CHAPTER 8
MAINTENANCE AND REHABILITATION

Section I. TIMBER PILES

8-1. Damage and deterioration.

Both untreated and treated piles are subject to deterioration and damage by decay, termites, marine borers, mechanical forces, and fire. Steps should be taken to insure that piles will remain durable in semipermanent or temporary structures. Untreated timber piles entirely embedded in earth and cut off below the lowest groundwater level, submerged in freshwater, or frozen into saturated permafrost soils are considered permanent. The lowest groundwater table should not be higher than the invert level of any sewer or subsurface drain existing or planned, nor higher than the water level at the site resulting from the lowest drawdown of wells or sumps. Percolating groundwater heavily charged with acids or alkalies can destroy piles. The following subparagraphs describe the most destructive forces on piles.

a. Decay. Decay is caused by fungi which penetrate the wood in all directions. Fungi feed on the wood, which breaks down and rots (figure 8-l). The probability and rate of decay depend on several factors.

(1) *Species.* Timber piles which are naturally durable have a useful life for many decades.

(2) *Preservatives.* Untreated timber piles that are alternately wet and dry may last from five to ten years, whereas treated piles will last from 10 to 20 years.

(3) *Temperature.* Timbers which last several years *in* temperate climates may last less than a year in tropical conditions.

(4) *Dampness (permanent or intermittent).* All timber piles will remain free from decay if the water content is kept below 22 percent. The decay is rapid if the pile is alternately wet and dry. Such a situation may exist in a waterfront structure where the tide causes large changes in the water level. On semipermanent structures on land, damage is caused by lowering the water table during the life of the structure.

(5) *Oxygen.* Wood-rotting fungi cannot develop without a supply of free oxygen.

b. Termites. Timber piles in warm climates are subject to attack by subterranean

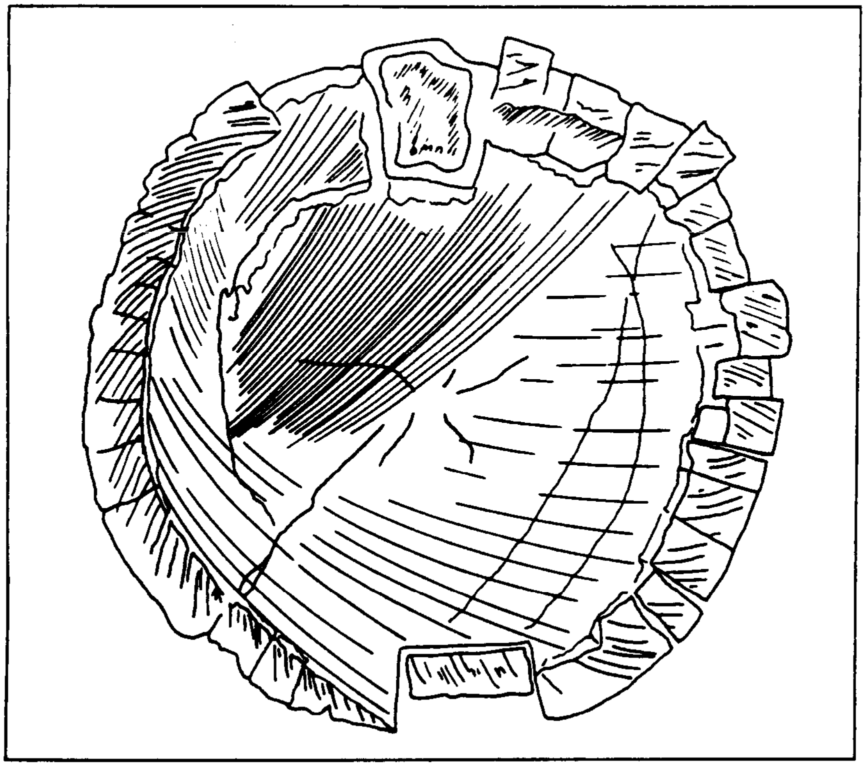

Figure 8-1 Decay of untreated timber pile

termites. Termites are active through the tropics and subtropics in both wet and and regions. Some species occur in the warmer parts of temperate countries—for example, in southern France—but they are not found in the colder parts of these regions. Termite activity is very destructive. In the tropics, timber piles in contact with the ground may be destroyed in a few weeks unless they are from a species resistant to termites.

c. Marine borers. Marine borers rapidly destroy untreated wooden structures in salt water (figure 8-2). In the tropics they can do severe damage in a few months unless the timber is one of the few resistant species such as greenheart or turpentine wood (see appendix). In temperate climates, attack is generally slower and sporadic. Except for certain resistant species, timber piles are likely to be destroyed in a few years.

d. Mechanical forces. Timber piles in waterfront structures or bridges are damaged by abrasive action between the mud line and the water or, in some cases, even above the high waterline. Wear can be caused by floating craft, drifting objects, ice, and wave or current action which scour the pile surface with pebbles or coarse sand.

e. Fire. Timber piles, especially if creosoted, are extremely susceptible to destruction by fire.

