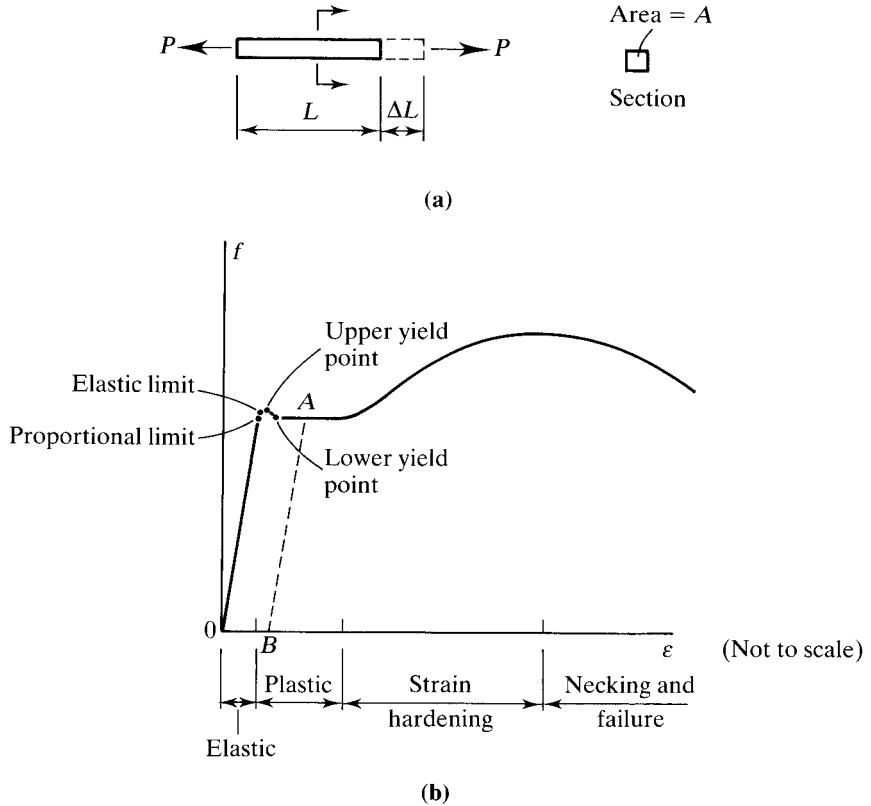


FIGURE 1.3



If the load is increased in increments from zero to the point of fracture, and stress and strain are computed at each step, a stress–strain curve such as the one shown in Figure 1.3b can be plotted. This curve is typical of a class of steel known as *ductile*, or *mild, steel*. The relationship between stress and strain is linear up to the proportional limit; the material is said to follow *Hooke’s law*. A peak value, the upper yield point, is quickly reached after that, followed by a leveling off at the lower yield point. The stress then remains constant, even though the strain continues to increase. At this stage of loading, the test specimen continues to elongate as long as the load is not removed, even though the load cannot be increased. This constant stress region is called the *yield plateau*, or *plastic range*. At a strain of approximately 12 times the strain at yield, strain hardening begins, and additional load (and stress) is required to cause additional elongation (and strain). A maximum value of stress is reached, after which the specimen begins to “neck down” as the stress decreases with increasing strain, and fracture occurs. Although the cross section is reduced during loading (the Poisson effect), the original cross-sectional area is used to compute all stresses. Stress computed in this way is known as *engineering stress*. If the original length is used to compute the strain, it is called *engineering strain*.

Steel exhibiting the behavior shown in Figure 1.3b is called *ductile* because of its ability to undergo large deformations before fracturing. Ductility can be measured by the elongation, defined as

$$e = \frac{L_f - L_0}{L_0} \times 100 \tag{1.1}$$

where

- e = elongation (expressed as a percent)
- L_f = length of the specimen at fracture
- L_0 = original length

The elastic limit of the material is a stress that lies between the proportional limit and the upper yield point. Up to this stress, the specimen can be unloaded without permanent deformation; the unloading will be along the linear portion of the diagram, the same path followed during loading. This part of the stress–strain diagram is called the *elastic range*. Beyond the elastic limit, unloading will be along a straight line parallel to the initial linear part of the loading path, and there will be a permanent strain. For example, if the load is removed at point *A* in Figure 1.3b, the unloading will be along line *AB*, resulting in the permanent strain *OB*.

Figure 1.4 shows an idealized version of this stress–strain curve. The proportional limit, elastic limit, and the upper and lower yield points are all very close to one another and are treated as a single point called the *yield point*, defined by the stress F_y . The other point of interest to the structural engineer is the maximum value of stress that can be attained, called the *ultimate tensile strength*, F_u . The shape of this curve is typical of mild structural steels, which are different from one another primarily in the values of F_y and F_u . The ratio of stress to strain within the elastic range, denoted E and called *Young’s modulus*, or *modulus of elasticity*, is the same for all structural steels and has a value of 29,000,000 psi (pounds per square inch) or 29,000 ksi (kips per square inch).

Figure 1.5 shows a typical stress–strain curve for high-strength steels, which are less ductile than the mild steels discussed thus far. Although there is a linear elastic portion and a distinct tensile strength, there is no well-defined yield point or yield plateau.

FIGURE 1.4

