CHAPTER 2 - TIMBER STRUCTURES

SECTION 1. PRESERVATION OF WOOD

2.1.1 PRESERVATIVE TREATMENT. Timber structures in a marine environment are subject to attack by a variety of destructive organisms. Thus, they should be properly treated with appropriate preservatives to prevent or retard this type of deterioration.

2.1.2 WOOD DESTROYING ORGANISMS. Of the many types of wood destroying organisms, this manual will mention only those that are responsible for the greatest amount of damage to waterfront structures. These organisms are fungi, marine borers, and termites.

2.1.2.1 Fungi. Briefly, fungi are low forms of plant life that contain no chlorophyll and, thus, must depend on organic materials for food (see References 2-1 and 2-2). They are divided into four groups according to the type of damage they cause: (1) molds, (2) sap stain fungi, (3) decay fungi, and (4) soft-rot fungi.

Mold damage is generally restricted to the surface of materials and can be removed by brushing or planing. However, its presence indicates that conditions are favorable for the development of decay bacteria.

Sap stain fungi produce sapwood discolorations that range from brownish or steel gray to blue and black. They penetrate deeply into the wood, and although they do not affect most strength properties, they can sharply reduce the shock resistance of wood.

The two major types of decay fungi produce two kinds of decay: brown rot (often called "dry rot") and white rot. Brown rot causes wood to shrink, collapse, and crack across the grain (Figure 2-1). White rot does not crack the wood across the grain, nor does the wood shrink or collapse until severe degradation has occurred.

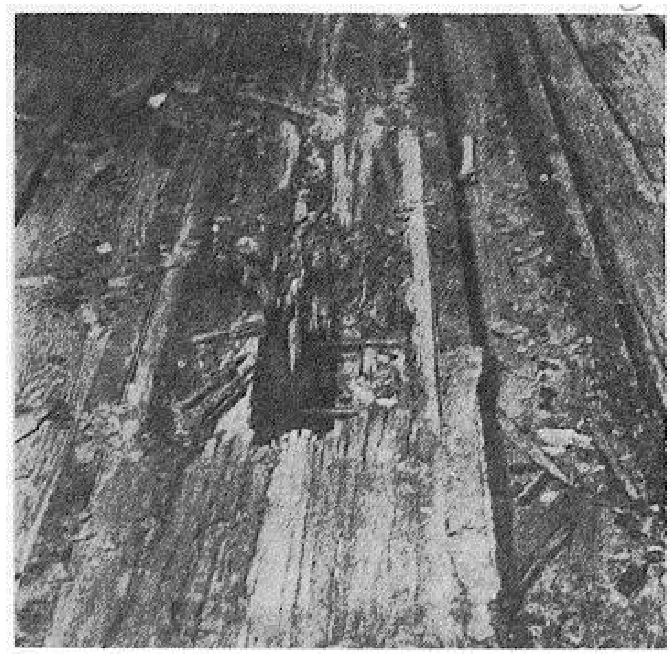

Figure 2-1. Example of brown rot.

Soft rot fungi can tolerate wetter and drier conditions than the more familiar decay fungi. Their depth of attachment is shallower, and the change from decayed area to undamaged area is very abrupt. Soft rot fungi are responsible for the surface "weathering" of wood.

Design and construction techniques that provide for quick drainage of wood waterfront structures will contribute much to minimizing damage from rot.

2.1.2.2 Marine Borers. Marine borers are organisms that live in seawater or brackish water and are capable of destroying wood (Figure 2-2). (See Reference 1-1.) There are two general types mollusks and crustaceans.

Figure 2-2. Destruction of wooden piers by marine borers.

There are two families of molluskan marine borers - pholads and teredines. Pholads bore into wood, soft rock, or concrete for protection; they are commonly known as rock borers. Their shells, which are pearshaped, can reach 2-1/2 inches in length; pholads can withdraw completely into their shells. *Martesia striata*, the species that causes considerable damage to waterfront structures, occurs worldwide between 35 degrees north latitude and 35 degrees south latitude. The presence of these organisms can be determined by visual inspection.

The teredines, *Teredo* and *Bankia*, are commonly referred to as "shipworm" because of their wormlike appearance (Figure 2-3). They enter the wood as larvae less than 1 mm in diameter, change to their adult form, and continue to grow as they lengthen their burrows. Only a pair of almost transparent tubes, called siphons, extend from the entry hole into the water. However, if the water is disturbed or becomes distasteful, the siphons are retracted, and the hole is blocked with a structure called a pallet. Because of this, the presence of teredines is most difficult to detect.

Of the three common crustacean wood borers *Limnoria, Sphaeroma*, and *Chelura* only *Limnoria* is considered to be economically important. *Limnoria*, commonly called gribble, is a small (3 to 6 mm long) animal with a segmented body and seven pairs of legs. It burrows at or just below the surface of the wood to form a network of tunnels or grooves. The three most economically important species are *Limnoria lignorum, Limnoria tripunctata*, and *Limnoria quadripunctata*. Of these, *Limnoria tripunctata* is considered the most important because it can attack creosoted wood (Figure 2-4).

2.1.3 PRESERVATIVE MATERIALS. The American Wood Preservers' Association (AWPA) classifies wood preservatives into three types: creosote and creosote solutions, oil-borne preservatives, and water-borne preservatives. Both AWPA standards and Federal specifications for wood preservations are subject to change, so in each case the latest standards and/or specifications should be used.

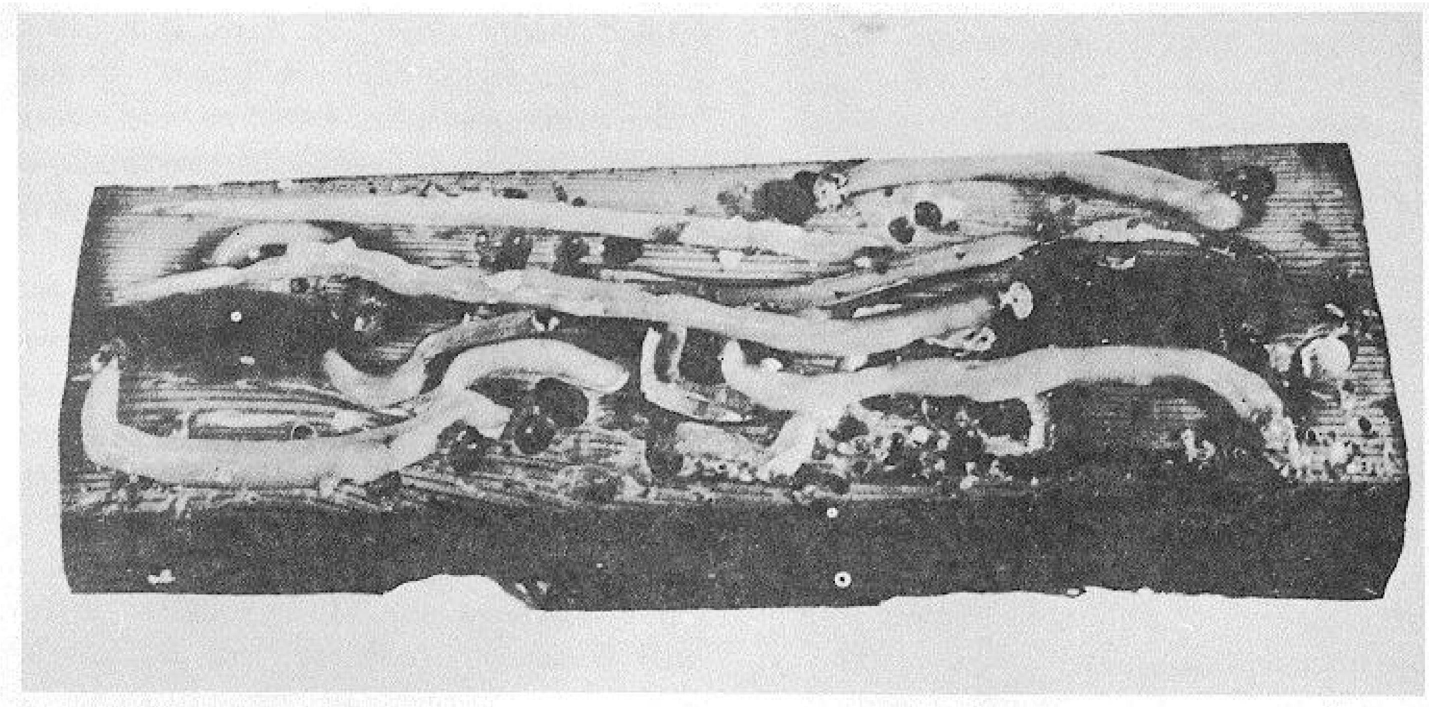

Figure 2-3. Bankia (shipworm) infestation of wood planking.

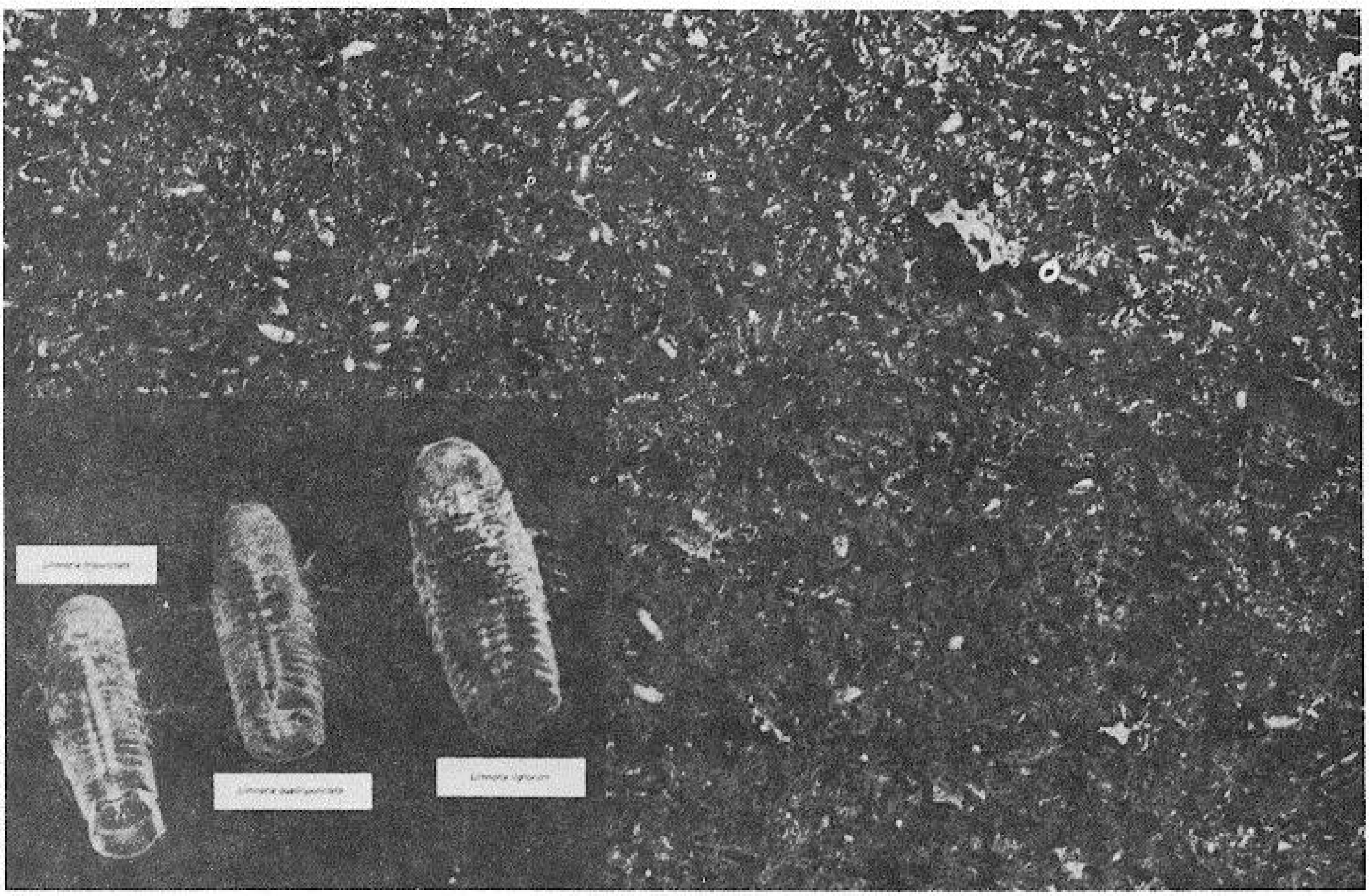

Figure 2-4. Surface of creosoted piling infested with Limnoria. Inset shows the three types of Limnoria.

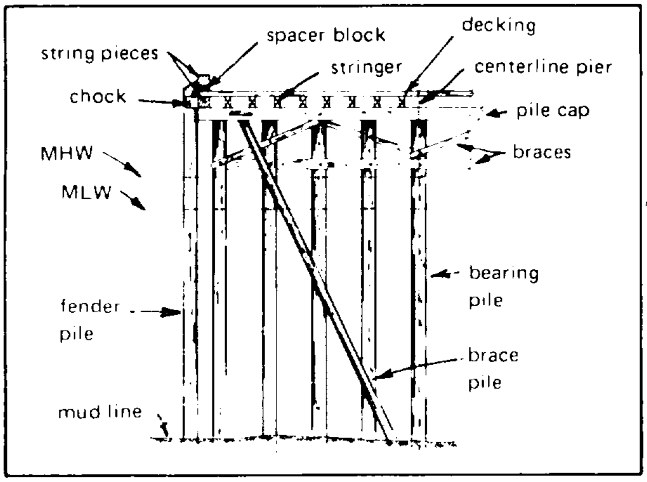

Figure 2-5. Pier components.