8-2. Preventive measures.

a. Basics. Protection against wood-destroying organisms can be obtained by selecting naturally resistant timber species (see appendix) or by applying preservative treatments. Natural resistance applies only to the heartwood. Sapwood, even of very

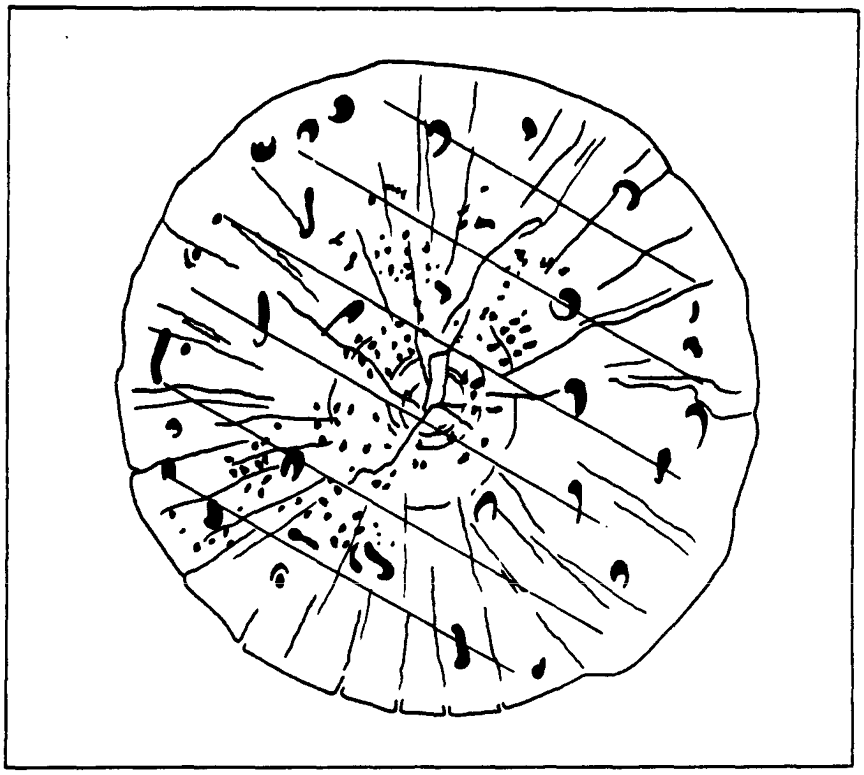

Figure 8-2 Marine borer damage to timber pile

durable species, is rapidly attacked by wood-destroying organisms. It is better, particularly in the tropics, to use preservative treatment rather than to rely on natural resistance.

b. Protection from decay and insects. The most effective prevention against decay is by applying creosote or other treatment to poison the food supply of insects. Charring the surface of the timber when practicable may provide protection against termites.

c. Protection from marine borers. Leaving the bark intact on untreated piles affords some protection. Bark adheres best to timber which is cut in the fall or winter. Creosoting will afford protection for five to ten years against some species of marine borers. With other species, it is necessary to encase the pile in concrete or sheath it in copper throughout With the activity zone (mud line to the high waterline).

d. Protection from mechanical forces. Pile fenders and dolphins are widely used to protect pile foundations against floating objects. Pile sheathing may be used to protect against damaging erosion.

e. Protection from fire. The danger of fire may be reduced when designing large waterfront structures by dividing the facility into unite with fire walls or bulkheads which extend from the underside of the deck to a level below the low waterline. On permanent structures, foam extinguishers should be installed.

8-3. Preservative treatment.

