as steel roof decking, which is typically not the case. Also, the liner panels can only provide lateral bracing for the bottom flanges of the purlins. They help little in bracing their top flanges or in providing torsional stability. (Because liner panels are more commonly used in metal walls than roofs, they are discussed in Chap. 7.) Other suppliers simply claim that their standing-seam roof is different and capable of serving as purlin bracing and a diaphragm—without offering any proof.

Another major disadvantage of structural standing-seam roofing is that it is best suited for rectangular buildings without too many design complications. For example, a large number of roof openings requires too many through-fastened connections at the edges that may defeat the roof's ability to "float." Similarly, complex plans tend to create situations for which standard design details, geared to a simple fixed end-expansion end assumption, are ill suited. Nonrectangular roofing panels not only require expensive field cutting and fitting but also could compromise the available closure, sealant, and finishing details. Even a rectangular layout may require a lot of design ingenuity to allow for roof movement at the corners and other critical locations. With some systems, a simple hip roof may present enough complications to negate the economy of the standing-seam design.[19] The difficulty of ensuring free movement of the roof should become apparent when one examines Fig. 6.18. It shows typical locations of the points where roof fixity is provided in hip roofs, as used by one manufacturer.

Standing-seam roofs may present some appearance problems, too. As Stephenson[19] points out, the often-utilitarian appearance of their closure and edge details may not be appropriate for esthetically demanding applications, where conventional batten-type (or other architectural) roofing may serve better. With standing-seam roofing, it might be difficult to achieve good-looking solutions for roof slope changes or fascia-soffit transitions. In such situations, structural vertical-seam or architectural roofing systems are more appropriate.

Sliding panels may produce a specific "metal" noise objectionable to some people. The noise can be masked by roof insulation to some degree.

On balance, all these limitations are far outweighed by the system's advantages. Standing-seam roofs remain a premium choice for metal building systems. Superior performance of standing-seam roofs is reflected in the warranties longer than those for lap-seam roofs. Indeed, the popularity of these roofs often attracts the prospective users to metal building systems. Standing-seam roofs, while more expensive initially, often prove very economical in long-term comparisons which take into account life-cycle costs.

6.5.3 Design Details for Structural Roofing with Trapezoidal Profile

Structural standing-seam metal roofing must be able to move unimpeded relative to purlins in order to function without leaks, buckling, and structural failure. Conceptually, the system of field-seamed

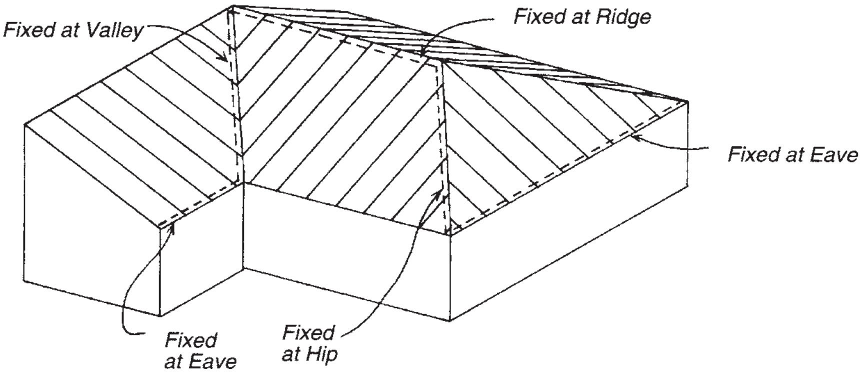

FIGURE 6.18 Points of fixity for a hip roof. Roofs of complex shapes compromise movement ability of the roofing. (*Centria.*)

metal sheets, concealed clips, and spliced ends should work without problems, as long as the roof size is consistent with the movement capacity of the clips and the purlins are well aligned. The misaligned tops of purlins tend to cause roofing binding and restrict movement.

The challenges arise at the edges, eaves, ridges, wall transitions, penetrations, and other areas where metal roofing can become restrained in the absence of well-thought-out details. The design details used by different manufacturers vary in their effectiveness. The Metal Building Manufacturers Association has compiled many generic details representing the best practice in its Metal Roofing Systems Design Manual.[14] Some representative designs for various conditions from this and other sources are examined here. Another good publication is the *NRCA Roofing and Waterproofing Manual,*[20] particularly its metal roofing section.

As already noted, the roofing must be positively fastened to the supports at some point, to prevent it from sliding down under its own weight. The point of fixity is often the eave and expansion end, the ridge. This approach allows the eave strut to be laterally braced by the roofing (to some degree at least) and helps resist high wind-uplift forces, which tend to be the largest at the eaves. According to some estimates, almost three-quarters of all wind damage to roofing occurs at the eaves.

The elimination of panel movement at the eaves holds an added benefit for roofs in cold regions, where the eaves are vulnerable to ice dam formation and sliding snow. The details of a fixed eave and floating ridge are illustrated in Figs. 6.19 and 6.20.

Some manufacturers prefer the opposite approach—through fastening the panels at the ridge and letting them float at the eave. Very wide roofs can be fixed neither at the eave nor at the ridge, but in the middle, which maximizes the expansion capacity of the roofing clips.

Regardless of which end of metal roofing is fixed, it is important to allow the panels to slide at the rake. Quite often, the roofing is through fastened to the endwall trim (Fig. 6.21), creating a connection that hinders the roof's ability to float at the rake. The result is a failure of the fasteners or roofing. The better details either allow the roofing to move relative to the endwall trim while keeping the trim laterally supported, or allow the trim to move relative to the endwall siding, as shown in Figs. 6.22 and 6.23.

The flashing details at high walls and parapets require some thought to avoid introducing unintended points of roofing fixity at those locations. A heavy-gage corner flashing of simple L-shaped configuration attached directly to the roofing may hinder its movement. The author is familiar with at least one leaking metal building where that happened. Even the W-shaped flashing of Fig. 6.24 may not provide enough flexibility if it is attached directly to the panel, rather than to the panel closure as shown. A flashing/cleat combination (Fig. 6.25*a*) or a W-shaped flashing with more pronounced bends (Fig. 6.25*b*) permits the roofing to slide more easily.

It is even more challenging to design a good detail for wall-to-roof transition at the roof edges, such as at the rake (Fig. 6.26) and at the inside corner (Fig. 6.27). These closure details must effectively seal the moisture out of the roof while preserving its ability to float to the largest practical degree.

Flashing details carry more than their share of design and construction problems. Ideally, flashing should be made of the same stock as the panels, and any sealant used under it should be continuous. The leaks can often be traced to the failed sealants in the flashing splices. How should the splices be made? Hardy and Crosbie[21] suggest that flashing be soldered when there is no movement between the joined flashing sheets, but the painting job done after the soldering is not as durable as the baked-on shop coat. It is best to solder metals that do not need painting, such as stainless or galvanized steel.

The exterior gutters, whether exposed or concealed, are common to all metal roofing, since a two-directional slope toward the internal drains is obviously impractical with this type of construction. The details of gutter attachment to trapezoidal structural roofing are shown in Figs. 6.19 and 6.28.

The roofing details at the building expansion joints running parallel to the roof slope deserve special attention. (The stepped joint in the perpendicular direction is shown above in Fig. 6.16.) There are two common design solutions for these expansion joints. In Fig. 6.29, the joint is made between the elevated edges of trapezoidal roofing panels supported by continuous rake angles. The latter are used in lieu of the roofing clips. An unobtrusive flat expansion trim can slide over the rake trim. The rake support angles have slotted holes at the bottom, in order not to impede panel movement. This relatively straightforward solution requires that the panel layout begin and end at the joint location.