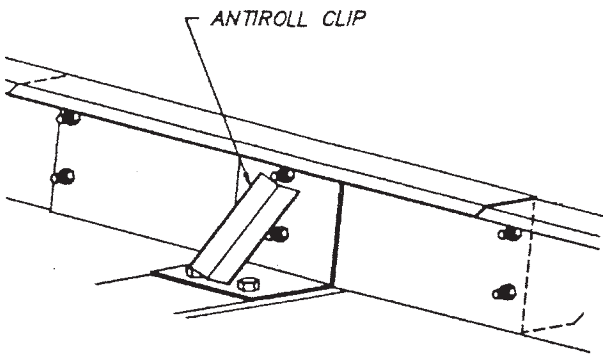

FIGURE 5.36 Antiroll clip. (*Star Building System.*)

5.5.6 Failures Due to Improper Bracing

Why do we devote so much attention to purlin and girt bracing? The answer is simple: Improperly braced purlins and girts are likely to fail in a real hurricane or during a major snow accumulation. Tondelli[16] reports: "The most prevalent purlin and girt failure is due to wind suction at walls and at roofs, usually at end bays." Also, a study of damage caused by the 1970 Lubbock Storm and Hurricane Celia, published by the American Society of Civil Engineers, pointed out that wind uplift "caused buckling of purlins and girts in many metal building system structures. Buckling of the laterally unsupported inner flanges of purlins and girts was the initial type of damage incurred in many cases."[20]

By way of comparison, pre-engineered buildings designed in Canada have a very good loss experience, according to Canadian offices of Factory Mutual Insurance Co. Canadian National Building Code requires purlin bracing at quarter points.

Without proper bracing, a theoretical possibility of progressive collapse can become reality, with devastating consequences. As we discuss in Chap. 10 among some additional examples of building failures, one large metal building collapsed in 10 s from start to finish. The author's own experience includes investigations of large, newly constructed pre-engineered buildings that lacked adequate purlin bracing and antiroll clips—and collapsed under heavy snow accumulation.

Curiously, many in the metal building industry regard some lateral flexibility of the purlins as a positive factor (and, logically, too much bracing as a vice). It is widely acknowledged that most metal building manufacturers rely upon purlin roll—rotation or horizontal displacement of the purlin's top flange—to reduce slotting of the through-fastened metal roofing.[21]

In standing-seam roofs, purlin roll can occur when the actual amount of roofing expansion or contraction exceeds the movement capacity of the clip. Essentially, the roofing becomes directly attached to the purlins in the direction of the movement. If the roofing continues to move, it drags the purlins' top flanges along with it, and the purlins start to "roll." When the direction of the roof movement reverses, the purlins can return to their original location, if not damaged by the previous movements.

If the purlins are well braced and cannot roll easily, the forces of expansion and contraction will tend to damage the roofing or its attachments to the purlins. Accordingly, some manufacturers and even some design authorities consider purlin roll a positive phenomenon. Yet while purlin roll may indeed help preserve the integrity of the roofing, it jeopardizes the load-carrying capacity of the purlins.

A purlin that has rotated more than a few degrees from its original position becomes severely weakened, and its capacity to support even the original design load is compromised. The displaced purlins carrying gravity loading also become subjected to the added torsional stresses, making the situation even worse. In the author's experience, both factors tend to be ignored by some manufacturers.

On top of the strength issues, the moment of inertia of the rotated purlins is diminished; they tend to sag much more than the purlins in the original position—and rotate still further. Beyond a certain point, there will be too much rotation, and the purlins will simply lay flat and fail. As discussed in Chap. 10, purlin failure may lead to a quick collapse of the whole building.

Up to this day, some metal building manufacturers ignore the need for adequate purlin bracing. Whenever the shop drawings indicate no purlin bracing at all, it is prudent to investigate the manufacturer's design approach to determine whether it is unconservative.

The best way to avoid such a situation is to provide the minimum bracing requirements in the contract documents, as discussed in Sec. 5.4.8.

Example 5.1: Preliminary Selection of Roof Purlins. Select a preliminary size of purlins for a 400 × 200 ft warehouse; use LGSI Z sections. From the load combinations of the governing building code (allowable stress design), the maximum combined design downward load, including dead and collateral, is 37 psf, and the combined design upward load is 15 psf. The spacing of primary rigid frames is 25 ft, and the roof slope is 1:12. There are no suspended ceilings, and the space below is unfinished. Select a preliminary purlin bracing scheme and the notes to be placed on the contract drawings suitable for public bidding.

Solution. Because of the size and slope of the roof, select standing-seam metal roofing with a trapezoidal profile, assumed not to contribute to the purlin bracing. Use continuous purlins with full lateral bracing of both flanges; in this case, the downward load will control the design. Assuming a 5-ft spacing of purlins, the combined downward load is

$$37 \text{ psf} \times 5 \text{ ft} = 185 \text{ lb/ft}$$

Using Table B.27 in Appendix B for a 25-ft span, select 9-in-deep purlins with 2.5-in flanges, made of 12-ga metal (purlin designation 9 × 2.5 Z 12 G), good for 199 lb/ft, which exceeds 185 lb/ft.

The maximum allowable deflection for purlins *not* supporting ceilings or spanning over finished space is $L/150$ (see discussion in Chap. 11). The maximum tabulated purlin deflection is given in Table B.27 as 1.37 in for a load of 199 lb/ft. The maximum deflection prorated for 185 lb/ft, is

$$\frac{(1.37)(185)}{199} = 1.27 \text{ in}$$

or

$$\frac{1.27}{25 \times 12} = \frac{L}{235} < \frac{L}{150} \qquad \text{(OK)}$$

Check if there is some other purlin section that is more economical. From Table B.33 in Appendix B for a 25-ft span, 8-in-deep purlins with 3-in flanges, made of 12-ga metal (purlin designation 8 × 3.0 Z 12 G), are good for 211 lb/ft, which also exceeds 185 lb/ft, with a maximum deflection under that load of 1.72 in. The design deflection of the 8 × 3.0 Z 12 G section under 185 lb/ft loading is

$$\frac{(1.72)(185)}{211} = 1.51 \text{ in}$$

or

$$\frac{1.51}{25 \times 12} = \frac{L}{199} < \frac{L}{150} \qquad \text{(Still OK)}$$

Check which purlin section is more economical (weighs less). From Table B.6 in Appendix B, both the 9 × 2.5 Z 12 G and the 8 × 3.0 Z 12 G sections weigh the same—5.333 lb/ft, so either section could be chosen. The deeper section has a smaller load-carrying capacity but a