The life of timber piles is greatly lengthened by treatment with preservatives. Creosote oil

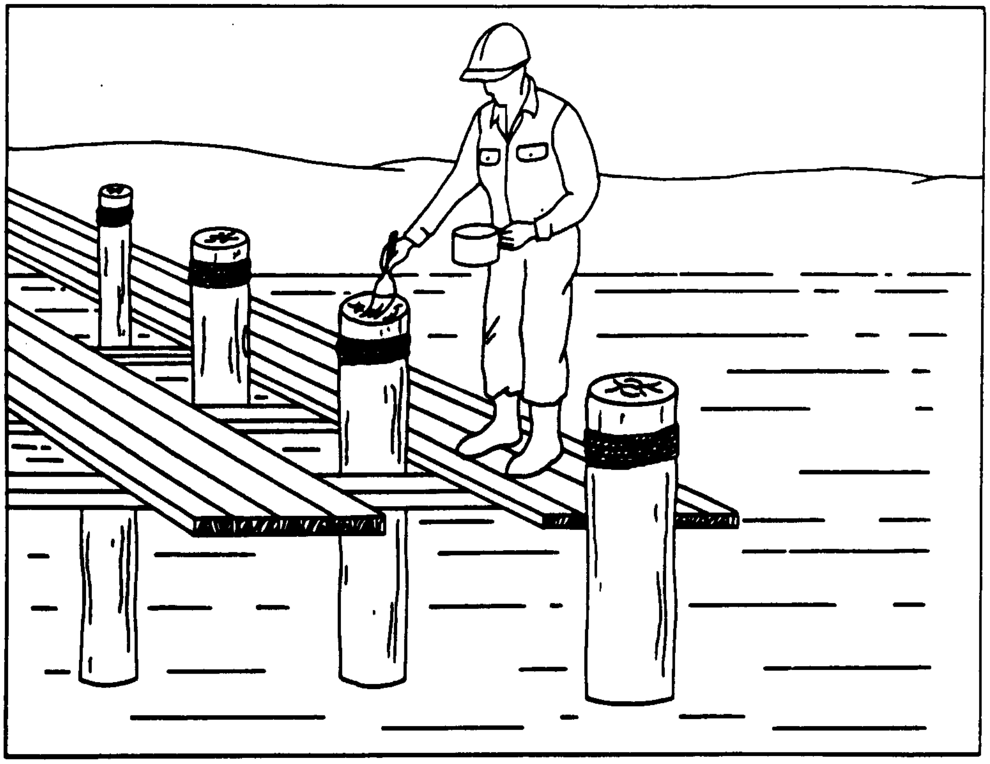

Figure 8-3 Brush application of preservative to cutoff ends

is the most satisfactory material for treating timber piles and is most likely to be available in military situations. Various other chemicals, such as copper sulfate and zinc chloride, are poisonous to animal life. Since most of these chemicals are soluble in water, they leach out, rapidly losing their protective effect.

a. Application. Wherever possible, all piling, as well as other timber members, should be treated at a preservative plant, normally located alongside a sawmill, before being dispatched to the site on which they are to be used. Piles intended for preservative treatment should have all of the outer bark and at least 80 percent of the inner bark removed. Remaining strips of inner bark should not be more than ¾-inch wide nor more than 8 inches long.

b. Handling. Care must be taken in handling treated timber to minimize the disturbance of the treated surface. The effectiveness of the treatment depends on keeping the creosoted surface unbroken. Timber hooks, pile poles, and the like are not used on treated timbers. If the surface must be punctured or cut, as in notching to apply a brace, protection is partly restored by mopping on two or more coats of creosote oil at a temperature between 175° F and 200°F. Methods of applying preservatives are the brush and pressure methods.

(1) *Brush method.* The least satisfactory method of treatment is the brush method (figure 8-3), in which the preservative is liberally applied like paint. The preservative penetration obtained by this method is slight. Some improvement over the brush

method is obtained by dipping the pile into hot creosote.

- 'The chief use of hand applications is in treating cuts or borings made on treated members during fabrication of a structure. Such cutting should be avoided as much as possible, since it is important that an unbroken shell of preservative be maintained for adequate protection. Any cuts that cannot be avoided should receive careful attention.

- Particular attention should be given to the protection of butt ends of treated timber piles when they are cut off. If the butt is to be exposed at the cutoff, as in fender piles, the end of the pile may be protected. The cutoff end should be brushed liberally with two coats of hot creosote oil, followed by a heavy coat of coal-tar pitch (figure 8-3). Protection is increased by applying two or three layers of pitch-soaked canvas coated with sealing compound. It is desirable to renew the protective coating every year by two heavy applications of hot creosote.

