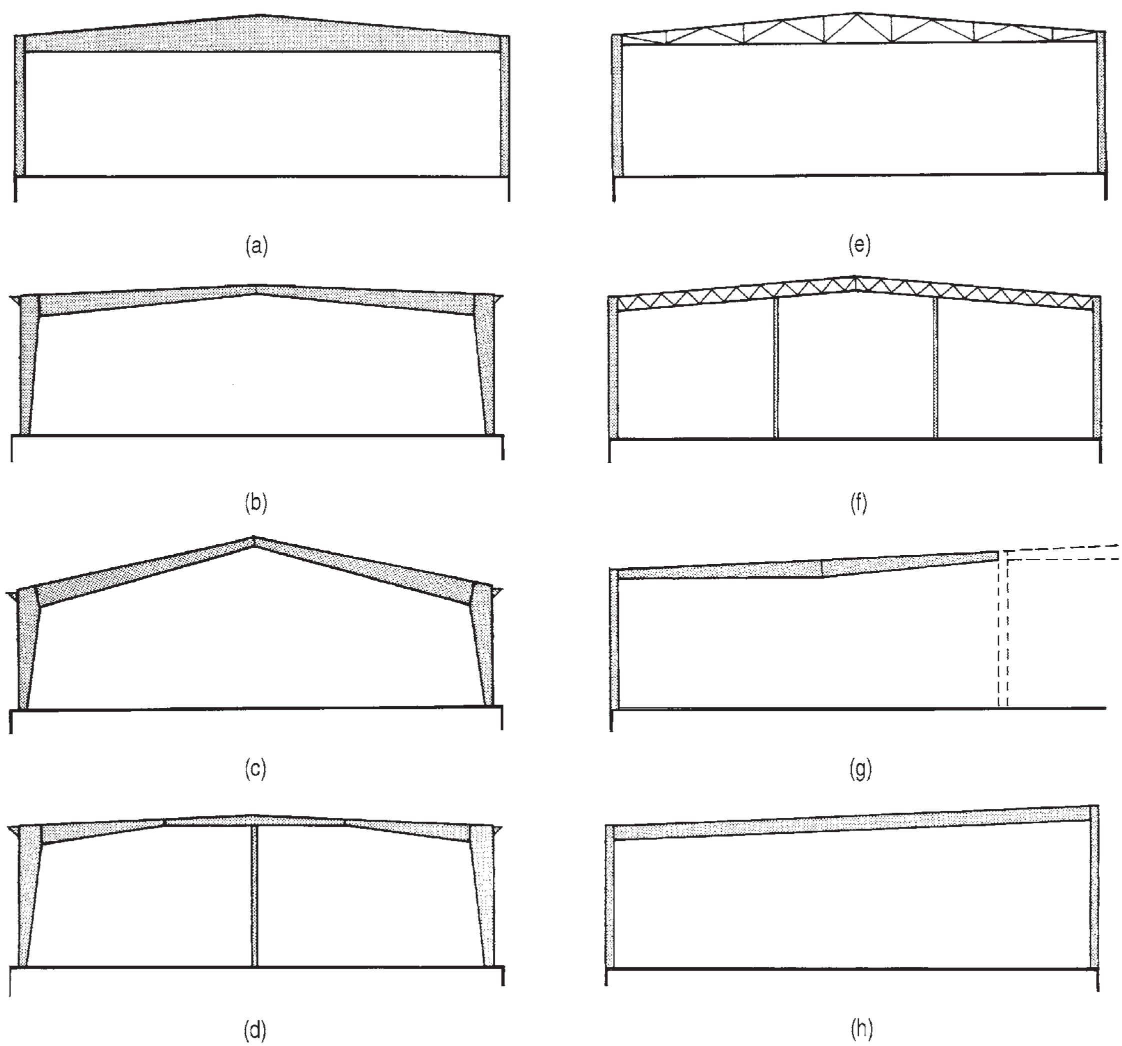


**FIGURE 4.1** Types of primary frames. (*a*) Tapered beam; (*b*) single-span rigid frame, low profile; (*c*) single-span rigid frame, medium profile; (*d*) multispan rigid frame; (*e*) single-span truss; (*f*) continuous truss; (*g*) lean-to; (*h*) single-slope post-and-beam. (*Adapted from Star Building Systems design manual.*)

between the inside faces of columns.* *Eave height* is measured between the bottom of the column base plate and the top of the eave strut; the *clear height* is the distance between the floor and the lowest point of the structure, usually the *rafter* (see Fig. 1.2 in Chap. 1).

