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).

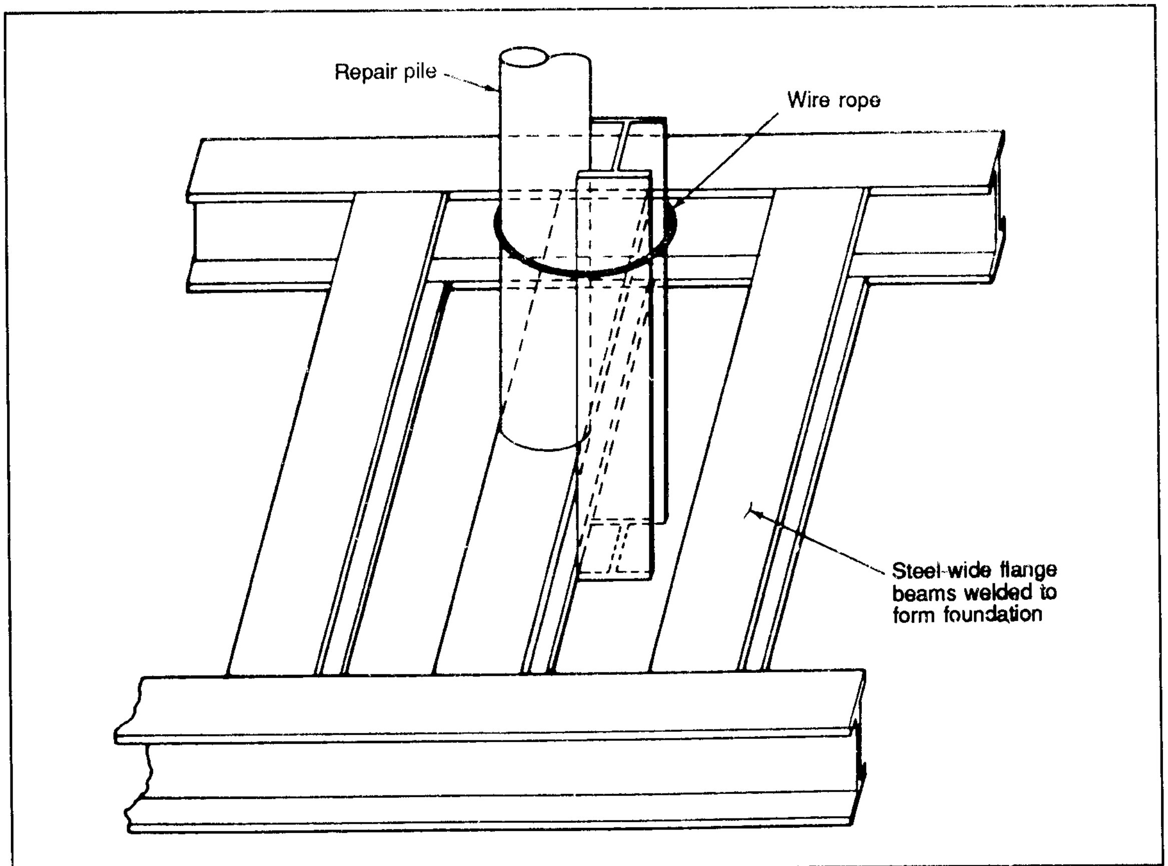

Figure 12-1. Steel Beam Foundation

(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).