- Treated piles that are to be capped stir cutting should be protected by application of hot creosote oil and tar pitch. It is desirable to place a sheet of heavy roofing paper or a metallic cap over the butt of the pile before placing a timber cap.

- Where treated piles in a foundation are cut off before receiving a footing, the cutoff should be given two heavy coats of hot creosote oil, allowing sufficient time between applications for absorption.

(2) *Pressure method.* The most satisfactory and enduring treatments are those carried out in plants with equipment for pressure processes. Specifications normally require a 12-pound retention of creosote per cubic foot of wood. Considerable equipment is required. The method is not described because it is impractical for military operations. Pressure-treated piles should be used for all marine construction and wherever possible in deliberate construction.

8-4. Concrete encasement.

Effective protection can be provided by encasing timber piles in concrete, usually by grouting the annular space between the pile and a section of pipe. Precast concrete jackets have been designed and used for permanent installations. Concrete jackets have also been formed by shooting concrete (guniting) on timber piles, either before or after driving. The protective coating is generally from 1½ to 2-inches thick and reinforced with wire mesh. Protection provided to the pile is excellent.

8-5. Sheathing.

Metallic sheathing is effective only if it is free from holes. The protection provided is not permanent. Metal casings are sometimes used around piles. The pile is prepared and driven, and the metal casing is slipped down around the pile after the driver has been removed. The space between the pile and the casing is then filled with concrete. For timber sheet piles, a layer of tar paper sealed with mop-coated bituminous material and protected by a wood sheathing placed over the face of the piling. A thick coating of bituminous material is effective as long as the coating remains intact. This protection may last for hasty construction in water infested by marine borers. A longer-lasting method is to wrap the pile with burlap or tar paper over the coating and add another coating.

8-6. Periodic inspection.

Periodic inspection of pile foundations after installation is important. Damage detected early can be more easily and economically repaired than later. For temporary waterfront structures, inspection of the piling down to the low water level may be sufficient. For important, permanent structures, inspection down to the mud line should be made by divers or by pulling a pile. The effects of marine borers should be watched carefully since deterioration may proceed very rapidly once they have entered the pile. Deterioration due to other causes may be accelerated by borer damage. With some types of borers, damage can be detected only by cutting the wood. In such cases, it is valuable to drive a pile like that used in the structure a short distance below the mud line. It may be pulled and inspected periodically.

Section II. STEEL PILES

8-7. Damage and deterioration.

The life of steel piles is generally not a matter of concern in temporary military structures. When a structure of longer life is involved or exposure conditions are severe, the load-carrying capacity and useful life of a steel pile may be reduced by corrosion or abrasion.

a. Corrosion. Corrosion is caused by the tendency of metals to revert from their free state to the combined form in which they normally occur as ores. It is caused by a difference in potential between two points on a conducting material in the presence of an electrolyte. In the case of a steel pile, the anode is the corroding surface; and the interior portion of the metal is the cathode. Corrosion may also be caused by sulphate-reducing bacteria which are widely distributed in soils and natural waters. The rate of corrosion vanes sharply with the soil, depth of embedment, water content, or the nature of the water in which the pile may be immersed.

- Steel piles in contact with undisturbed soil below the groundwater level will not be subject to significant corrosion.
- Steel piles are subject to corrosion only when extending through fresh water polluted by industrial wastes which contain large amounts of corrosive acids.
- Deterioration of steel piles in seawater can be rapid when waves spray salt deposits on the piles. The zone of most active corrosion lies between the low-tide and high-tide levels.
- Steel piles are subjected to rusting when exposed to the air at the ground line and for several feet beneath the ground surface.

b. Abrasion. Corrosion is accelerated by abrasion caused by waterborne sand or gravel which is agitated by tidal action. Abrasion alone is not a serious problem, except that when it damages the protective covering of the pile, corrosion proceeds more rapidly. Timber cladding offers temporary protection.

