CHAPTER 3

STRUCTURAL

3-1. General. This chapter extends the basic structural design criteria to cover items that are unique to arctic and subarctic regions. It extends the criteria provided in TM 5-852-1/AFR 88-19, Volume 1, and other criteria documents.

3-2. Structural design. Structural design of building construction in arctic and subarctic regions is unique only in that conditions found elsewhere are compounded there. Large, and often indeterminate design loads, wide seasonal temperature variances, short construction seasons, and limited availability of skilled labor, construction materials, and transportation form the basis of design problems. Department of the Navy, NAVFAC DM 9, and Department of the Army, TM 5-349, discuss these problems.

3-3. Special considerations.

a. Design loads. Design loads for selected arctic locations are listed in TM 5-809-1/AFM 88-3, chapter 1, and TM 5-80910/NAVFAC P-355/AFM 88-3, chapter 13, and American National Standards Institute (ANSI) A58.1. Climatological data at remote sites should be obtained from individual sites to determine snow and wind loads. Precipitation varies greatly between sites in the same general area and between areas; consequently, snow depths and densities also vary. Many military installations have building sites at two or more greatly differing elevations, and usually have different snow and wind loads at each location. Roof systems with vertical irregularities are subject to increased snow loadings due to drifts and, in certain roof configurations, snow can slide from high roofs to low roofs. Additional loads due to snow drifting, plus additional loads and impact forces associated with sliding snow, must be considered during structural design of roof systems.

(1) *Wind loads and related problems.* Metals that extend through building walls from the exterior to interior will contract in the extreme outside cold and expand in the interior heat. If metals are restrained at the wall, this expansion/contraction can result in unusual stress on the buildings. Solar radiation on metal surfaces of one side of a structure, with extreme cold in shadows on the opposite side, has caused buildings to rack or be distorted. These conditions can be minimized or avoided by painting, by providing for expansion and contraction in connections, and by avoiding designs which require continuous metal connections through insulated walls. When used as exterior walls, metal-surfaced sandwich panels with insulation as a fill material can cause problems. When the outer skin is exposed to extreme cold, it will contract, while the inner skin, exposed to room temperature, maintains a constant size. As a result, the panels deflect inward, which could result in outer skin failure, excessive shearing stresses in the insulation, or excessive tensile stresses in the inner skin. Providing adequate skin plate thickness or internal ribs will reduce the deflection.

(2) *Ice loads.* Solar radiation and heat transferal from within the building melts snow on the roof. As the roof cools with a drop in air temperature or with darkness, this water turns to ice. Repetition of this process results in glaciation. Glaciation occurring on a building eave is frequently referred to as an "ice dam" (see figure 3-1). This concentrated type of loading must be accounted for in the design.

b. Material considerations. Common structural materials can be used in arctic and subarctic regions with few problems. Some special considerations must be remembered, however.

(1) *Wood.* Low humidity conditions are common in buildings where subfreezing temperatures reduce the amount of moisture in the air which can be taken into heating Systems from outside. Frequently, other considerations prevent the addition of moisture as the air is heated. The resultant dry atmosphere draws moisture out of the wood. As a result, wood shrinks, adhesives dry, planks and timbers check and split, fasteners loosen, and warping occurs. The use of kiln-dried lumber or laminated beams will prevent some of these problems.

(2) *Steel.* At cold temperatures, steel will change from a ductile to a brittle material. This change takes place at a point called the transition temperature, which can vary over 100°F due to differences in composition and grain size. Increases in carbon and phosphorus content will raise the transition temperature. Adding nickel will lower the transition temperature, as will decreasing the grain size by heat treatment. When designing structures subject to impact loadings, consideration should be given to specifying steel that has impact resistance at low temperatures. Building foundation pilings have broken while being driven and

