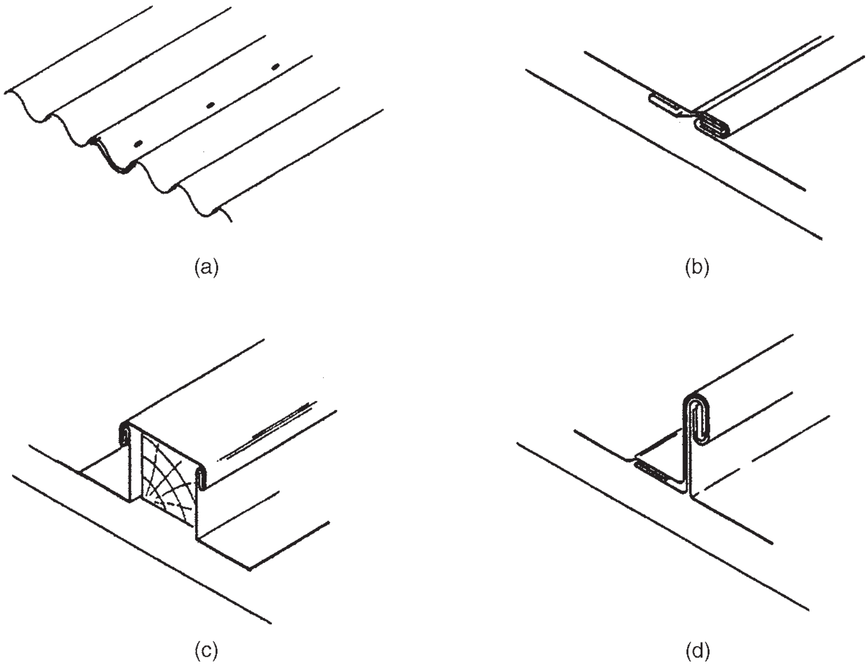

FIGURE 6.2 Various seam configurations: (*a*) lapped panels; (*b*) flat seam; (*c*) batten seam; (*d*) vertical standing seam. (*Adapted from Means Square Foot Cost Data 1995. Copyright R.S. Means Co., Inc., Kingston, MA, 617-585-7880, all rights reserved.*)

2. *Flat seam* is formed by bending the sides of two adjacent roofing sheets 180° and hooking them together (Fig. 6.2*b*). It is relatively rare.

3. *Batten seam* originated in the times of hand-forming, when the sides of two adjacent panels were bent up, separated by a wood batten strip, and covered with a snap-on cap (Fig. 6.2*c*). Most modern batten seam systems dispense with wood but preserve the metal batten design (Fig. 6.3).

4. *Vertical-seam* (*standing-seam*) roofing has the seams elevated 2–3 in above the flat panel part that carries water (Fig. 6.2*d*). The picture shows a so-called Pittsburgh double lock, a 360° roll-formed seam resembling the seam of a food can. Other types of vertical seams include those that are simply snapped together, usually with a sealant in between.

The majority of modern metal roof systems use concealed-fastened standing-seam metal roofing, discussed in Sec. 6.2.3. A 2001 survey[2] of the readers of *Metal Architecture* reported that about 80% of them specified standing-seam roofing; 29% exposed-fastener ribbed roofing; 22% corrugated metal; 18% batten seam; 12% foam-core sandwich panels; 8% tile, shake, and shingle-profiled panels; and more than 7% individually formed metal shingles. Metal panels can be made to resemble any traditional type of roofing—even thatch.

Most panels are manufactured, or "preformed," from precoated coils of light-gage metal at the factory, where the coils are handled with great care to preserve the finish during forming. Attempts to apply coatings after forming tend to result in some quality problems with color, thickness uniformity, and durability.[7]

Recently, portable roll-forming machines have become available, and many types of panels can now be formed on-site. Factory forming, however, is still likely to provide a better-quality finish.