2.1.4 PRESSURE TREATMENT. All timber products (Figure 2-5) used in a marine environment should be pressure treated with an appropriate preservative. The choice of preservative depends on how the timber product is to be used (pile, cap, stringer, decking, etc.) and what kind of climate exists where the installation is to be made (cold, temperate, semitropical, tropical). Thus, the requirements are greatest in warm water harbors where *Limnoria tripunctata* and pholads are present. Pacific Coast Douglas fir has less sapwood than Southern pine so that retention measurement of preservative is generally made in the outer 2 inches for fir as compared to the outer 3 inches for pine. The AWPA standards and Federal specifications for treatment indicate the required retention level of the various wood preservatives.

2.1.4.1 Piles. Wood piling should be treated according to their particular purposes (e.g., cold water marine, warm water marine, freshwater) as specified by AWPA standards or Federal specifications.

2.1.4.2 Marine Pile Top Caps (Cut-Offs). After installation, piles are cut off at the desired final elevation; therefore, the newly exposed surface mainly the heartwood must be treated with a preservative. Swabbing the cut-off with hot creosote provides no preservation for the exposed heartwood. The preferred method is to drill a series of evenly spaced 3/4-inch-diameter holes about '1-1/2 inches deep in the untreated area. These holes are filled with creosote, and then a cover made from lead sheet is applied. As an alternative, an iron ring can be driven into the pile top or clamped around the piles so as to extend above the pile top. Hot creosote is poured into the ring and allowed to soak into the untreated area. Then the ring is removed, and a cover of soft, corrosion resistant metal (copper, high copper alloy, or zinc) or a tarimpregnated fabric is fastened into place. The metal top caps have a longer service life than the fabric ones.

2.1.4.3 Marine Pile Caps and Braces. Pile caps and braces can be periodically submerged by high tides, although waterfront structure design should be such that this situation is avoided. If submergence cannot be avoided, then those members involved should be treated in the same way as piles. Timbers that are difficult to treat should be incised before treatment. The life of submerged braces can be extended 20 to 25 years by wrapping them with a poly(vinyl chloride) (PVC) sheet. A simple modification of the method used for protecting wood piles from attack by marine borers is followed.

2.1.4.4 Freshwater Pile Top Caps (Cut-Offs). These should be treated in the same manner as marine pile top caps.

2.1.4.5 Freshwater Pile Caps and Braces. These should be treated the same way as freshwater piles. However, those woods that are difficult to treat should be incised before treating.

2.1.4.6 Stringers (Marine and Freshwater Environments). Stringers should be treated with creosote, creosote-coal tar solution, creosote-petroleum solution, pentachlorophenol solution, or inorganic salts.

2.1.4.7 Spacer Blocks (Marine and Freshwater Environments). Spacer blocks, which are installed between piles and braces to correct for misalignment, should be pressure-treated in the same manner as the piles and braces. They should be treated after all cutting and drilling has been done, or the untreated wood will be exposed to marine borers and decay.

2.1.4.8 String Pieces. The string piece is sometimes referred to as the curb, bullrail, or backing log. Because of its exposed position, it is subject to much wear and to constant wetting and drying. Therefore, it should be treated with the same preservatives and to the same retention as decking. Because string pieces are large timbers, they should be incised before treating. Cut-off surfaces should be treated with a gelled or grease-type preservative.

2.1.4.9 Chocks. Chocks, which serve as bracing between piles, should be treated in the same manner as string pieces.

2.1.4.10 Decking. Wear from traffic is often stated as the cause for deck failure; however, surface decay is a frequent cause. Decking should be treated with an appropriate preservative. Creosote, creosote-coal tar solutions, or creosote-petroleum solutions are effective preservatives, but present a possible contamination problem from being tracked onto vessels. Salt treatments are effective, but may embrittle or promote accelerated wear of the deck surface. Solutions of pentachlorophenol in oil are effective, but they also may cause a pollution problem. Treatment with pentachlorophenol in liquefied petroleum gas should provide protection without the contamination problems, especially if a clean surface is specified in the procurement.

2.1.4.11 Fire Curtain Walls. Substructure fire walls or fire stops can be made of wood planking built up to a thickness of 6 inches and fastened to the bearing piles (Figure 2-6). Because these walls extend to the low water line, they should be treated with the same preservative systems as the piles. Also, each side of the wall should be protected by automatic sprinklers or by nearby openings in the deck through which revolving nozzles or other devices can be used to form an effective water curtain [2-3].

2.1.5 HANDLING OF TREATED WOOD. Treated wood components should not be handled with pointed tools or dropped so that their surfaces are crushed, gouged, or chipped. Those areas of treated piles that will be submerged in seawater should not be notched, dapped, or counterbored for bolt heads or nuts. Those areas of treated piles that will always be above water can be notched or dapped, but all surfaces exposed by these operations must be treated with an appropriate preservative specified by AWPA standards or Federal specifications. All bolt holes should be treated with a preservative containing a bolt hole treater (no longer

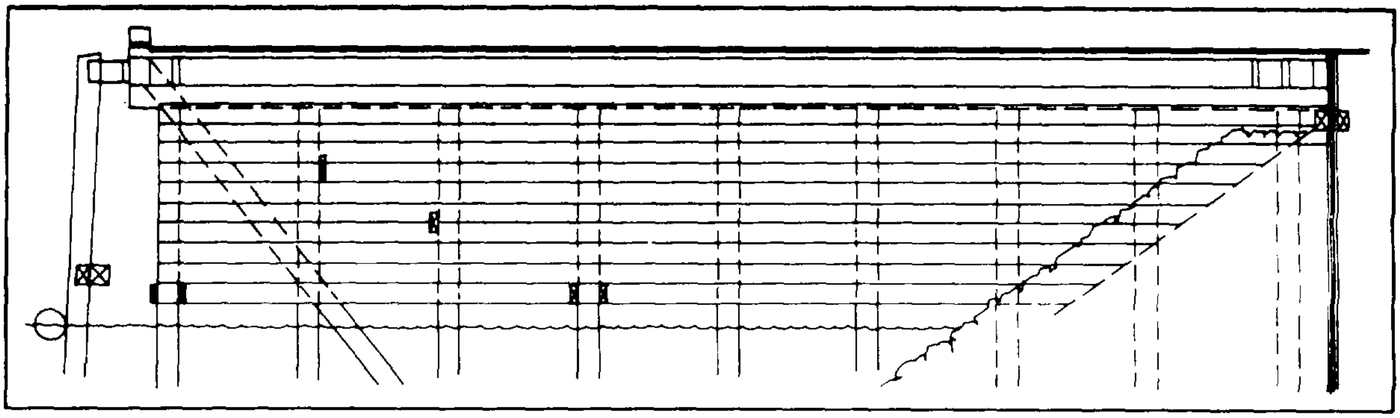

Figure 2-6. Fire-curtain wall.

manufactured) if one is available. Otherwise, a funnel with a bent stem can be used to pour preservative into the bolt hole. Any hole that is drilled, but then for some reason is not used, should be treated with the appropriate preservative and then stoppered by driving in treated plugs.

