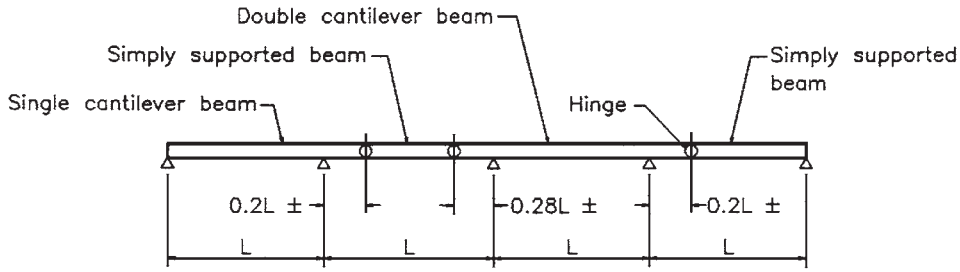

FIGURE 3.35 Cantilevered beam framing.

hinges, so to speak, on the proper joint design. Connections that are excessively rigid tend to convert this system into a continuous beam, with all its limitations.

Other avenues to efficiency could be taken by using the LRFD method (see Sec. 3.2.1) and by specifying high-strength steels.

3.4.3 Steel Trusses

Long-span steel trusses have been used for many decades in both bridge and building structures. Prior to the advent of metal building systems, roof trusses were the framing of choice for industrial, warehouse, and commercial applications. Roof trusses have been, and still are, quite economical for clear spans ranging from about 40 to 140 ft. For example, a portal truss has been designed to span some 132 ft over an existing building[11]; in some recent projects, trusslike open-web joists have been employed to span almost 200 ft. Steel trusses can be designed with a single or double slope of the top chord. The double slope results in a deeper section at midspan, structurally beneficial.

Historically, trusses supported steel wide-flange purlins, and truss spacing was limited by the length the purlins could span. Today's purlin choices include not only those still popular sections but also open-web joists and even extra-deep steel roof deck. The optimum truss spacing, governed by the purlin capacity, is generally between 20 and 30 ft, the same as in pre-engineered buildings.

As in the previous two structural systems, lateral stability is provided by horizontal roof diaphragms made of either steel deck or diagonal bars, in combination with vertical wall bracing. In the past, trusses were commonly braced laterally by knee braces to the first panel point (Fig. 3.36*a*). This solution sacrificed some interior headroom and has lost popularity in favor of a truss design with some depth at supports, incorporating the column into the trusswork (Fig. 3.36*b*). In the latter case, the column is erected and braced first, followed by relatively simple truss-to-column connections. The trusses are partially assembled in the shop to the maximum permissible shipping width, around 12 ft, and fully assembled in the field.

3.4.4 Hot-Rolled Steel Rigid Frames

A rigid frame, also known as a moment-resisting frame, consists of the column and beam sections rigidly joined together by moment-resisting connections. The resulting unified structure is stable and does not need bracing in its own plane. We have already mentioned rigid frame as the most popular structure for metal building systems, but the frames can be built by others, too.

In fact, low-rise buildings had traditionally utilized gable frames made of regular wide-flange members or tapered sections. The taper was achieved by cutting a wide-flange beam web at an angle, turning one section around and welding the webs together, or simply welding the frame from steel plates. With the benefits of pre-engineered construction becoming apparent, and with labor costs rising, custom fabrication of rigid frames fell into disrespect.

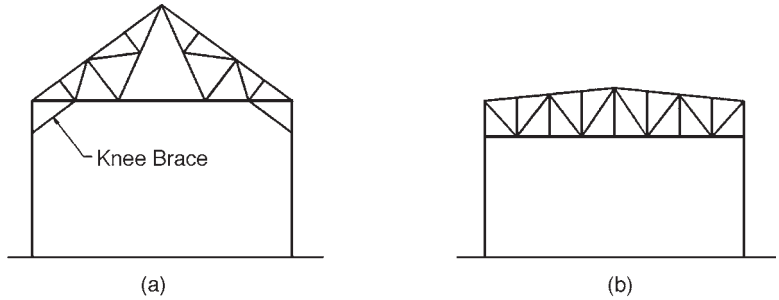

FIGURE 3.36 Roof trusses. (*a*) Fink truss; (*b*) Warren truss.

Still, one report[12] stated that an efficient steel fabricator in cooperation with an innovative structural engineer produced gable frames priced under the lowest bids from pre-engineered building manufacturers. Among other features, the engineer could accommodate column fixity in the sidewall direction into the foundation design, since both the foundation and the superstructure were designed in-house. This would have been difficult were the foundations and the frames designed by different parties (see discussion in Chap. 12). It remains to be seen whether this experiment can be successfully replicated.

Rigid frames offer many advantages over the other framing types, such as more effective use of steel than in simple beams, ease of maintenance and cleaning, as compared to trusses, and ability to support heavy concentrated loads. The disadvantages include relatively high material unit cost and susceptibility to differential settlement and temperature stresses. The frames produce horizontal reactions on the foundations, an additional design complication. And, as in any solid-web framing, pipes and conduits must be placed below the bottom flange unless expensive web openings are provided.

3.4.5 Heavy (Hybrid) Structures

For large industrial and multistory buildings with flexible and variable loading, extremely long spans, or heavy cranes, the advantages of the conventional structural systems listed above are readily apparent. Rather than concede this market to the competition, some far-sighted metal building manufacturers established "heavy structures" divisions instead. In essence, these hybrid structures utilize conventional structural steel trusses or rigid frames for primary framing, but have cold-formed secondary members. The buildings are generally clad in metal roofing and siding.

Carter[13] traces the increasing popularity of heavy structures to the fact that the relationship between labor and material costs has changed, and the large fabrication costs of metal building systems often outweigh the material savings, the traditional advantage of pre-engineered buildings. Also, the new steel mills have become very efficient in producing steel shapes. As a result, the structure with the least weight is not necessarily the most economical any longer. Further, structural steel trusses have an advantage in buildings where framing deflections must be tightly controlled, such as aircraft hangars, theaters, and precision manufacturing plants. The trusses can be accurately cambered, while rigid frames are difficult to camber. Other reasons for using hybrid structures, according to Carter, include corrosive environments and fatigue-inducing applications, where welded frames are at a disadvantage.

3.4.6 Other Structural Systems

There are many other types of structural framing which could, in some circumstances, be more appropriate for the project at hand than metal building systems. Lack of space precludes discussing all of them even in passing detail. Among the most popular systems we would mention the following: