FIGURE C10-1 Glaze Ice Accretion Due to Freezing Rain.

freeze as icicles, resulting in a variety of accretion shapes that range from a smooth cylindrical sheath, through a crescent on the windward side with icicles hanging on the bottom, to large irregular protuberances, see Fig. C10-1. The shape of an accretion depends on a combination of varying meteorological factors and the cross-sectional shape of the structural member, its spatial orientation, and flexibility.

Note that the theoretical maximum density of ice (917 kg/m^3 or 57 lb/ft^3) is never reached in naturally formed accretions due to the presence of air bubbles.

HOARFROST: Hoarfrost, which is often confused with rime, forms by a completely different process. Hoarfrost is an accumulation of ice crystals formed by direct deposition of water vapor from the air on an exposed object. Because it forms on objects with surface temperatures that have fallen below the frost point (a dew point temperature below freezing) of the surrounding air due to strong radiational cooling, hoarfrost is often found early in the morning after a clear, cold night. It is feathery in appearance and typically accretes up to about 1 in. (25 mm) in thickness with very little weight. Hoarfrost does not constitute a significant loading problem; however, it is a very good collector of supercooled fog droplets. In light winds a hoarfrost-coated wire may accrete rime faster than a bare wire (Power 1983).

ICE-SENSITIVE STRUCTURES: Ice-sensitive structures are structures for which the load effects from atmospheric icing control the design of part or all of the structural system. Many open structures are efficient ice collectors, so ice accretions can have a significant load effect. The sensitivity of an open structure to ice loads depends on the size and number of structural members, components, and appurtenances and also on the other loads for which the structure is designed. For example, the additional weight of ice that may accrete on a heavy wide-flange member will be smaller in proportion to the dead load than the same ice thickness on a light angle member. Also, the percentage increase in projected area for wind loads will be smaller for the wide-flange member than for the angle member. For some open structures other design loads, for example, snow loads and live loads on a catwalk floor, may be larger than the design ice load.

IN-CLOUD ICING: This icing condition occurs when a cloud or fog (consisting of supercooled water droplets 100 m or less in diameter) encounters a surface that is at or below-freezing temperature. It occurs in mountainous areas where adiabatic cooling causes saturation of the atmosphere to occur at temperatures below freezing, in free air in supercooled clouds, and in supercooled fogs produced by a stable air mass with a strong temperature inversion. In-cloud ice accretions can reach thicknesses of 1 ft (0.30 m) or more since the icing conditions can include high winds and typically persist or recur episodically during long periods of subfreezing temperatures. Large concentrations of supercooled droplets are not common at air temperatures below about 0 °F (–18 °C).

In-cloud ice accretions have densities ranging from that of low-density rime to glaze. When convective and evaporative cooling removes the heat of fusion as fast as it is released by the freezing droplets, the drops freeze on impact. When the cooling rate is lower, the droplets do not completely freeze on impact. The unfrozen water then spreads out on the object and may flow completely around it and even drip off to form icicles. The degree to which the droplets spread as they collide with the structure and freeze governs how much air is incorporated in the accretion and thus its density. The density of ice accretions due to in-cloud icing varies over a wide range from 5 to 56 pcf (80 to 900 kg/m^3) (Macklin 1962 and Jones 1990). The resulting accretion can be either white or clear, possibly with attached icicles; see Fig. C10-2.

The amount of ice accreted during in-cloud icing depends on the size of the accreting object, the duration of the icing condition, and the wind speed. If, as often occurs, wind speed increases and air temperature decreases with height above ground, larger amounts of ice will accrete on taller structures. The accretion shape depends on the flexibility of the structural member, component, or appurtenance. If it