US Geological Survey or from the appropriate Corps of Engineers district office. Outside CONUS, data, on subsurface soil conditions may be obtained from local sources, the theater army engineer; or military hydrology and hydrographic teams. All data should be checked by the engineer unit commander.

TABLE 11-1. Suitable and Non-suitable Soils for Erecting DeLong Barges

Types	Group Symbols	Suitability
Impenetrable surfaces	-----	Unacceptable
Organic soils	Pt, OH, OL	Unacceptable
Fine-grained clays and silts, wet (mud)	MH, CH	Unacceptable
Fine-grained clays and silts, partly consolidated	ML, NH, CL-CH, CL-CM	Marginal
Fine-grained clays and silts, dry	ML, CL	Acceptable
Sand or sand with silt and clay	SW, SP, SM, SC	Acceptable
Gravel or gravel with silt and clay	GW, GP, GM, GC	Excellent
NOTE: Table based on weight of barge loaded to capacity		

c. Wave action. Waves under 3 feet high cause little problem when dropping the caissons. Waves from 3 to 5 feet high require care to ensure that the barge stays in position. Waves over 5 feet high require extreme caution to ensure that the barge remains in place with equipment stowed securely. More time is needed to erect these barges in bad weather.

d. Shore accessibility. Ships must be able to dock under all tide conditions. Shore accessibility comes first in site selection. The depth of water at low tide must be at least 50 feet at the construction site. A distance of up to 1,000 feet between the shore and the end of the wharf or pier is desirable. Local bathymetry may help shorten selection time.

e. Approaches. Site selection should also consider onshore road networks. Construction of a new approach from the road net to the shore connection is expensive. However, the approach and the road net should have the following characteristics:

* Straight for at least 150 feet back from the shore connection to avoid vehicles turning onto the connection.

* Less than 10 percent grade at the shore connection.

* At least two lanes (23-foot) travel width (41-foot clearance width), regardless of the connection width.

* Constructed to withstand deterioration in wet weather.

f. Barge arrangements. There are many practical combinations of barges. Figures 11-4 and 11-5 illustrate some of the most promising arrangements.

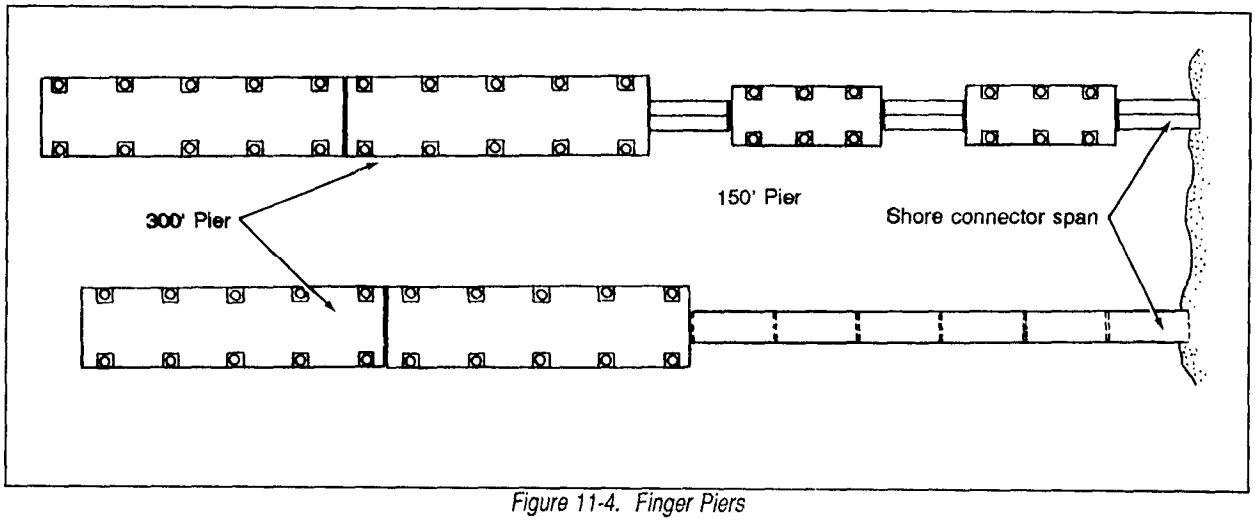


Figure 11-4. Finger Piers

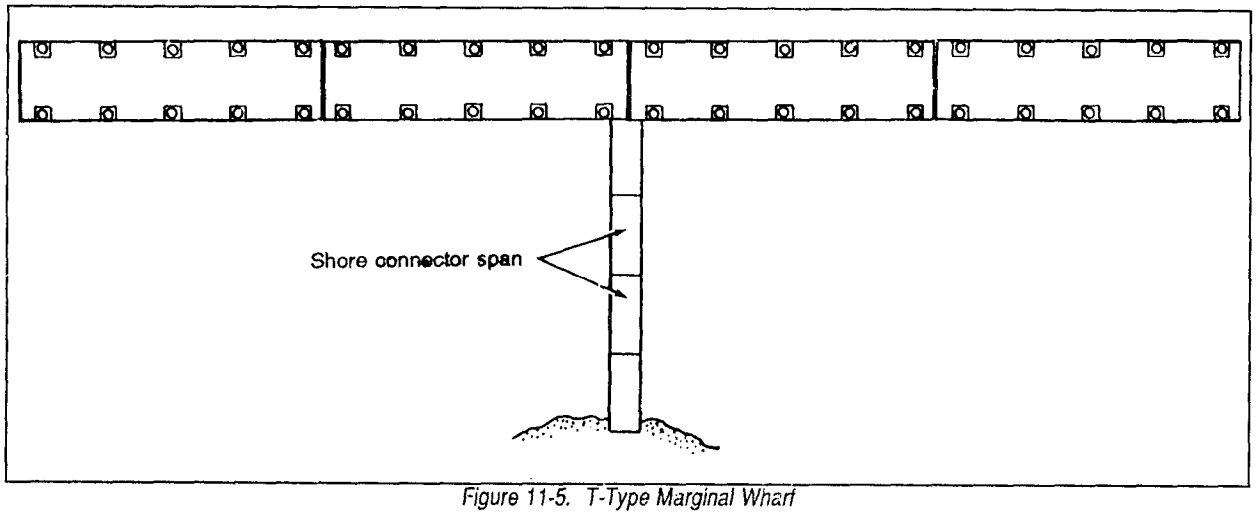


Figure 11-5. T-Type Marginal Wharf

PAST USES OF DELONG BARGES IN MILITARY CARGO HANDLING

a. Platforms for floating cranes. A large off-load crane mounted on a floating DeLong barge is one of the best methods for offloading container ships under an open sea of 5- to 6-foot waves and 28-knot winds.

b. Construction of general and / or break-bulk cargo piers. The live-load design of DeLong barges allows them to be used as general and / or break-bulk cargo piers. Barges are jacked to the desired elevation. Grippers within the jacks are inflated to 350 psi. The shutoff locks and isolation valves are closeed.

c. Construction of container ports. Modified DeLong barges were used as a military container-handling facility in Camh Ranh Bay, Vietnam. The individual barges of this facility accepted the wheel loads of the container gantry crane. This type gantry crane weighs approximately 1,000,000 pounds and has design wheel loads of about 100,000 pounds on 5-foot centers. The gantry at Camh Ranh Bay had a lifting capacity of 27.5 tons.

LIMITS OF DELONG BARGE PIERS IN CONTAINER-PORT CONSTRUCTION

a. Erection time. Each DeLong barge requires from 24 hours to 8 days for installation, depending on terrain and crew efficiency.

b. Structural integrity. DeLong barge pier design takes a 500- to 600-pound per square foot live load. Modern military container ports need a minimum 1,000-pound per square foot live load. Unmodified DeLong barge piers cannot meet modern container port structural requirements.

c. Container-handling capability. If modified DeLong barges are used to construct a temporary installation, cranes must boom up and down to keep from striking individual caissons. The top of the caissons severely affects the off-loading performance of most container-handling cranes. The barge is also jacked to the desired elevation. Grippers within jacks are inflated to 350 psi. Shut-off locks and isolation valves are closed.

d. Relocation. Temporary installations made with DeLong barges are not easily moved. Semipermanent installations are much more difficult because caissons are driven to refusal, cut off, and then welded to the larger gantries. Seldom is it feasible to relocate them.

e. Foundation limitations. Suitable foundations are limited to consolidated clays and nonplastic materials.

f. Shore-connection spans. Shore-connection spans provided with DeLong barge piers do not possess the structural integrity for handling containers.

g. Fender systems. Historically, fender systems provided with DeLong barges have not operated as desired. Damage has occurred to both vessel and pier. Expedient systems using old tires have been more successful in limiting damages.

Section II. Fenders for Barge Units

PURPOSE OF FENDERING

A fender system protects both the vessel and the docking facility from damage caused by contact between the two during docking. Berthing forces are critical because the loading centers on a small part of the facility. However, situations may occur when a ship is retained at a pier under environmental conditions too dangerous to risk berthing. A ship approaching from an angle of 10 degrees may come in contact with as little as 10 to 30 linear feet of the fender. After mooring, the same ship will normally have about one-half its length resting against the fender.

FENDER DESIGN

a. Fender design for marine structures requires working technical knowledge of the--

(1) Size and berthing velocities of ships.

(2) Magnitudes of surge and wave action.

(3) Hull configurations of ships and other vessels using the facility.

(4) Allowable force and deflection of pier or wharf structure.

(5) Soil conditions.

(6) Velocity and direction of winds.

(7) Tidal variation.

(8) Velocity and direction of currents.

(9) Availability and cost of materials. skilled labor, and equipment.

(10) Skill and experience of pilots.

(11) Approach difficulty.

(12) Availability of tugs.

(13) Amount of list that will occur in vessels, especially floating cranes and derricks.

(14) Willingness of operating personnel to maintain mooring lines.

(15) Presence and activity of marine borers and other causes of gradual deterioration.

(16) Facility design and lift.

b. This large number of factors means that a single standard design for all sites is not appropriate.

FORCES FROM WINDS AND CURRENTS

Table 11-2, page 11-12, shows some of the forces from winds and currents acting on ships. This table shows the importance of mooring a ship parallel to strong currents. Wind and current forces are normally static. But when they combine with surge forces, they can impose large roll and surge movements on a vessel. In this situation, a highly resilient fender system may tend to amplify movement of the vessel. Large movements can quickly damage the pier, ship, and fender. Engineers should change the natural frequency of the ship and its mooring system so that it is out of phase with the combined waves and surge. Some remedial steps are:

a. Hold the ship against the pier with a tugboat or constant-tension winch.

b. Relocate or reorient the facility.

c. Install mooring buoys or dolphins outboard of the pier face.

d. Move bow and stern anchors to the outboard sides of the ship during berthing maneuvers.

e. Change to more or less elastic bow, stern, and breasting lines or install elastic snubbers or dampeners in the mooring lines.

f. Add or remove fender units.

g. Place mooring dolphins inboard of the pier face if there is significant pier movement.

RECOMMENDED TECHNIQUES FOR FENDER DESIGN

Fender system designs must conserve energy. The port construction engineer must determine the amount of energy added to the system. Then he must devise a means to absorb the energy within the force and stress limitations of the ship's hull, fender, and pier. One method for devising a fender system to absorb this energy includes--

a. Determining the energy delivered to the pier upon initial impact (Table 11-3, page 11-13). The selection of a design vessel should be based on recommendations from the Military Traffic Management and Terminal Service and the Military Sealift Command.

b. Determining the energy that can be absorbed by the pier or wharf and consider distribution of loading. For structures that are linearly elastic, the energy is one-half of the maximum static-load level times the amount of deflection. Allowance must also be made for other vessels moored at the pier. A rigid structure can absorb no energy.

c. Subtracting the energy that the pier will absorb from the effective impact energy of the ship to determine the energy the fender must absorb.

d. Selecting a fender design that can absorb the energy determined above without exceeding the maximum allowable force on the pier. Consider that the thickness of the fender will affect the lifting capacity of the ship's gear and dock cranes.

Section III. Shore Connections

Self-elevating, spud-barge, pier units are usually erected as finger piers and, to a lesser degree, as marginal wharves. Since each must be in water deep enough to accommodate modern shipping, they require shore correctors. The following equipment may satisfy these requirements:

a. DeLong Barge Wharf or Pier. One or more of the DeLong "B" units (150 by 60 by 10 feet) may connect the "A units (300 by 80 by 13 feet) to shore. This method jacks the connecting units to the same elevation as the wharf or pier (5 to 6 feet above mean high water). They would be less susceptible to weather than most floating connections.

b. Military bridging. Several military floating bridge units, including amphibious river crossing equipment, are described in Chapter 10. Because of its rapid installation (FM 5-210) and large loading capacities, this equipment can provide shore connections for most types of offshore ports.

c. Navy pontoon gear. Shore connections for many offshore wharves or piers may be provided with the P-series Navy pontoon gear outlined in Chapter 11.

d. Other connections. Pile-supported approaches or earth and rock fill causeways may be used when shore conditions, time, equipment, and material permit.