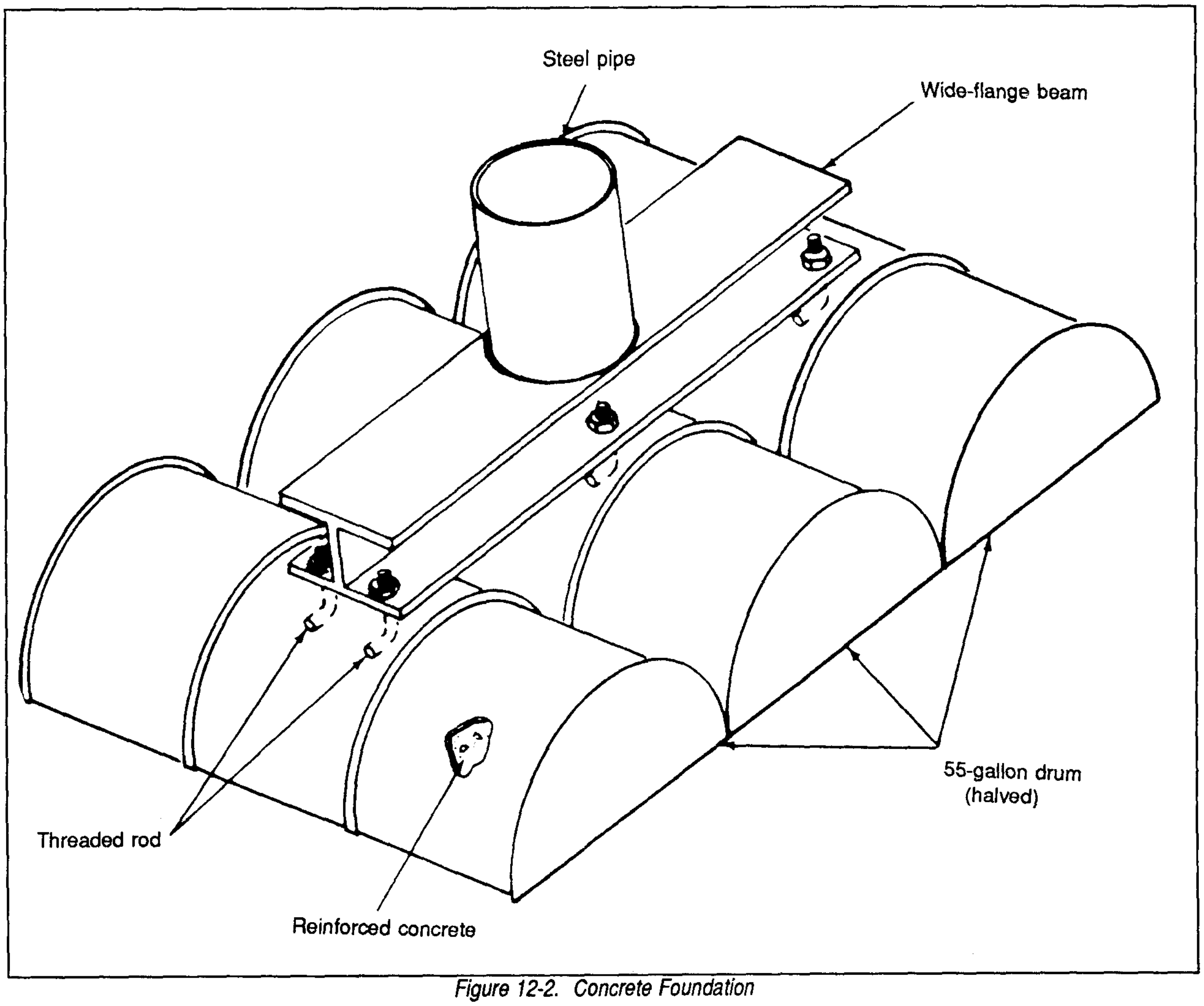

Figure 12-2. Concrete Foundation

(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).

