CHAPTER 5 - RUBBLE-MOUND STRUCTURES

SECTION 1. STRUCTURAL COMPONENTS

5.1.1 MOUND. A mound is an artificial embankment or ridge composed of sand, gravel, and cobbles, constructed on the oceanic floor by dumping the material from scows and barges. The dumping operation continues until the mound emerges a certain distance above the mean seawater level. Wave action on the mound gives the sides a natural stable slope. Since wave action decreases as the oceanic depth increases, the natural side slopes of the mound normally are steeper in deeper water; this is a function of top elevation of the mound, bottom configuration, and tidal range. Rubble-mound structures are used extensively, because they are adaptable to most any depth of water in the vicinity of harbors and can be repaired readily. If the oceanic floor is not rocky, rubble can protect the floor against scouring that otherwise might occur at the foot of the mound.

5.1.2 RUBBLE. Rubble is irregularly shaped, rough stones, ranging in size up to 1,000 cubic feet each and in weight up to nearly 90 tons each. The stones are in the same condition as when quarried but without any preparation (i.e., dressing) other than removing very sharp angles and any objectionable protruding points. Hard rock, which is more desirable, usually consists of either granite or traprock (fine-grained igneous rock). Limestone, dolomite, and sandstone are undesirable because of their lesser hardness, toughness, and durability.

Since the rubble used as riprap must be available in large sizes, the quality, condition, and shape of stone are important. Each piece should be devoid of planes of weakness, have a specific gravity not less than 2.6, and have excellent resistance to abrasion and weathering. Massive, compact, fine-grained igneous rock is the best source of rubble.

5.1.3 RIPRAP. Riprap is a mixed assemblage of rubble, either dumped indiscriminately (as a foundation for the waterfront structure) from scows and barges or deposited on the surface of a mound to protect the mound against erosion by waves and scouring by tidal action and underwater currents. Where it can be procured in large quantities at low cost, riprap can be useful as a filter blanket over a sandy bottom, as fill behind moles and quaywalls, and as protection for the sloping sides of mounds. Riprap submerged en masse weighs no more than earthen fill and rests at a steeper slope (approximately 1-1/4 to 1) than does earth.

The riprap in older breakwaters consists of large cubical or rectilinear blocks of quarried stone. Since 1950, a number of precast concrete armor units have been developed; the prevalent types are tetrapods, tribars, and dolosse (Figure 5-1). Smaller concrete armor units can often be substituted for larger quarry stones and still obtain comparable protection of the

