underlayment, such as 30-lb roofing felt, and is sometimes separated from it by a friction-reducing paper slip sheet.

In contrast, water barrier, or *waterproof,* roofs are intended to function under occasional standing water. Reflecting this fact, these roofs are sometime called "hydrostatic." Another name used for this roofing is "low-slope," as opposed to "high-slope" water-shedding roofing. The system is not designed to be completely leak-free under long-term water immersion, however, and still requires some minimum roof slope for best performance. Tobiasson and Buska[3] recommend a minimum slope of 1:12 (1 in/ft) for "waterproof" standing-seam roofs and state that the slopes larger than the minimum perform better, especially in cold regions. Others consider the slopes as low as $^1/_4$:12 to be adequate. In any case, as Ref. 4 points out, water-barrier metal roofs are "usually not watertight at their valleys, eaves, ridges, rakes and penetrations."

### 6.2.2 Architectural versus Structural Roofing

The terms *architectural* and *structural* are somewhat misleading, as either type of metal roofing serves architectural purposes and is available in a variety of finishes and profiles. The main difference between the two types is this: Architectural (or "nonstructural") roofing relies on structural support to be provided by decking or by closely spaced subpurlins, such as furring channels, while structural roofing can span the distance between the roof purlins on its own.

In practice, architectural roofing is akin to water-resisting cladding or, more specifically, to water-shedding roofing. True to the name, architectural roofing may be used to create dramatic visual effects not possible with other types of roofing. It can be installed on very steep slopes, including vertical, although good sealants and sturdy structural supports become critical for steep-slope installations (Fig. 6.1). The so-called specialty types of architectural roofing are made to resemble clay tile, roof shakes, and shingles, even though these are supplied as panels. Individual metal shingles, used in lieu of the conventional variety, are also available.

**FIGURE 6.1** Architectural roofing provides a bold visual effect.

Structural roofing is often implied to be of "waterproof" design, although these two terms refer to different concepts. Structural roofing may be used on shallow slopes, perhaps as low as 1/4:12, even though a larger slope is preferable, as was just pointed out.

Structural roofing may be considered a form of roof decking and, as such, is required to meet certain wind uplift criteria as well as to support a worker's weight (250 lb). Architectural roofing does not have to meet these requirements. Both kinds of metal roofing typically weigh only 1 to 2 lb/ft$^2$.

As discussed in Chap. 3, wind loading is not uniform from one part of the roof to another. The loading is much higher along the roof's perimeter, for example, and sometimes along the ridge. Instead of using structural roofing panels of heavier gages in the areas of high localized loads, it is better to space the purlins closer. A common design involves supports for structural roofing at 5 ft on centers in the field of the roof, but only half that within the areas of higher wind loading, such as 10 ft or so from the roof edges.

The contract documents should indicate the maximum deflection criteria for structural roofing. For steel roofing, the limit of $L/180$ is reasonable, although there are circumstances when a more stringent or a more lenient limit may be justified. For aluminum roofing, which has a much lower elastic modulus than steel, a limit of $L/60$ is often specified.[5] The topic of vertical deflection limits for roofs is discussed in more detail in Chap. 11. Structural design of sheet-metal roofing follows the AISI Specification mentioned in Chap. 5. Some engineers specify minimum section properties of the roofing—the moment of inertia and the section modulus—right on the contract drawings.

### 6.2.3 Classification by Method of Attachment and by Direction of Run

Metal roofing can also be classified by method of attachment to supports. *Through-fastened roofs* are attached directly to purlins, usually by screws or rivets. *Standing-seam* roofing, on the other hand, is connected indirectly by concealed clips formed into the seams. It is more accurate to call this product "concealed-fastened standing-seam metal roofing," to differentiate it from any other roofing with vertical ("standing") seams described in the section that follows, but the unwieldy term has not gained wide popularity. The U.S. Government's *Unified Facilities Guide Specifications* call it "Structural Standing Seam Metal Roof (SSSMR) System."[6] In this book, we call the concealed-fastened roof simply standing-seam roofing and the other kind, vertical-seam roofing. We should note that the first standing-seam metal roofing, introduced by Armco Buildings in 1934, had exposed fasteners. It was only in 1969 that the concealed-clip design was introduced by Butler Manufacturing Company.

A separate type of concealed-fastened roofing is represented by insulated structural panels, also called foam-core sandwich panels. These roof panels consist of two layers of formed metal sheets with insulation in between, as discussed in Sec. 6.6.

Metal roofing comes in ribbed panels with seams normally located along the slope. One exception to this rule is *Bermuda roofing,* which runs horizontally. The panels of this unique roofing are through-fastened to supports with concealed clips and resemble clapboards with reveals of 9.5 to 11.5 in. The inherent design weakness posed by a horizontal seam orientation makes the use of Bermuda roofing more popular in locales without snow and ice accumulation.

## 6.3 VARIOUS SEAM CONFIGURATIONS

Contemporary roofing panels come in the following seam configurations.

**1.** *Lapped seam,* normally found in through-fastened roofs, offers the simplest and most economical design (Fig. 6.2*a*). The edges of corrugated roofing panels are simply overlapped, receive a bead of sealant, and are fastened to roof purlins. Despite the economy, the fasteners of lapped panels are exposed to weather—and sight. This system lacks a certain sophistication and is reserved for relatively basic, functional structures.