CHAPTER 3

LAYOUT OF HARBOR FACILITIES

3-1. Harbor entrance.

a. Location and orientation. The following factors in the location and orientation of harbor entrances should be considered:

(1) *Water depth*. Locate the harbor entrances in an area where the natural water depth is adequate for passage of the largest ship.

(2) *Sheltering*. Locate on the lee side from most severe storm waves, and between overlapping breakwaters.

(3) *Channeling external disturbances*. Location and orientation will direct any external wave disturbances to areas of the harbor remote from locations of berthing and anchorage areas.

(4) *Navigation.* Navigation through the entrance should be easily accomplished. In particular, locate so that there will be strong beam currents in the harbor entrance at all tidal stages.

(5) *Littoral drift.* Orientation should prevent the entrance of littoral drift into the harbor. Where possible, the entrance will be located in an area relatively free of littoral drift.

(6) *Multiple entrance.* Where possible, provide two entrances with different exposures, which can be used as alternates depending on the direction of the wind. Multiple entrances are advantageous in wartime, since they make the harbor more difficult to block. Double entrances also reduce the velocities of the tidal currents because of the increased area.

b. Channel entrance width. Provide minimum channel entrance width consistent with navigation needs. The approximate requirements of channel entrance width related to size of vessel to be accommodated are as follows:

Harbor classification	*Width of entrance, ft*
Medium Vessel	300 to 500
Large Vessels	600 to 1,000

(1) *Entrance*. Except in unusual circumstances, a width of 1,000 feet is ample for very large container vessels, and under favorable conditions of entry, a width of 800 feet may be considered.

(2) *Secondary entrances*. For secondary entrances, or those not to be used by large ships, a width of 300 feet may be considered, provided that entrance conditions are favorable.

(3) *Currents*. Entrance widths should be adequate to reduce currents to acceptable values. The maximum allowable current in the entrance channels is a function of the type of ship or ships to be accommodated. Except under special circumstances, current is not to exceed 4 knots. The maximum velocity of the tidal current through the entrance channels may be estimated from equation (3-1).

$$\mathbf{V} = \frac{4}{5} \times \frac{p}{T} \times \frac{A}{S} \times \mathbf{H} \qquad \mathbf{(3\text{-}1)}$$

where

V = maximum velocity of the tidal current occurring at the center of the opening, feet per second
T = period of the dice, seconds
A = surface area of the harbor basin, square feet
S = cross-sectional area of openings, square feet
H = range of the tide, feet

The tidal current in midchannel is about one-third stronger than that at each side.

(4) Discharge of upland drainage. Entrance widths must be adequate to discharge the accumulated upland drainage without exceeding the maximum permissible current value given in paragraph (3) above.

(a) The maximum velocity of the current resulting from discharge of a given flow may be roughly estimated from equation (3-1) by substituting the rate of upland drainage to be discharged for the quantity AHIT.

(b) The total current velocity in the entrance due to tidal influence plus runoff may be obtained by adding the value obtained from equation (3-1) and corrected for quantity AH/T.

(5) Reduction of incident wave height through entrance. Although the model tests will give a more accurate picture of wave conditions, the wave height within the harbor can be approximated from the following equation:

$$\mathbf{h} = \mathbf{H}\left[\sqrt{\frac{b}{B}} - 0.02\sqrt[4]{D}\left(1 + \sqrt{\frac{b}{B}}\right)\right] \qquad (3\text{-}2)$$

h = height of the wave at location 'X", feet
H = height of the unrestricted wave at the harbor entrance, feet
b = width of the entrance, feet
B = breadth of the harbor at location "X", feet (this being the length of the arc with its center at the harbor entrance center and radius D)
D = distance from harbor to location "X", feet

Reduction of wave height through the entrance may be predicted more accurately by using diffraction and refraction diagrams. For the construction of diffraction and refraction diagrams, refer to Shore Protection Manual, Vol. I (app A).

3-2. Breakwaters.

a. Locations and alinement. A breakwater is normally the most costly single item required for the harbor development. Special care is required to minimize the length and height. The following factors in the location and alinement of breakwaters shall be considered:

(1) *Minimum height*. Locate the breakwater in the shallowest water consistent with harbor area requirements.

(2) *Flank protection*. Join headlands and rock outcrops to natural abutments on shore to prevent flanking.

(3) *Foundation conditions*. Where there is a choice, locate the breakwater along hard or sandy bottom, avoiding locations with poor foundation conditions.

(4) *Channeling incident waves*. Aline so that the refraction and reflection of incident waves are away from the entrance and toward the shore.

(5) *Sheltering entrance*. Stagger the breakwater head on the weather side of the entrance with respect to the breakwater head on the lee side (fig 3-1). This arrangement will minimize the risk of a ship being blown against the lee breakwater head. This configuration improves the entrance conditions and increases sheltering in the harbor.

