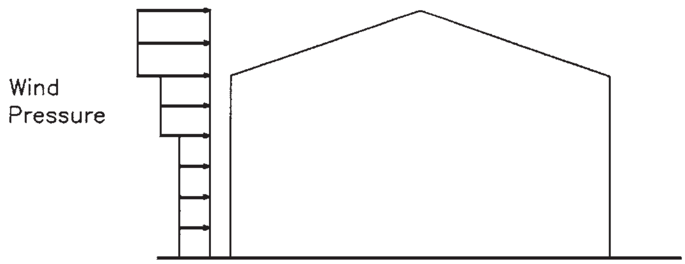

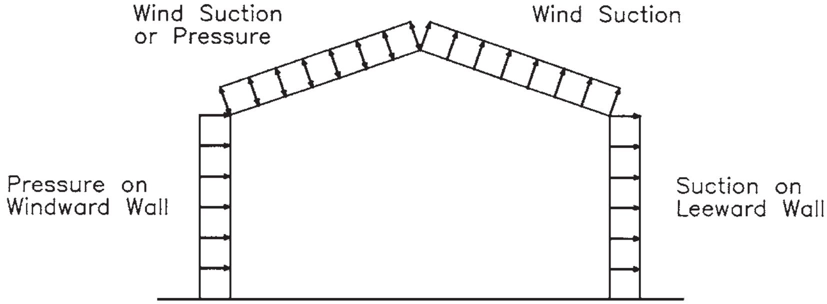

FIGURE 3.3 Wind load on gable buildings. (*a*) Projected area method of wind load application. It is generally obsolete, but a variation of it, where roof uplift loading is placed on the projected area or the roof, is used in Uniform Building Code, 1997 ed. (*b*) Wind applied normal to all surfaces.

surrounding soil that are perceived by humans as ground shaking; the waves diminish with the distance from the earthquake epicenter. The wave analogy explains why earthquakes are cyclical and repetitive in nature.

The second seismic axiom states that, unlike wind, earthquake forces are not externally applied. Instead, these forces are caused by inertia of the structure that tries to resist ground motions. As the earth starts to literally shift away from the building, it carries the building base with it, but inertia keeps the rest of the building in place for a short while. From Newton's first law, the movement between two parts of the building creates a force equal to the ground acceleration times the mass of the structure. The heavier the building, the larger the seismic force that acts on it.

Factors affecting the magnitude of earthquake forces on the building include the type of soil, since certain soils tend to amplify seismic waves or even turn to a liquidlike consistency (the liquefaction phenomenon). The degree of the building's rigidity is also important. In general terms, the design seismic force is inversely related to the fundamental period of vibration; the force is also affected by the type of the building's lateral load-resisting system.

The notion of ductility, or ability to deform without breaking, is central to modern seismic design philosophy. Far from being just desirable, ductility is fundamental to the process of determining the level of seismic forces. The building codes may not explicitly state this, but a certain level of ductility is required in order for the code provisions to be valid. Without ductility, the design forces could easily have been four or five times larger than those presently specified. The systems possessing ductile properties, such as properly detailed moment-resisting frames, may be designed for smaller seismic forces than those with less ductility, such as shear walls and braced frames. Why?

To answer this question, one needs to examine the goals of seismic design in general. Most building codes agree that the structures designed in accordance with their seismic code provisions should resist minor earthquakes without damage, moderate earthquakes without structural damage, but with some nonstructural damage, and major ones without collapse. Since the magnitude of the actual earthquake forces is highly unpredictable, the goal of collapse avoidance requires the structure to deform but not to break under repeated major overload. The structure should be able to stretch well past its elastic region in order to dissipate the earthquake-generated energy.

To achieve this goal, the codes are filled with many prescriptive requirements and design limitations; particular attention is given to the design details, since any disruption of the load path destroys the system.

It is important to keep in mind that real-life seismic forces are *dynamic* rather than static, even though their effects are commonly approximated in practice by a so-called equivalent static force method. This method is used partly for practicality, as dynamic analysis methods are quite cumbersome for routine office use, and partly for comparison of the results to those of wind-load analysis and using the controlling loading to design against overturning, sliding, and other modes of failure discussed in Sec. 3.1.4.

The actual formulas for determination of seismic forces differ widely among the building codes and even among the various code editions. In general, these formulas start with the weight of the structure and multiply it by several coefficients accounting for all the factors discussed above.

3.1.7 Crane Load

This type of loading is produced by cranes, monorails, and similar equipment. Crane loads are discussed in detail in Chap. 15.

3.1.8 Temperature Load

This often-ignored and misunderstood load occurs whenever a steel member with fixed ends undergoes a change in temperature. A 100-ft-long piece of structural steel, free to move, expands by 0.78 in for each 100°F rise in temperature and similarly contracts when the temperature drops. If something prevents this movement, the expansion or contraction will not occur, but the internal stresses within the "fixed" member will rise dramatically. A basic formula for thermal stress increase in a steel element with fixed ends is

$$\text{Change in unit stress} = E \cdot \epsilon \cdot t$$

where E = modulus of elasticity of steel (29,000,000 psi)
ϵ (epsilon) = coefficient of linear expansion (0.0000065 in/°F)
t = temperature change (°F)

For example, if the temperature rises 50°F, a steel beam 50 ft long that is restrained from expansion will be under an additional stress of $29{,}000{,}000 \times 0.0000065 \times 50 = 9425$ psi, a significant increase.

Temperature loads seldom present a problem either in conventional bolted-steel construction or in metal building systems. Indeed, the author is not aware of any building failures caused solely by temperature changes, although he has investigated a metal building system damaged by heat buildup due to fire—a separate issue. Thermal loading is insignificant and may often be ignored in the design of primary framing for small pre-engineered buildings, or of buildings located in the areas with relatively constant ambient temperatures, or of climate-controlled buildings. It may be