TABLE 11-2. Ship Data for Mooring Operations

Vessel	Length ft	Beam ft	Draft, ft Light	Draft, ft Deep	Loaded Displacement (long tons x 1000)	Area, ft² x 1000: Above Waterline, Bow, Light	Above Waterline, Bow, Deep	Above Waterline, Beam, Light	Above Waterline, Beam, Deep	Below Waterline, Bow, Light	Below Waterline, Bow, Deep	Below Waterline, Beam, Light	Below Waterline, Beam, Deep	Force, kips: 30-Knot Wind, Bow, Light	30-Knot Wind, Bow, Deep	30-Knot Wind, Beam, Light	30-Knot Wind, Beam, Deep	4-Knot Current, Bow, Light	4-Knot Current, Bow, Deep	4-Knot Current, Beam, Light	4-Knot Current, Beam, Deep
Assault Ships																					
LHA	820	106	—	26.0	39.3	5.6	—	—	—	—	2.8	—	21.3	20.2	—	—	—	—	33.8	—	1055
LPD 4	570	84	17.0	22.0	16.9	3.5	3.1	30.0	27.2	1.4	1.9	9.7	12.5	12.7	11.2	108	98.0	12.7	21.7	472	614
LPA 249	564	76	22.0	27.0	18.0	2.9	2.5	22.8	19.9	1.7	2.1	12.4	15.2	10.4	9.0	80	72.0	11.1	23.5	610	751
LKA 113	575	82	15.1	25.5	12.2	3.4	2.5	22.2	16.5	1.3	2.1	8.9	14.6	12.2	9.2	80	59.0	11.5	24.1	435	722
LSD 36	555	84	15.0	19.0	13.7	3.5	3.2	28.1	25.0	1.2	1.6	8.2	10.5	12.7	11.9	100	60.0	10.7	19.0	402	520
LST 1179	518	68	11.5	15.0	8.3	2.3	2.1	26.8	25.0	1.6	1.0	6.0	7.8	8.3	7.5	97	90.0	13.9	12.7	294	386
Roll-on/Roll-off																					
Comet	500	78	25.0	29.0	18.3	3.0	2.7	26.6	24.1	1.1	2.3	7.0	14.5	10.9	9.7	96	87.0	17.3	25.0	615	717
Sealift	540	83	19.5	29.0	21.5	3.5	2.7	25.0	18.5	1.6	2.4	10.6	15.7	12.4	9.6	90	67.0	14.3	26.9	520	776
Admiral Callagham	694	92	19.5	27.0	23.7	4.2	3.5	29.9	24.7	1.8	2.5	13.5	18.7	15.2	12.7	108	88.9	15.9	29.8	665	925
General Cargo																					
C-2	455	63	15.0	27.0	13.9	2.0	1.2	19.5	14.0	1.0	1.7	6.8	12.3	7.1	4.4	70	50.0	8.5	19.0	336	608
C-3	492	70	16.0	29.0	18.2	2.5	1.5	21.4	15.0	1.1	2.0	7.9	14.3	8.8	5.5	77	54.0	10.0	22.6	388	706
C-4	564	72	20.0	33.0	22.1	2.6	1.7	23.3	16.0	1.4	2.4	11.4	18.7	9.3	5.9	84	58.0	12.8	26.7	555	923
Tankers																					
T-2	524	68	14.0	30.0	21.9	2.3	1.2	23.9	15.5	1.0	2.0	7.3	15.7	8.3	4.4	86	56.0	8.5	23.0	359	775
T-5	656	86	16.5	35.0	35.1	3.7	2.1	31.1	19.0	1.4	3.0	10.9	23.0	13.3	7.6	112	68.0	12.6	34.2	535	1136
MSTS	595	84	14.5	32.5	31.3	3.5	2.0	29.2	17.5	1.2	2.7	7.7	19.4	12.7	7.3	105	63.0	10.9	30.7	378	959
AOR 2	659	96	21.0	35.0	32.0	4.6	3.3	34.1	25.0	1.3	3.2	9.0	22.0	16.6	11.8	122	90.0	11.9	36.2	443	1087
Universe Ireland	1135	175	26.0	79.0	375.8	15.3	6.0	92.2	32.0	4.6	14.0	30.0	89.0	55.0	21.8	342	115.0	40.5	150.0	1450	4429
Barge Transports																					
LASH	860	107	20.0	37.0	61.0	5.7	3.9	49.6	35.0	2.1	4.0	17.2	31.8	23.0	14.0	178	126.0	19.0	46.5	850	1572
Seabee	875	106	17.5	32.0	44.7	5.6	3.7	45.0	33.0	1.9	3.4	15.3	28.0	21.2	13.3	162	118.0	17.0	40.9	755	1385
Break-Bulk Freighter																					
VC-2	455	62	15.5	29.0	15.2	1.9	1.1	19.9	14.0	0.9	1.8	7.1	13.0	6.9	4.0	72	50.0	8.5	19.7	346	640
Mariner	563	76	18.0	30.0	21.2	2.9	2.0	22.8	16.0	1.4	2.3	10.2	17.0	10.4	7.1	82	58.0	12.2	25.8	500	835
Gulf Banker	495	69	18.5	30.0	17.2	2.4	1.6	19.1	13.4	1.3	2.1	9.2	14.9	8.6	5.7	69	48.0	11.4	23.1	450	734
Freighter/Container																					
Seamaster	572	82	21.0	30.5	21.4	3.4	2.6	23.9	18.4	1.7	2.5	12.0	17.5	12.1	9.3	86	67.0	14.5	28.6	595	865
Santa Lucia	560	81	20.0	30.0	21.7	3.3	2.5	23.0	17.5	1.6	2.4	11.2	16.8	11.8	8.9	83	63.0	14.5	27.1	553	830
Wolverine Mariner	564	76	21.5	32.0	22.8	2.9	2.1	25.0	17.0	1.6	2.4	12.1	18.0	10.4	7.5	90	61.0	14.4	27.3	595	889
Challenger	560	75	20.0	31.5	21.1	2.8	2.0	24.0	16.5	1.5	2.4	11.2	17.6	10.1	7.0	87	59.0	13.3	26.6	550	870
Container with Crane																					
Pacific Trader	544	70	21.0	32.0	22.9	2.5	1.7	21.0	15.5	1.5	2.2	11.4	17.4	8.8	6.0	76	56.0	13.1	25.8	560	861
American Liberty	700	90	21.0	32.0	32.6	4.1	3.1	29.0	21.5	1.9	2.9	14.7	22.4	14.6	11.0	105	77.0	16.8	34.3	725	1108
Container without Crane																					
Portland	523	72	22.0	31.0	20.2	2.6	2.0	20.5	15.5	1.6	2.2	11.5	16.2	9.3	7.0	74	56.0	14.0	24.9	565	801
Oakland	685	78	19.0	30.0	32.1	3.0	2.2	24.1	16.3	1.5	2.3	13.1	20.6	11.0	7.8	87	59.0	13.2	27.6	640	1112
Jacksonville	524	68	19.5	31.0	22.9	2.3	1.5	22.0	16.0	1.3	2.1	10.2	16.2	8.3	5.5	79	58.0	11.8	24.3	505	871

NOTE: Table data obtained from WES Technical Report H-73-9.

TABLE 11-3. Energy to be Absorbed by Fenders

Vessel	Length ft	Beam ft	Draft, ft Light	Draft, ft Deep	DWT (long tons x 1000)	Velocity, ft/sec, Sheltered	Energy, ft-kips, Sheltered	Velocity, ft/sec, Moderate	Energy, ft-kips, Moderate	Velocity, ft/sec, Exposed	Energy, ft-kips Exposed
Assault Ships											
LHA	820	106	—	26.0	—	0.30	91.7	0.40	163.00	.60	366.70
LPD 4	570	84	17.0	22.0	7.0	0.30	40.3	0.50	111.96	0.70	219.50
LPA 249	564	76	22.0	27.0	6.1	0.30	48.2	0.50	133.86	0.70	262.40
LKA 113	575	82	15.1	25.5	14.0	0.30	31.0	0.55	104.10	0.80	220.30
LSD 36	555	84	15.0	19.0	5.5	0.30	31.1	0.55	110.12	0.70	169.60
LST 1179	518	68	11.5	15.0	3.5	0.35	25.5	0.60	74.88	0.90	168.50
Roll-on/Roll-off											
Comet	500	78	25.0	29.0	6.5	0.30	49.9	0.50	138.73	0.70	271.90
Sealift	540	83	19.5	29.0	12.1	0.30	57.2	0.50	158.80	0.70	311.20
Admiral Callaghan	694	92	19.5	27.0	13.5	0.30	60.5	0.50	168.00	0.70	329.30
General Cargo											
C-2	455	63	15.0	27.0	9.7	0.30	40.4	0.55	135.80	0.80	287.40
C-3	492	70	16.0	29.0	12.7	0.30	52.1	0.50	144.69	0.70	283.60
C-4	564	72	20.0	33.0	14.0	0.30	66.3	0.50	184.16	0.70	361.00
Tankers											
T-2	524	68	14.0	30.0	16.5	0.30	64.5	0.50	179.23	0.70	351.30
T-5	656	86	16.5	35.0	23.6	0.30	99.7	0.45	224.22	0.60	398.60
MSTS	595	84	14.5	32.5	25.5	0.30	86.9	0.45	195.52	0.60	347.60
AOR 2	659	96	21.0	35.0	25.0	0.30	86.6	0.45	194.87	0.60	346.40
Universe Ireland	1135	175	26.0	79.0	326.5	0.20	497.5	0.30	1119.66	0.40	2984.70
Barge Transports											
LASH	860	107	20.0	37.0	44.0	0.30	161.5	0.35	219.83	0.50	443.60
Seabee	875	106	17.5	32.0	27.0	0.30	112.2	0.40	199.48	0.55	374.00
Break-Bulk Freighter											
VC-2	455	62	15.5	29.0	10.6	0.30	46.1	0.50	127.91	0.80	327.40
Mariner	563	76	18.0	30.0	12.9	0.30	59.4	0.50	164.94	0.70	323.30
Gulf Banker	495	69	18.5	30.0	11.0	0.30	50.3	0.50	139.81	0.70	274.00
Freighter/Container											
Seamaster	572	82	21.0	30.5	12.8	0.30	62.5	0.50	173.60	0.70	340.30
Santa Lucia	560	81	20.0	30.0	12.7	0.30	59.1	0.50	164.23	0.70	321.90
Wolverine Mariner	564	76	21.5	32.0	12.7	0.30	65.7	0.50	182.61	0.70	357.90
Challenger	560	75	20.0	31.5	13.5	0.30	60.8	0.50	168.80	0.70	330.80
Container with Crane											
Pacific Trader	544	70	21.0	32.0	12.2	0.30	68.1	0.50	190.59	0.70	373.60
American Liberty	700	90	21.0	32.0	19.0	0.30	87.3	0.45	196.45	0.65	409.87
Container without Crane											
Portland	523	72	22.0	31.0	9.7	0.30	58.6	0.50	162.64	0.70	318.80
Oakland	685	78	19.0	30.0	17.0	0.30	89.9	0.45	200.00	0.65	414.80
Jacksonville	524	68	19.5	31.0	11.6	0.30	68.5	0.50	190.34	0.70	373.10

NOTE: Table data obtained from WES Technical Report H-73-9.

CHAPTER 12
EXPEDIENT CONSTRUCTION

GENERAL

a. Standard port designs allow delivery of cargo. Nonstandard expedient construction port designs must serve as substitutes when engineers lack time or resources to construct or rehabilitate standard ports. The engineer has only his ingenuity. This chapter does not focus on prescribed construction methods. It provides engineers with expedient replacement or repair concepts.

b. The modern container port may need expedient construction repairs. Lack of port expertise and marine construction equipment will complicate this problem. Rehabilitation of damaged ports to their original condition would be impossible. The alternative is to develop repairs which can be completed in the shortest possible time, while minimizing requirements for sealift shipping and worktime. Many of the concepts discussed in this chapter have not been tried or proven in either commercial or military container ports. Most details discussed in this chapter are shown graphically in Appendix A.

EXPEDIENT CONSTRUCTION EQUIPMENT

Expedient construction equipment consists of the following:

a. Launchers or tugboats with shorelines to haul and hoist loads during waterfront construction.

b. Floating cranes made by erecting a derrick or installing a crawler- or truck-mounted crane on a regular barge, LCM, pontoon cubes, or a barge fabricated from military floating bridge units.

c. Rafts for pile-bent bracing may be built on the job, using oil drums, heavy timbers, spare piles, or local material.

d. Floating dry docks for small craft made from Navy pontoons.

e. Light barges, floating wharf approaches, and small floating wharves made from steel oil drums.

EXPEDIENT PIERS OR CAUSEWAYS

Expedient piers or causeways include the following:

a. DeLong piers provide quick and lasting off-load capability.

b. Marathon-LeTourneau barge piers erected quickly (50 feet per hour) reproduce or upgrade existing pier facilities.

c. Bailey bridges and standard military float bridging make expedient causeways or pier supports.

d. Navy P-series pontoons offer excellent light cargo off-load capability.

e. Hulls of capsized or sunken vessels can provide substructures for piers or causeways.

EXPEDIENT REPAIR CONCEPTS FOR PILE FOUNDATIONS

An expedient foundation is a fabricated base, transferring loads from the pile to the ocean floor. This base distributes pile loads over a large area. The bearing capacity of the soil supports the load. A worst-case soil bearing capacity is 2,000 lb/sq.ft. Expedient pile foundations serve where no previous pile existed, or where the existing foundation cannot be used because of damage. The entire foundation can be assembled before lowering it to the ocean floor. This speeds the repair process and cuts diver time underwater.

a. Steel beam foundation.

(1) Concept: Steel wide-flange beams used to form an expedient foundation for pile repair (Figure 12-1).

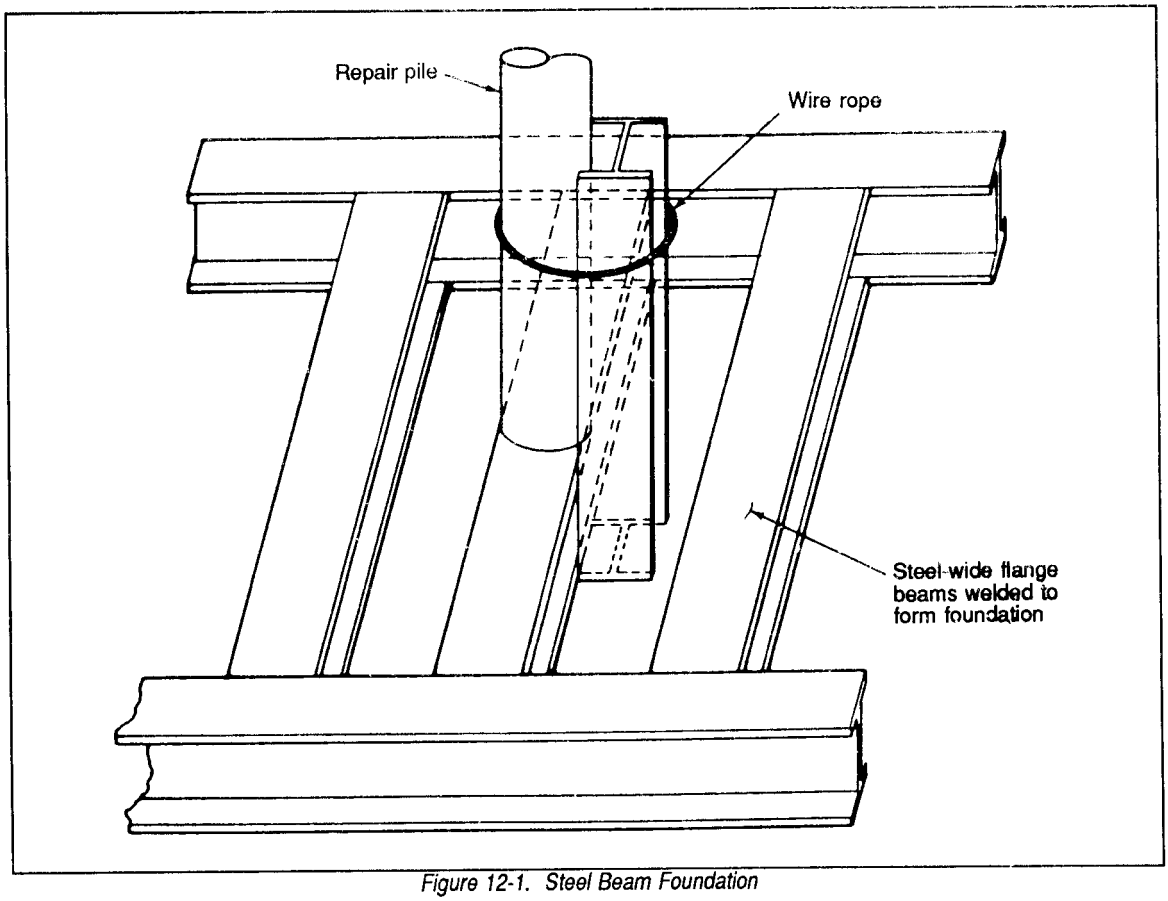


Figure 12-1. Steel Beam Foundation

(2) Description: Pile placement may be required where a site has no pile or where a driven pile is damaged and cannot serve as a foundation. Here, expedient foundations can be built from steel wide-flange beams that distribute the pile loads to the ocean floor. The beams are welded together, and the repair column is placed on top. A worst-case soil bearing value of 2,000 lb/sq.ft. is assumed. This value and the pile loading determine the total area of steel beams required in contact with the ocean floor. Placement of this foundation requires a level area clear of debris. This requirement and the likely settling of the foundation mean one should use this method only if the base of the existing pile cannot serve as a foundation.

b. Concrete foundation.

