# CHAPTER 11

## Effects of Ice on Design

11-1. General. In regions where ice formation can be expected, the problems to ship navigation from ice should be considered in project design. Generally, deep-draft ice-prone areas in the United States include the Great Lakes, St. Lawrence Seaway, and Alaska. Ice cover affects the maneuverability of ships, power required to sail, the operation of navigation locks, and the stability of structures. Obviously, navigation ice effects increase with the thickness and extent of coverage of the ice. Some of the problems encountered with ice include larger ship turning radius; greater ship required power, which can increase movement of bottom sediment; ice accumulation on ship bottom increasing effective ship draft; higher loads on structures from moving ice; ice accumulation on lock walls, gates, and operating mechanism; and in some cases, increased vibration in homes and structures near the navigation channel. Ice effects are treated in some detail in EM 1110-2-1612, and by Tuthill (1985) and Tuthill and Carey (1986).

11-2. Design of Channels with Ice. All vessels, but particularly long cargo ships with vertical sides and a blunt bow, have difficulty turning in ice. Since very few prototype tests have been made to determine turning radii in ice, no specific recommendations can be made for channel widths in bends or turning basins when subjected to ice cover. Local conditions of ice thickness and extent of coverage will be necessary to develop adequate channel designs. It is important that turning basins be kept clear of ice to allow ship maneuvers and prevent damage to hulls by ice. It should be noted that conventional commercial ships not specifically designed for ice operation are usually unable to leave the navigation channel through an ice cover once it has been created. Furthermore, repeated transits through the channel may lead to accumulation of brash ice and the formation of underwater ice ridges along the edges of the channel.

Line bubblers have been used with some success in the Great Lakes to mitigate channel ice growth problems. Additional depth might be required for the installation of a bubbler system unless the channel is sufficiently wide to permit the placement of the bubbler line outside of the ship channel. Bubbler systems do not provide ice clearing but do create a line of weakness along which ice breaking is made easier. Channels should be aligned so that navigation can rely on range lights and markers rather than floating navigation aids, which can be covered by ice or displaced by ice movements.

In addition to the navigation impact of ice formation on the surface of the water, under certain conditions ice can accumulate on the bottom of vessel hulls. As a vessel progresses at slow speed through brash ice, pieces become submerged and can be entrained underneath the hull. When these conditions occur, the relative water speed is insufficient to flush the ice. This process is enhanced when the vessel's bow is sloped or raked, as for a barge on inland waters or when an ocean-going ship is empty. Under extremely cold conditions, the brash ice can become adhered to the hull of an empty or near-empty vessel because of heat loss as the result of air contact through the sparsely loaded hold. In the event that ice forms on the bottom of a vessel, the result would be increased draft and resistance causing maneuvering difficulties.

11-3. Locks. Lock operation during icing conditions can be difficult and time-consuming. Ice buildup on lock walls may reduce the width of the lock chamber to such an extent that it would

be too narrow for the ship. Coatings to reduce ice adhesion to lock walls and methods of ice control and removal are covered in EM 1110-2-1612. Consideration should be given to the use of heating devices in or ice-preventive coating on lock walls in the design of new structures or rehabilitation of existing locks. Ice can be prevented from collecting in the miter gate recesses by large-volume air bubblers. Ice in the approach to the lock can be minimized by the placement of an air screen at the upper end of the guide or guard wall. Ice accumulating on the bottom of ships increases their draft, which can present problems in clearing the lock gate sills. Consideration should be given to increasing the depths over the sill and along loading docks in ice-prone areas. When it is not possible to prevent large amounts of ice from entering the lock in front of the ship, it may be necessary to provide a skimmer or water flushing system to remove the ice from the lock before the ship can enter.

11-4. Erosion and Sediment Movement. Studies on sediment movement under ice cover in rivers and restricted channels and studies on the Great Lakes have not been sufficient to indicate any change in the rate of shore erosion resulting from ice. Ice formed on a shore or riverbank could isolate and protect the shore. However, ice formation may cause damage to training and stabilization structures or shore by gouging, removing protective vegetation, or entraining sediment within the ice. Ice cover tends to damp ship-induced bow and stern waves which have relatively short periods. However, ice cover has little effect on relatively long-period water-level fluctuations such as those resulting from drawdown, which can be significant, particularly in restricted channels. Greater power will be required to move a ship through ice, and occasionally a ship will get stuck with its screws turning with maximum power without moving. High power and propeller rotation will tend to increase scour and bottom sediment movement and should be considered, particularly over underwater cable and pipeline crossings.

11-5. Vibration. Reliable reports indicate that there is an increase in the vibration of shore structures near ship channels in winter. The reason for this increase is not known. Preliminary investigations indicate that the energy causing the vibration is primarily from the propellers and not from ice breaking or from pieces of ice hitting each other. Based on some verbal reports that conditions are worse during light snow years, it is probable that the vibrations are transferred through frozen soil structure. Until more observations and measurements are made, no definite recommendations can be made to minimize this problem.

11-6. Mitigation of Ice Problems. Maintenance of navigation in ice-covered channels requires ice breaking, which is the responsibility of the U.S. Coast Guard. Usually this is done with dedicated, specially designed icebreakers. In thin ice (up to 6 in.), normal ships break ice as they move through the channel; however, most commercial ships do not have the hull strength and power to break ice with thickness greater than 15 centimeters (cm) (6 in.). The maritime insurance companies have specifications by which they will underwrite certain ships to operate in varying ice conditions. Small harbor tugs specifically built for ice breaking are required for ice-prone ports. These should have the capability of breaking ice that is at least half the maximum anticipated thickness during a normal winter season. These tugs are expected to operate throughout the season, keeping ice broken up in the channel and turning basin and along docks and assisting ships in the channel and turning basin. The effects of ice can be reduced by using waste heat from power plants and sewage disposal facilities and prohibiting municipalities from disposing of snow in the channel or tributaries. In tidal zones, air screens or ice booms should be considered for intermittent use to prevent ice from entering the channel during rising tide. The drawdown and the amplitude of the

bow wave generated by a vessel is a function of ship size, channel blockage, and speed. A surrounding ice sheet will dampen the wave, but the ice may be broken by large drawdown. Broken ice floes could then drift into the navigation channel causing additional difficulties, especially to smaller ships. The broken ice can refreeze into thicker ice, depending on temperature, thus creating more severe channel blockage. If ice breakage extends to the shores, movements of ice floes by wave action and induced currents resulting from subsequent vessel transits may lead to damage of unprotected banks or environmentally sensitive areas. Since the drawdown and bow wave amplitudes decrease rapidly with decreasing ship speed, a minor reduction in vessel speed could avoid or minimize ice breakup and resulting potential ice damages.