the critically loaded foundations. For large buildings founded on poor soils, soil borings should be spaced not over 50 ft apart and perhaps much closer.

How deep to carry the borings? The BOCA Code requires the borings to be carried to rock or to "an adequate depth below the load-bearing strata." For low-rise buildings, some engineers specify a depth of borings to be 20 ft below the anticipated foundation level, with at least one boring continuing deeper, perhaps to a lesser of 100 ft, the least building dimension, or refusal. If the longer boring encounters no unsuitable materials deep down, the rest of the borings could be stopped at the originally planned depth. A boring should never be terminated in an unsuitable material. Since the extent—and the cost—of the program can change a lot during field operations, it is advisable that a competent engineer be present at the site to observe the process and modify it if circumstances warrant.

Sometimes, instead of soil borings or in addition to them, test pits are excavated. Test pits are especially appropriate for lightly loaded foundations supported by good soil at some depth but by a questionable material near the surface. A test pit can provide a clear visual picture of the soil condition at a shallow depth, up to about 10 ft. Test pits are fairly inexpensive, since no specialized equipment is needed, and are often useful in supplementing the information provided by soil borings. For example, a refusal encountered by the boring rig could be a sign of a rock ledge or of a large boulder. A test pit can quickly provide an answer.

The end result of subsurface exploration is a soils investigation report prepared by the geotechnical engineer. The report describes soil conditions at the site and recommends the maximum allowable bearing pressure and other pertinent engineering characteristics of the soil.

12.3 WHAT MAKES THESE FOUNDATIONS DIFFERENT?

Three main factors distinguish pre-engineered building foundations from the rest: substantial horizontal column reactions, large column uplift, and a common need to design the foundations before column reactions are determined. Experienced structural engineers can easily spot an improper foundation design, because the first two issues are often overlooked by the uninitiated.

12.3.1 Horizontal Column Reactions

Lateral forces, such as from hurricanes and earthquakes, act on all buildings and result in both vertical and horizontal column reactions. In "conventional" buildings with moderate footprints and relatively closely spaced columns, horizontal reactions are distributed to a number of column and wall foundations. It's a rare case when the column foundation has to resist large horizontal loads. The situation is quite different in pre-engineered buildings.

Rigid frame, a staple of metal building systems, generates a large horizontal thrust from gravity loads (Fig. 12.1*a*), as well as horizontal reactions from lateral loads (Fig. 12.1*b*). Assuming that the frame columns are pin-connected, column reactions on a typical foundation are shown in Fig. 12.2*a*. For fixed-base columns, the fixity moment M (Fig. 12.2*b*) is added.

Horizontal column reactions tend to produce two modes of foundation failure—overturning and sliding—that will be elaborated on in Sec. 12.5.3.

12.3.2 Uplift

Uplift—an upward force—is a natural result of wind acting on gable-frame buildings (Fig. 12.3). In two- and multistory conventional buildings, wind uplift rarely exceeds the combined roof and floor dead loads and thus almost never governs the foundation design. Single-story metal building

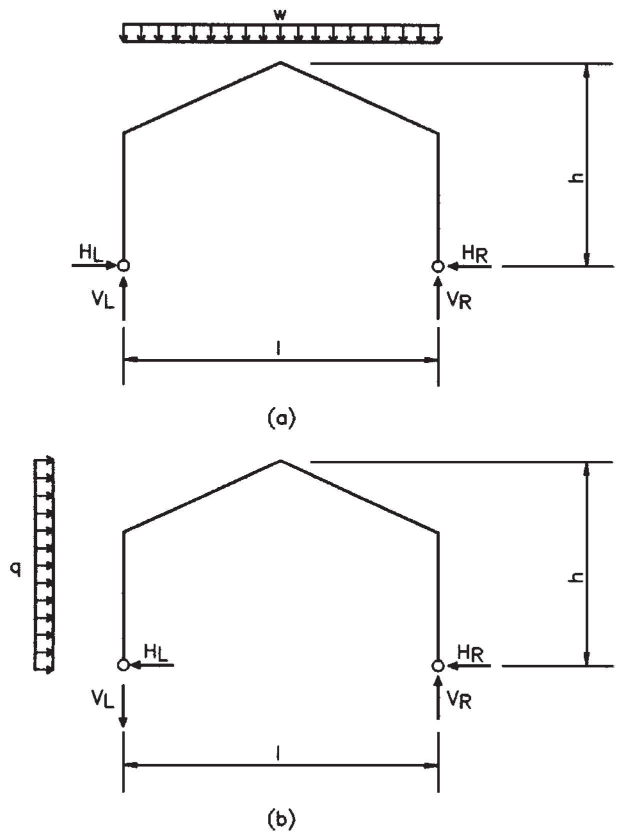

FIGURE 12.1 Column reactions of a rigid frame structure: (*a*) from gravity loads; (*b*) from lateral loads.

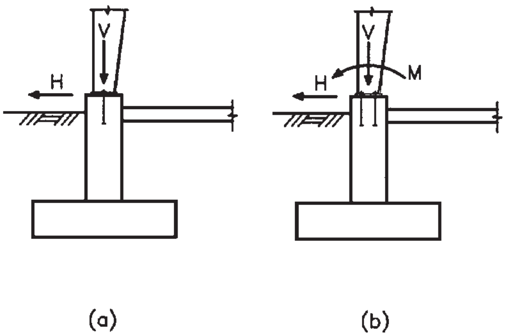

FIGURE 12.2 Forces acting on foundations supporting rigid-frame columns: (*a*) pin-base columns; (*b*) fixed-base columns.