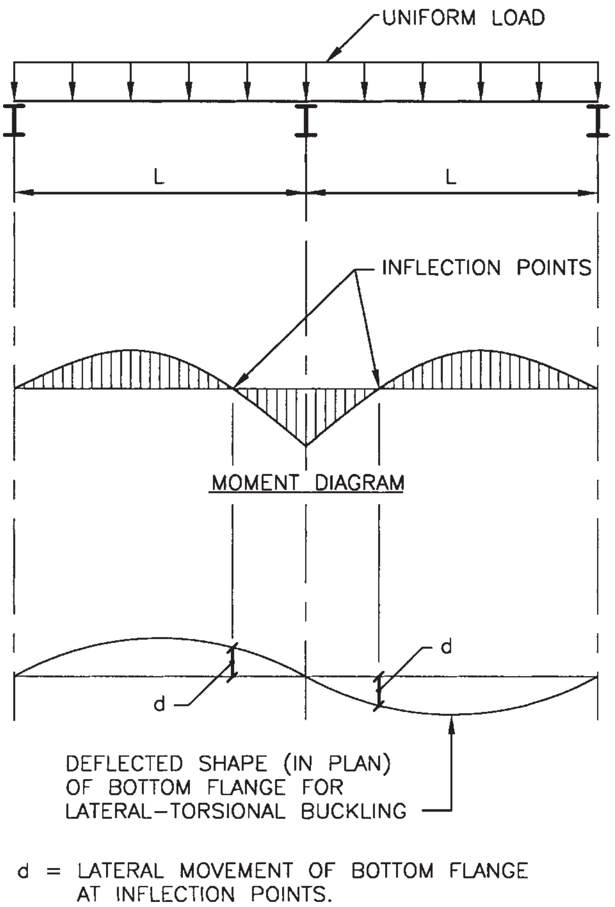

FIGURE 5.13 A point of inflection does not prevent the bottom flange of a continuous beam with laterally supported top flange from translation under lateral-torsional buckling. (*After Ref. 12.*)

continuously laterally supported top flange from moving sideways under the failure mode of lateral-torsional buckling. Yura[13] concludes that "not only it is incorrect to assume that an inflection point is a brace point but also that bracing requirements for beams with inflection points are greater than [for] cases of single curvature."

5.3.6 Some Other Purlin Design Assumptions

In addition to the main design assumptions discussed above, a few more should be mentioned. First, a relatively minor point: if the unbraced purlin length is measured from the end of the splice, where exactly is that point taken? It is possible to regard the end of the splice as the point where the bolts are located and the purlins are physically joined together. A more typical approach is to place the end of the splice at the actual end of the overlapping purlin, which adds an extra 1.5 in or so on each side to the splice length and correspondingly decreases the unbraced purlin length.

Another common design assumption is to consider the splice region between the support and the end of the lap as being fully laterally braced (as stated, among other sources, in the AISI Manual's design example). Despite its wide use, this assumption seems to make sense only if both flanges of the purlins in the lapped area are effectively restricted from rotation and translation under load. Restraint of this type can be provided by sturdy antiroll clips, as described in Sec. 5.5.5. Alternatively, the top purlin flanges must be laterally braced by the roofing or purlin bracing. The bottom flange can be considered restrained if it is connected directly to the support.

In real life, however, the purlins supporting standing-seam roofing are not always so restrained. All too often, Z purlins are simply through-bolted to the supports—and forcing them into the splice tends to cause their rotation as in Fig. 5.8—and are not restrained at the top by anything more than standing-seam roofing with sliding clips. In dissecting this issue, Epstein et al.[11] conclude: "The presently accepted assumption that the lapped region is laterally braced…does not appear to be justified and may significantly overestimate the calculated strength."

A related assumption treats the negative moment region between the end of the lap and the inflection point as a cantilever with an unbraced free end. Obviously, if one questions the stability of the lapped region itself, this assumption could be questioned as well.

5.4 PURLIN BRACING: AVAILABLE SYSTEMS

5.4.1 Why Purlin and Girt Bracing Is Needed

As structural engineers have long known, an unbraced compression flange of any single-web flexural member, even of a perfectly symmetrical one loaded through its web, has a tendency to buckle laterally under vertical loading. A singly symmetrical (C section) or a point-symmetrical (Z section) cold-formed purlin is even more susceptible to buckling because it has its shear center in a location quite different from the point of loading application, which is typically the middle of the top flange. Plus, the principal axes of a Z section are inclined to the web, and any downward load produces a lateral component. Because of these factors, the unbraced C and Z sections tend to twist and to become unstable even under gravity loading on a perfectly horizontal roof.

In sloped roofs, the purlin web is tilted from the vertical position, a fact that further complicates the problem of twisting. Gravity loading acting on a sloped C or Z purlin can be resolved into the components parallel and perpendicular to the roof, both of which tend to overturn the purlin, although in the different directions if the purlins are properly oriented as shown in Fig. 5.14. A computation based on the member geometry quickly finds that the two components equalize each other when the slope equals the ratio of the dimensions of the purlin's flange to its depth. For example, for an 8.5-in-deep Z purlin with a 2.5-in-wide flange, this slope is about 3.5:12. The torsional (twisting) loading increases as the roof slope decreases, and reaches its maximum at a perfectly level roof, because the force component perpendicular to the roof then predominates. The overall torsional loading effect from the two force components is rather small in a purlin with a slope of 4:12 (Fig. 5.14*a*), but if the slope decreases to $^1/_4$:12, torsion becomes significant (Fig. 5.14*b*).

At the roofs with appreciable slopes (over $^1/_2$ to 12), proper purlin orientation is facing upslope, as shown in Fig. 5.15. For near-flat through-fastened roofs the purlins are frequently located in alternating positions (Fig. 5.16), a design that relies on the roofing acting as a compression brace between the two purlins facing each other. This design is not applicable for standing-seam roofs because, as discussed below, standing-seam roofs may not qualify as lateral bracing for purlins. The opposing purlins are sometimes used in single-slope buildings, where placing all the purlins in the same direction would produce large bracing forces without a counterbalance from the opposite slope.

To summarize our discussion in this section and elsewhere, the effective purlin and girt bracing should accomplish the three main objectives listed below. The origin of the first two criteria is Section D3 of the AISI Specification[1,4] and of the third, the Commentary to Section D3.2.1. The braces must be designed and spaced to avoid local crippling at the points of attachment.