2.1.6 SEASONING CHECKS OR CRACKS. Seasoning checks or cracks often develop in treated wood before it is used. If they do, the affected timber should be placed in the structure so that water cannot flow into the check or crack and, thus, promote rot in the untreated heartwood. Seasoning checks or cracks in piles also provide entry for marine borers to the untreated heartwood and, thus, allow for rapid destruction of such piles.

2.1.7 HARDWARE. Bolts, washers, nuts, spikes, drift pins, and other hardware used in timber structures shall be heavily galvanized.

SECTION 2. INSPECTION

Investigation of wood structures is necessary to detect voids and other deficiencies before they become serious.

Observations should include:

(1) Losses of cross-sectional area
(2) Types of organisms present
(3) Location and extent of damage
(4) Defects (i.e., splits, checks, holes, or hollowed-out areas)
(5) Alignment problems
(6) Condition of fastenings and surrounding material
(7) Overall evaluation of the structure and "degree-of-hazard"

2.2.1 EXPOSED AREAS. Above the water line where fungus rot can occur, inspection consists of visual examination, sounding with a hammer, probing with a thin-pointed tool, such as an ice pick, and by taking a boring.

2.2.2 SUBMERGED SECTIONS. From the mud line to high water, assistance from divers is required. (See Reference 2-4.) Observation from a boat even in clear, shallow water is unsatisfactory. There are two ways to inspect wood underwater: visually and ultrasonically. Visual inspections require removal of fouling to make accurate estimates of damage. This is accomplished by divers using hand axes, scrapers, or pneumatic tools. Although the work proceeds slowly and is fatiguing to a diver, this method is the one most widely used. Some fouling removal has been done by blasting and by air-powered machines equipped with rotating brushes that move along the pile surface.

When the diver or activity determines the need to make additional investigations for internal voids, ultrasonic equipment may be used. Under "normal" conditions about 100 piles can be inspected in one day. It is not necessary to remove fouling from the piles if the fouling does not increase the pile diameter by 1 foot or more.

SECTION 3. MAINTENANCE

2.3.1 REPLACEMENT

2.3.1.1 Bearing Piles. Bearing piles that have lost more than 50% of their cross-sectional area or have been broken should be replaced. The existing pile should be pulled and a properly treated one driven in its place (Figure 2-7). When an existing pile cannot be pulled or broken off, it should be cut off as far down as possible, and the replacement pile should be driven alongside the stub, pulled into place under the cap, and fastened to it with a drift pin and with fish plates. A more satisfactory installation would be to cut off the old pile below the mud line and cover the stub with backfill once the replacement pile is driven.

2.3.1.2 Pile Caps. Decayed or damaged pile caps should be replaced with properly treated members as described in 2.1.4. Replacement caps shall be the same size and length as the original member unless redesigned.

2.3.1.3 Braces. Diagonal braces that have been attacked by fungi or marine borers or have been broken should be replaced completely rather than be spliced. After they have been drilled, bolt holes should be treated with a preservative. Where braces are fastened to a piling, the pile should not be cut or dapped to obtain a flush fit. Braces should be located well above high water. Where decking has been removed for repairs, it is often possible to drive diagonal brace piles to provide lateral stiffness. This procedure eliminates all bolt holes except those at the top of the structure immediately below the decking.

2.3.1.4 Stringers. Decayed or damaged stringers should be replaced with properly treated members. Replacement stringers should be tightly bolted to existing stringers which are to remain in the structure. Connections between replacement and existing stringers shall be made directly over a pile cap and they should be bolted or pinned to the pile cap. Decayed or damaged

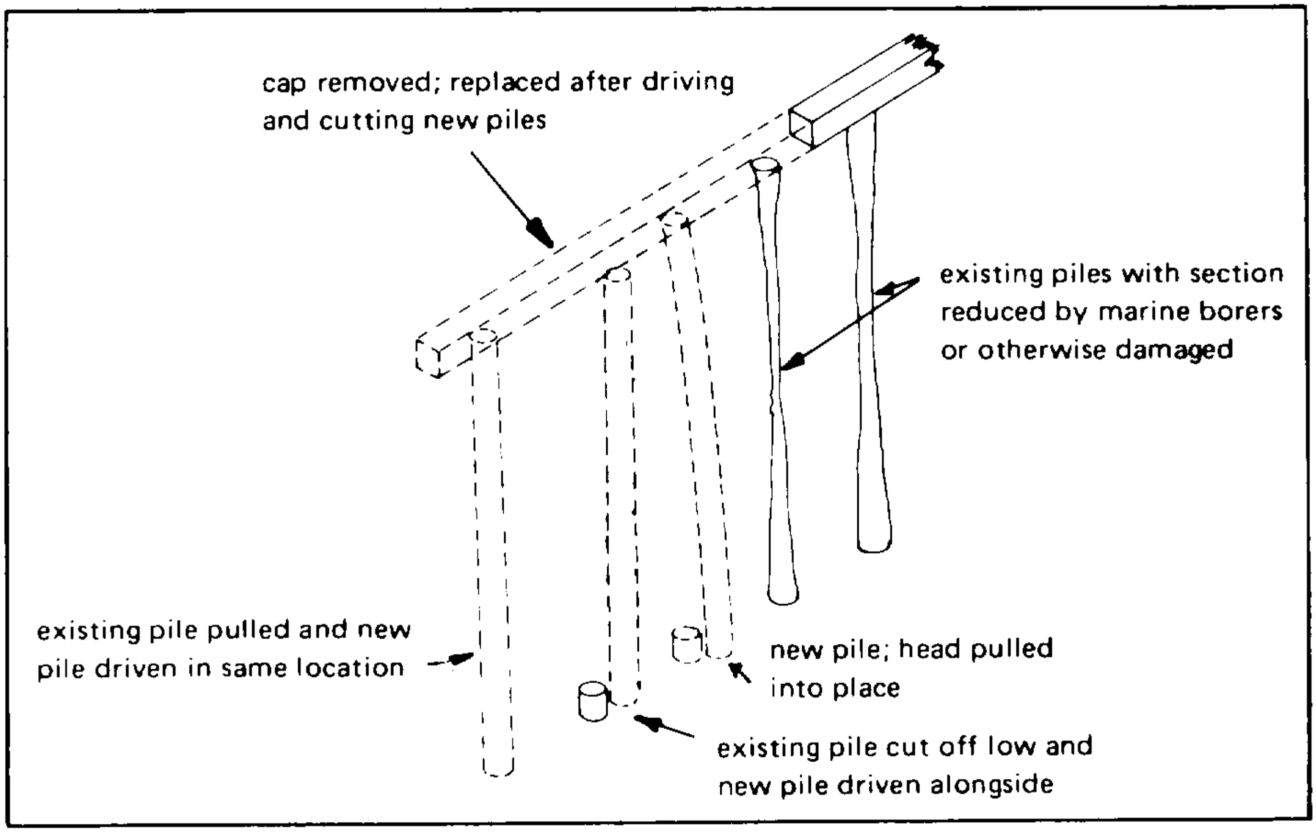

Figure 2-7. Wood pile replacement.

areas of long stringers can be removed and replaced with properly treated new sections. Again, splices should be made directly over a pile cap; splices in adjacent stringers should be staggered where possible. A typical splice is shown in Figure 2-8.

