The rain-on-snow surcharge load, with the maximum value of 5 psf, is applied to the roofs with slopes less than $^1/_2$ to 12, if the ground snow load does not exceed 20 psf. It is intended to reflect a condition common in northern climates when a snowstorm changes to rain. If the roof pitch is small, the rainwater cannot quickly drain away and is instead absorbed by the snow. (Being able to avoid this load is one good reason to specify a minimum roof slope of at least $^1/_2$ to 12—and preferably larger, as discussed in Chap. 6—rather than the all-too-common slope of $^1/_4$ to 12.)

Rain load is specified in a different code section than rain-on-snow surcharge and represents a different phenomenon—the weight of rainwater that can accumulate on the roof if the drainage system is blocked. This load includes the weight of "water that rises above the inlet of the secondary drainage system at its design flow."[2] The weight of water is taken as 5.2 psf per inch of depth.

As discussed in Chapters 5 and 11, the roof secondary framing in metal building systems is rather flexible, and rapid removal of rainwater is critical to its survival in a heavy rain. For this reason, pre-engineered buildings are typically designed with exterior gutters rather than with interior drains. It is important to understand that exterior parapets, which are becoming increasingly popular, interfere with free drainage and require special steps to avoid roof failure and leakage under accumulated weight of water. One such step is locating an interior gutter behind the parapet.

### 3.1.5 Wind Load

Ever since being told about the sad experience of the three little pigs, most of us have an appreciation of the wind's destructive power. Several recent hurricanes, such as Hugo, Andrew (1989), and Iniki (1992), have highlighted our vulnerability to this common natural disaster. The property losses attributed to wind are enormous.

To design wind-resisting structures, the engineers need to know how to quantify the wind loading and distribute it among various building elements. Unfortunately, the wind effects on buildings are still not perfectly understood; the continuing research results in frequent building code revisions.

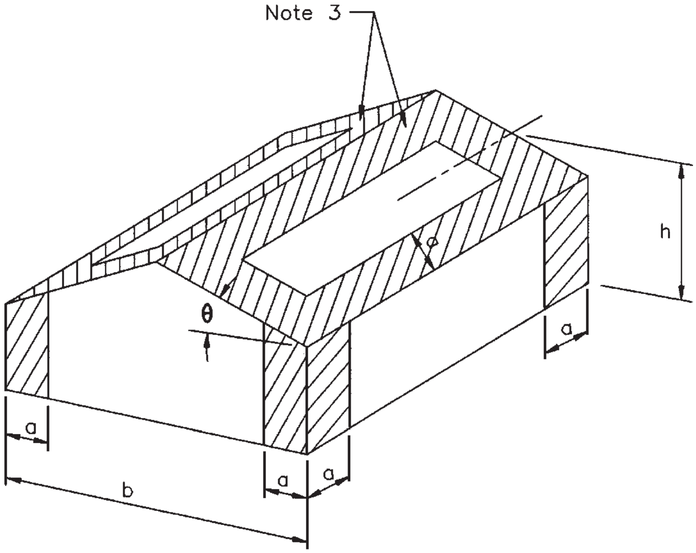
Most modern building codes contain maps specifying *design wind speed* in miles per hour for various locales. Design wind speed used to be defined as the fastest-mile wind speed measured at 33 ft above the ground and having an annual return probability of 0.02. The 1995 and later editions of ASCE 7,[3] however, define it as the maximum three-second gust, reflecting a new method of collecting data by the National Weather Service. By using the code-provided formulas, it is possible to translate wind speed into a corresponding *velocity pressure* in pounds per square foot. From the velocity pressure, the design wind pressure on the building as a whole can be determined as a function of height and *exposure* category that accounts for local ground surface conditions.

Hurricane damage investigations reveal that local failures of walls and roofs occur most often near the building corners and roof eaves. The secondary members and covering in those areas should be designed for much higher wind loads—both inward and outward—than those in the rest of the building. The actual formulas for such an increase vary among the building codes and are not reproduced here, but the basic definition of the "salient corner" areas subjected to the higher wind loads is similar. Figure 3.2 illustrates the traditional approach of defining these.

Winds can damage buildings in four basic ways:

1. *Component damage,* when a part of the building fails. Some examples include a roof being blown off, wall siding torn out, or windows shattered.
2. *Total collapse,* when lack of rigidity or proper attachments causes the building to fall apart like a house of sticks.
3. *Overturning,* when the building stays in one piece and topples over, owing to insufficient weight and foundation anchorage.
4. *Sliding,* when the building stays in one piece but loses its anchorage and slides horizontally.

For a long time, engineers considered wind to be a strictly horizontal force and computed it by multiplying the velocity pressure by the projected area of the building (Fig. 3.3*a*). As wind research



Notes:

1. The dimension "a" ("The Salient Corner" distance) is defined as the smaller of 0.1b or 0.4h (but not less than 0.04b nor 3 feet)
2. The dimension "h" is taken as mean roof height (when $\theta < 10°$, eave height may be used)
3. Areas adjacent to the ridge are included only when $10° < \theta \leq 45°$

**FIGURE 3.2** Areas of high localized wind loading for low-rise buildings. (The actual numbers vary from code to code.)

progressed, often pioneered by the metal building industry, a more complex picture of the wind force distribution on gable buildings gradually became acknowledged (Fig. 3.3*b*). In the current thinking, the wind is applied perpendicular to all surfaces; both pressure and suction on the roof and walls are considered, as are internal and external wind pressures. Sorting out the various permutations of all these wind load components takes some practice and should be delegated to experienced professionals.

### 3.1.6 Earthquake Load

Earthquake damage makes front-page news; even if not witnessed firsthand, devastating effects of the earth shaking appear uninvited on our living room TV screens, accompanied by familiar commentaries about the limitations of scientific knowledge in this area. As the forces of nature become better understood, building codes prescribe increasingly sophisticated methods of earthquake analysis. Still, the most basic notions of seismic design do not change, and it is worthwhile to review some of them.

The first classic theory holds that the majority of earthquakes originate when two segments of the earth crust collide or move relative to each other. The movement generates seismic waves in the