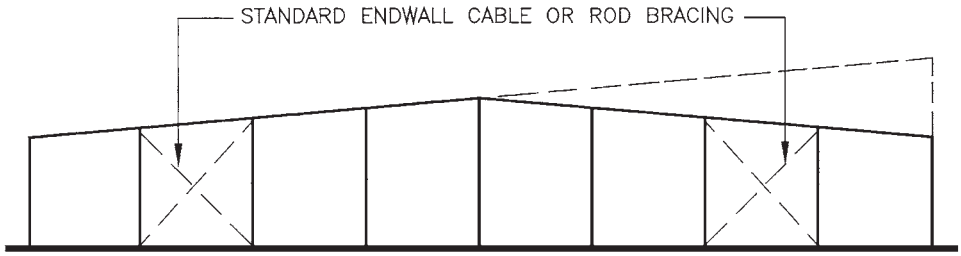
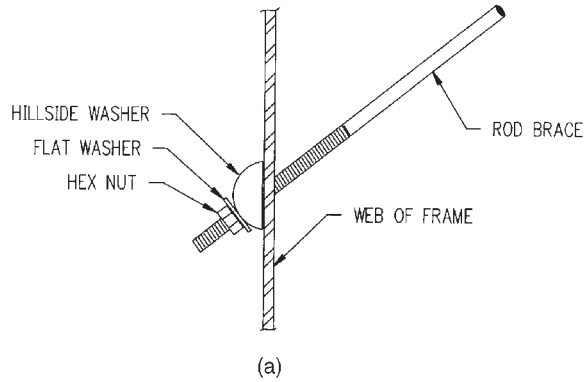


FIGURE 3.12 Typical endwall bracing locations. Buildings not exceeding 100 ft in width may need only a single set of bracing; when the width is between 100 and 240 ft, two sets are required, as shown. (*Nucor Building Systems.*)



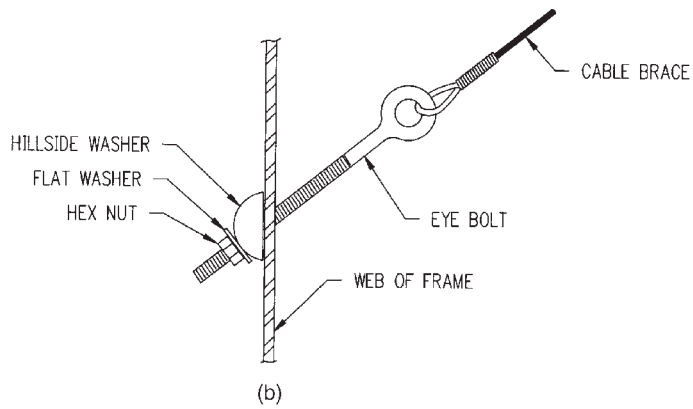


FIGURE 3.13 Typical rod and cable brace details. (*a*) Rod brace to frame detail; (*b*) cable brace to frame detail. (*Metallic Building Systems.*)

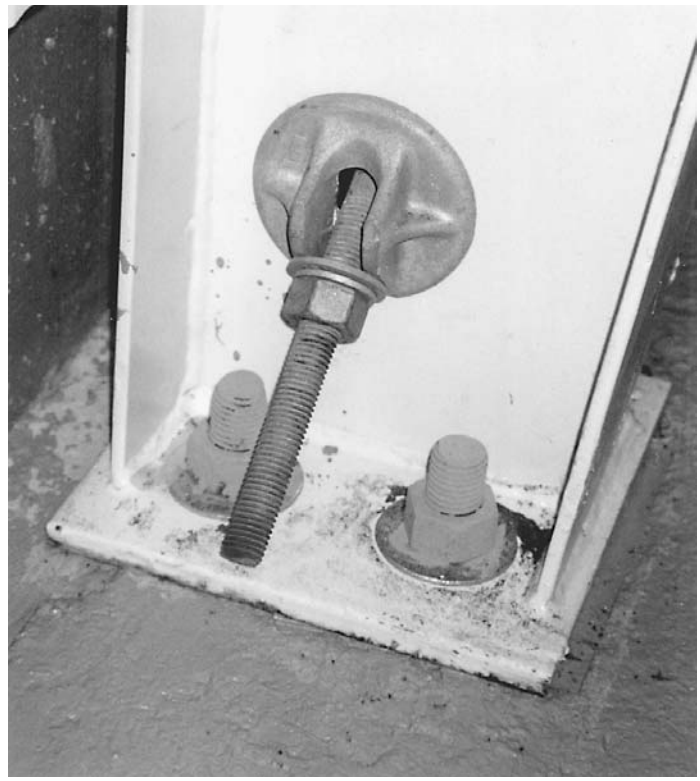


FIGURE 3.14 Hillside washer.

Failures of the hillside washer-to-web connection were reported by Miller,[8] who investigated damage to several metal buildings from the Feb. 17, 1994, Northridge earthquake in California. He reported that five out of six such connections in one building failed. The failure mechanism involved fracture of the hillside washers (Fig. 3.15) and in some cases subsequent pull-through of the rods. The missing washer of Fig. 3.15 was located more than 15 ft away from the column.

Surprisingly, the building did not collapse. Why? Miller attributed the positive outcome to its light weight—so that little seismic load was generated—and to framing redundancy. In this context, redundancy refers to the beneficial effects not normally considered in design, e.g., partial fixity of column bases and even some help from sheet metal flashing.

Sinno[9] attempted to conduct a definitive study of the ultimate behavior of the connection. His laboratory tests identified five possible failure modes, including a fracture of the rod and four failure modes in the column material and welds. Surprisingly, fracture of hillside washers documented by Miller was not among them. In any case, it seems that widespread use of standard hillside washers attached directly to thin webs should be reevaluated.

Fortunately, the problem has been recognized, and now there is an alternative. The proprietary line of washers has been developed by Triangle Fastener Corp. of Cleveland, Ohio (reportedly, inspired by a discussion on this topic in the first edition of the book); one heavy-duty product is shown in Fig. 3.16. The illustrated washer appears so massive as to preclude its fracture under load. However, the thin column web can still be damaged, and we recommend that a steel reinforcing plate be placed under the washer. The plate should be fitted between the column flanges and welded to them (Fig. 3.17). The plate's thickness can be determined by calculations.