(1) Concept: 55-gallon steel drums used as concrete forms to build an expedient foundation for pile repair (Figure 12-2).

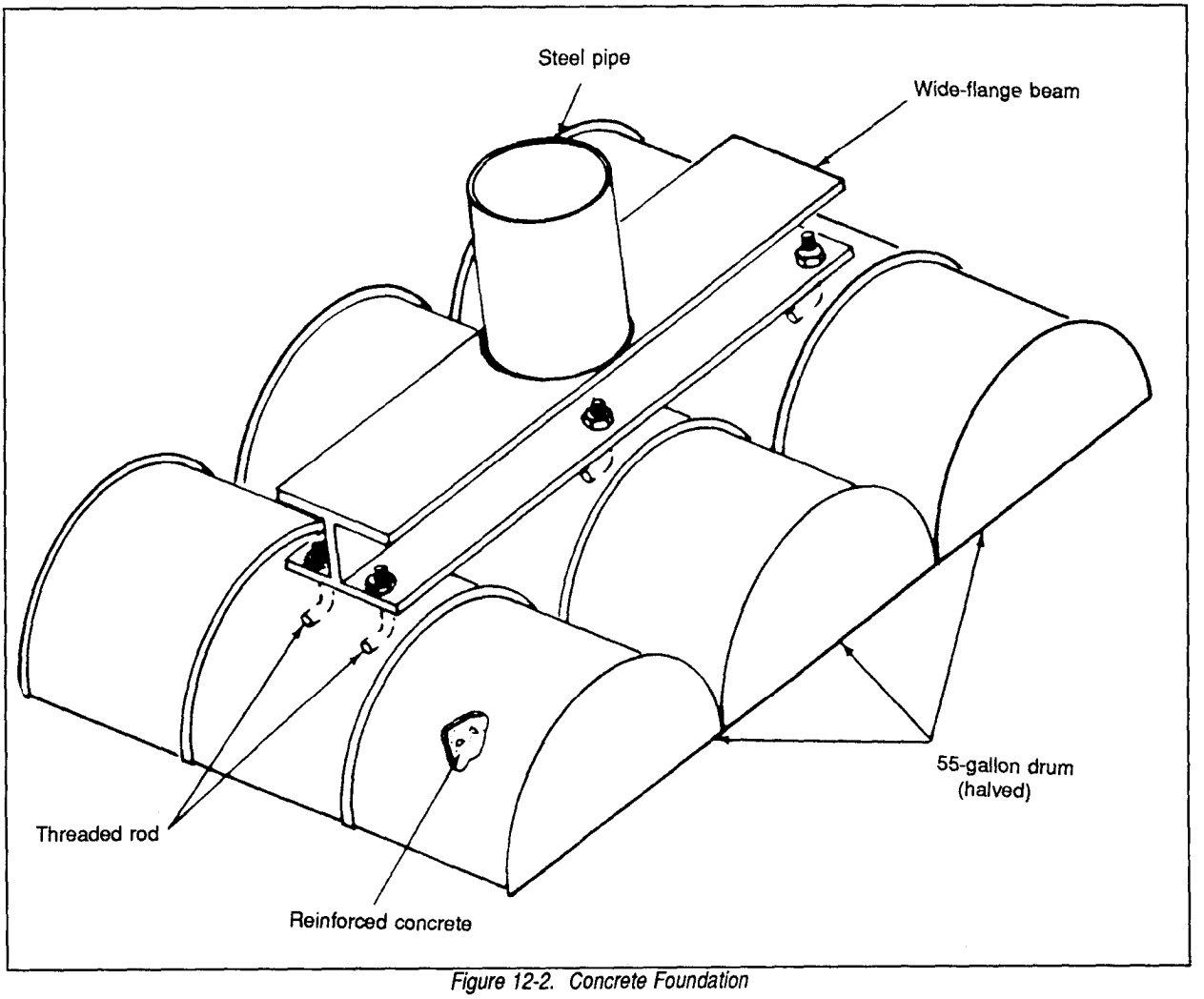


Figure 12-2. Concrete Foundation

(2) Description: This technique is used if the base of the pile being repaired cannot serve as a foundation or when the foundation is new. The 55-gallon steel drums are halved lengthwise and filled with reinforced concrete. A threaded rod is embedded in the concrete of each foundation member to attach the individual forms together. A steel wide-flange beam is attached to the threaded rods. This beam distributes the load, evenly, to each of the individual foundation members.

c. Container-floor or steel-plate foundation.

(1) Concept: A flat steel plate or the floor of an ISO container used as a foundation for a pile repair (Figure 12-3).

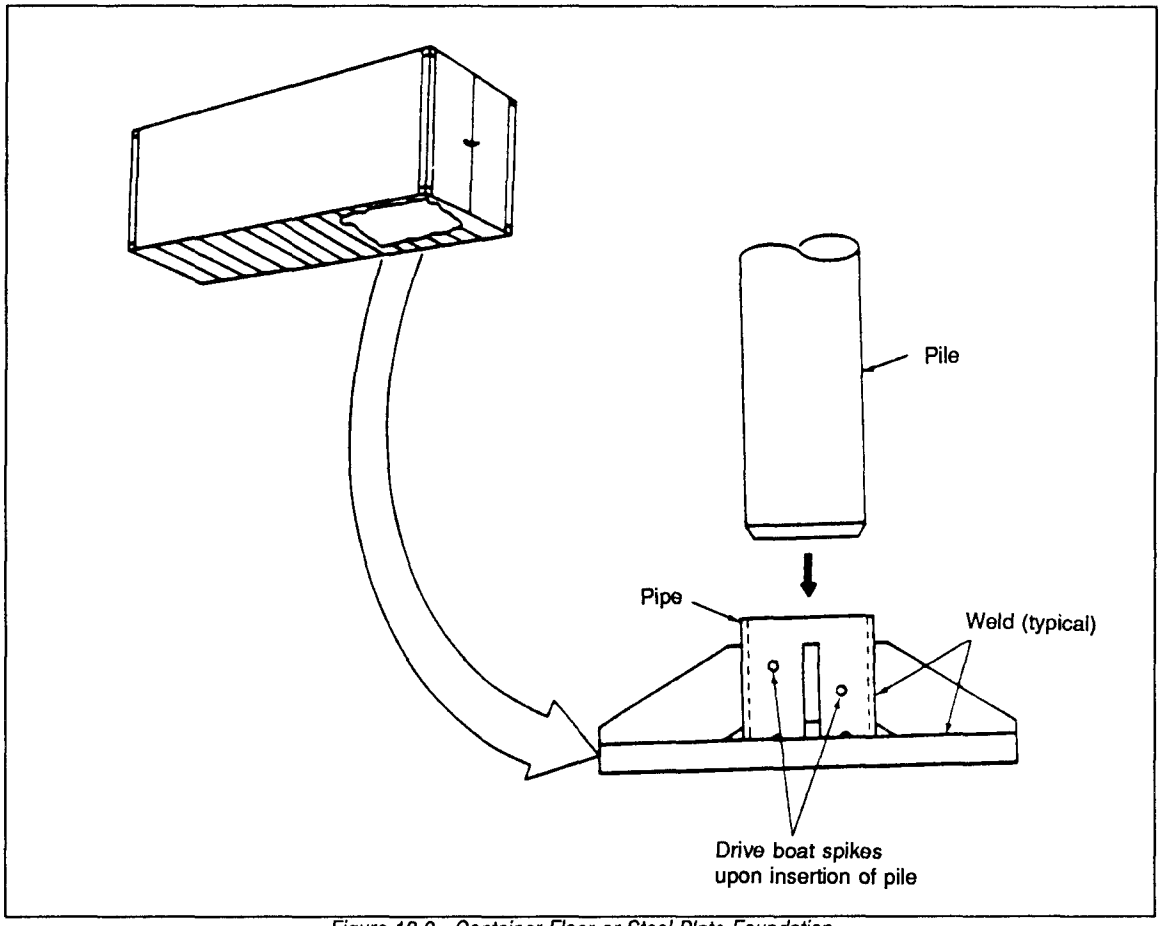


Figure 12-3. Container-Floor or Steel-Plate Foundation

(2) Description: An expedient pile foundation can be made using steel plate or a portion of an ISO container floor. This foundation permits the transfer of the pile loads to the ocean floor. A steel pipe is attached to the center of the foundation. Gussets, to resist bending, run from this pipe to the outer edges of the plate. This foundation requires a large level area at the point of application, and should be used when the base of the pile cannot be used or is not there.

d. Rubble foundation.

(1) Concept: Rubble and high-early-strength concrete used to provide a pier pile foundation (Figure A-1).

(2) Description: An expedient pile foundation can be formed using steel scraps, concrete debris, and large rocks. The sea floor is excavated at the foundation site. The rubble is placed in the resulting cavity, partially falling it. The repair column is placed on top the rubble and braced in position. The hole is then filled with additional rubble, and high-early-strength concrete is pumped into the rubble to consolidate the foundation. This expedient foundation distributes the load from the pile to the ocean floor.

REPAIR CONCEPTS FOR PILE-SUPPORT STRUCTURES

a. The decision on whether to repair or replace is made on a case-by-case basis. Several questions must be answered before deciding to repair or replace:

(1) Is the pile repairable? (For example, is it split lengthwise, has it been extensively damaged by marine borers, is it severely splintered?)

(2) Are repair materials available?

(3) Is the pile stub accessible, and can it be removed with the equipment available?

(4) Is a pile driver operator available to drive the replacement pile?

(5) Will the proposed repair withstand the anticipated load?

(6) Do operational requirements allow the time needed for pile replacement?

b. The following section describes repair concepts that supply strength equal to the original undamaged pilings. Figure A-2 identifies structural elements of a pier or wharf with a damaged pile. Figure A-3 presents several cross-sectional pile shapes and the corresponding area formulas used for calculations. Table 8-1, page 8-10, assumes the maximum load per pile to be the actual loading for each size and type of pile listed. Equating like loads can determine equivalent pile sizes, or diameters for steel, wood, or concrete piles (Figures A-4 and A-5). All pile replacement concepts use this method of equivalency to determine the minimum-sized column required. Using this method, designers do not need to know deck-load capacities to repair the support structure.

(1) Wood columns.

(a) Concept: A single wood column used to replace an existing wood, concrete, or steel pile on a foundation (Figure A-6).

(b) Description: This repair uses, as a foundation, the undamaged portion of the existing disabled pile embedded in the ocean floor. In this way, the frictional resistance developed from driving the original pile can still transfer the vertical loading of the column to the ocean floor. A wood column placed on top of this foundation is used to bridge the distance to the pile cap. Marine borer or mechanical damage can make this portion of the pile useless as a foundation. An expedient foundation can be built using concepts in Chapter 4. The bracing pattern shown in Figure A-6 is typical. It resists lateral loads from mooring, wind, current, and wave forces.

(2) Bundled wood columns.

(a) Concept: A bundle of wood columns to replace an existing wood, concrete, or steel pile on a foundation (Figure A-7).

(b) Description: As examined in the single wood column concept, this repair uses the undamaged portion of the existing disabled pile as a foundation. If material for a single column replacement is not available, several smaller-diameter wood columns may be used. These columns will be bundled together in groups of two, three, or four members. Steel band strapping, spaced every foot of column length, is used to hold the separate members together. The bundled column then bridges the gap between the foundation and the pile cap. Bracing is required. A steel bearing plate is also required to transfer the load from the pile cap to the column, and from the column to the foundation.

(3) Steel columns.

(a) Concept: A steel column used to replace an existing wood, concrete, or steel pipe on a foundation (Figure A-8).

(b) Description: This concept also uses the bearing capacity of the base of the damaged pile. It uses a steel column of sufficient strength to transfer the deck loading to this foundation. The strength of the steel column member depends upon its cross-sectional area and shape. The shape determines the member's ability to resist buckling for a given column length. Bracing is required to resist lateral forces.

(4) Welded steel rail columns.

(a) Concept: A steel rail used to form a column and replace a damaged wood pile, concrete, or steel pile on a foundation (Figure A-9).

(b) Description: Three sections of steel rail can be welded together to form a column. This column has improved strength characteristics resulting from its configuration. The column runs between the pile cap and the undamaged portion of the original pile. The common 115 pounds per yard rail, serves for column lengths of 37.7 feet or less. Bracing is required to resist lateral forces.

(5) Reinforced concrete pile repairs.

(a) Concept: Reinforced concrete is used to repair a damaged section of a wood, concrete, or steel pile (Figure A-10).

(b) Description: This method repairs a damaged pile that is still intact from the sea floor to the pile cap. This method repairs split or broken timber piles, cracked or chipped concrete piles, or mechanically damaged steel piles. Steel reinforcement is placed around the repair area, and a form is placed to contain the concrete. If "Sea Form" fabric forms are not available, culvert pipe, oil drums, or corrugated roofing can make expedient forms. The damaged part of the pile is then encased in concrete for alternate forms (Figure A-11).

(6) Container used as a pile replacement.

(a) Concept: Stacked ISO containers used to replace a pier pile (Figure 12-4).

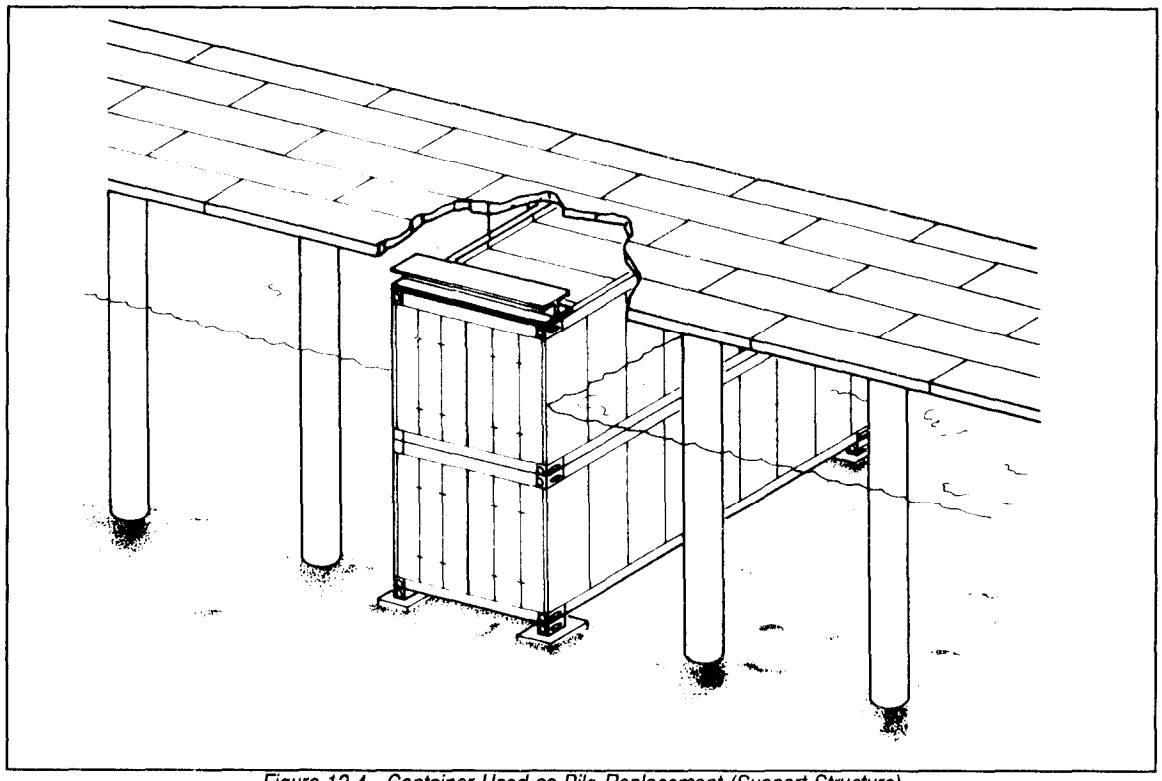


Figure 12-4. Container Used as Pile Replacement (Support Structure)

(b) Description: This repair uses the corners of an ISO container as a column. If the repair requires a column of greater length, up to five containers can be stacked. Only the corners of these containers can support a substantial load. A beam is used to span the distance from corner to corner.

c. The corners must be placed on individual foundations to minimize the are of ocean floor to be cleared of debris. These foundations must have a total area equal to the minimum foundation area, as required in Chapter 4. The containers must be made level for proper load distribution by shimming the foundation footings. Lightening holes in the sides, tops, and bottoms of the containers lessen the effect of water forces (current or wave) acting on these surfaces.

