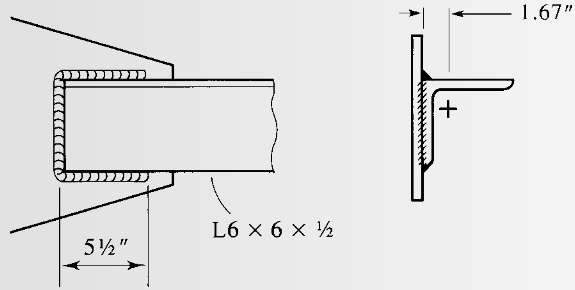
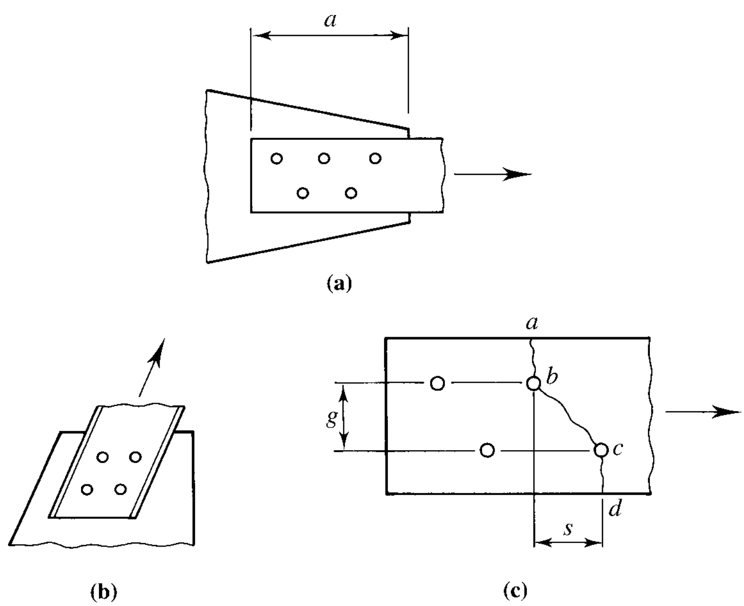
FIGURE 3.13




## 3.4 STAGGERED FASTENERS

If a tension member connection is made with bolts, the net area will be maximized if the fasteners are placed in a single line. Sometimes space limitations, such as a limit on dimension *a* in Figure 3.14a, necessitate using more than one line. If so, the reduction in cross-sectional area is minimized if the fasteners are arranged in a staggered pattern, as shown. Sometimes staggered fasteners are required by the geometry of a connection, such as the one shown in Figure 3.14b. In either case, any cross section passing through holes will pass through fewer holes than if the fasteners are not staggered.

FIGURE 3.14



If the amount of stagger is small enough, the influence of an offset hole may be felt by a nearby cross section, and fracture along an inclined path such as *abcd* in Figure 3.14c is possible. In such a case, the relationship $f = P/A$ does not apply, and stresses on the inclined portion *b–c* are a combination of tensile and shearing stresses. Several approximate methods have been proposed to account for the effects of staggered holes. Cochrane (1922) proposed that when deducting the area corresponding to a staggered hole, use a reduced diameter, given by

$$d' = d - \frac{s^2}{4g} \tag{3.2}$$

where $d$ is the hole diameter, $s$ is the stagger, or pitch, of the bolts (spacing in the direction of the load), and $g$ is the gage (transverse spacing). This means that in a failure pattern consisting of both staggered and unstaggered holes, use $d$ for holes at the end of a transverse line between holes ($s = 0$) and use $d'$ for holes at the end of an inclined line between holes.

The AISC Specification, in Section B4.3b, uses this approach, but in a modified form. If the net area is treated as the product of a thickness times a net width, and the diameter from Equation 3.2 is used for all holes (since $d' = d$ when the stagger $s = 0$), the net width in a failure line consisting of both staggered and unstaggered holes is

$$\begin{aligned} w_n &= w_g - \sum d' \\ &= w_g - \sum\left(d - \frac{s^2}{4g}\right) \\ &= w_g - \sum d + \sum \frac{s^2}{4g} \end{aligned}$$

where $w_n$ is the net width and $w_g$ is the gross width. The second term is the sum of all hole diameters, and the third term is the sum of $s^2/4g$ for all inclined lines in the failure pattern.

When more than one failure pattern is conceivable, all possibilities should be investigated, and the one corresponding to the smallest load capacity should be used. Note that this method will not accommodate failure patterns with lines parallel to the applied load.

## EXAMPLE 3.6

Compute the smallest net area for the plate shown in Figure 3.15. The holes are for 1-inch-diameter bolts.

**SOLUTION**

The effective hole diameter is 1 + ⅛ = 1⅛ in. For line *abde,*

$$w_n = 16 - 2(1.125) = 13.75 \text{ in.}$$