8-8. Preventive measures.

a. Bitumastic surfacing. It is often desirable to provide a protective coating over a portion of a steel pile. Paints used on structural steel generally do not provide sufficient protection under severe corrosive conditions. Some special paints, when available, are used with greater success. Coal-tar pitch or a bitumastic paint (hot or cold) is applied to the active zone before the pile is driven. The portions exposed to the air are maintained like other steel structures. The success of surface coating depends upon keeping the protective surface intact. If any cracks or pinholes are left in the coating, heavy corrosive attack may occur at such points. The surface must be prepared, and the material applied evenly and completely.

b. Concrete encasement. Positive protection against severe corrosion, particularly where abrasion is a contributing factor, can be provided by encasing a steel pile in concrete

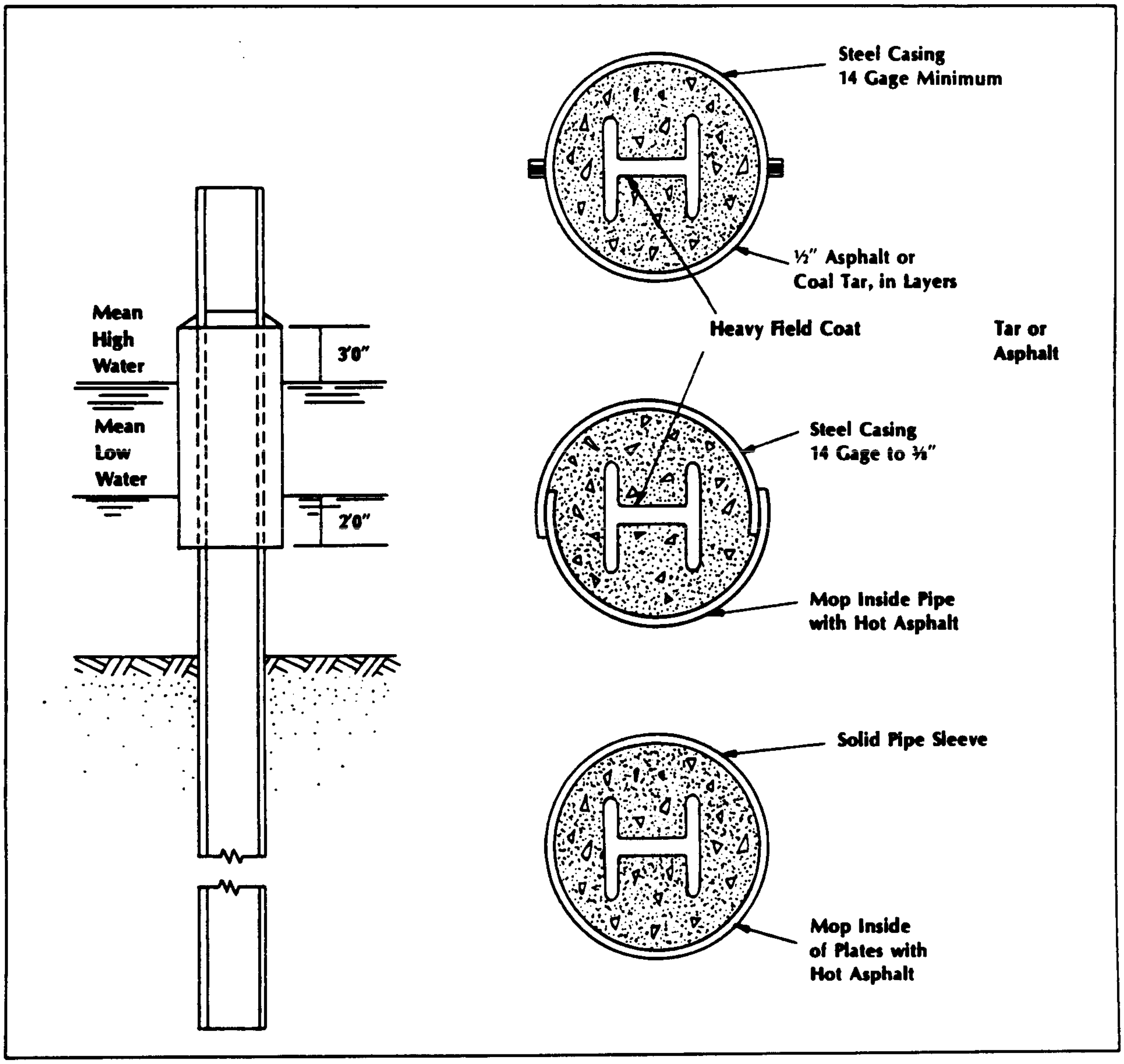

Figure 8-4 Typical concrete encasements of steel piles

over the length under the greatest attack. Poured concrete encasements are used most often (figure 8-4). A metal form is placed around the pile over the desired length of protection, and the form is filled with dense concrete. Protection is from 2 feet below mean low water to 3 feet or more above mean high water. The metal form may be left in place, thus providing additional protection. Many other schemes have been used to form a concrete jacket around steel piles on permanent and important structures. Details of these methods are beyond the scope of this manual.

c. Other measures. For temporary structures where severe corrosion is expected, an obvious solution is to increase the size of steel piles. If piles are designed as columns, working stresses used in the design may be reduced in anticipation of future reductions in sections caused by corrosion, thus achieving a similar result. Cathodic protection, if used correctly, will solve many corrosion problems; however, it is seldom practical in military structures.