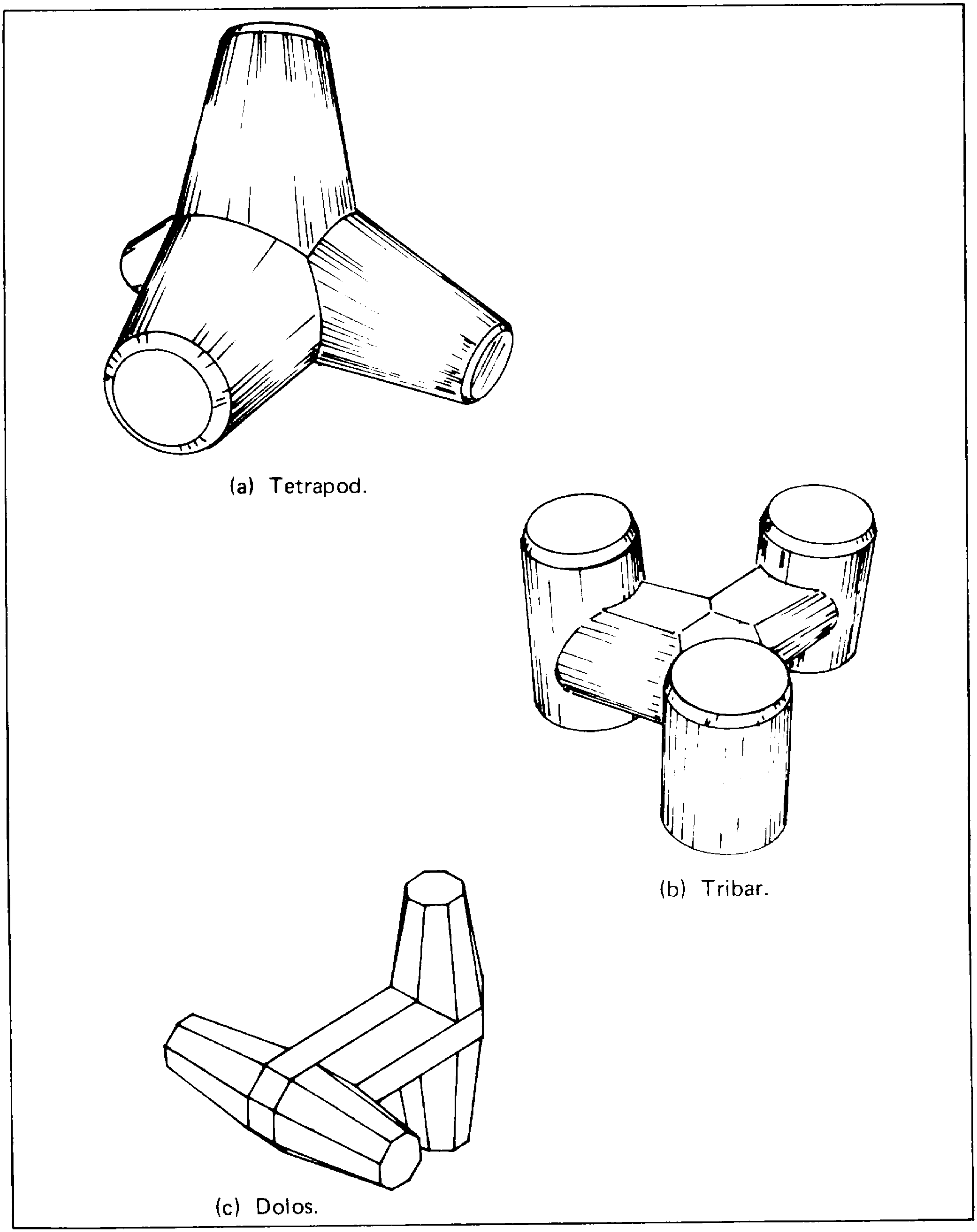

Figure 5-1. Concrete armor units.

mound of rubble. No reinforcing steel or steel lifting eyes are used in dolosse and tetrapods; consequently, corrosion is not a problem, and unit cost is minimized. Dolos and tetrapod units are less vulnerable to damage during placement and storms than the various other types of concrete armor units. The Army Engineer Waterways Experiment Station considers the dolos armor unit the most efficient [5-1].

SECTION 2. CAUSES AND TYPES OF DETERIORATION

5.2.1 TYPES OF DAMAGE. The three principal types of deterioration in rubblemound structures are: (1) sloughing of side slope in the riprap, (2) slippage of base material as the result of scour by offshore currents, and (3) dislodgment of stones, especially capstones covering the crown of the structure, from their original position as the result of intense wave action.

Scour at or near the base of a rubblemound structure does not normally occur if the structure is correctly designed and the floor is stabilized by means of a properly designed filter blanket and ample riprap. However, if one or more groins should be subsequently installed at incorrect locations nearby, then radical changes in currents and their velocities could adversely influence the base of the structure.

5.2.2 STRUCTURAL DAMAGE.

5.2.2.1 Seawall. A seawall can suffer loss of riprap; this successively leads to erosion, by subsequent wave action, of the toe of the structure and later to undermining of the base.

5.2.2.2 Groin. Correctly designed, located, and constructed groins seldom undergo damage by wave action, because the littoral drift tends to fortify the structures (Figure 5-2). Ideally, the shoreline remains stable as long as the rates of deposit and erosion are equal. If the erosion rate the deposition rate, the shore decreases in area, and the groin is then subjected to gradual destruction.

5.2.2.3 Breakwater. Breakwaters are often subjected to extreme wave action that dislodges riprap and washes out portions of the mound. During violent storms, sections of a breakwater can occasionally be broken through. A typical rubble-mound breakwater is shown in Figure 5-3.

5.2.2.4 Jetty. Jetties are designed to direct the flow of currents and tides through the entrance channel so as to ensure a minimum velocity. Though to all outward appearances they may be satisfactorily sustaining the pressure, the flowing water can gradually scour the base material on the channel side and eventually cause either subsidence of a portion of the jetty or sloughing of the riprap comprising the side slopes.