TRUSSES

a. Timber truss.

(1) Concept: A timber truss used to replace a damaged pile using two neighboring undamaged piles (Figure A-12).

(2) Description: The truss members run from the pile cap to adjoining undamaged piles. The truss repair is actually two trusses, which are attached on both sides of the adjoining piles to transfer the load. These neighbor piles support a greater load. The rating of the affected area of the pier must be lowered to two-thirds of its initial load capacity. The truss members are sized to meet tension and compression forces, and to resist buckling. This method can replace timber or steel pipe piles. Figure A-13 shows the connection of a truss to the pile cap, and Figure A-14 shows the connection of the truss to the pile.

b. Steel truss.

(1) Concept: A steel truss used to replace a damaged pile using two neighboring undamaged piles (Figure A-15).

(2) Description: Same as for a timber truss connection to the pile (Figure A-16) and a connection to the pile cap (Figure A-17).

BRACING AND CONNECTING METHODS

Bracing in the repair area resists lateral loads from mooring, wind, current, and wave forces (Figures A-18 through A-21). Transverse bracing is typically 4 by 8- or 4 by 10-inch timbers. Bracing is applied diagonally and attached to each pile with a single 3/4-inch bolt. Transverse bracing has a vertical spread from the low water line to the lower edge of the cap.

Figures A-22 through A-28 show suggested connecting methods. The final connection depends on the logistics of the particular repair and on the replacement pile and connecting material available. Figures A-22 to A-25 show connecting methods which serve as column to base or cap connections, and Figures A-26 through A-28 present ideas for column to base connections.

a. Bracing Method 1.

(1) Requirements:

(a) Connection area must be free of loose debris.

(b) One bolt is used per connection.

(c) Galvanized steel fasteners are preferred, but threaded rods may be used.

(2) Procedure:

(a) If using a timber pile, drill through the diameter of the pile.

(b) If using a steel pipe pile, drill or torch a hole through the diameter of the pile.

(c) Attach the brace to the pile with a bolt, nut, and washers.

b. Bracing Method 2.

(1) Requirements:

(a) Connection area must be free of loose debris.

(b) One bolt is used per connection.

(c) Galvanized steel fasteners are preferred, but threaded rods may be used.

(2) Procedure:

(a) Drill or torch a hole through the beam flange.

(b) Attach the brace to the pile with a bolt, nut, and washers.

c. Bracing Method 3.

(1) Requirements:

(a) Connection area must be free of loose debris.

(b) One brace bracket is used per connection.

(c) Galvanized steel fasteners are preferred, but threaded rods may be used.

(2) Procedure:

(a) Drill two holes in each steel flatbar, 1 1/4 inch from each end.

(b) Attach the brace to the pile using the brace bracket, bolts, nuts, and washers.

d. Bracing Method 4.

(1) Requirements:

(a) Connection area must be free of loose debris.

(b) One concrete anchor is used per connection.

(c) Bracing Method 3 is the preferred method of connecting a brace to concrete.

(2) Procedure:

(a) Drill a hole in the concrete pile.

(b) Attach the brace to the pile with the concrete anchor using a flat washer.

e. Connecting Method 1.

(1) Requirements:

(a) The diameters of both spliced connections must be the same.

(b) Bolts must fit snugly along the sides of the column and base.

(c) If either the column or base is a steel pipe, a 1/4-inch steel plate must be placed between the column and base or cap.

(d) Galvanized steel fasteners are preferred, but threaded rods may be used.

(2) Procedure:

(a) Drill holes in the steel plates to allow bolts along both sides of the base and the repair column.

(b) Place the repair column directly between the base and cap.

(c) Loosely connect the two plates by installing four bolts along only one side.

(d) Slip the plates over the area to be spliced, and insert the four remaining bolts through the plates.

(e) Tighten the bolts evenly and torque the nuts to 100 foot/pounds to complete the splice.

f. Connecting Method 2.

(1) Requirements:

(a) The diameters of both spliced connections must be the same.

(b) Steel channel or I-beam sections may be used as splicing members.

(c) If either the column or base is a steel pipe, a 1/4-inch steel plate must be placed between the column and base or cap.

(d) Galvanized steel fasteners are preferred, but threaded rods may be used.

(2) Procedure:

(a) Drill holes in the splice members and column through the center to accommodate the two 3/4-inch bolts. First, drill two holes through the column at least 6 inches horn the column end and 6 inches apart then drill two holes in the splice members to match the column holes.

(b) Loosely bolt the splice members to the column.

(c) Position the column directly between the base and cap, with the splice members loosely over each side of the base and cap.

(d) Torque nuts to 100 foot/pounds to align the column, base, and cap and to complete the splice.

g. Connecting Method 3.

(1) Requirements:

(a) The diameters of both spliced connections must be the same.

(b) If either the column or base is a steel pipe, a 1/4-inch steel plate must be placed between the column and base or cap.

(c) Galvanized steel fasteners are preferred, but threaded rods may be used.

(2) Procedure:

(a) Drill clearance holes through the center of each 3/8- by 2-inch steel flatbar to accommodate the 3/4-inch bolts.

(b) Drill two holes through the column at least 3 inches from the column end and 3 inches apart.

(c) Place the 3/4-inch bolts loosely through the steel flatbar, the column, and the flatbar on the other side of the column.

(d) Install the steel angle sections lengthwise along the column between the flatbar and the column. Tighten the bolts to hold the angles in place.

(e) Weld flatbars to angles.

(f) Loosen bolts.

(g) Place the column directly between the base and cap, with the splicing members loosely over each side of the base foundation.

(h) Torque nuts to 100 foot/pounds to align column, base, and cap and to complete the splice.

h. Connecting Method 4.

(1) Requirements:

(a) Welded angles must fit snugly along the sides of the base foundation or pile cap.

(2) Procedure:

(a) Drill clearance holes for two 3/4-inch diameter bolts through the shorter leg of one of the steel angles (#l), 3 inches from each end.

(b) Lay the steel angle #1, holes down, on the steel plate, aligning the edges of the angle with the edge of the plate. Mark the location of the two bolt clearance holes.

(c) Drill the two bolt clearance holes in the steel plate.

(d) Drill and counter-bore holes in the steel plate for the drift pins.

(e) Weld steel angle #l, without holes, to the steel plate.

(f) Weld the second steel angle (#2) to the steel plate.

(g) Center the plate on the end of the repair column and the drive drift pins through the plate into the column.

(h) Position the repair column directly between the base pile and cap.

(i) Bolt the remaining steel angle (#l) to the bottom of the steel plate to complete the splice.

i. Connecting Method 5.

(1) Requirements:

(a) Must be able to closely align the repair column to the base foundation to match bolt holes and install bolts.

(b) Preferably all fasteners are galvanized steel.

(2) Procedure:

(a) Drill four 1-inch diameter holes in the corners of the top steel plate, 1 1/2 inches in and 1 1/2 inches down from each corner.

(b) Drill four 1-inch diameter holes in the corners of the bottom steel plate to match the holes in the top plate.

(c) Center and weld the steel pipe sleeve to the bottom plate.

(d) Center and weld the steel pipe column to the top plate.

(e) Center the bottom plate over the base pile.

(f) Place the column directly between the base and cap, align bolt holes, and install the four 3/4-inch bolts and nuts.

(g) Torque the nuts to 100 ft-lb to complete the splice.

i. Connecting Method 6.

(1) Requirements:

(a) Make splice below the ocean floor.

(b) If either the column or base is a steel pipe or the repair column diameter is greater than the base pile diameter, a 1/4-inch steel plate must be placed between the column and base.

(2) Procedure:

(a) Place the repair column through the culvert pipe.

(b) Place and hold the repair column directly over the base pile.

(c) Lower the culvert pipe over the splice area and bury the bottom 2 inches into the ocean floor.

(d) Hold the repair column in place by inserting four metal wedges between the culvert pipe and the column.

(e) Pump concrete into the space between the culvert pipe and the pile to complete the splice.

k. Connecting Method 7.

(1) Requirements:

(a) Make splice below the ocean floor.

(b) If either the column or base is a steel pipe or the repair column diameter is greater than the base pile diameter, a 1/4-inch steel plate must be placed between the column and base.

(2) Procedure:

(a) Position the repair column directly above the base foundation and hold it in position.

(b) Concentrically locate the sheet metal form around the repair column and base, and bury the bottom two inches into the ocean floor.

(c) Place band clamps around the sheet metal form.

(d) Hold the repair column in place by inserting four metal wedges between the metal form and the column.

(e) Pump concrete into the space between form and piles to complete the splice.

EXPEDIENT REPAIR CONCEPTS FOR PIER AND WHARF DECKING

a. Steel Plate Concept. Steel plates can quickly cover the damaged area of a pier. A 2-inch steel plate with a yield strength of 60 kips per square inch can bridge a gap of 8 feet for a Caterpillar (Cat) 988 Forklift with a fully loaded container. An 8-foot wide plate can resist the load. No edge support is provided in repairing a rectangular gap (see Figure A-29). If the crater is round and 8 feet in diameter, the plate requires some side support and only one wheel could be in the center of the hole. The other must be on the undamaged surface of the pier. It might be possible to support one wheel of a fully loaded Cat 988 in the middle of an 8.4-foot crater with a 1-inch, 60-kips per square inch (ksi) steel plate. The raised edge of the plate will not cause operational problems for container handling vehicles.

(1) An 8-foot width of plate may resist the load of a container-handling vehicle. Sometimes the loads will be carried by two separate plates (see Figure A-29) with lower material stresses. Loads may also be carried by the edge of the plates, but with higher material stresses. The 8-foot effective width is used for preliminary sizing during the design phase.

(2) Plate repairs are attractive because of their simplicity and easy installation. Ten 1,000-pound steel plates can be selected from a stack, loaded onto a truck, unloaded, and placed in 1.5 hours. An 8-foot by 10-foot, 2-inch steel plate weighing 6,400 pounds could be used to repair the 8.4-foot diameter craters specified in the original scenario. At least six such repairs could be made in a 9-hour day. Instead of cranes, a large vehicle could drag the plate to the installation site since friction is slight between steel and concrete. The plate may be secured against sliding at the repair site by anchoring it to the undamaged deck with anchor bolts. Attaching rods to the plate and allowing them to protrude down through the open area in the deck and bear against the edges of the crater will also prevent slippage. Holes in the plates should be provided on 12-inch centers for bolts, attachments, and handling aids.

(3) Steel plates will deflect before ultimate failure. Personnel observing the deflection are warned of impending overload. Small overloads will cause permanent distortion of the plate, but not complete collapse. Plates, bent by handling or overload, may be placed so that it arches up. They may, however, fail in fatigue after being bent several times. Two-inch thick, 60-ksi plates offer sufficient moment resistance to be useful. Little field modification is required to install plates, fabricating high-strength plates is not a problem. Two-inch thick, 60-ksi plates span gaps up to 8 feet for heavy container handling equipment, up to 18 feet for the 1,000 lb/ft^2 loading, and up to 23 feet for the HS 20-44 loading. Maximum deflections will be approximately 2, 10, and 13 inches respectively.

(4) Two-inch thick, 60-ksi plates are not available as a standard product. However, high-carbon proprietary steels are available in the 50- to 80-ksi range. ASTM A514 Quenched and Tempered 100-ksi steel is available as a standard product. The A514 can be welded with some difficulty and has reasonable toughness and ductility. An 8-foot effective width of plate which is 2-inch, 100-ksi steel plate will span a gap of 13 feet with a Cat 988 or 250-ton truck crane, 23 feet for a 1,000 lb/ft^2 load and in excess of 30 feet for the HS 20-44 load. Maximum deflections are 10, 27, and more than 30 inches respectively. A gap spanned by 100-ksi, 2-inch steel plate will be limited by deflection criteria rather than bending failure. If one steel plate does not offer sufficient resistance, another one may be stacked on top, doubling the resistance.

b. Erector-Set Concept. A larger moment-carrying capacity may be created by separating the tension and compression areas of a flexural member. Repair modules may be made with wide flange steel beams which are sandwiched by 1-inch steel plate (Figures A-30 and A-31). The assembly may be bolted together to develop the composite strength of the whole module (Figure A-32). The following parts are required:

(1) Top and bottom plates 8 by 40 feet, 1-inch thick with holes drilled on 4-inch centers for 1-inch bolts over the entire area. These will act as tension and compression flanges.

(2) Wide-flanged, rolled sections with corresponding holes in the flanges. These will provide shear resistance between the tension and compression flanges.

(3) Some type of transverse stiffening member is necessary to ensure that the entire section width acts together.

(4) One-inch diameter bolts.

(5) Special clips or cages which will hold the nuts in place while the bolts are being turned. The nuts may be inaccessible during certain stages of construction.

(6) Twenty 4-inch wide by 1/2-inch thick plates with a bolt hole pattern to match the other components. These will be used to splice the 1-inch plates.

(7) End ramps for nonflush repairs. These may be made from materials salvaged in the TO.

(8) Angle iron with matching hole patterns to create boxes.

(9) A shim package for matching the repair components to the existing structures. All components will be packed into containers or assembled into racks compatible with the containers.

(10) The repair components can be configured in several different ways:

(a) The modules may be laid on top the deck over the damaged area and ramps provided to accommodate vehicles (Figure A-33, Type A).

(b) The deck may be sawcut to accept the modules so their tops will be flush with the deck. The modules will be supported by bearings attached to the bottom of the deck or to the pile caps (Figure A-33, Type B).

(c) Steel beams may be attached to the plate so they protrude only through the damaged area. The repair will be supported where the plate overlaps the undamaged portion of the deck (Figures A-34 and A-35).

(d) A combination of steel beams and plates may be assembled to create an expedient pile cap. A steel beam will be clamped on either side of the undamaged portion of the pier cap. If extra strength is needed, a plate will be bolted on the top and bottom of the two beams. A shim package is necessary to provide proper spacing so the holes in the plates and the beams line up (Figures A-36 and A-37).