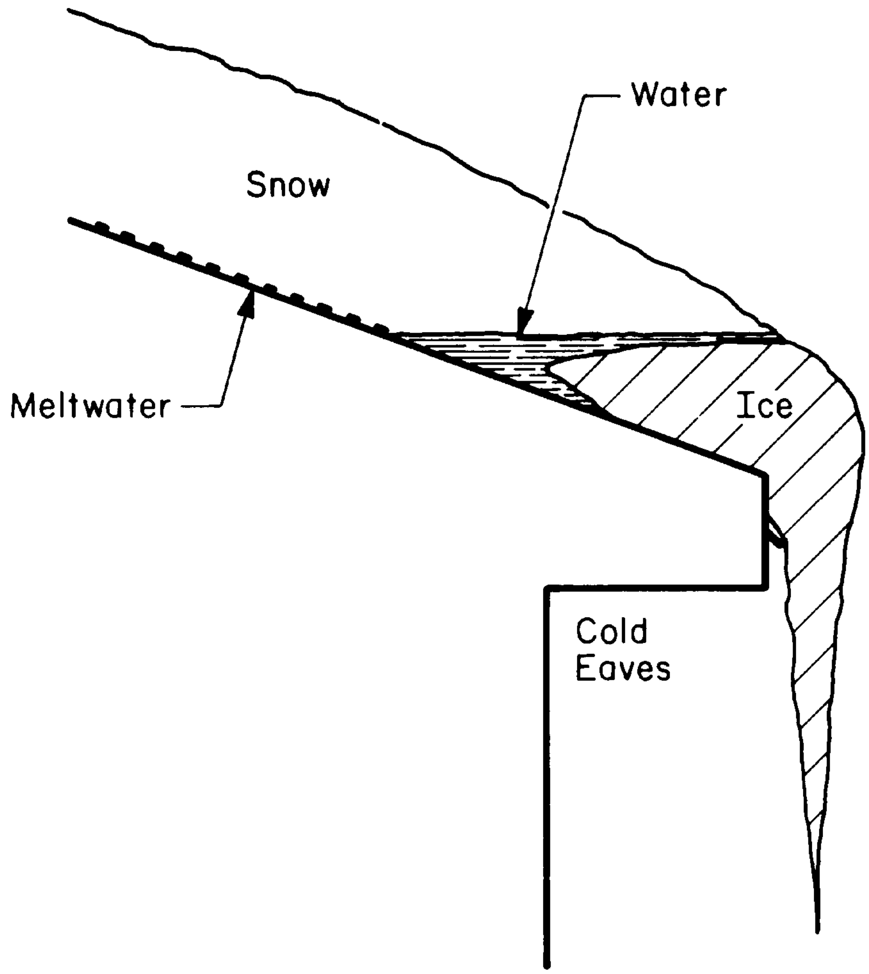

Figure 3-1. Example of an ice dam.

reinforcing steel has broken while being bent. Nickel alloy steel provides needed ductility; however, it may not be economically feasible. Steel conducts heat through walls, causing condensation and ice formation on structural members or melting snow which subsequently forms ice on the exterior surfaces. Where feasible, metals should not extend through exterior walls. Insulation or other materials should be used to interrupt the heat transmission. For example, rails armoring floors against abrasion or other damage from operation of tracked vehicles should be interrupted at entrance doors. This is discussed further in TM 5-852-4/AFM 88-19, chapter 4.

(3) *Concrete.* Concrete structures are very successful in the arctic when concrete mix is properly designed and cold weather concreting is accomplished in accordance with ACI Standard 306, or when the concrete is placed in warmer weather. The concrete mix should be designed with entrained air to provide durability against freeze-thaw effects. Precast and prestressed concrete techniques, including tilt-up panels, have been used without problems. Most commonly, failure of properly placed concrete has occurred because the concrete has been subjected to water saturation, then allowed to freeze. This can frequently be avoided by diverting the water. The temperature of the concrete, when placed, should not be less than 40°F and special protection should assure it is not subjected to temperatures less than 40°F before final set has occurred.

(4) *Epoxy bonding agents.* When using epoxy, be sure to check the manufacturer's recommendations. Some epoxy cannot be successfully applied when surfaces are below 50°F.

3-4. Foundations. As in all climates, foundation design is of major importance. The unusual consideration in arctic and subarctic environments is the presence of deep seasonal frost or permafrost. Depending on the characteristics of the soil and its thermal regime, foundation designs may be either passive (maintaining the foundation materials in a frozen state for the entire service life of the structure) or active (thawing and consolidating the foundation material, or replacing it with more suitable material). In areas where permafrost is stable, the passive approach is generally used. One common passive method is placing the structure on a layer of gravel on top of rigid insulation. This layer of gravel and insulation must be designed to isolate the frozen foundation from the building heat, keeping the ground permanently frozen. Ventilation ducts are often placed in the gravel layer to control the temperature of the frozen ground by maintaining air movement. Another common passive method is placing the structure on piling. The piling either extends into the permanently frozen material, with an insulating layer under the building, or the structure is elevated, permitting free passage of exterior air to dissipate the building heat. Where the permafrost is fragile, special piling called thermal piling is sometimes used. There are several thermal pile designs, all intended to keep the foundation material permanently frozen. In all cases, particular attention must be given to ensuring proper surface and subsurface water drainage away from the structure. Poor drainage and ponding of water can seriously affect the ground thermal regime and cause structural damage from permafrost degradation and frost action. Building foundation design is discussed in TM 5-852-4/AFM 88-19, chapter 4. For structures on spread or continuous wall footings, a soil investigation should be made at the site to determine the possible presence of layers of silty soils that may be susceptible to frost heave during the freeze-thaw cycle. Foundation designs should require removal of frost-susceptible soils under a building which will be affected by freezing, and replacement of those soils with non-frost-susceptible gravelly backfill. Design should consider the thaw bulb which will develop under the building upon completion; therefore all of the frost susceptible materials may not require removal. The contract document should require the contractor to assure these materials do not freeze and cause jacking during construction.