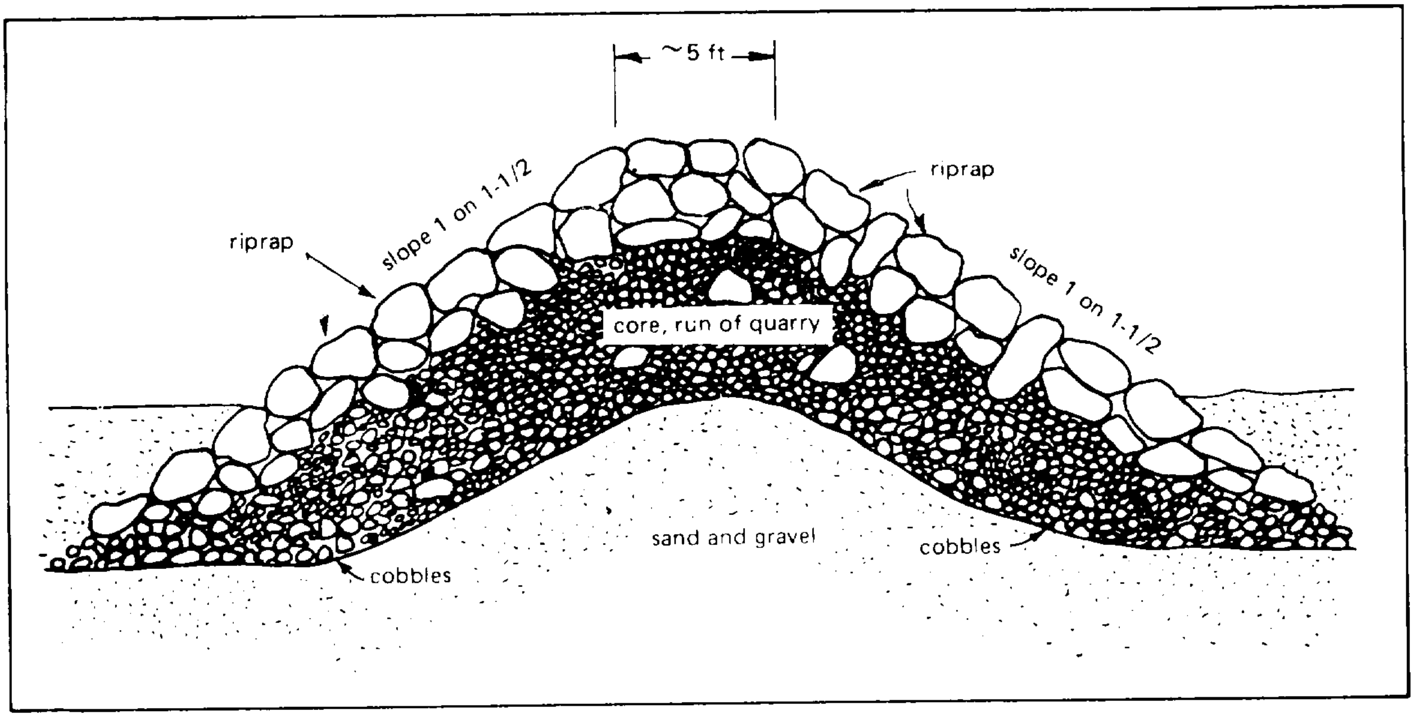

Figure 5-2. Cross section of semipermeable rubble-mound groin.