(e) Any of the previously mentioned repairs could be supported by piling. An appropriate attachment could be made to the bottom of the module to distribute the load.

(f) Placement of beam and plate elements could be optimized, so the repair provides the correct amount of moment, shear resistance, and transverse stiffness where it is needed most (Figure A-38).

(g) The steel beams could be used as piling, if necessary.

(h) Heavy angle plates assembled to form rubble boxes for gravity retaining walls could be used for expedient quay wall repair (Figure A-39).

(11) The advantages of the "erector set" concept involve versatility. The components may be assembled in any configuration with adjustments made for unforeseen circumstances. Engineer units will also find other uses for the components.

(12) The disadvantages to the "erector set" concept involve assembly problems. Bolting consumes most of the assembly time. Misalignment of bolt holes is an inevitable problem. However, steel erection crews have a variety of techniques and tools available to remedy misalignment problems. The use of a different fastening system, possibly copied from another expedient military device, might speed the assembly.

c. Steel Beam Mat Concept. A continuous mat of steel beams laid side by side may also be used as a bridge. The weight of a container-handling vehicle is shared by at least four beams because the wheels are wide enough to bear on at least two beams each (Figure A-40). The flanges of the beams will be about 1 foot wide. Scheduled time and workhours are one-third the "erector set" full rectangular repair module concept because the beams must only be bolted together enough to prevent lateral instability and shifting. One bolt per square foot is used to estimate manhours and schedule time. This concept is not as flexible as the "erector set" concept for forming alternative repair configurations.

d. Steel Beam and Timber Deck Concept. Timber or laminated wood could be used to provide a deck for an expedient repair. Wood may be the material of choice because of its availability within the TO. Army construction troops find this concept compatible with the construction methods and materials which they know best. This repair is constructed as follows:

(1) Remove unsound concrete and rebar from the edge of the crater.

(2) Drill bolt holes for the beam hangers through the deck with a pneumatic jackhammer or diamond coredrill.

(3) Position beams under the slab. This could be done with some difficulty by passing them through the opening with a crane. An alternative is to float them into position.

(4) Install bolts and bearing plates to secure the beams.

(5) Cut the timbers to fit snugly into the damaged areas.

(6) Install "J" bolts to secure the timbers to the beams. "J" bolts are routinely used by railroads to secure timber ties to steel stringers.

(7) Cover the repair with layers of plywood to protect the protruding bolts from damage. The result is a flush repair that will not hinder container handling.

(8) Disadvantages are that the edges of the crater must be cleaned, underslinging the beams is difficult, and no preassembly is possible. Several different operations and several different components are required to make the repair. The repair must be custom-built, which requires more supervision.

(9) Another alternative was developed to answer objections to the previous alternative. Panels may be prefabricated and transported to the repair area and laid on top of the deck over the repair area with access ramps provided. If time permits, a flush repair may be provided by attaching bearing assemblies to pile caps or to the bottom of the deck. These panels may be preassembled and stockpiled before they are needed. Preassembly may occur in back areas while clean up and cutting proceed on the wharf.

e. Steel Beam and Steel Bar Grate Concept. Steel bar grate is occasionally used as a deck material on draw bridges. It could replace timber decks for expedient repair purposes. An equivalent repair made with bar grate instead of timber will handle the same or more shipping tonnage and less shipping cubage. Bar grate has only one-way structural resistance, and composite action cannot develop between the bar grate and supporting beams. Bar grates can carry container-handling vehicles over 2- to 6-foot spaces between supporting beams.

f. Prestressed Concrete Girder Concept. Prestressed concrete slabs and box beams are most useful when custom-made for a specific wharf and stored nearby. After a prestressed girder has been cast, it is impossible to trim it in the field. The beams must be handled carefully. They will crack if they are not set and lifted properly. If a precasting plant is available near the port, prestressed beams could be cast and cured in seven days. If high-strength concrete is used, the beams cure to the required strength sooner. Given favorable circumstances, beams may be ready for use 24 hours after casting.

g. Railroad Flatcars Concept. Railroad flatcars are designed to carry trucks used in intermodel (piggyback) service. A typical piggyback, 9-foot wide flatcar is 90 feet long and spans 66 feet between truck centers. The cars should be taken off their trucks and mounted on bearing assemblies that simulate truck centers. The cars would rest on the undamaged portion of the deck. End ramps would be necessary. Container-handling vehicles might also be accommodated if two railroad cars are laid side by side, and the vehicle is driven with one wheel on each railroad car.

h. Sheet Pile Concept. Sheet piling may be driven to form a sheet the shape of the crater in the deck. This cell could be filled with suitable rubble to the level of the finished deck. Time to construct such a cell could, however, be excessive.

EXPEDIENT MARINE RAILWAY CONSTRUCTION

Marine railways consist of inclined groundways extending into the water, cradles moving on ground-way tracks, wheels attached to the cradles, roller trains not attached to the cradle or the track, hoisting machinery, and chains or cable for hauling the cradles into and out of the water. The railways are used to haul ships out of the water for repairs. In the TO, large commercial marine railways require excessive time and skilled personnel support. They are expensive and unsuitable for expedient military construction. An example of an expedient military marine railway for small craft is a string of Navy pontoons equal in length to the railway required. Rails are bolted to the pontoons which are, in turn, towed to a foundation and sunk in place.

MARINE LIFTS

Another substitute for commercial marine railways, in addition to Navy pontoons, is the marine lift. Building a marine lift, also called a vertical lift or elevating platform, does not involve the extensive or expensive underwater work involved in building marine railways. The lift has a movable platform supported in a slip between rows of piles or columns. The hoisting gear, resting on these supports, raises or lowers the cradle or platform. In operation, the vessel is floated into position over the platform and lifted vertically to the desired elevation, where it is repaired in place. A separate cradle on wheels can be rolled to another position. Some marine lifts can transfer vessels from their lifts to desired repair locations using a wheeled carriage and rail-transfer system. The transfer may be both longitudinal and sideways. This permits quick movement of vessels to specialized repair areas.

CHAPTER 1
MISSIONS AND RESPONSIBILITIES

Section I. General

FM 100-10 RESPONSIBILITIES

Building and operating a TO port is a large and vital undertaking with many divisions of responsibility between Navy and Army forces. Engineers at the theater headquarters and the Theater Armv Support Command (TASCOM) make basic decisions concerning ports including location, capacity wharfage, and storage facilities. General responsibilities; of the theater commander, theater Army commander, and TASCOM commander are stated in Field Manual (FM) 100-10.

TASCOM ASSISTANT CHIEF OF STAFF, MOVEMENTS

The TASCOM Assistant Chief of Staff, Movements (ACS,M) is responsible for port operations and liaison with the Navy, Coast Guard, and other military and authorized civilian agencies, from both the U.S. and allied countries. Army engineer responsibilities include minor salvage operations, such as clearing obstructions and debris from harbor entrances, and channel improvement. However, the Navy is responsible for large-scale salvaging operations. The ACS,M requests, advises, and makes recommendations concerning engineer operations.

Theater, theater Army, and TASCOM functions for construction of a specific port include--

a. Study of intelligence reports and all available reconnaissance applicable to each port area.

b. Tentative choice of ports or coastal areas to use as part of the overall strategic planning.

c. Assignment of the port mission.

d. Determination of port requirements.

e. Tentative choice of the construction, engineer units, special equipment, and material required.

ENGINEER RESPONSIBILITIES

Engineer units are responsible for port construction and rehabilitation. They coordinate all work with naval units engaged in harbor work such as clearance and salvage or neutralization of mines or underwater obstacles in the harbor. Engineer units coordinate with transportation units to assist in establishing construction requirements, plan construction, and recommend priorities.

TRANSPORTATION RESPONSIBILITIES

Transportation units operate the port facilities and coordinate construction needs with engineer units. They also assist in planning construction and recommending priorities.

Section II. Waterfront Utilities

WATER

a. Responsibilities.

(1) Quartermaster units are responsible for supplying potable water in the TO.

(2) Engineer units are responsible for construction and maintenance of water distribution facilities in the TO. Engineers are also responsible for water reconnaissance, well drilling, and water point improvement.

b. Methods. Even though newer ships can provide fresh water from sea water, not all ships making port calls in the TO can provide this service. Engineers must supply potable and nonpotable fresh water for these ships. Methods include--

(1) Fresh-water jetties similar to fueling jetties, with dolphins for mooring.

(2) Barges to supply ships moored offshore.

(3) Water supply at wharves. Operation orders normally specify that fresh water be piped and stored at the first deep-water berth.

c. Quantities. Daily requirements may go as high as 200,000 gallons. The logistics office determines potable and nonpotable water requirements for ports, including fire protection.

ELECTRICITY

a. Responsibilities. Engineer units are responsible for the construction, operation, and maintenance of electrical power distribution systems.

b. Sources. The source of electrical power is part of the integrated base design. Local electrical distribution systems and power generation stations are rehabilitated and used where possible. This may require electrical conversion equipment. Where no systems are available, military generators and/or Army Facilities Components System (AFCS) designs will be used. Assistance is available from the Office of the Chief of Engineers (OCE) Power Detachments.

c. Uses.

(1) Wharves or piers. Normally, only lighting is required. Wiring is in conduit. Overhead poles and lines are kept to a minimum. The DeLong pier has its own power generation capability.

(2) Area lighting.

(3) Street/road lighting.

(4) Security/perimeter lighting.

(5) Billets, administration, maintenance, and mess facilities.

FIRE PROTECTION

a. When engineers rehabilitate or construct ports, they ensure that there is adequate fire-fighting and fire-protection equipment. Engineers require water mains, hydrants, and standpipes/hoses supplemented by water sumps, buckets, and various types of hand extinguishers.

b. Fire-fighting units. Five fire-fighting teams are authorized:

(1) Team FA, fire-fighting headquarters.

(2) Team FB, fire trucks.

(3) Team FC, water trucks.

(4) Team FD, brush fire trucks.

(5) Team FE, aviation fire crash/rescue.

c. These teams, or their components, will provide port fire protection.

BULK PETROLEUM

a. Engineer units are responsible for the design, construction, rehabilitation, and major maintenance of bulk petroleum facilities from the high water point/mark downstream.

b. Quartermaster units are responsible for the operation and routine maintenance of bulk petroleum facilities.

Section III. Logistics-Over-the-Shore (LOTS) Operations

GENERAL

The Army needs LOTS to support cargo delivery to the TO. Army engineer units support LOTS missions because ports may be unavailable for long periods of time due to such causes as damage from combat, vulnerability to enemy combat action, or extended repair/construction. LOTS terminals handle at least 40 percent of all cargo entering contingency theaters by surface means. Rapid establishment of viable LOTS terminals depends on engineer units for construction and maintenance.

RESPONSIBILITIES

a. Transportation units have overall responsibility for LOTS. Each LOTS terminal is under the direct control of a transportation/terminal battalion which is made up of two service companies and appropriate support units.

b. Engineer units give construction, repair, and maintenance support to LOTS. An engineer unit may expect to encounter the following missions in supporting LOTS:

(1) Constructing semipermanent piers and causeways.

(2) Clearing beach obstacles.

(3) Preparing and stabilizing beaches.

(4) Constructing access and exit routes from beaches.

(5) Providing access to marshaling areas and adjoining LOTS sites.

(6) Constructing marshaling and storage areas.

(7) Constructing road and rail links to existing LOCs.

(8) Constructing utility systems.

(9) Constructing POL storage and distribution systems.

(10) Providing other assistance or maintenance support assigned by the terminal commander.

CHAPTER 2
HARBOR STUDIES AND SURVEYS

IMPORTANCE OF HISTORICAL INFORMATION

Until recently, scientific design criteria for shore protection developed slowly. Long trial and error expedience led to structures best suited to local conditions. Engineers had to experiment to find a suitable protected site long enough for an inner harbor without the rapid shoaling of channel approaches. The history of early structures and construction methods is practical background for new construction.

ENGINEERING DESIGN

Wherever possible, standard designs can save time in design, construction, and maintenance. Standard designs and bills of material allow advance procurement of materials and equipment. Using them requires a knowledge of the site and the existing foundation. Reconnaissance, construction surveys, soil bearing tests, driving of test piles, and sieve analyses of local sands and gravels precede final design. Engineers design nonstandard expedient structures only when they cannot use standard designs.

RESPONSIBILITY FOR HYDROGRAPHIC SURVEYS

The mapping organization in the TO follows policies set by the G2. The theater engineer coordinates the work of the topographic units in carrying out policy. The theater engineer also coordinates the work of all topographic units of subordinate commands. The unit engineer plans and executes work needed by a particular unit that is not included in the theater mapping program. The engineer includes special maps and map overlays. His topographic units make astrofixes for map control and to tie into the existing triangulation system. Construction units establish azimuth and some vertical control for assigned construction jobs.

HYDROGRAPHIC SURVEY METHODS

Technical Manual (TM) 5-235 describes military equipment and methods of taking and locating soundings. Specific information includes--

a. Factors considered in hydrographic surveys. To locate a wharf site, the engineer must determine the submerged relief at the proposed site.

(1) Water depth. Water depth is critical to the operation of ships and craft. Engineers must obtain bathymetric measurements in the port area and seaward approaches to the facilities. The normal draft for a container ship is approximately 40 feet.

(2) Bottom character. Engineers must study the character of the bottom. They must locate and remove or mark foreign and random objects, including boulders, oil drums, and ship wreckage.

(3) Tidal characteristics. Tidal parameters that require determination are heights, range intervals, times, and behavior of tidal currents on a daily and seasonal basis and during storms. Daily tidal ranges exceed 20 feet.

(4) Discharge volumes and river flow velocity. These factors affect traffic regulation, structure location and orientation, sediment transport and deposition, and dredging.

(5) Extent, duration, and causes of inland flooding. Harbor routine may vary during flood seasons. Sediment introduced in harbor areas may create navigation problems. Historical data helps accurate forecasting.

(6) Tidal and river currents. Current direction and velocity affect navigation. There are longshore currents, wind currents, river currents, and permanent great currents. Several currents may act together.

(7) Shoreline data. Shore tidal conditions must be established for daily, seasonal, and extreme tide stages.

(8) Location of landmarks as navigational aids. Hydrographic and topographic maps and aerial photography simplify locating landmarks. Field checks ensure acceptable visibility.

(9) Location of current and abandoned structures in the water and along shore margins.

(10) Sub-bottom characteristics. These include sediments, layering, bearing capacities, and consolidation.

b. Types of surveys. To obtain the required information, engineers make the following separte surveys:

(1) Construction planning survey. Establishes basic facts of shoreline, water depth, bottom character, and existing structures.

(2) Special detail survey. Serves specific projects of construction or rehabilitation.

(3) Survey of operating harbors. Obtains data on channel characteristics, aids and hazards to navigation, wharf location, and harbor structures.

c. Methods of hydrographic survey.

(1) Contemporary. Methods depend on type of data required, equipment of the team making the survey, area to cover, and character of the body of water being surveyed.

(2) Sounding methods. Engineers make and plot soundings to ensure proposed wharf locations have adequate depth. TM 5-235 describes current Tables of Organization and Equipment (TOE) equipment for sounding operations. It includes automatic depth recorders, sounding poles (to 2 fathoms), leadlines (more than 2 fathoms), sweeps and drags, special survey vessels, buoy markers, signals (tripods, pylons) set up ashore, sextants, and others. Recording tide heights is a standard process, but soundings make recording easier. Depths measured and recorded below the water level are corrected on charts of the location.