2.3.1.5 String Pieces. The string piece, sometimes referred to as the curb, bullrail, or backing log, is subjected to much wear and to constant wettings and dryings. Properly treated replacement sections should be long enough to reach between a minimum of two bents. New preservative-treated blocks, 2 to 3 inches thick, should be placed under each replacement section on 3-to-4-foot centers to provide for drainage. If any part of the lower string piece has deteriorated, the entire piece of timber should be replaced (see Figure 2-9).

2.3.1.6 Chocks. Deteriorated chocks should be replaced by properly treated, tightly fitting chocks that are bolted to one string piece or to a waler below the deck (see Figure 2-10).

2.3.1.7 Decking. Decking over which vehicular and pedestrian traffic passes should be replaced when its top surface becomes excessively uneven, hazardous, or worn to a point of possible failure. It should be replaced with properly treated quarter-sawn timber. Spacing between decking planks should be provided for ventilation and drainage. Decking for relieving platforms which have an earth fill should be laid in a double layer without spacing between the planks.

2.3.1.8 Fire Curtain Walls. Wood fire curtain walls are usually made of two layers of planking which run diagonally to one another. All deteriorated planks should be replaced to restore the wall to its original condition - as airtight as possible.

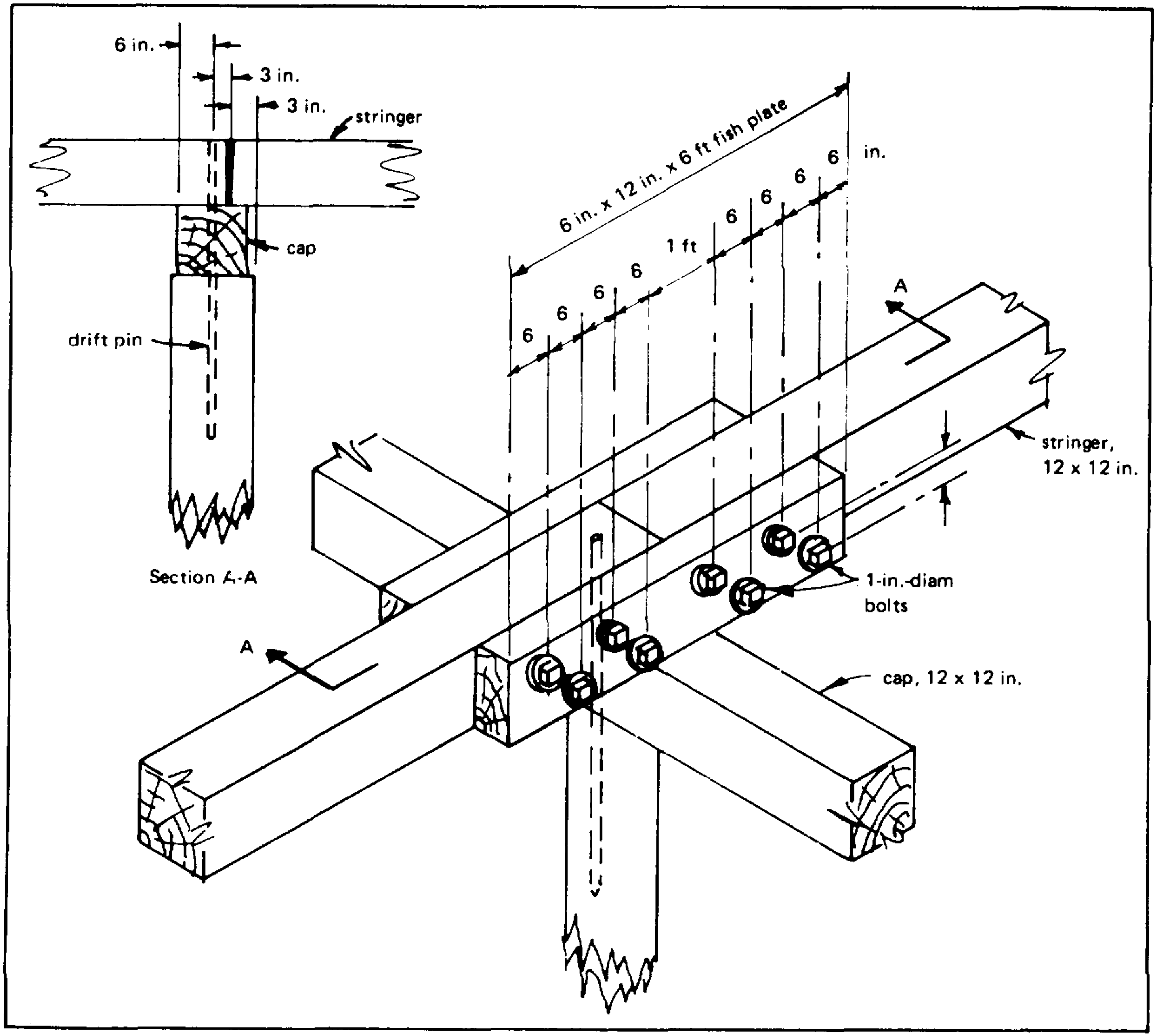

Figure 2-8. Stringer splice.

2.3.1.9 Fender Piles. Decayed, marine borer attacked, or broken fender piles that cannot be adequately repaired should be pulled and replaced with a properly treated new pile. Installation of a steel "shoe" on the outer (wearing) surface of each fender pile is recommended. Adequate camel logs should be provided.

2.3.1.10 Sheeting. Piers and quay walls may have wood sheet pile bulkheads to retain fill on the shore side. Deterioration of these bulkheads results in loss of fill and settlement of the material above the affected areas. In the early stages of deterioration, repairs can be made by using a plastic marine splash-zone compound, such as an epoxy-polyamide.