(6) *Alinement.* Avoid a concave shape or one with reentrant angles, as entrapped waves will cause major disturbance in such areas.

(7). *Seiche*. If the occurrence of a seiche appears likely, realine the breakwater to reshape the harbor basin or provide structures for dissipating wave energy.

b. Types. There are two main types of breakwaters, the mound type and the wall type.

(1) *Mound-type breakwaters*. These types of breakwaters are generally constructed from natural rock, concrete block, a combination of rock and concrete block, or concrete shapes such as tetrapods, quadripods, hexapods, tribars, modified cubes, and dolosse. The mound type may also be supplemented in each case by concrete monoliths or seawalls to break the force of the waves and to prevent splash and spray from passing over the top.

(2) Wall-type breakwaters. These breakwaters can be classified as concrete-block gravity walls, concrete caissons, rock-filled sheet-pile cells, rock-filled timber cribs, or concrete or steel sheet-pile walls. The type of breakwater to be used is usually determined by the availability of materials at or near the site, the depth of water, the condition of the sea bottom, its function in the harbor, and the equipment suitable and available for its construction.

3-3. Jetties.

a. Function. Harbor jetties function to prevent the movement of littoral drift into the entrance channel and are required in the case of natural harbors located in estuaries, in rivers, in lagoons, or other areas where sandbars or other offshore accumulations or silt and debris must be cut through for navigation channels; to ensure the required water depth.

b. Location and alinement. The factors influencing location and alinement of jetties are as follows: (1) Number required. Use two jetties where feasible. Where funds are limited or other restrictions apply, one jetty in the updrift side may be used.

(2) *Length.* Jetties shall line the entrance channel through the offshore bar and extend a sufficient distance past to reach the required water depth with allowance for assumed silt accumulation.

(3) *Cleansing velocity*. Current flow through the entrance channel shall be adequate to scour and remove silt accumulations. Where the natural current is inadequate, use offshore jetties to restrict the channel to reach the cleansing velocity.

(4) *Silting*. Where possible, orient the jetties perpendicular to the clittoral drift.

(5) *Anchorage.* Anchor the jetty on shore to prevent flanking.

c. Form. The forms of jetties are as follows: (1) Parallel jetties. Use this form where the harbor entrance is not the mouth of a river having a pronounced flow or where the configuration of the existing, natural estuary indicates a prolongation in the form of parallel walls.

(2) *Divergent jetties.* Use this form in tidal estuaries or in lagoon inlets where ebb and flood flows are about equal. Under this circumstance, there is a tendency for a parallel channel to silt up due to the reduction in volume of the influence tide. The slope of the divergence shall be limited to about 2,000 feet per mile so that a bore will not be created.

(3) *Convergent jetties.* Use this form in lieu of parallel jetties where the attenuation of waves incident on the harbor entrance must be promoted by lateral expansion; that is, where the run-in is not adequate or where the wave traps are insufficient or undesirable.

3-4. Anchorage basins.

a. Location and size. The factors affecting the location and size of anchorage basins are as follows: (1) Isolation. Locate the anchorage basins near the entrance, away from channels, out of traffic, and in