8-9. Inspection.

Steel piles which form a part of a permanent structure should be inspected periodically, particularly in waterfront structures. Careful attention must be given to the zone where the most severe corrosion is likely to occur to detect damage as early as possible and to apply remedial measures. If a protective coating or concrete encasement is used, its condition should be checked periodically to make sure that it continues to fulfill its intended function. Inspection to low water may be adequate in many cases; in other cases, inspection by divers should be earned out to the mud line. As with timber piles, it may be desirable to pull a pile for inspection.

Section III. CONCRETE PILES

8-10. Damage and deterioration.

Groundwater may contain destructive acids, alkalies, or salts which damage concrete. High concentrations of magnesium or sodium sulphate salts are particularly destructive. In humid regions, moisture penetrates the portion of the pile exposed to the air and causes the steel reinforcement to rust and the concrete to span on the surface. Alternate thawing and freezing accelerates deterioration as water in the voids or cracks in the concrete freezes, creating an expansive force which furthers cracking and spalling. Occasionally, concrete piles in salt water are damaged by rock-boring mollusks (pholads), similar to marine borers that attack timber piles. The greatest damage to concrete piles is caused by the rusting of the reinforcement steel and consequent cracking and spalling of the concrete. Prestressed piles tend to be more durable, as tension cracking is minimized.

8-11. Preventive measures.

Deterioration and damage are most pronounced in piles of poor quality concrete. Generally, difficulties do not arise if a dense, impervious concrete mix is used and if the steel reinforcement is provided with an adequate (2 to 3 inches) cover of concrete. Careful handling and placing of precast piles will avert excessive stresses and subsequent cracking. When concrete piles are subjected to abrasion, metal shielding or timber cladding is used in the area of greatest exposure.

8-12. Periodic inspection.

As with other types of pile foundations, a careful watch should be kept for signs of deterioration, particularly for spalling of the concrete and deterioration of the reinforcing steel.

Section IV. REHABILITATION

8-13. Considerations.

Pile foundations may be destroyed or damaged by deterioration or explosive action in a tactical situation. In either case, it is necessary to evaluate the situation and determine what to do. Most discussion in this section applies to all types of piles. Evaluating factors are as follows.

- Is the pile foundation capable of supporting the loads anticipated without rehabilitation?
- If the pile foundation has a limited capacity, what load limits can it carry without damage to the foundation?

- Has the load-carrying capacity of the pile foundation been reduced so seriously that its satisfactory use is impractical? In such a case, it may be possible to repair the existing piles or drive new piles.

8-14. Evaluations.

The objective of an evaluation is to obtain all information possible to evaluate the load-carrying capacity of the foundation and to determine the most efficient rehabilitation procedures. Attention should be given to the number and type of piles; size and alignment external damage, such as the twisting or breaking from explosive charges; deterioration which may have taken place in the areas of critical exposure; and underlying soil conditions. Examine the remaining portions of the superstructure, classify it, and calculate the loads for which the superstructure was originally designed. If the original design followed good engineering practice for the materials, construction, and design load, the piles are assumed to be able to carry loads for which they were designed, less the effects of damage or deterioration. Details for this process are contained in FM 5-36 and TM 5-312 for bridges and in TM-360 for port and harbor structures. This estimate is appropriate for buildings unless they are unusually heavy structures.

8-16. Replacement and repair.