METHODS OF SWEEPING TO LOCATE OBSTRUCTIONS

a. Sweeping locates pinnacles or other navigation obstacles above the draft limits required for the largest ships to use the area. Sweeping is always used as a final check after dredging. Sweeping is discussed in TM 5-235.

b. Methods of sweeping.

(1) Leadlines. Leadlines indicate the depth in waterways with regular bottoms. They cannot reliably show minimum depth over rock pinnacles, sunken wrecks, or other dangers.

(2) Wire drag. The wire drag is a horizontal bottom-wire. It is supported by adjustable upright cables suspended from surface buoys. The upright cables can be adjusted to sweep at a given depth. They make adjustments for the rise and fall of the tide. They hang nearly vertical with weights at their lower end. The drag wire is kept from sagging by several intermediate wooden floats attached to the wire. The drag wire, which may be 5 miles long, is towed by two launches. A buoy is placed over each obstruction located, then the drag is cleared. A small sounding boat makes careful soundings in the buoyed area to find the minimum depth over the obstruction.

(3) Wire sweep. The wire sweep is a modification of the wire drag. Buoys are placed farther apart. The wire sweep cannot vary the depth of the wire while dragging. It cannot prevent sag of the wire between buoys. It can be put in operation quicker than the drag. It is used in areas with few obstructions and with water deeper than required for navigation.

(4) Sweep bar. Surveyors use sweep bars to determine minimum clear depths. They locate obstructions and navigation dangers in confined areas, such as shoals, rock pinnacles, reefs, or wrecks. The sweep bar is a heavy section of railroad rail, steel pipe, or a structural steel section. It is held by two vertical cables. It can be suspended from a float, catamaran, or boat of suitable size. The suspending craft may be either towed or self-propelled. It must maneuver to maintain horizontal sweeping control. The sweep bar is suspended to avoid sag or deflection. The supporting craft can control depth by adjusting the cables holding the bar. Sweep bars have wide applications. They range from small hand sweeps operated from a rowboat for locating minor obstructions to specially-designed crafts for sweeping large channels and harbors.

(5) Specialized sweeping. Naval units are required when sweeping for mines.

METHODS OF BOTTOM INVESTIGATION

a. Types and uses.

(1) Underwater investigations of bottom materials are made from wash borings, core borings, probing, and diving.

(2) A hydrographic survey includes superficial bottom examination based on materials that adhere to grease kept in a cup-shaped depression in the bottom of the sounding lead.

(3) Investigations of bottom materials are made to--

* Indicate the probable length and size of adequate bearing

* Establish the most suitable pile material.

* Determine the type and depth of dredging or type of dredging equipment to use.

b. Wash borings.

(1) The bottom material must be soft enough so a casing pipe can penetrate it. The casing is driven into the bottom, a few feet at a time. A hollow drill rod is inserted in the casing. The nozzle at the lower end of the drill rod usually has a chisel point for boring. Water is washed down the rod as it is raised and lowered in the casing. Water and bottom material are forced to the surface between the casing and the rod. This overflow is discharged into a bucket. Suspended material is allowed to settle for analysis.

(2) To obtain a dry sample, the drill is removed. In its place, a short length of sample pipe is attached to the rod. The rod is placed in the casing and driven a foot or more into the bottom to force a sample of material into the sample pipe. The casing stands in place until the rod and sample pipe are removed with the dry sample.

c. Core borings. Core drilling is necessary for rock stratum and for soils containing clay or clay with boulders. A casing is driven through the overlying soil to its limit of penetration. Materials within the casing are then removed. Rotary-drill coring equipment is then inserted into the casing to remove the core.

d. Probing. Probing serves mainly to determine the depth to the surface of rock or hardpan. It obtains bottom materials and tests bottom hardness. Lengths of pipe are forced into soft bottom materials by hand or are driven with a maul.

e. Diving. Usually divers investigate underwater piling and other foundations or obstructions.

TIDES AND TIDAL CURRENTS

Tides have a variety of effects on port construction (see TM 5-235). Tidal currents are the alternating horizontal movements of water associated with the rise and fall of the tide. They are caused by astronomical forces.

a. Information. The Naval Oceanographic Office, Washington, D. C., maintains files of hydrographic charts for areas throughout the world, exclusive of the U.S. The office also prepares tide tables and other hydrographic data, which are available upon request. Lists and publications include sailing directions, lists of lights, radio weather and navigational aids, current atlases, fleet guides, marine geographies, surface temperature charts, tide tables, tidal current tables, general navigation charts, and coastal hydrographic charts. Information about the coastal waters of the U.S. and its possessions is published in detail by the National Ocean Survey (formerly Coast and Geodetic Survey), U.S. Department of Commerce. Winds or river discharge may cause currents to vary from predictions by as much as half an hour in well-documented areas. In poorly documented areas, variation may be greater.

b. Effects of tidal waves by type.

(1) Progressive. A progressive wave leads to maximum current flow near high and low tides. The rate of progress of the rest of the tidal wave is much greater than the speed of the current. For example, the crest of the tidal wave in the Hudson River advances at a rate of about 16 knots; however, the average maximum rate of the tidal current is less than 2 knots.

(2) Stationary. Oscillation of the water in the basin leads to maximum current flow at half tide. Strength of current is greatest at the axis of oscillation. It decreases as it approaches the end of the basin, where the range of the tide is greatest.

TIDAL PRISM

The tidal prism is the total amount of water flowing into a harbor or estuary or out again with movement of the tide. It excludes any freshwater flow. The tidal prism may be estimated by measuring the volume of the area or the volume of flow through the harbor entrances. Changes in the tidal prism and restrictions of the waterways may change the depth or direction of existing channels. These changes happen through scour or sedimentation. Such changes are difficult to predict or evaluate. Constructing pile structures, where practical, can avoid changes in the tidal prism.

WAVES

The familiar ocean waves are wind waves generated by winds blowing over water. They range in size from ripples on small bodies of water to large ocean waves as high as 100 feet. Wind waves cause most of the damage to ocean coasts. At sea or near the shore, the most noticeable waves are often swell associated with winds over great distance. Another type of wave, the tsunami, is created by earthquakes or other tectonic disturbances on the ocean floor. Tsunamis have caused spectacular damage at times. Fortunately, tsunamis occur infrequently.

a. Wave characteristics. Wind waves are known as oscillatory waves. They are defined by height, length, and period.

(1) Definition of wave terms. Wave height is the vertical distance from the top of the crest to the bottom of the trough. Wave length is the horizontal distance between successive crests. Wave period is the time between successive crests passing a given point.

(2) Determination of wave characteristics. Four variables determine the height, length, and period of wind waves--

* Fetch, or the distance the wind blows over the sea in generating the waves.
* Wind speed.
* Length of time the wind blows.
* Decay distance, or distance the wave travels after leaving the generating area.

Generally, the longer the fetch, the stronger the wind. The longer the wind blows, the larger the waves. If shallow enough, the water depth affects the size of wave generated.

b. Wave classifications. A description of a wave involves both its surface form and the fluid motion beneath it. A wave describable in simple mathematical terms is called a simple wave. Complex waves have several components and are difficult to describe in form and motion. Other classifications include oscillatory or nearly oscillatory waves. In these, water particle motion is described by orbits which are closed or nearly closed for each wave period. The type of wave most important to port construction and rehabilitation is the gravity wave. Gravity is the principal restoring force. Gravity waves are further classified as deep water, transitional, or shallow-water waves.

c. Deep-water waves. Deep-water waves are at a water depth more than one-half the wave length or when d/L (Figure 2-1) exceeds one-half. The phase velocity is the length of the wave divided by the time required to travel this length. It is an important characteristic of wave motion.

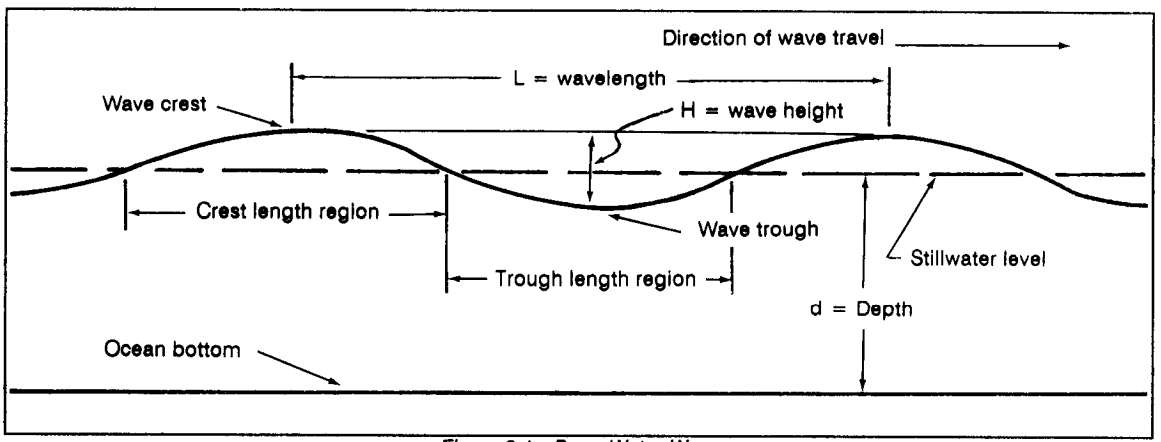


Figure 2-1. Deep-Water Wave

WAVE ENERGY AND ACTION

a. Energy content of waves. The total energy of a wave system is the sum of its kinetic energy and its potential energy. The kinetic energy is that part of the total energy due to water particle velocities associated with wave motion. Potential energy is the energy resulting from the part of the fluid mass above the trough. According to the Airy (first-order) theory, potential energy may be determined relative to mean water level. All waves may be propagated in the same direction. Potential and kinetic energy components may be equal. Under these conditions, the total wave energy (E) is one wave length per unit crest width, as given by Equation 1.

$$E = E_k + E_p = \frac{\rho g H^2 L}{16} + \frac{\rho g H^2 L}{16} = \frac{\rho g H L}{8} \qquad \text{(Equation 1)}$$

where:

E_k = kinetic energy
E_p = potential energy
ρ = mass density = w/g (w = unit weight) = $\frac{2.0 \text{ lb-sec}^2}{4\text{ft}}$ (slugs/ft^3) for salt water
g = gravitational acceleration
H = wave height
L = wave length

Substituting p = 2.0 slugs / ft^3, the equation can be reduced to a proximately $E = 8LH^2$. This equation indicates a wave 12 feet high and 1,300 feet long with an energy content of nearly 1,500,000 foot- pounds per foot of wave length. Dynamometer readings on breakwaters exposed to the direct force of waves show wave pressures as high as 7,000 pounds per square foot. These are maximum readings over an area of about 1 square foot. It is improable that equally great pressures are experienced over the total area of a bulkhead or break water.

b. Forces exerted by a blocked wave. When a wave is suddenly stopped by an obstacle, it generates the following forces, which act alone and together on the obstacle:

(1) Direct horizontal force combining impact and continued pressure. A breakwater with a constant water level on the sheltered side feels pressure on the exposed side. One end of fluctuation is the result of a positive combined pressure from the kinetic energy of the moving water and the static head of the wave at maximum height. The other end is a negative pressure when the trough of the wave is at the breakwater.

(2) Deflected vertical force upward.

(3) Vertical downward force resulting from the collapse of the wave.

(4) Downward kinetic and static pressure on top of the structure.

(5) Suction from the backwash, which tends to produce negative pressure inside the structure

c. Height of rise of a blocked wave. The energy content of a wave is equally divided. One part is the kinetic energy of the moving particles of water. The other is the potential energy of the mass of water raised above still water level. A wave may encounter a vertical obstruction in water greater thsn its breaker depth. The kinetic energy of the moving particies is then largely converted to potential energy. The wave rises to nearly twice its normal height. This fact is important in the design of structures in water with a depth eater than breaker depth because it permits calculating the maximum height needed to keep waves from breaking over the top.

d. Effect of wave action on a structure. Waves have many effects on natural and man-made coastal features. The tremendous wave forces generated by a storm make damage likely. The forces exerted by a blocked wave may cause the following effects on obstacles:

(1) Vibration or weaving, which tends to weaken connections.

(2) Hydrostatic pressure or suction in all directions in the joints and interstices.

(3) Alternate compression and expansion of volumes of air in cavities, which transmit pressure to internal parts.

(4) Deflected vertical force, which tends to shear off projections beyond the face line of a structure.

(5) Direct horizontal force of impact and continued pressure, which tends to overturn or slide.

e. Battering -ram action of floating objects. The energy of a wave is contrated as a battering ram when it hurls a floating object.

CHAPTER 3
PORT PLANNING

Successful port construction requires careful planning based on detailed reconnaissance. Reconnaissance continues until actual occupation. Planning may appear complete before occupation, but last-minute enemy action may necessitate a major change in plans.

FACTORS INFLUENCING SEAPORT LOCATIONS

A seaport should lie near sheltered waters. Shelter comes in any of the following ways:

a. A bay or river forms a natural location for a seaport.

b. Engineers create shelter by increasing the length or height of natural formations, such as land arms, rocks, reefs, islands, or other barriers.

c. Engineers build breakwaters or jetties as protection for the inner water.

PLANNING PRIOR TO OCCUPATION

a. Before occupying a port, planners must consider estimated logistical requirements and both the current and expected physical condition of the port to be occupied. Planning prior to occupation covers a long period of time. Operation orders then give construction assignments, facilities required, and target dates for development.

b. The theater commander must evaluate ports according to the possible quantity and nature of cargo and personnel they will handle. Often this phase of planning depends on the first reconnaissance. The commander examines previous plans critically in view of the physical condition of the port. Priorities in the operations order may change in light of the port's actual physical condition. The commander coordinates indicated changes and their impact on logistics through Army engineer, transportation, and other command channels, as well as with naval units engaged in clearance, dredging, and other harbor projects. Planning and scheduling depend on meeting all immediate needs and making all work contribute toward meeting final requirements.

c. During final development, planning depends on a full knowledge of the theater-wide logistical situation. Planners study the relative value of rehabilitation and construction, and the value of specific facilities to the construction effort required. Selection of the best sites for development depends on need for dispersion, location of logistical requirements, time and effort needed to move construction units, locally available material, and civilian or prisoner-of-war labor. Similar factors determine the best development within a port.

STANDARDS FOR ESTIMATION

The following terms establish standards for estimation:

a. Port capacity. The estimated amount of dry cargo, containerized cargo, and bulk and roll-off equipment. It is usually expressed in weight, measurement tons, or number of containers per day that can be discharged onto the available piers, wharves, quays, jetties, moles, and beaches of a port.

b. Standard minimum width. The wharf width for deep-draft noncontainerized ships using one-side discharge is 60 feet, or 90 feet for two-side discharge. Container ships require 80 feet, and lighterages either 35 or 42 feet.

c. Minimum required depth below mean low water. The depth required by the draft of a ship. For deep-draft noncontainer ships, the minimum required depth is 30 feet. For high-speed container ships, it is 40 feet. Shallow-draft crafts require a minimum of 12 feet.

d. Wharf systems. Wharves include any extensions built from shore to water of minimum required depth to provide direct contact for handling cargo between deep- or shallow-draft ships and shore. "Wharves" also include structures described as quays, piers, or marginal wharves.