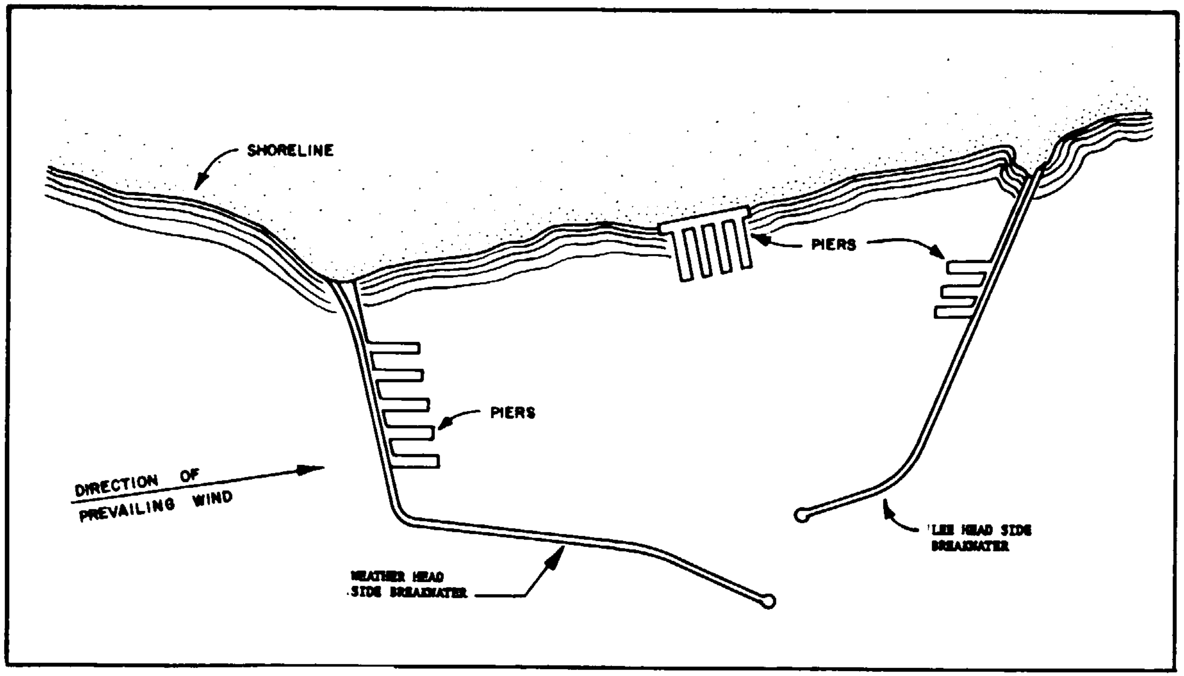

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Figure 3-1. Use of offset breakwater heads to shelter entrance.

shelter. The area shall be isolated, insofar as possible, from attack by surface or subsurface craft.

(2) *Depth*. Locate in an area of sufficient natural depth to minimize dredging.

(3) *Currents.* The area shall be free from strong currents.

(4) *Accessibility of shore facilities*. The area shall be accessible to fresh water, fuel, and other shore facilities.

(5) *Foundation conditions*. Where possible, locate over a bottom of loose sand or gravel, clay, or soft coral. Avoid locations where the bottom consists of rock, hard gravel, deep mud, and deep silt.

(6) *Subaqueous structures*. Anchorage areas should be free of cables and pipe lines and cleared of wrecks and obstructions.

(7) *Expansion*. Provide for future expansion.

(8) *Size*. See chapter 2 for approximate overall size and depth requirements. Use free swinging moorings where the available area will permit. Where the available area is limited, use fixed moorings or moorings in which the swing of the vessel is restricted. Various types of moorings are discussed in TM 5-360 (app A).

b. Dangerous cargo. Anchorages for tankers and similar vessels will be at least 500 feet from adjacent berths, and located so that prevailing winds and currents carry any spillage away from general anchorage and berthing areas. For vessels carrying explosives, the anchorages will be separated in accordance with the criteria established in DoD 4270.1-M (app A).

3-5. Berthing basins.

a. Location. The wave height in the berthing basin should not exceed 2 feet for comfortable berthing, but in no case will the wave height exceed 4 feet. The factors influencing the selection of the location of berthing basins are as follows: (1) Protection. Locate berthing basins in harbor areas that are best protected from wind and wave disturbances in areas remote from the disturbances incident upon the harbor entrance.

(2) *Orientation.* Orient berths for ease of navigation to and from the entrance and the channel.

(3) Offshore area. Provide sufficient offshore area for ship movement, preferably without use of tugs.

(4) *Quayage adequacy*. Adequate quayage shall be provided for the estimated traffic.

(5) *Supporting shore facilities*. Locate supporting shore facilities in proximity to their respective berths. Adequate space and access for roads and railroad facilities are essential.

(6) *Expansion*. Provide area for future expansion.

(7) *Fouling and borers*. Locate berthing basins in harbor areas to minimize fouling conditions and incidence of marine borers.

(8) *Foundations*. Locate foundations in an area of favorable subsoil conditions, to minimize the cost of berthing structures.

b. Arrangement of berths. The arrangement of berths and types of pier and wharf layout are discussed in chapter 6.

c. Size and depth of basin and berths. These characteristics are discussed in chapter 6.

3-6. Turning basins.

a. Use. Where space is available, provide turning basins to minimize the use of tugs. Where space is restricted, tugs may be used for turning vessels and turning basins eliminated.

b. Location. The following requirements should be met: (1) Locate one turning basin at the head of navigation.

(2) Locate a second turning basin just inside the breakwater.

(3) Where especially heavy traffic is anticipated, provide intermediate basins to reduce traffic congestion and save time.

(4) Where feasible, use an area of the harbor that forms a natural turning basin of the required size and depth.

(5) Provide a turning basin at the entrance to drydocks or at the inboard end of long piers or wharves.

c. Size and form. A vessel can normally be turned comfortably in a radius of twice its length or where maneuverability is not important, in a radius equal to its length. For shorter turning radii, the vessel must be turned around some fixed point, must utilize the ship's anchor, or must be assisted by tugs.