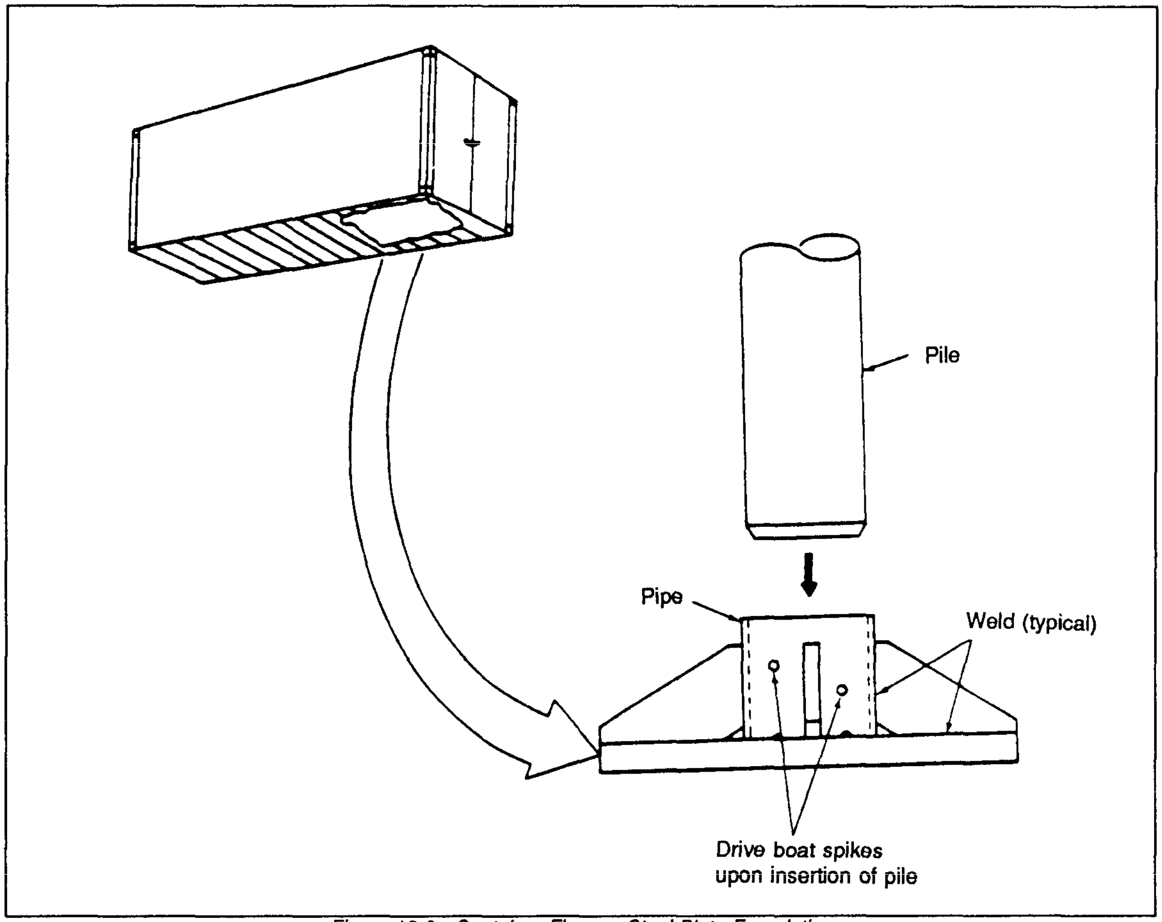

Figure 12-3. Container-Floor or Steel-Plate Foundation

(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).

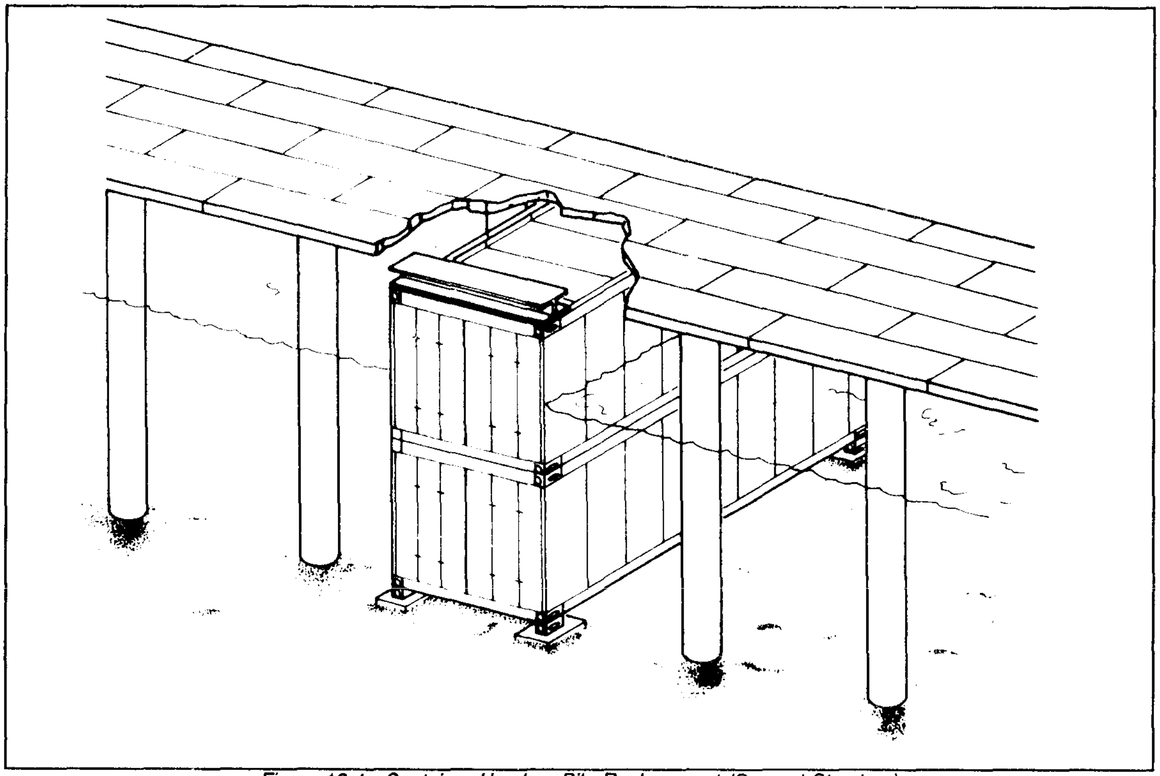

Figure 12-4. Container Used as Pile Replacement (Support Structure)

(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 l/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.