compression flange. Whether this presents a problem or not depends on the size of the member, level of stress, and web thickness. A 5-ft-deep moment frame section may easily tolerate a 4-in eccentricity, while an 8-in-deep purlin will not.

The bracing should be designed for a compression force required to restrain the compression flange from buckling. The force to be resisted by the bracing is usually taken as 2 percent of the compressive flange force in simple-span members and is sometimes increased to 4 percent for continuous members. Brace stiffness should be carefully evaluated, since a deflected brace is essentially useless. Bracing of primary framing and purlins will be revisited in the following two chapters.

3.4 THE COMPETITION OF METAL BUILDING SYSTEMS

Our study of metal building systems will not be complete without a cursory review of the competition. Even the die-hard enthusiasts of pre-engineered buildings can benefit from an objective comparison with other framing systems, as there is no single most economical framing solution for all circumstances.

3.4.1 Open-Web Steel Joists

One of the most economical contemporary framing systems consists of open-web steel joists carrying galvanized metal deck and supported on joist girders or wide-flange steel beams (Fig. 3.33). Open-web steel joists, popularly known as bar joists, are typically made of double-angle chords (top and bottom horizontal members) and round bar or angle diagonals. The joists are designed and built by their manufacturers in accordance with Steel Joist Institute Specifications,[10] often using proprietary steel design software.

Utilizing high-strength steel, the open-web joists offer an exceptional strength-to-weight ratio. The joist system is ideal for roof framing supporting uniformly distributed loads, suspended ceilings, and mechanical ducts. The open-web design saves space by allowing passage of piping, conduits, and even small HVAC ducts. Concentrated loads present a problem, however, and should be applied only at the panel points, where diagonals intersect the chords, because the chord sections are usually rather weak in local bending and the joist capacity may be insufficient. Heavy point loads may require special joist design.

The joists are unstable during erection, and SJI specifications require several rows of bridging for lateral bracing. Once the bracing is properly secured and roof deck attached, the system is stable. The steel deck, together with perimeter steel beams, forms a horizontal roof diaphragm serving the same function as horizontal roof bracing in metal building systems. Joist spacing is governed by the roof deck's capacity.

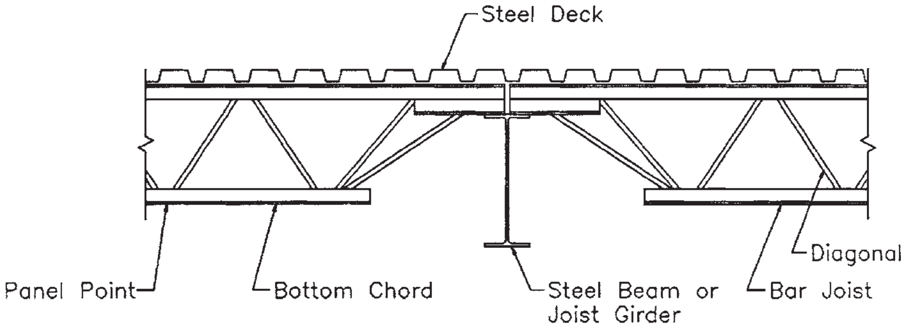

FIGURE 3.33 Open-web joist and steel deck system.

Historically, bar joists have been used with relatively flat roofs, since large slopes present some difficulties in making sloped bearing seats and require a careful structural analysis. Many engineers avoid this system when roof slope exceeds 45°.

The open-web joist system is very economical for spans ranging from 25 to 50 ft. Long-span steel joists are cost effective for even longer spans, from 60 to 144 ft. For a rectangular column layout (a 30- by 40-ft grid is considered by many to be the most economical bay size for an office building), the joists normally run in the long direction (40 ft in a 30- by 40-ft bay).

Open-web joists can be supported by either hot-rolled wide-flange beams or joist girders. The joist girders function on the same principle as bar joists—as a minitruss—but are commonly made of heavier all-angle sections. The panel points of joist girders coincide with bar joist locations. Joist girders are often preferred to wide-flange sections, especially for longer spans and for larger projects where more than a few are needed. The system is customarily supported on wide-flange or tubular columns and requires wall bracing for lateral stability.

3.4.2 Hot-Rolled Wide-Flange Beams

Wide-flange beam and girder system supporting steel roof deck should be familiar to most people involved in building construction. It is the simplest and most versatile of the framing systems, easily adaptable to any roof slope and accommodating suspended, concentrated, and axial loads with ease. The beams can be cantilevered and arranged in complex configurations for nonrectangular plans, altered or reinforced for localized loads. The flexibility has a price, of course. Unless some of these complications are actually present, steel beams are likely to be more expensive than bar joists. The beams tend to become overly deep and heavy as the spans exceed about 40 ft.

Structural engineers have identified two ways to increase the efficiency of this system. The first one is a *continuous-beam* principle. Three simply supported beams (Fig. 3.34*a*) have higher maximum bending moments and larger vertical deflections than one continuous beam (Fig. 3.34*b*) covering the same three spans. Therefore, a three-span continuous beam is more efficient and requires less metal than three single-span beams.

Continuous framing has its limitations. Being statically indeterminate, it does not tolerate well any differential settlement of the supports, which can result in large secondary stresses threatening its integrity. Another problem is a possibility of large temperature stress buildup in a long single piece of metal. The design professional of record should carefully investigate a potential for problems caused by these two factors before specifying the continuous framing scheme.

A second way to increase the efficiency of the system lies in the *cantilevered-beam* scheme. Instead of one continuous beam, this framing consists of alternating cantilevered and simply supported beams (Fig. 3.35). The beam connections form *hinges,* designed not to transmit any bending moments. The length of cantilevers is selected to produce approximately equal negative moments in the cantilevers and positive moments in the simply supported beams. This system is statically determinate and is less affected by differential settlement or by temperature stresses. The design success

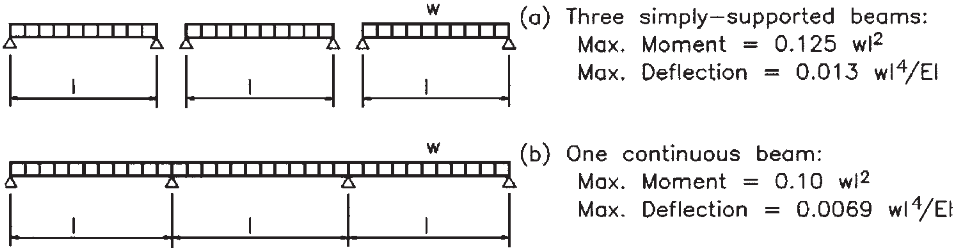

FIGURE 3.34 The efficiency of continuity.