PORT-CAPACITY FACTORS

a. Engineer responsibility. Port-capacity requirements are estimated by Headquarters, Transportation Command (TRANSCOM) or by the TASCOM ACS,M. The construction engineer usually makes an independent estimate of the capacity of the port under various alternative methods of construction, repair, or rehabilitation. This estimate is used to determine priorities for engineer projects. The person doing this estimate must understand how the capacity estimates of TRANSCOM and TASCOM work with respect to military loads. The engineer recommends schedules for repair and maintenance of port cranes and other equipment and facilities, roads and railways within the port area, and storage and marshaling areas.

b. Wharf facilities. Rehabilitation, construction materials, and plans affect wharf capacity.

c. Discharge rates. Port capacity estimates depend on the discharge rates of ships either at the wharf or in the stream. Priority goes to expedient methods that allow ships to discharge quickly. Construction coordinated with transportation units cuts interference with the discharge of ships.

d. Anchorage available. Sheltered anchorage allows for discharging cargo while deep-water wharves are constructed or repaired. Continuous lighter craft usage allows the following:

(1) Continuous dredging of the deep-water approach channel using the shallow-draft approach with discharge outside the dredging areas.

(2) Use of the shallow-draft parts of wharves while some of the deep-water wharves are under construction.

(3) Unloading the shallow-draft vessels over deep-draft wharves when removing obstructions that prevent deep-draft use.

e. Other factors. Base periods of time, such as the 2-shift, 20-hour working day or a specified number of days in a month, allow engineers to consider bad physical conditions peculiar to the location in preparing time estimates. For example, they can estimate time needed in some harbors to work in ice during winter. Extreme range of spring tides may bear upon work. Where heavy seasonal rains, snowfall, icing, severe winds, fog, and heat or cold exist along a coastline, engineers modify their estimates to allow for these conditions.

DETERMINATION OF WHARF REQUIREMENTS

Standard wharfage requirement estimates match only the specifications for noncontainer ships, but only an 80- by 900-foot wharf is sufficient to support the latest container vessels. Total estimated container wharfage is the basis for up-to-date wharf layout. To compare density where shore front is limited, use Table 3-1 and Figure 3-1, page 3-4.

TABLE 3-1. Linear Feet of Berthing Spaces per 1,000 Feet of Shore Front

Type of layout	Freighter	Lighter	Total
(1) Quay	1,000		1,000
(2) Square pier	2,143		2,143
(3) Right-angle pier for one freighter on each side	3,120	313	3,433
(4) Right-angle pier for one freighter plus one lighter on each side	3,120	1,250	4,370
(5) Acute-angle pier for one freighter on each side	2,690	270	2,960
(6) Right-angle pier for two freighters on each side	4,160	208	4,368
(7) Acute-angle pier for two freighters on each side	3,600	180	3,780
(8) T-type marginal wharf for freighter on outside face and lighters on inside face	770	*1,380	*2,150
(9) U-type marginal wharf	1,000 or less		1,000 or less
(10) Finger pier	3,120	**313	**3,433

Note. These figures are for purposes of comparison only.
** 1,682 feet and 2,452 feet if traffic conditions are such that lighters can be worked along the faces of the causeway.*
*** Up to 813 feet and 3,933 feet if traffic conditions are such that lighters can be worked along the faces of the causeway.*

QUAY SYSTEMS

a. Characteristics. A quay (Figure 3-1,(1)) is a marginal wharf supported by either the shore itself or by solid fill. Quays are used in water with minimum required depths. A piled marginal quay is supported by shore bracing and piling. The linear feet at the face of the quay is the length of berth accommodations.

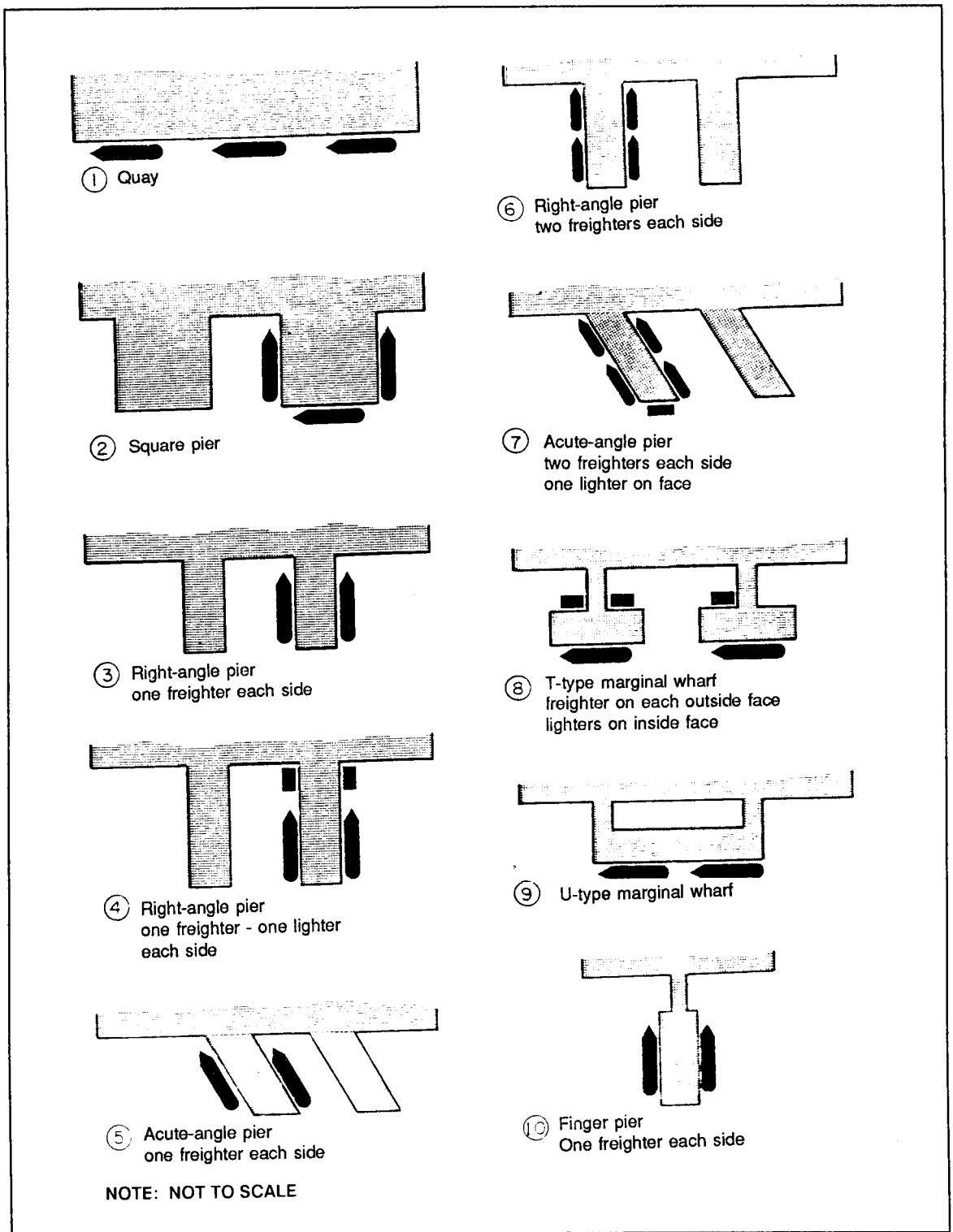


Figure 3-1. Wharf Layout

b. Advantages.

(1) Stability and bearing strength of the solid fill supports the load, especially when handling cargo in containers.

(2) Accessibility of the upshore work area.

(3) Use of surplus fill.

c. Disadvantages.

(1) Moving earth or other material to provide fill requires equipment and personnel.

(2) Berth length is limited to the length of the wharf face, unless mooring dolphins extend the usable length.

SQUARE-PIER SYSTEM

a. Characteristics. A square pier (see Figure 3-1, (2)) has berth accommodations at the sides as well as at the face. It is supported by solid fill or piling. Usually the area of the deck is so great that it precludes all-pile construction. For this reason, this type of pier is rarely adaptable for new construction. For linear feet of berthing space per 1,000 feet of shore front, see Table 3-1.

b. Advantages.

(1) Solid fill offers stability and bearing strength.

(2) Upshore areas are accessible for storage and traffic circulation.

(3) Side berths add to berthing accommodations.

c. Disadvantages.

(1) Moving earth for fill requires equipment and personnel.

(2) Requirements for fill or piling are great compared to usable space on the deck.

(3) When on fill, the square pier changes the natural current system.

OFFSHORE MARGINAL WHARF SYSTEM

a. Characteristics. An offshore marginal wharf (Figure 3-1, 8 and 9) is located offshore but parallel to the shoreline. Causeways are used to connect the wharf to the shore. The wharf provides deep-water berths at its outer face. Shallow-water berths often lie along the causeway section and shoreward face. The wharf is either floated or supported by piles or solid fill. Causeways are solid construction resting on piles or floating. U-type causeway and wharf arrangements allow truck traffic to circulate.

b. Advantages.

(1) The layout allows many construction methods. Navy pontoon gear normally supplies needed floating wharfage.

(2) Moorings for shallow-draft craft range along the sides of the causeway. When multiple causeways are used, a movable section can provide access to space(s) between causeways for mooring or unloading vessels of suitable draft.

(3) Along rocky shores, offshore construction is likely to save costs.

c. Disadvantages.

(1) If only a single causeway is available, unloading or traffic problems may occur.

(2) The large area of the wharf structure not tied to shore anchorages requires moorings that are not supported by the wharf structure.

PIER-AND-SLIP SYSTEM

a. Characteristics. The pier-and-slip system (Figure 3-1, (3), (4), and (6)) provides alongside-berthing space perpendicular to the shore. Commercial ports generally use this system. The piers are long enough to accommodate the ships and wide enough to provide adequate working space for cargo handling. The slip should provide depth for the ships and width between two berthed ships at adjacent piers for floating cranes and other harbor craft and equipment. Piers are usually built on piles, but may have solid-fill mass support. Pier construction is obviously impractical in water that is too deep for the available piling. If water depths cause large unsupported piling lengths, dump rock fill after the piles are driven.

b. Advantages.

(1) Offers more linear feet of berthing for a given length of shoreline.

(2) Pier work space is directly accessible from the shore area.

c. Disadvantages.

(1) Limited space between piers causes dense navigational traffic in and around the piers.

(2) Piers are an encroachment on the restricted waterway.

(3) Pier- or bulkhead-limit may affect the line set to ensure adequate channels or anchorage.

ANGLED PIER-AND-SLIP SYSTEM

a. Characteristics. The angled pier-and-slip system (Figure 3-1, (5) and (7)) provides alongside berthing, but the piers are not placed at right angles to the shore. This type of system is frequently used where strong currents or strong prevailing winds would adversely affect perpendicular piers.

b. Advantages. This layout fits narrow shorelines where the perpendicular-pier layout cannot be used or where the pier system is located on a narrow waterway, with insufficient room for a ship to make a 90-degree turn to enter the slip.

c. Disadvantages.

(1) With normal current and wind conditions and adequate approaches, ships berth and moor more readily in slips with a 90-degree layout.

(2) Construction is difficult and requires more material.

(3) Abnormal currents or winds make the use of tugs critical.

FINGER-PIER SYSTEM

a. Characteristics. The finger-pier (Figure 3-1, (10)), like the pier-and-slip system, provides alongside berthing space. If built wide enough, finger-piers can accommodate vessels on each side. A simple causeway of pile construction or solid fill, or a floating causeway is used to connect the pier to the shore.

b. Advantages.

(1) Adaptable to many types of construction. It may be built using piles, floating wharfage, or the steel-spud or spud-type barge.

(2) Shallow-draft craft can discharge onto the causeway.

(3) Pier can serve in marshes and mud flats.

(4) Where tides fluctuate, the finger-pier causeway can extend out into deeper water to ensure an adequate depth, regardless of the tide.

c. Disadvantages.

(1) The single causeway may result in unloading and traffic problems.

(2) Separate moorings, which are not supported by the wharf structure, may be required for mooring ships at the wharf.

ACCESSORY STRUCTURES

a. Lighter wharves and basins. Lighters are shallow-draft craft used for loading or unloading larger vessels. They may be either self-propelled or towed. The controlling depth for lighter crafts is the same as that of the tugs which use them, usually 12 feet. However, at lighter wharves, extremely shallow water or breaching on the soft bottom is possible. Self-propelled lighters, especially those with outboard engines, need more depth than their actual draft to prevent fouling of their cooling systems while navigating over the soft bottoms. Required slip width is based on the beam of the craft and navigational requirements.

b. Floating wharves.

(1) Characteristics. Floating wharves, typically fabricated from Navy pontoon gear, can be assembled in almost any size layout. Use hinged joints to avoid long, rigid structures. A typical floating wharf for a single noncontainer cargo ship has a 43- by 431-foot deck with two or more pontoon bridge approaches. Existing designs and equipment specifications will require modification and strengthening to support container operations.

(2) Advantages.

* Floating wharves can be moored in water that is too deep for pile driving. They are good in areas with very high (30 feet or more) tides.

* Pontoon cube bridges or sections can be assembled elsewhere and towed into place, reducing in-port assembly time.

* These wharves permit quick assembly, movement, and disassembly. Piecemeal disassembly during replacement by a fixed wharf is also possible.

(3) Disadvantages.

* Initially light maintenance requirements may later become heavy because of weakened connections and corrosive effects of salt water.

* Equipment will not support the large deck loads of containers.

* Operations using floating wharves must stop during high seas.

c. Jetties, breakwaters, and moles. Jetties and breakwaters are usually designed and located primarily to protect the harbor and its channels. When favorably located and furnished with a vertical face on the protected side, both structures may serve as tie-ups for ships and, when surfaced, as wharves. When used this way, a breakwater is called a mole.

d. Bulk petroleum handling facilities. Facilities consist of wharves, dolphin moorings, ship-to-shore pipelines, and shore pumping stations and storage tanks. For fire protection, these facilities must be a safe distance from other structures and storage areas. Terrain barriers, ground slopes, and current charts are used to keep gasoline from flowing overland or floating on water. If the port is small and congested, an outside location at a protected cove or roadstead is preferable. Coordination with the Quartermaster Corps, Transportation Corps, and Navy helps in selecting locations.

e. Marine railways and graving docks. Engineers allocate space not needed for wharfage, navigation, or onshore facilities to provide for marine railways. They allow space for the marine railway from the piling that marks the deep-water end of the railway to the winch, or other equipment, handling the cable on shore.

(1) A marine railway consists of a platform with a cradle. It operates on a railway from deep water to shallow water or dry land. Small vessels are secured to the cradle on the platform and hauled ashore.

(2) A graving dock is a basin into which a vessel is floated. The basin is then emptied to do work on the underwater part of the hull. After completion of the work, the basin is flooded and the vessel floats back into service.

CHAPTER 4
CONSTRUCTION PLANNING AND ORGANIZATION

PURPOSE

a. Careful construction planning cuts costs and creates an orderly sequence for the project.

b. Construction planning enables the manager to--

(1) Determine the tasks.

(2) Establish priorities.

(3) Determine time schedules for each task and for the entire project.

(4) Identify personnel and equipment needs.

(5) Forecast requirements for materials and special equipment to prevent delays.

(6) Establish responsibility.

c. Effective port construction planning requires--

(1) Reconnaissance and study of the proposed port site.