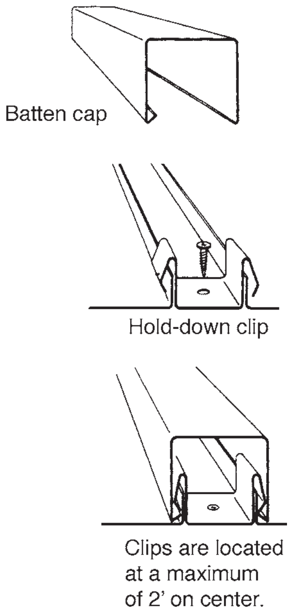

FIGURE 6.3 Batten seam details. (*Carlisle Engineered Metals.*)

6.4 THROUGH-FASTENED ROOFING

6.4.1 Advantages and Disadvantages of the System

Through-fastened lapped-seam roofing represents the oldest design approach to metal roofs. Still a popular choice for industrial and warehouse buildings of small and moderate size, the system is inexpensive, straightforward, and easy to erect. This structural roofing possesses some diaphragm capacity and in many cases can provide lateral flange bracing for roof purlins. The attachment to purlins is typically made by self-tapping or self-drilling screws; some manufacturers also use lock rivets or proprietary fasteners.

Through-fastened roofing suffers from two major disadvantages. First, the roofing is penetrated by fasteners, and each penetration is a potential leak in the waiting. The only protection there is provided by a rubber or neoprene washer under the fastener's head.

The second problem is that the roofing is prevented by the fasteners from thermal expansion and contraction. As discussed in Chap. 3, a long piece of metal can buckle if temperature stresses become excessive. Even if it does not, repeated expansion and contraction will tear the metal around the connecting screws and lead to leaks.[8] Or the screws may become so loosened by the continuing sidesway motions that the roofing might be blown off during a hurricane. To limit buildup of thermal stresses, the width of buildings with through-fastened roofs should not exceed approximately 60 ft. In such smaller buildings, through-fastened roofs may have a better chance of survival.

Another potential problem with screw-fastened roofing is metal fatigue. Xu[9] and others have shown that this type of roofing may fail locally, by cracking around the fasteners, when subjected to strong fluctuating wind loading. Lynn and Stathopoulos[10] have concluded that wind-induced fatigue was the only possible cause of several failures of through-fastened roofs in Australia during cyclone Tracy in 1974. One study attempted to identify the areas most susceptible to fatigue damage in hip and gable roofs. In gable roofs, these areas seem to be located near the gable ends and the roof ridge; in hip roofs, they are near the side walls and the hip ridges.[11]

6.4.2 Roofing Products

Through-fastened roofing is usually 1–2 in deep and is made of steel 26–24 gage thick. The 24-gage material has better dimensional stability and impact resistance. The manufacturers offer load tables for various panel configurations, such as those of Figs. 6.4 and 6.5, to facilitate roofing selection given the roof live or snow loads, purlin spacing, and wind uplift rating. Another selection criterion concerns insurance requirements, which may actually control the design. Factory Mutual, for example, often requires panels of larger depth or gage than needed for strength alone.[12]

Some manufacturers attempt to overcome the vulnerability of through-fastened roofing to thermal movements by providing slotted holes in the panels. For example, Butlerib II roof system by Butler Manufacturing Company utilizes prepunched slotted holes in the bottom sheet of the end joint and regular holes in the top sheet (Fig. 6.6*a*). A typical panel is shown in Fig. 6.6*b*. The manufacturer points out that it has taken extraordinary steps to perfect this system by providing a long return leg, which increases dimensional stability under roof traffic, by using constant-grip lock rivets instead of sheet-metal screws, and by incorporating a special sealant groove in the seam (Fig. 6.6*c*). These steps have resulted in a premium through-fastened system with a unique 10-year weathertightness warranty.

A few other manufacturers attempt to justify lack of slotted holes in their panels by relying on purlin roll—a slight rotation under thermal loading. The purlin roll, while quite real, exists mostly in roofs with cold-formed C or Z sections without top-flange bracing. As discussed in Chap. 5, the practice of relying on purlin roll raises some serious questions.