How to dimension metal buildings on contract drawings? Manufacturers expect building width and length to be shown as the distances between the outside surfaces of wall girts (that plane is known as the *sidewall structural line*), not between the centerlines of exterior columns.

*The term *clear span* is occasionally misunderstood, despite its name, as some people measure it at the base and some at the widest point of the column such as the knee.

Misunderstanding this convention leads to arguments between designers and manufacturers and to buildings being supplied in sizes slightly less than the designers had anticipated.

## 4.3 TAPERED BEAM

Tapered beam, also known as wedge beam or slant beam, is a logical extension of conventional post-and-beam construction into metal building systems. Indeed, what makes this system different from a built-up plate girder resting on two wide-flange columns are variability of the beam depth and partial rigidity of beam-to-column connections.

Most often, the beam is tapered by sloping the top flange for water runoff and keeping the bottom flange horizontal for ceiling applications (Fig. 4.1*a*). A less common version, reminiscent of a scissors truss, involves the beam with both flanges sloped. That configuration may be especially useful for the roof with a steep pitch used in combination with a low-slope cathedral ceiling. The splices typically occur at midspan. Tapered-beam system is appropriate when:

- The frame width is between 30 and 60 ft, and eave height does not exceed 20 ft.
- Straight columns are desired (an important consideration for office and retail buildings with drywall interiors).
- The roofing material can tolerate a relatively low roof slope.

Tapered beams lose their attractiveness at spans exceeding 60 ft. Similarly, if the frame width is under 30 ft, standard hot-rolled framing might be less costly. Tapered-beam frames are typically specified for offices and small commercial and retail uses with moderate clear span requirements. Tapered beams are sometimes preferred for buildings with bridge cranes, because their bottom flanges, being horizontal, make for easy attachments and local reinforcing.

The system is shown in detail in Fig. 4.2. Typical frame dimensions for various spans and roof live loads are indicated in Fig. 4.3.

Design of tapered beams involves a frequently overlooked nuance. The manufacturers sometimes assume that beams in this system are connected to columns with "wind connections," rigid enough to resist lateral loads but flexible enough to behave under live loads in a single-span fashion. The question is, how realistic is this assumption? In structural steel design, as *AISC Manual of Steel Construction,* vol. II, *Connections*[1] points out, there are certain definitive criteria that these semirigid connections must satisfy. One such requirement is that "the connection material must have sufficient inelastic rotation capacity" to prevent it from failure under combined gravity and wind loads.

The AISC manual's semirigid connection of choice is a pair of flexible clip angles that attach top and bottom beam flanges to the column (see Fig. 4.4). A flexible behavior of this connection has been experimentally demonstrated. On the other hand, in metal building systems members are normally connected to each other by through-bolted end plates as shown in Fig. 4.2. This type of joint is rather rigid and does not pass the flexibility muster for "wind connections."

If a joint lacks reserve rotational capacity, it is considered nearly rigid and thus capable of transmitting bending moments across the interface. The ends of the beam so connected to columns will have some bending moments partially transmitted to the columns. If a simple-span assumption is made by the manufacturer, the columns are not designed for this bending moment. This dangerous oversimplification could conceivably result in the columns becoming overloaded by combined axial and flexural stresses. Whenever a tapered-beam system is proposed, it is wise to investigate the manufacturer's approach to this issue.

There are certain steps manufacturers can take to increase the connection flexibility. One solution might be to introduce compressible deflection pads shown in Fig. 4.14 (in a context of another system) that absorb some movement of the beam's ends.

The specifiers could of course sidestep the entire issue by simply adding a note to the contract documents stating that all beam-to-column connections in the tapered-beam system are to be considered rigid for the design purposes, but this approach might result in heavier column sections.