(2) Estimates of material, equipment, and personnel.

(3) Consideration of nonorganic equipment.

(4) Preparation of construction time schedules.

(5) Knowledge of unloading capacities.

CAPABILITIES OF CONSTRUCTION FORCES

The engineer unit responsible for major port construction or rehabilitation is the engineer construction group. It includes an engineer port construction company or companies, pipeline construction and support companies, engineer combat (heavy) battalions, dump truck companies, engineer construction support companies, dredge teams, and other units the mission may require. When several groups work together, they are organized as an engineer brigade with various capabilities.

a. The headquarters and headquarters company in an engineer construction brigade supervises a force of two to four engineer construction groups and supporting troops--5,800 to 15,000 soldiers.

b. When organized for port construction, an engineer construction brigade can plan and carry out any port construction or rehabilitation project in military operations.

c. The engineer construction group is a flexible organization. It becomes operational only when working units are assigned or attached to it. The headquarters and headquarters company in an engineer construction group command supervises three to five engineer combat (heavy) battalions or their equivalent in assigned or attached troops. Two or three combat (heavy) battalions and at least one port construction company help organize the group for typical wharf construction. Pipeline construction support companies, dredge teams, construction support companies, and dump truck companies are added as required.

d. The engineer combat (heavy) battalion is the basic unit assigned to a specific project or to separate minor projects. When working on port construction projects, the battalion can draw on several sources. It can have a port construction company, pipeline construction support company, dump truck company, construction support company, and dredge team.

e. The engineer port construction company operates as one element of a large-scale, coordinated construction operation under an engineer group. It can serve separately on minor projects at separate locations. Its main activities are construction or major repair of waterfront structures and POL off-loading facilities and anchorages. It is better to assign related on-land sub-projects to a construction battalion or other specialized unit. The port construction company should handle specialized waterfront construction. It is organized for two-shift operation. Its equipment includes crane-shovels with attachments for dredging, excavating, pile driving, and other work; pipeline equipment; hydraulic jacks; air compressors; pumps; tractors; concrete mixers; barge assembly sets; diesel-powered outboard propelling units; bridge erection boats; and landing crafts, mechanized (LCMs).

f. The pipeline construction support company provides technical skills and special equipment to assist engineer units. It can work separately on minor projects. It is normally attached to a construction group on the basis of one per construction battalion.

g. The engineer dump truck company augments the earthwork capabilities of other units. It operates 48 dump trucks on a two-shift basis. The trucks are loaded by the supported unit.

h. The engineer construction support company is assigned to an engineer group to provide equipment and operators for large-scale earthmoving, quarrying, or surfacing work.

i. Engineer dredge teams of TOE 5-500 (Series) are assigned to operate organic cutter-head pipeline or seagoing hopper dredges. Other types of dredges are best operated by local personnel.

j. Other units required for engineer service may include forestry, topographic, intelligence, maintenance, fire-fighting, and utility units.

FLOATING PLANT AND SPECIAL EQUIPMENT

Floating plant items used in the construction, rehabilitation, and operation of a harbor include--

a. Lighters, barges, and rafts. These include lighters and barges for general cargo, fuel oil barges, fresh-water barges, and rafts to haul piles and do general work on offshore structures. They may be towed or self-propelled. Their simple design and shallow draft allow them to perform well in construction work. Binges and lighters are made self-propelled by installing 165 horsepower outboard motors from the port construction company.

b. Tugs. These vessels tow lighters, barges, or rafts, and assist ships in berthing and unberthing.

c. Amphibian vehicles. These units handle cargo during beach operations. If available, they supply an offshore construction job.

d. Floating cranes. These are available to transportation or engineer units.

e. Floating pile drivers. The engineer port construction company provides either the drop hammer or diesel-powered hammer floating pile drivers. See Figure 4-1, page 4-4.

f. Floating marine repair shop. This shop includes fully equipped machine, electrical, engine repair, carpenter, blacksmith, pipe, and welding equipment. Mounted on a nonself-propelled barge, it is used to repair floating equipment in harbors and adjacent areas. It may be used when opening and rehabilitating captured ports.

g. Landing craft. During the first phase of rehabilitation or new port construction, LCMs deliver construction material, equipment, personnel, and supplies over beaches.

CLASS IV SUPPLIES

Class IV supplies include construction materials and installed equipment. After initial occupation, supplies received from the continental United States (CONUS) follow an automatic rate prescribed by Department of the Army. At a later stage, the basis of supply changes from automatic shipment to requisition. Theater requisitions for engineer construction materials must include project requirements for special large-scale operations. Issues from stocks are based on these requirements. The G-4 approves issue of critical items of Class IV supplies. Uncontrolled items are issued on call.

AVAILABILITY OF LOCAL MATERIALS

Providing engineer construction supplies to a modern Army from CONUS is a large, complex, and costly operation. Local procurement is better where possible. The project officer maintains a continuous inventory of stocks of construction materials and equipment available locally. Class IV supplies suitable for local procurement may include lumber, cement, structural steel, sand, gravel, rock, plumbing and electrical supplies, hardware, and paint.

AVAILABILITY OF LOCAL LABOR

Local port authorities may provide technical assistance on electrical circuits, operation of tidal locks, and cargo-handling equipment. They may also give information on foundation conditions. Personnel in port reconstruction units should draw experience from civilian construction firms. Prisoners of war may be a source of highly skilled workers.

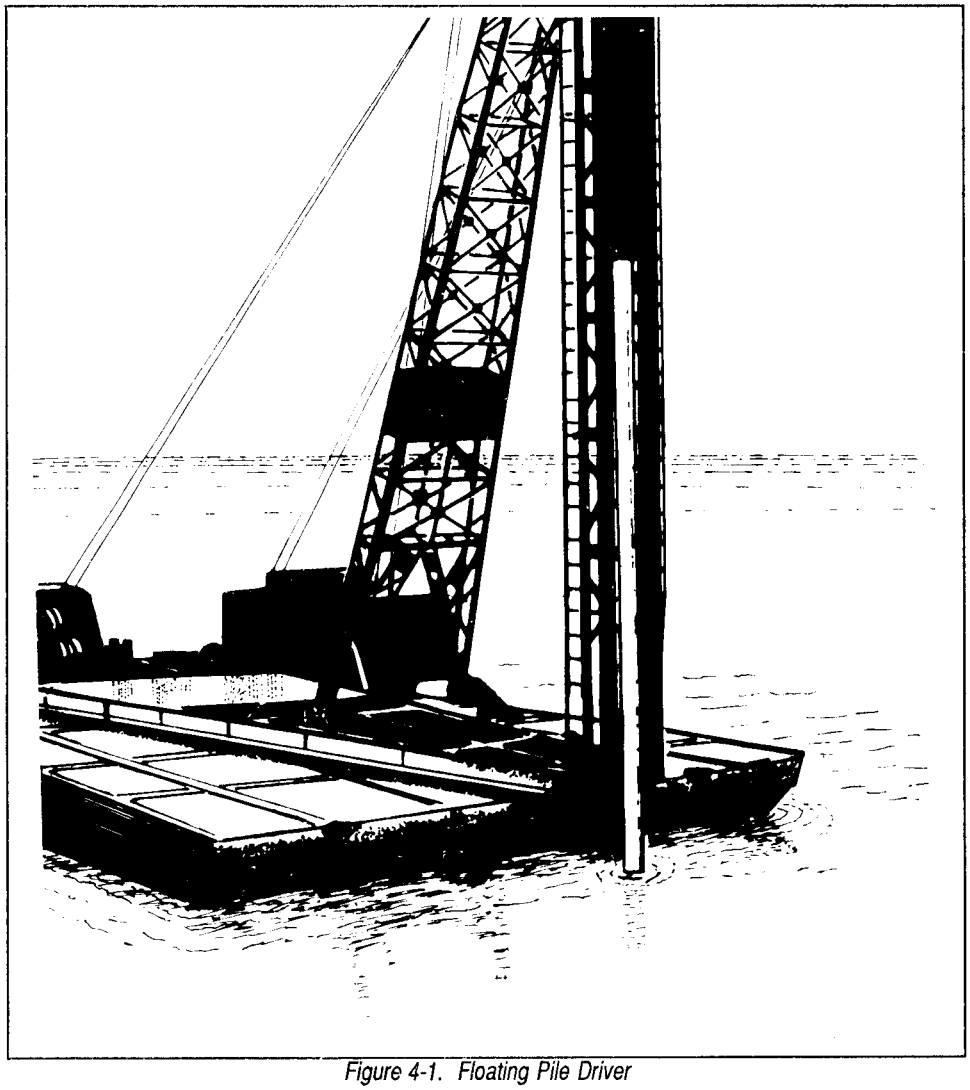


Figure 4-1. Floating Pile Driver

CONSTRUCTION PLANNING

a. Planning stage (TM 5-333). Military construction makes it advisable to divide the planning phase into two stages:

(1) Preliminary. This consists of a quick overall review of the assigned task and the capability of the constructing unit. It includes an estimate of critical items to be procured. Preliminary planning guides the detailed planning which follows.

(2) Detailed. This results in an estimate of the materials, labor, and equipment needed to accomplish each sub-task in the project and a time schedule for the entire project. It includes--

* Review of drawings and specifications.

* Detailed estimates.

* Schedules.

* Procurement.

* Construction plant layout.

b. Construction schedules. Construction schedules for projects may be represented by a bar diagram or a network analysis. A major port construction or rehabilitation project uses the critical path method (CPM) of network analysis. The CPM provides a method of handling critical tasks which sets the duration of the project. It warns the manager where he can expect trouble in meeting schedules.

c. Progress reports. The CPM helps to predict the day-by-day progress in terms of percentage of completion. Daily reports indicate how the job stands.

d. Allocation of equipment and material. The CPM indicates tasks engineers must do in early phases of construction to maintain the scheduled rate of progress. Priority goes to securing material and equipment required for these tasks. Tools and equipment are assembled in advance and prepared for use.

e. Delivery schedules for materials.

(1) General. Schedules for the delivery of material depend on site conditions, construction methods, work priority, and availability of supplies. The CPM can establish the materials required and the date they must be on the site.

(2) Bill of materials. Consolidated list of required materials.

PHASES OF RECONSTRUCTION

Port reconstruction is generally carried out in three phases:

a. Phase One.

(1) Subject to operation orders, the Navy carries out major clearing, salvage, and dredging for channels and slips. In an area intended as a naval base, Navy units construct other facilities. In areas intended for ground-force use, the Navy only opens waterways and frees them from mines and similar hazards.

(2) Operation orders for the assault of a port area state the engineer missions in the port area as well as arrangements for liaison between ground forces and naval units.

(3) During phase one, engineer construction units reconnoiter harbor facilities and routes of communication. They note beach improvements and interim facilities available from shore-party activities. They restore any accessible deep-draft or lighter wharfage not heavily damaged. They consider possible uses for vessels sunk alongside piers or wharves, and consult naval units for advice and assistance in improvising wharf decks over their hulls.

b. Phase Two.

(1) Initial construction: Engineers rehabilitate existing port structures. They use expedient methods of lightening and port construction to handle cargo.

(2) Existing noncontainer cargo ports.

* Continuation of Phase One by shore parties.

* Construction of floating wharf structures with Navy pontoon gear or Army floating bridge equipment, if available.

* Erection of self-elevating DeLong barge piers, if available.

* Expedient repair of existing structures.

* Lightering with TOE equipment.

(3) Existing container ports.

* Continuation of Phase One by shore parties.

* Construction of floating container wharf causeways with modified Navy pontoon gear and self-elevating DeLong barges.

* Repair of existing container wharves by any expedient method possible.

* Lightering with TOE equipment.

(4) Future military container ports. Current recommendations are that all military ports constructed in the future be suited for container handling. The recommended design specifies the use of large self-elevating, spud-type barge pier units. These can support live deck-loads of 1,000 pounds per square foot. These barge pier units are equipped with pedestal-mounted off-loading cranes and self-propelled engines. They can be raised or lowered 50 feet per hour. This capability allows undamaged units to perform the following tasks during rehabilitation:

* Serve as lighters during repair of the damaged units.

* Form into smaller freed-pier units, depending on the size of ships to be accommodated.

* Use pedestal-mounted off-loading cranes in clean-up operations.

c. Phase Three.

(1) Existing noncontainer ports.

* Repairable wharf structures are now permanently rehabilitated. Structures are limited to a live-deck load of 500 pounds per square foot.

* New unloading facilities are constructed. Plans for standard structures limit the live-deck load to 500 pounds per square foot.

* Work on highways, railways, canals, and storage facilities outside the wharf area of the port continues. It must keep pace with the development of berthing and unloading facilities at the waterfront.

(2) Existing container ports. Similar to the third phase of existing noncontainer ports, but special designs or modified AFCS designs for port decks must support live loads of 1,000 pounds per square foot or more.

(3) Future military container ports. Recommended designs for future military container ports are planned for expedient construction. The third-phase work for these ports is limited to adjoining facilities.

CLEARING UNDERWATER MINES AND OBSTRUCTIONS

The detection and removal of underwater mines and obstacles are naval specialties.

a. Obstructions. Berths, slips, and charnels may be blocked by sunken ships, vehicles, debris, and rubble.

b. Harbor clearance. Naval units perform large-scale underwater clearing and salvage. Engineer units may assist or provide equipment and operators.

c. Sweeping. After mine clearance, naval units sweep the water area to locate underwater obstructions.

INSPECTION OF DAMAGE AND DETERIORATION

a. Conventionally constructed port structures.

(1) Rehabilitation. The decision to rehabilitate or abandon port structures depends on the extent of damage, importance of the structure, and limits on its use.

(2) Wharf inspection. A wharf inspection includes--

* An underwater inspection by divers to check for possible demolition damage or deterioration of footings.

* An inspection of the piling at low water from a boat to check for decay, borer attack, or other damage. The stringers and deck are examined from below to determine the need for repair.

b. Expediently constructed port structures of the future. All military ports constructed in the future should handle the largest containers (67,200 pounds gross weight) within the U.S. container inventory. The most promising design is the large self-elevating, spud-type barge pier discussed in Chapter 11. This pier allows structural items to be inspected above water for damage.

c. Harbor inspection. Breakwaters, jetties, or seawalls are inspected for damage. If breached, such structures are repaired to avoid scour and further damage.

REPLACEMENT AND MAINTENANCE

Repair corrects damage to facilities. For conventional and proposed construction, repair maintenance consists of the following:

a. Emergency repair. Engineers repair storm, accident, or other damage to forestall further loss and larger repairs. Included are--

(1) Repairing breached breakwaters.

(2) Repairing wharf damage to restore structural strength.

(3) Dumping rock to control foundation scour or beach erosion.

b. Major repair. Major repair is replacement work of nonrecurrent nature, such as--

(1) Replacing wharf decks.

(2) Resurfacing access roads and earth-filled quays.

(3) Replacing wharf bracing and anchorages destroyed by decay or corrosion.

(4) Replacing entire spud barge piers, spuds, or other major barge pier accessories.

REHABILITATION OF LOCKS AND BREAKWATERS

a. Rehabilitation of locks. Gates are repaired only when they are essential to full operation of the facility.

b. Rehabilitation of breakwaters. Repair of breakwaters and similar structures protects the characteristics of a harbor. Use suitable rock to repair breached breakwaters.