FIGURE 10.20 Total collapse of a metal building. (*Photo: Structural Engineers Association of Hawaii.*)

erectors are inexperienced or careless. Completed buildings can be brought down under heavy snow or wind overload if their load-carrying systems are compromised in some fashion or not put together properly.

The superstructure-related construction defects can include missing, loose, or incorrectly installed purlin bracing, missing or loose roof and wall bracing, and missing connection fasteners (high-strength frame bolts, wall screws, concealed-clip fasteners, etc.). If there are extra pieces left after building erection, it is not a good sign. The damage to vital parts of structure during construction, as in Fig. 10.9, facilitates a failure down the road.

The relatively common substructure-related defects include anchor rods that are omitted, mislocated, too short, or of the wrong size and type. L-shaped anchor rods used instead of the specified headed anchors have been known to pull out of concrete, as the author has seen. Tie rods have been installed with insufficient hook embedment into the foundation piers, and later pulled out under load, allowing the building columns to spread out under load. Only the supervisor's and inspector's vigilance limits the possibilities for construction errors.

10.9.9 Failures Caused by Deterioration

As with any other type of construction, deterioration of building elements leads to failures ranging from roof leaks to total collapse. Damage to structural members is of course the most serious, since it affects the strength and stiffness of the building. Steel corrosion is perhaps the most familiar deterioration mode of metal structures.

Corrosion can result from roof leaks, condensation, and even groundwater entry. In one ocean-front industrial pre-engineered building of early vintage, the author found the bases of loadbearing

wall studs supporting light-gage trusses completely rusted (Fig. 10.21). The deterioration was determined to be the result of repeated flooding during several storms and hurricanes that took place during the long life of the building. The integrity of the steel was virtually nonexistent—to the point that the wall siding probably carried the building weight!

Framing damage caused by fire tends to result in warped primary framing and twisted secondary members. Because the thickness of metal framing in pre-engineered buildings is rather modest, even a minor fire can result in buckling and other serious distress. A small fire in Fig. 10.22 barely charred the roofing and purlins, but inflicted severe, if local, damage on the main structural frame. As shown in Fig. 10.23, the heat distorted both rafter flanges and caused the top flange to tear away from the web.

Deterioration of nonstructural elements can cause less dramatic but no less noticeable effects. In Fig. 10.24, the roof leak was traced to a damaged pipe boot flashing, which should have looked as in Fig. 10.14. Where is the rubber part of the boot? Reportedly, pecked away by seagulls that found it tasty.

10.9.10 Other Causes of Failure

Building failures can result from improper building maintenance, or even from careless alterations done during its service life. It is not uncommon to hear about plumbers who remove primary frame

FIGURE 10.21 Bases of cold-formed wall studs supporting trusses in this early-vintage pre-engineered building are completely corroded from repeated saltwater entry.