Five procedures are used in replacing and repairing foundation piles.

a. Replacing damaged piles. If a wharf, pier, or span can support the weight of a pile driver, several floor planks are removed; and the new piles are placed and driven through the hole. When an entire bent is replaced, it is capped and wedged tightly against the existing stringers.

b. Adding bents above the waterline. Timber piles damaged or deteriorated above the high waterline can be cut off level and capped with a trestle bent to attain the elevation of the old stringers.

c. Using concrete extension piles. Another method of rehabilitating timber piles damaged above the waterline is to cut off the damaged pile, shape the butt end (tenon), and add an upper concrete section.

d. Using cutoff and splice. Upper portions of damaged or deteriorated piles may be repaired by cutting them off level and splicing them. When long, unsupported timber piles are spliced with timber, the bending strength at the splice usually is much less than that of the unspliced pile. A stronger splice can be obtained with a reinforced concrete encasement. To make this type of splice, four 6-inch straps are bolted across the splice joint to hold together the two sections of timber pile. The ends of ten to twelve 6-foot reinforcing steel bars (¾ inch) are bent, and the bars are placed longitudinally across the splice joint. The ends are driven several inches into the pile. A cage of No. 10 wire mesh (4 inches x 6 inches), the same length as the unbent portion of reinforcing bar, is fastened to the bars. Five or six turns of wire are fastened to the top and bottom of the cage and stapled to the pile. A sheetmetal form is then placed around the reinforcement for 5 inches of concrete encasement around the splice. Bituminous material is used to seal the joint between the concrete encasement and the pile after the form is removed (figure 8-5).

e. Reconstructing damaged concrete piles. Damaged portions of concrete piles may be cut off with the original reinforcing bars extending above the concrete cutoff level. Forms are placed, reinforcement is added, and the piles are extended to the necessary level as described in chapter 2, section IV.

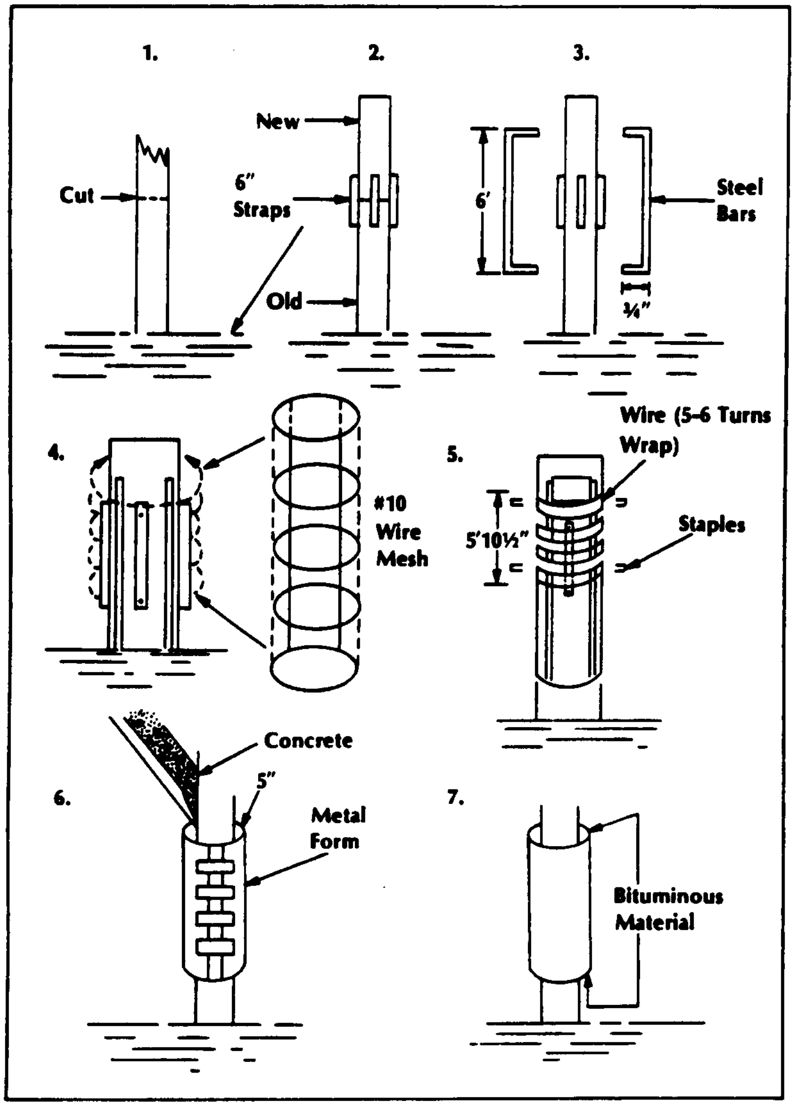

Figure 8-5 Timber splicing using reinforced concrete