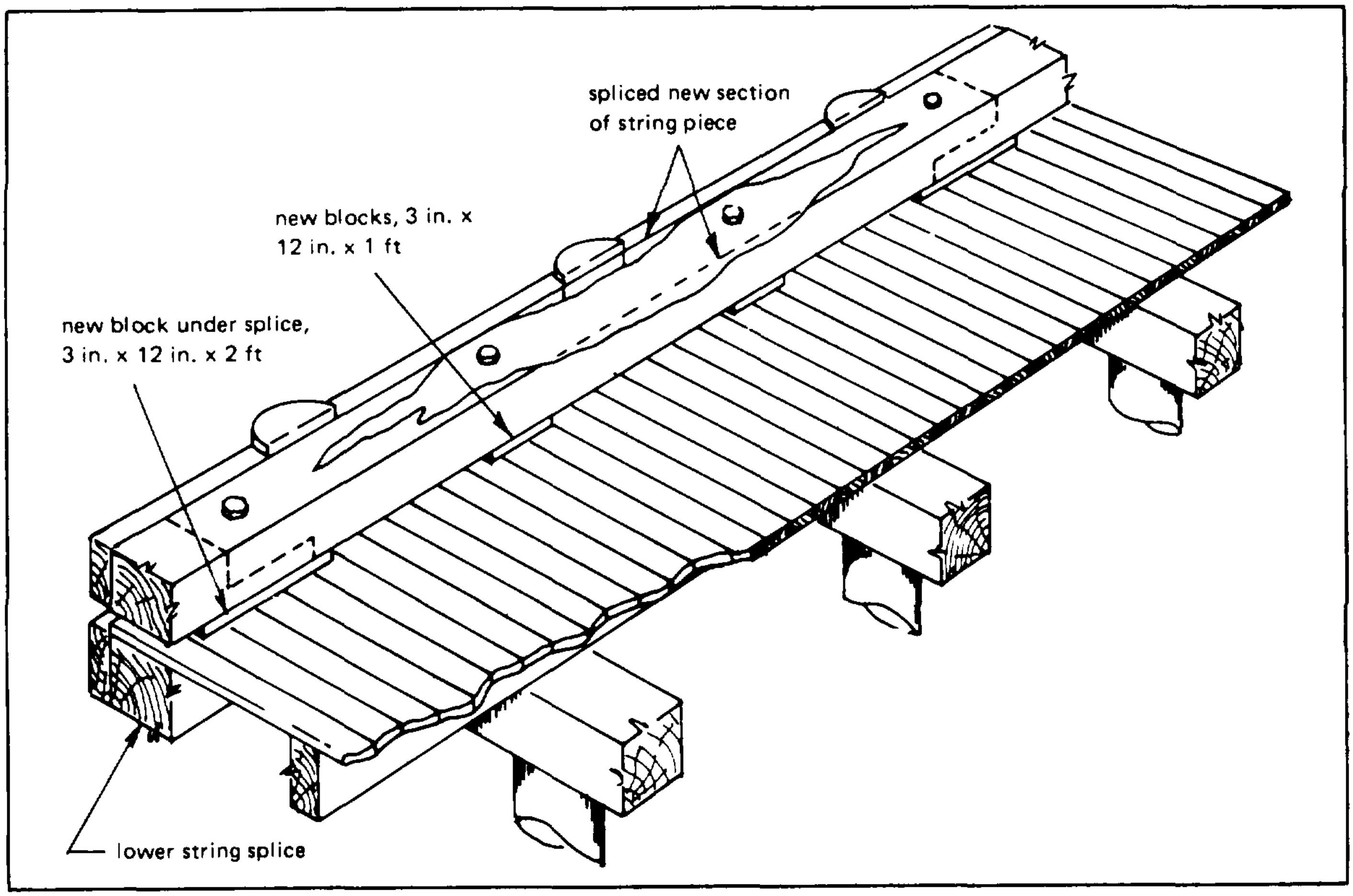

Figure 2-9. Repair of string piece.

When deterioration is more extensive, sheet piling is driven to form a new bulkhead a minimum of 1 foot behind the existing one in order to avoid the driving frames or wales attached to it. Steel sheet piling, driven to a minimum of 3 feet below the toe of the deteriorated wood sheeting, is normally used for the new bulkhead. The fill at the inside edge is normally removed before driving the new sheet piling. When this is done, a concrete cap should be placed over the new sheeting to form a seal with the existing construction.

2.3.1.11 Dolphins. The maintenance of timber dolphins includes the replacement of fastenings and any wire rope wrapping that has become defective through corrosion or wear. The maintenance of a catwalk that connects dolphins includes the replacement of damaged or deteriorated timbers; steel members should be cleaned and painted, or replaced. The repair of dolphins includes replacement or rehabilitation of piles, wire rope wrappings, and blocking. If it is necessary to replace any piles, the fastenings should be removed only as far

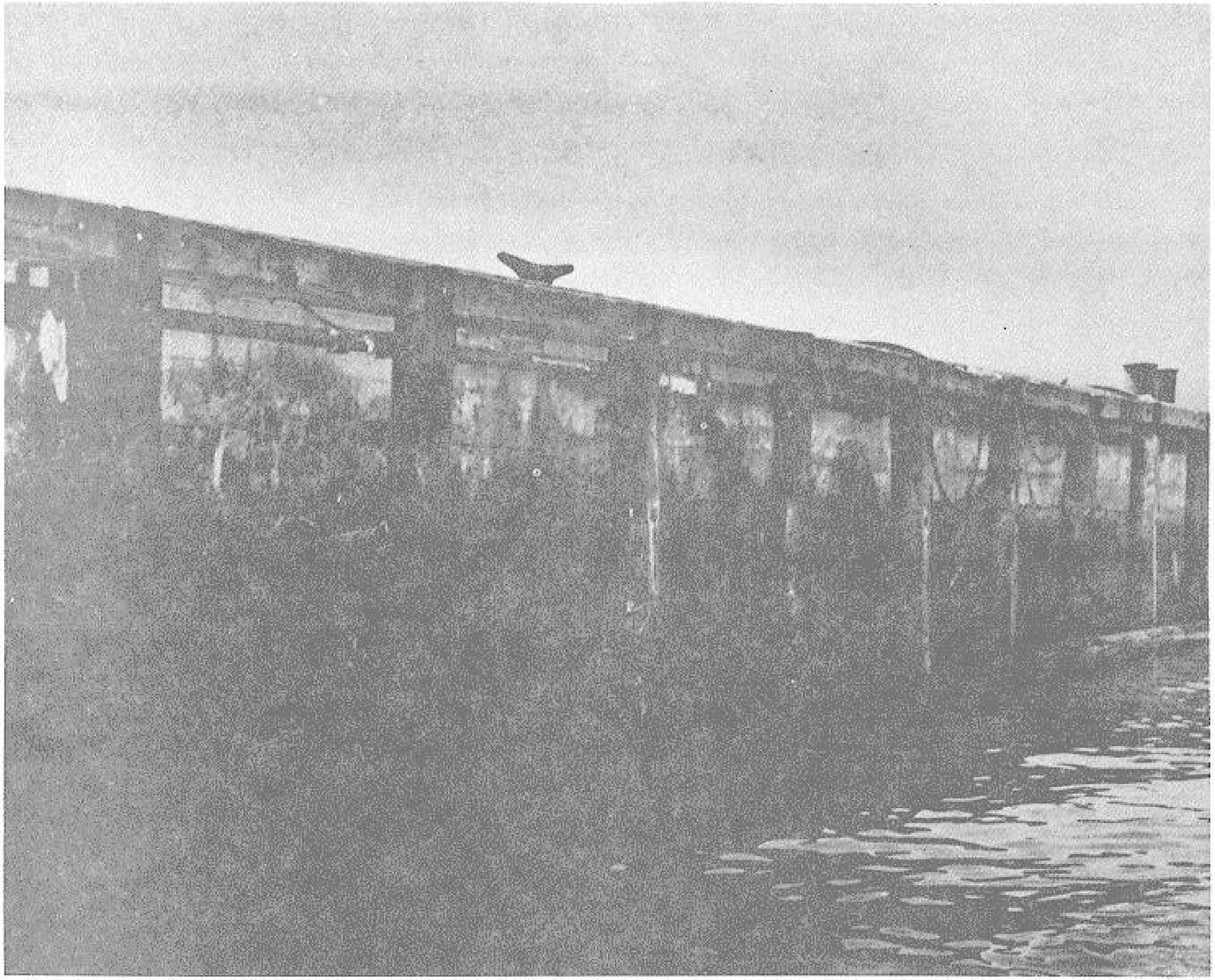

Figure 2-10. 100% deterioration of chocks, lower wales, and fender piles.