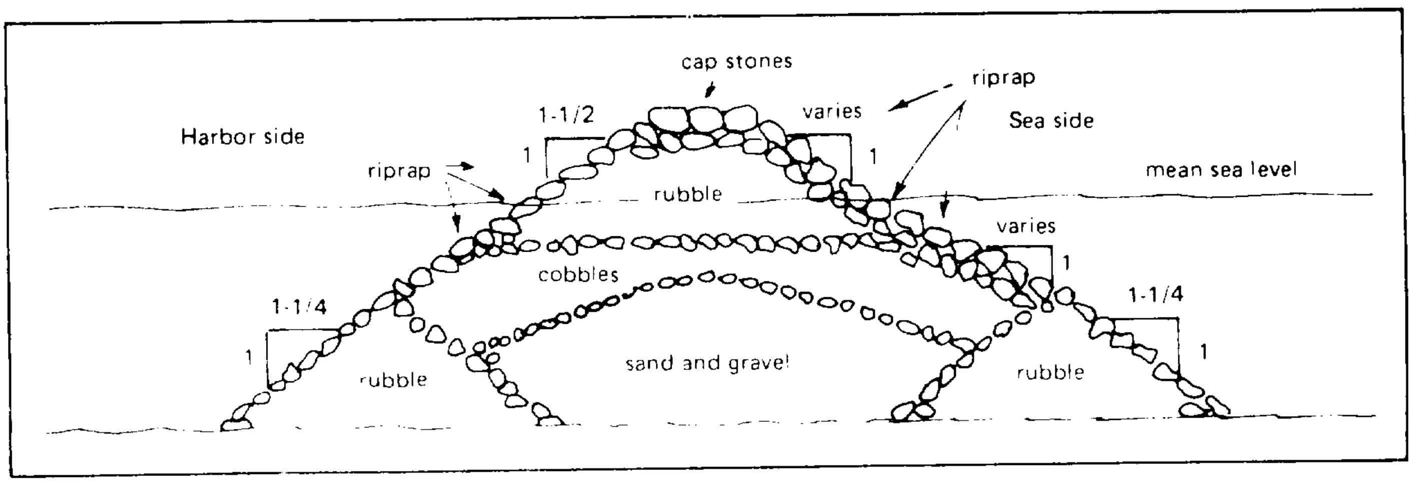

Figure 5-3. Rubble-mound breakwater.

SECTION 3. INSPECTION

Rubble-mound structures are always subjected to wave action and, consequently, to deterioration. The inspection should provide for detecting beginning weaknesses in the bases of these structures (e.g., washout of small stones in the riprap and any core material in the mound).

5.3.1 COMPONENTS. The crown of a rubble-mound structure is inspected visually on foot; the portions above water level are inspected visually from a dinghy or small craft; and the portions below the water line are inspected by divers or underwater TV cameras. The intended depth of the structure is determined from the design drawings; the as-built depth should be compared with depth data obtained by soundings taken at stations that are located at equidistant intervals. As much of the structure as possible should be inspected at low tide. If scouring or sloughing is apparent an engineering investigation should be initiated. The inspection by the divers when tidal conditions and wave actions permit may be able to verify the indicated deficiency or damage. Underwater television can be effective as a visual means of inspection, but is frequently negated by turbulence, suspended sediment, or inability of the operator at the surface to maneuver the apparatus readily.

5.3.2 DRAINAGE. A rubble-mound mole requires proper drainage of backfill to prevent a pressure differential. Visual inspection of the surface of the backfill will reveal any discrepancies concerning drainage. Dredging alongside a rubble-mound mole must be restricted to depths not greater than contemplated in the original design. If any portion of the base becomes undermined (e.g., dredging too closely to the riprap) the structure is likely to slip and fail. If the backfill in either a mole or seawall shows evidence of settling (e.g., cracking and cave-in of paved surface) as illustrated in Figure 5-4, the condition of the backfill should be investigated to determine whether or not either improper surface drainage or loss of backfill through the riprap is the cause. Stabilization of the backfill, either by replacing the lost fill with properly graded material in the filter blanket and in the core or by careful grouting, may correct the problem (see Chapter 6). After stabilizing the backfill, all defective pavements should be repaired to prevent any erosion of the underlying backfill.

SECTION 4. METHODS OF REPAIR

5.4.1 AS-BUILT DRAWINGS. Drawings showing the construction as actually built, rather than as originally designed, should be used in preparing plans for repair of rubblemound structures. All drawings and records pertaining to any previous repairs should be reviewed before undertaking new repairs.

5.4.2 REPLACING COMPONENTS. Maintenance on rubble-mound breakwaters is greater than on any of the other types. Proper grading of the seaward slope and

Figure 5-4. Cave-in, indicating settlement of mole.

use of the correct classes of stone for core and capping will, to a great extent, minimize the amount of annual maintenance required. Any material lost through scouring and washing must be replaced periodically with materials of the same kind and size as used originally. Adjustments in seaward slope may be necessary. Material should not be replaced to the original slope if investigation shows that a change is in order. A change in the type of capping material also may be necessary with the passage of time, and use of concrete tetrapod, tribar, or dolos armor units may improve the structure. If large facing and capping stones are set in a tight pattern, the vertical joints between the stones may need venting (by leveling the corners of individual stones) to permit entrapped air and water to escape. This reduces the lifting action beneath the stones and improves their stability.

