Figure 10.17 illustrates building damage caused by local wind overload. The investigators have traced it to a microburst—a small-scale but severe wind downdraft. Microbursts have been blamed for many aircraft crashes during takeoffs and landings. Note that the endwall girts and columns, as well as the roof purlins in the first exterior bay, have buckled—and that the purlins have buckled upward. The overhead door has failed as well, quite consistent with our discussion in Sec. 10.4.

10.9.3 Effects of Temperature Loading on Member Overload

Another example of possible overstress under common but sometimes unplanned-for conditions concerns additional stresses and displacements resulting from the temperature loading. As explained in Chap. 5, if the primary frames cannot move laterally under temperature load, the purlins restrained from free expansion and contraction will undergo a significant buildup of compressive axial stresses. At the other extreme, when the frames are completely free to move, expanding and contracting purlins will push and pull the frames out-of-plane, away from their original positions. This will introduce additional torsional loading into the frame rafters. To some degree, properly designed and installed flange bracing can relieve this torsion. Regardless of the design assumptions, either additional purlin stresses or additional rafter stresses will need to be acknowledged. Most likely, there will be some of both.

FIGURE 10.17 This building in Southern California partly failed under wind loading. Note buckling of endwall girts and roof purlins and failure of overhead door. (*Photo: J.R. Miller & Associates.*)

In a cold climate, the worst-case scenario tends to involve the primary frames in frigid and snowy winters, when the added frame torsion (if not relieved) from its inward movement is combined with the flexural stress from heavy snow. In a hot climate, the worst-case scenario could occur in the summer in the presence of heavy roof live load: the compressive flexural stresses in the purlins from the live load would be combined with compressive axial stresses from temperature restraint.

To appreciate the numbers involved, consider an uninsulated 500-ft-long warehouse with purlins bolted to one another without any expansion devices. The roof purlins are subjected to a 100° temperature change. If free to move, the purlins will expand and contract by a total of almost 4 in—meaning that the end primary frames on each side will be displaced from the original position by 2 in. If purlin movement is restrained by the adjacent construction, the purlins will accumulate more than 19,000 psi of axial stress!

10.9.4 Failures Caused by Incorrect Design

The causes of some metal building failures can be traced to inadequate design. Sometimes, unconservative and unrealistic design assumptions are being made. Sometimes, the loading is improperly specified, as explained above in the sections dealing with collateral loading and the difference between snow and roof live load.

Sometimes, both of those factors are compounded by improper maintenance. Consider the hypothetical case of heavy snow accumulation on a metal roof. The building is still able to carry the uniform and balanced snow loading (perhaps barely), but the situation changes when the owner decides to start removing the snow. Without proper guidance, the workers begin by completely clearing the end bays. This leads to a partial-loading condition, which proves more critical than the previous uniformly applied load, and results in purlin overstress and failure. Here is a combination of design deficiency (the building was not designed for partial loading) and improper snow removal techniques (which created the partial loading in the first place).

Incidentally, Appendix A8 of the MBMA Manual[10] provides an overview of good snow removal techniques. It recommends consulting the building manufacturer or a structural engineer before removing any snow and suggests, among other steps, gradual snow removal "in layers from all over the roof," rather than from one whole bay at once.

The common areas of questionable design include the framing around overhead doors, as discussed in Sec. 10.4, and particularly the design of cold-formed girts and purlins. The secondary members deserve a special discussion.

10.9.5 Failures of Purlins and Girts

The controversies of designing secondary roof and wall members are many. As we stated in Chap. 5, structural design of cold-formed C and Z sections is rather complex, and their actual behavior is not fully understood. It is not surprising that designers of these sections use different design assumptions, some of them arguable, and different construction techniques. Among the controversial issues discussed in Chap. 5 are:

- Using prismatic (reduced stiffness) versus nonprismatic design. While simpler to use and acceptable, prismatic design might result in some member overstress in the negative regions and at the splices vis-à-vis the more realistic nonprismatic (full stiffness) design.
- Forcing heavy Z sections into one another at supports, which could lead to some built-in purlin rotations (see Fig. 5.8 in Chap. 5).
- Considering the imaginary inflection point as a brace point (this assumption in particular happens to have a number of well-known proponents).
- Lack of consideration for partial loading.