being restrained at each purlin by screws or other fasteners is a major improvement on the old through-fastened roof design.

Various kinds of standing-seam roofing and methods of their attachment to supports are described in Chap. 6. In summary, standing-seam roofing is attached to purlins indirectly, by means of concealed clips that allow the roofing to slide relative to purlins. The clips, engaged into the seams of the roofing sheets, are connected to purlins by bolts or screws.

The maximum sliding distance is controlled by the clip design. The clips for trapezoidal standing-seam roofing profiles commonly used in industrial and commercial buildings can provide from 1 to 1.5 in of roofing movement in each direction from the "neutral" position. (In the neutral position, the movable part is placed in the center of the clip, permitting the roofing to slide the same amount up and down the slope.)

The concealed clips are carefully engineered not to impede roofing movement. The less they restrain expansion and contraction of the roof, the better they perform. However, there is a flip side to this structural decoupling of roofing and purlins: a formed metal sheet that can slide effortlessly relative to the supporting purlins provides little, if any, lateral bracing for them.

This conclusion is rather obvious, and many structural engineers consider standing-seam roofing fundamentally incapable of providing lateral bracing to purlins. According to their point of view, it may well be that standing-seam roofing provides *some* degree of purlin bracing owing to friction between roofing and purlins. Similarly, the roofing probably has *some* diaphragm rigidity because of friction between the adjacent roofing sheets. But this friction is undesirable—and great efforts are made to minimize it by design—if the free-floating ideal of standing-seam roofing is to be realized.

The R&D departments of the metal roofing manufacturers are undoubtedly searching for ways to reduce, not to increase, sliding friction. Indeed, the best roofing systems use easy-sliding clips and have slippery sealants placed in the roofing seams. One premium product is a so-called articulating clip, designed to further reduce binding during roofing movement. The design of this clip, shown in Chap. 6, allows its movable part to adjust its slope to the deflected shape of the roof under load. A continual improvement of the roofing systems holds little promise for those who rely on roofing friction to brace purlins laterally.

5.5.3 Changes in AISI Specification Provisions Dealing with Standing-Seam Roofing

Once it is realized that standing-seam roofing makes for a poor purlin bracing, it is wise to inform the specifiers of this fact and to adopt the appropriate design safeguards. As modern standing-seam roofing continues to displace the old basic through-fastened sheets, the issue becomes more and more pressing. One could have expected stringent specification provisions to be promptly enacted to ensure that adequate purlin bracing is maintained whenever standing-seam roofing is used. Surprisingly, exactly the opposite has taken place: the latest specifications appear to accept the notion that standing-seam roofing may be capable of providing adequate purlin bracing.

In the 1986 edition of the AISI Specification (and in the 1989 Addendum), Section D.3.2.1, "Anchorage of Bracing for Roof Systems under Gravity Load with Top Flange Connected to Sheathing," the only type of metal roofing specifically recognized as "deck or sheathing" capable of providing purlin bracing was through-fastened roofing. The "deck or sheathing" had to be "fastened directly to the top flanges [of purlins] in such a manner shown to effectively inhibit relative movement between the deck or sheathing and the purlin flange.…" If this "sheathing" was absent, the purlins were considered laterally unbraced and Section D.3.2.2, "Neither Flange Connected to Sheathing," applied instead.

According to Section D.3.2.2 of the 1986–1989 Specification editions, purlins had to be stabilized with discrete purlin braces attached to the top and bottom flanges of C and Z sections "at the ends and at intervals not greater than one-quarter of the span length, in such a manner as to prevent tipping at the ends and lateral deflection of either flange in either direction at intermediate braces." Additional bracing was required at the concentrated load locations. To meet these provisions, at least three lines of purlin bracing at the top and bottom flanges were needed, plus some sturdy clips capable of providing purlin bracing against both translation and rotation at the supports.

By contrast, Section D.3.2.1 of the 1996 edition and of the 2002 North American Specification included standing-seam roofing in the category of "deck or sheathing" capable of providing purlin bracing. The requirement for the minimum diaphragm stiffness of this "deck or sheathing" was removed. The earlier requirement for purlin bracing at one-quarter points and at supports disappeared from Section D.3.2.2.

To be sure, Section D.3.2.1 has retained an important provision that required the purlins connected to "deck or sheathing" be so restrained that "the maximum top flange lateral displacements with respect to the purlin reaction points do not exceed the span length divided by 360." Applying this provision to a typical purlin span of 25 ft, one finds that the maximum displacement of the top flange shall not exceed 0.83 in. Recalling that the typical clips used in standing-seam roofing allow for 1 to 1.5 in of lateral movement—much more than 0.83 in—it becomes clear that the roofing alone cannot provide the lateral restraint to qualify under this section. Therefore, the roofing must still be supplemented by discrete bracing.

A new Section C3.1.4, "Beams Having One Flange Fastened to a Standing Seam Roof System," was introduced in the 1996 edition. In the 2002 North American Specification, this section (identical in wording to the 1996 edition) was moved to an appendix. The new Section C3.1.4 stated that the nominal flexural strength of C and Z purlins supporting standing-seam roofing could be designed under one of two approaches:

1. Using discrete purlin bracing and the provisions of Section C3.1.2.1, which contained rather complex formulas for determination of lateral-torsional buckling strength; or
2. Using the formula $M_n = RS_eF_y$, where M_n, S_e and F_y are as described above (in Sec. 5.5.1), and R is a reduction factor that reflects the degree of bracing ability provided by the given type of standing-seam roofing. (It should not be confused with another R factor used in Eq. C3.1.3-1.) The R factor is determined by a special test called the "Base Test Method for Purlins Supporting a Standing Seam Roof System."

5.5.4 Base Test

The base test procedure is described in the AISI *Cold-Formed Steel Design Manual,*[2] Part VIII. The purpose of the test is to assess the degree of reduction in ultimate load-carrying capacity of purlins attached to various types of standing-seam roofing, with or without discrete purlin braces, in relation to the capacity of the same purlins with full lateral bracing. As has already been discussed, full lateral bracing can be provided by through-fastened roofing or by properly designed and spaced discrete bracing. The base test is intended for gravity load application rather than uplift loading.

The base test uses two simply supported purlins to approximate a very complex behavior of the whole building with continuous purlins carrying standing-seam roofing. The purlins are placed on steel support beams within the test chamber. They carry the standing-seam roofing, clips, fasteners, roof insulation, and discrete purlin bracing that are used in actual field construction. The purlins are oriented as they would be in service—facing either in the same on in the opposite direction (see Figs. 5.15 and 5.16).

Manufacturers naturally desire that the test results apply to the whole range of purlin material thicknesses produced by them, rather than only to the tested gages. To accomplish this, for each size of purlin at least three tests are required for the members made with the thinnest and three with the thickest gage of metal produced in the purlin line. To prevent separation of the roofing seams at the ends of the sheets, a small angle ($1 \times 1 \times 1/8$ in) is fastened underside the sheets. When the purlins are oriented in the same direction, a $3 \times 3 \times 1/4$ in continuous angle may be used in lieu of the smaller angle, to approximate the effects of the eave strut. "Adequate space" is supposed to be provided around the edges of the roofing for lateral displacement of the assembly under load. The basic test setup is shown in Fig. 5.34.

The assembly is gradually loaded and the corresponding deformations recorded. The test stops when the maximum load is reached. The ultimate tested capacity is then compared with the flexural capacity of the fully braced purlins (as calculated or as determined by testing) and the reduction