CHAPTER

3

Structural Elements

This chapter treats the considerations for investigation of the behavior of various basic structural elements. These are the building blocks from which structural systems are developed.

3.1 BEAMS

The generic name for a structural member (element) that is used for spanning, sustains lateral (perpendicular) loading, and develops internal resisting force actions of bending and shear is a *beam.* Depending on its particular task in a structural system, a beam may be further described as a *joist*, *rafter, purlin*, *girder*, *header*, or *lintel*; however, for its fundamental behavior, it is classified as a beam.

Types of Beams

The most frequently used beam is the *simple beam*. As shown in Figure 3.1*a*, this consists of a single-span beam with supports at each end, offering only vertical force resistance. Because the supports do not offer restraint to the rotation of the beam ends, the beam takes the simple curved form of deformation as shown in the figure.

Supports that do not restrain rotation are called *free*, *pinned*, or *simple* supports. Thus the beam in Figure 3.1*a* is actually a simply supported beam, although it is more commonly called a simple beam.

A *cantilever beam* consists of a single-span beam with only one end support, as shown in Figure 3.1*b*. For stability of the beam, this support must be a rotation-resisting support, called a *fixed support* or a *moment-resisting support*.

Cantilevers exist less often as shown in Figure 9.2*b* than as extensions of beam ends over their supports, as shown at the right end of the beam in Figure 3.1*c*. The beam with an extended end is called an *overhanging beam*.

While the simple beam and single cantilever have deformed shapes with simple single curvature, the overhanging beam has multiple, or double, curvature (S shaped when the beam has a single extended end). This form of curvature is also found in beams that are continuous through more than one span, as shown in Figure 3.1*d*.

Figure 3.1*e* shows a single-span beam with both ends fully fixed against rotation. This is called a *restrained beam* or a *fixed-end beam* and it takes the profile of the doubly inflected curve shown.

Visualization of the deformed shape of a beam is a useful tool in investigation. It helps to establish the character of support reactions as well as the nature of distribution of internal force effects in the beam.

It is possible for beam support conditions to approach the true situation of fully fixed or complete freedom of moment restraint. Many supports, however, tend to offer partial restraint, being somewhere between the extreme conditions illustrated in Figure 3.1. Details of the connections at the beam supports as well as the nature of the supporting structures will qualify these conditions. For initial investigation, however, it is common to assume either simple or fully fixed supports, reserving judgment as to any need for adjustment until more is determined about the final form and details of the structure.

Load and Support Conditions

Members that serve as beams exist in a variety of situations and sustain many types of loads. The most common types of loading conditions are the following (see Figure 3.2):

Uniformly Distributed Load. The dead weight of the beam itself is constituted as a load that is distributed evenly along the beam length, as shown in Figure 3.2*a*. This is a common loading and is called a uniformly