as is necessary to release the piles that are damaged. Care should be taken to drive the new piles at the proper angle so that they will not have to be pulled too far to fit them in place. The size of piles to be replaced should be carefully noted, particularly at the head or intermediate point where they are fitted together with the other piles. Much trouble in cutting and fitting the replacement piles can be avoided by selecting piles with the proper size head. All replacement piles should be driven before any are brought together. After all piles are driven, the center cluster should be brought together first, fitted, chocked, bolted, and pinned; when all rows have been properly fitted, etc., they are then wrapped with wire rope. All cuts in piles for fittings, bolts, and wrappings should be thoroughly field-treated with creosote. These cuts should be avoided if at all possible, however, because field treatment with creosote gives only marginal protection against marine borer attack.

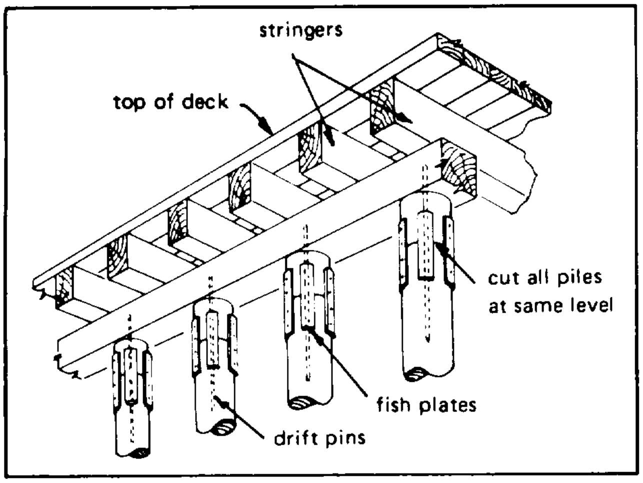

Figure 2-11. Replacing tops of piles.

2.3.2 REPAIR

2.3.2.1 Decayed Bearing Piles. The decayed top of a wood bearing pile can be repaired by cutting off the damaged portion and fumigating the exposed cut-off to destroy any remaining hyphal threads. A section of sound timber is installed and secured with epoxy cement or drift pins and fish plates to build the pile to the proper height (see Figure 2-11).

2.3.2.2 Marine-Borer-Damaged Bearing Piles. Wood bearing piles that have lost 10 to 50% of their cross-sectional area can be repaired by any of several methods.

2.3.2.2.1 Flexible Barrier. When a diver or ultrasonic inspection reveals that a pile has lost approximately 10 to 15% of its cross-sectional area because of marine borer attack, a flexible PVC barrier may be installed (Figure 2-12). An in-place barrier not only prevents further attack on a pile, but it also creates a stagnant area between it and the pile surface, thus killing organisms already present on or within the pile. In this method, the pile is sheathed with a prefabricated unit consisting of a 30-mil PVC sheet with a full-length, half-round apitong wood pole piece attached to each vertical edge. Lengths of flexible polyurethane foam, 1/2 x 3/6 inch, are stapled about 1 inch from the upper and lower horizontal edges. When only the intertidal area is to be sheathed, the PVC wrap is placed around the pile, and the pole pieces are fitted together with one inserted into a pocket attached to the bottom of the other. The excess material is rolled on the combined pole pieces and tightened around the pile with a special ratchet wrench. Aluminum alloy nails are driven through the rolled material and the pole pieces to secure the wrap initially. Then rigid plastic bands are nailed at the top and bottom directly over where the polyurethane foam is located under the wrap. Additional bands are installed on equidistant centers between the top and bottom bands. For protection extending to the mud line, approximately 12 inches of soil is excavated around the pile, and the wrap is placed around the pile, lowered into the excavated area, and secured as above. Then the excavated area is backfilled with soil. When it is necessary to wrap a pile that has creosote bleeding from its surface, a sheet of polyethylene film is stapled to the pile surface prior to installing the PVC wrap. (Creosote will soften and swell PVC, but it does not affect polyethylene.)

2.3.2.2.2 Concrete Barrier. When a diver or ultrasonic inspection reveals that a pile has lost approximately 15 to 50% of its cross-sectional area because of marine borer attack, a reinforced concrete barrier may be installed.

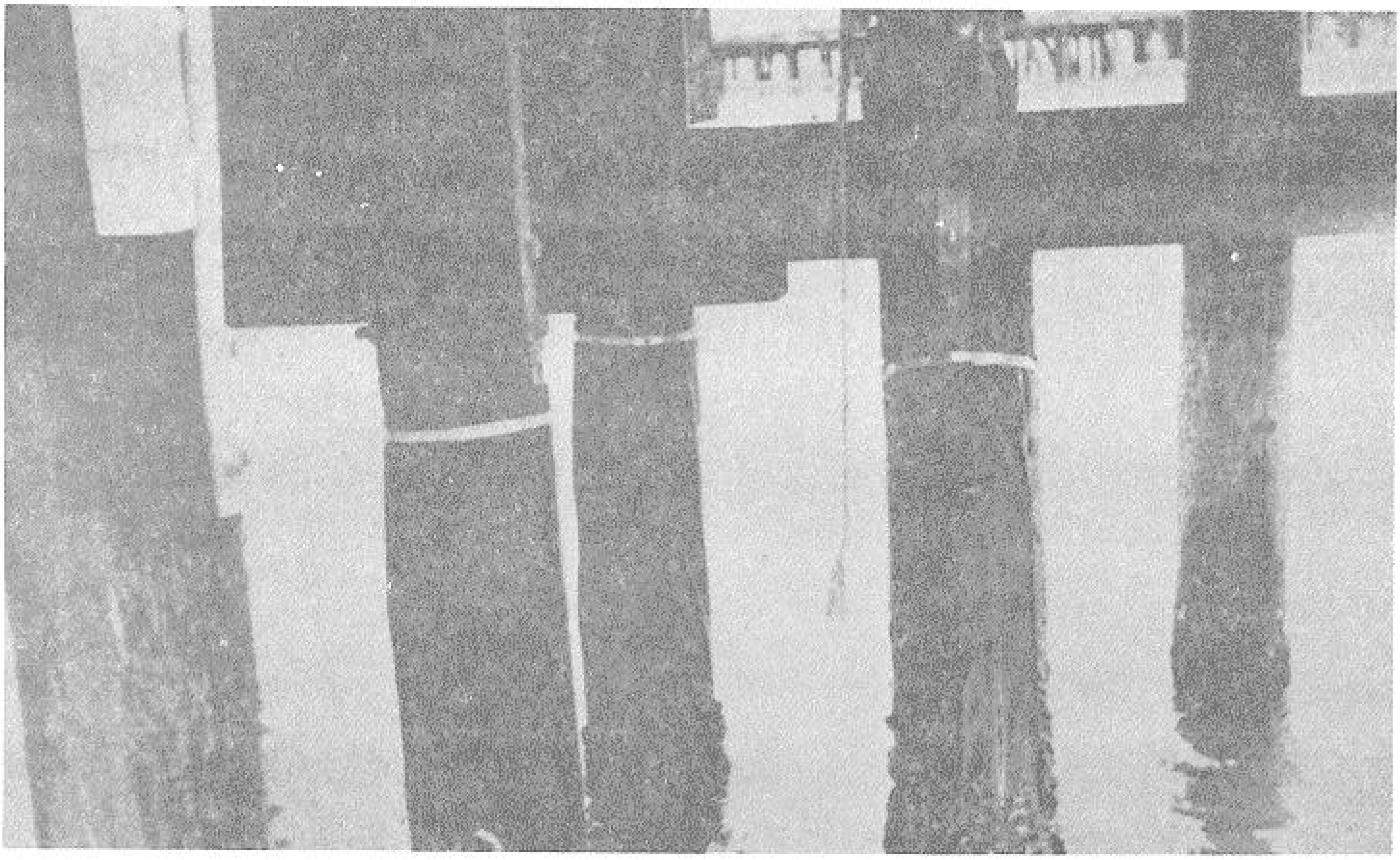

Figure 2-12. A flexible PVC barrier installed on wooden piles.

Various types of metal, nylon mesh, and pitch-impregnated fiber tube forms can be used. Two very important requirements for installations of this type are (1) a tight bottom seal between the form and the pile, and (2) a grout-dispensing pipe that extends to the very bottom of the form so that seawater within the form can be pushed up and out by the rising column of pumped-in grout.

Another system uses a reinforced plastic jacket which is placed to within 1/8 inch of the pile surface. A two-component resin mix is prepared, an equal part of fine sand is added, and this mortar is poured slowly into the void to replace the water.

2.3.2.2.3 Replace Section. Replacement of damaged wood pile sections with a reinforced concrete pile section can be accomplished as follows: soil is excavated at the mud line, the damaged pile is cut off where undamaged wood is present, and the section is removed from the structure. In one patented method, a specially designed, partly reusable form is clamped to the pile stub and to the pile cap. Grout is pumped through a hose connected to a nipple in the lower form clamp and is continued until the grout reaches the pile cap. When the concrete has set, the upper and lower form clamps are removed, and the expendable form tube is left in place.

2.3.2.3 Braces. A diagonal brace, which extends into the water and has been lightly attacked by marine borers, can be saved by (1) removing the bolt which secures it to the pile, (2) wrapping the freed end with 20-mil flexible PVC sheet in a manner similar to applying electrical tape to a cut-off wire, (3) driving the bolt through the wrapping and through the existing hole, and (4) rebolting the brace to the pile.

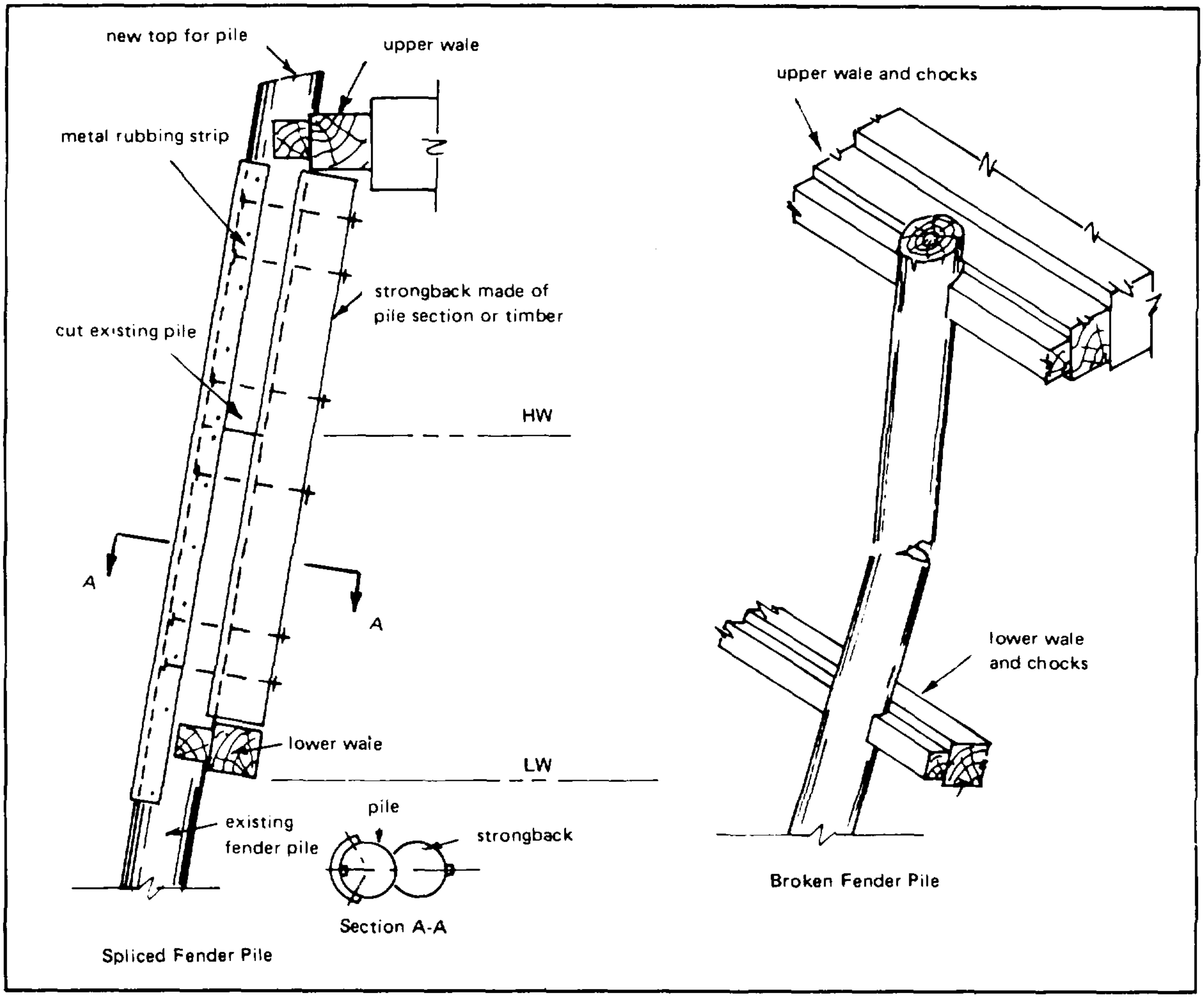

Figure 2-13. Fender pile repair.

2.3.2.4 Fender Piles. Fender piles that have been broken between the top and bottom wales can be repaired by cutting off the pile just below the break, installing a new section of pile, and securing w; n epoxy cement. A strongback (pile or timber section) is fitted and bolted in place directly behind the fender pile and between the top and bottom wales. A metal "shoe" (wearing strip) should be attached to the wearing edge of each fender pile (see Figure 2-13).