The replacement of riprap (after replacement of any material washed out of the mound) should either retard or prevent further scouring. If the scour is produced only by wave action, the problem can be solved by fortifying the toe of the structure with a thick layer of riprap which serves to stabilize the bottom; the rubble must be carefully emplaced so that the smaller stones become wedged in the spaces between the larger stones. Units weighing less than 1 ton each should constitute about 15% (by weight) of the additional riprap, and the maximum weight of each of the larger stones should approximate 3 tons. The minimum dimension of any stone should be at least one-third of its maximum dimension.

If the scour is caused by offshore underwater currents, installation of groins at strategic locations along the shoreline may be necessary. If the bottom is scoured so extensively that the stability of the structure is endangered, an underwater groin consisting of very heavy rubble may be effective in deflecting the underwater current; in such an installation, the groin is designed to accumulate waterborne material so that the floor around the foot of the structure builds up and serves as a stabilizing influence.

Rubble-mound breakwaters, jetties, and seawalls occasionally are repaired by adding crushed stone to the crowns and seaward slopes and grouting the new surfaces. Repairs of this type, which must be made in stages because of tides, must produce a thick (3 feet or more) protective layer or blanket of grouted stone. Figure 5-5 illustrates the general scheme of repairs.

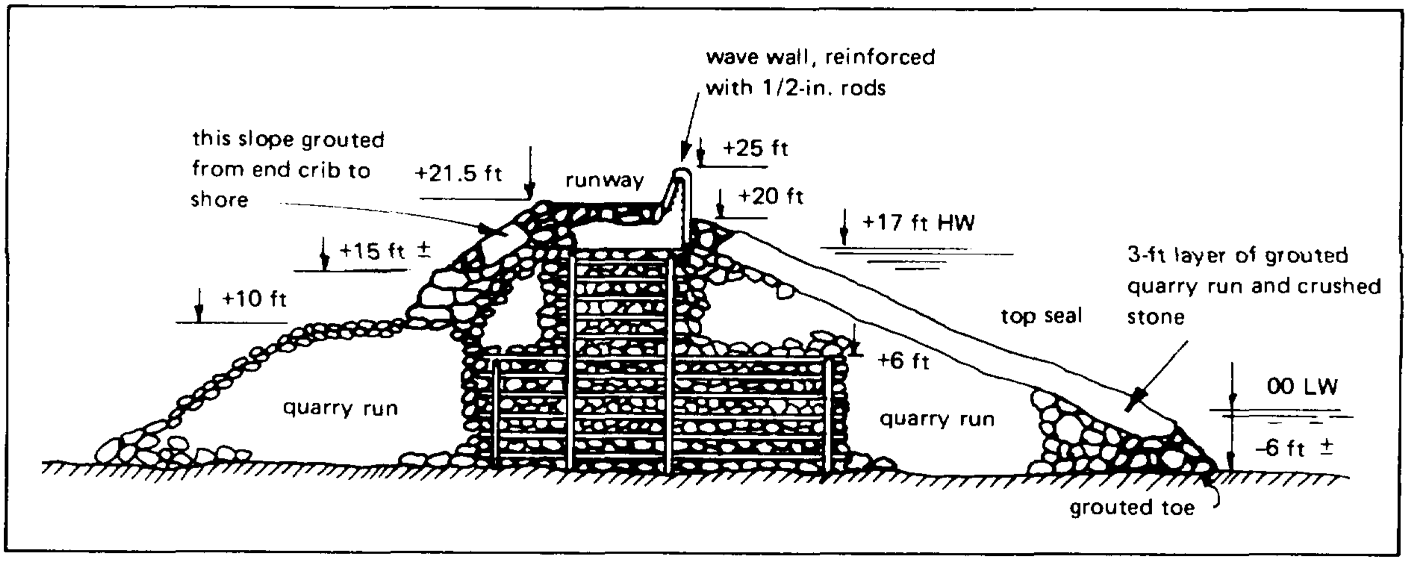

Figure 5-5. The grouted sheathing of face of a breakwater, which is exposed to storms.