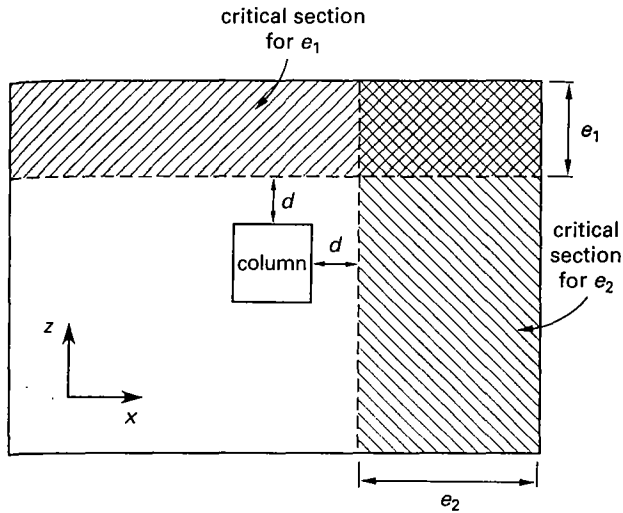


Figure 55.3 Critical Section for One-Way Shear

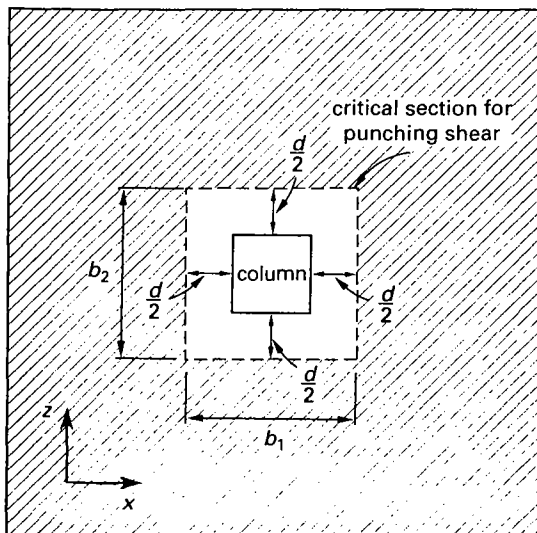


In addition to the footing failing in shear as a wide beam, failure can also occur in *two-way shear* (also known as *double-action shear* and *punching shear*). In this failure mode, the column and an attached concrete piece punch through the footing. Although the failure plane is actually inclined outward, the failure surface is assumed for simplicity to consist of vertical planes located a distance $d/2$ from the column sides.

The area in punching is given by Eq. 55.12. b_1 is the length of the critical area parallel to the axis of the applied column moment. Similarly, b_2 is the length of the critical area normal to the axis of the applied column moment.

$$A_p = 2(b_1 + b_2)d \quad 55.12$$

Figure 55.4 Critical Section for Two-Way Shear



Assume for generality that the column supports a moment. The maximum shear stress on the critical shear plane is computed as the sum of the shear stresses resulting from the axial load and the moment. The punching shear stress is given by Eq. 55.13.

$$v_u = \frac{P_u - R}{A_p} + \frac{\gamma_v M_u (0.5b_1)}{J} \quad 55.13$$

In Eq. 55.13, R is the resultant of the factored soil pressure acting over the area $b_1 b_2$. The stresses from the moment cancel over this area, so R is

$$R = \frac{P_u b_1 b_2}{A_f} \quad 55.14$$

γ_v is the fraction of the moment M_u that is assumed to contribute to shear stress [ACI 318 11.12.6.1 and ACI 318 13.5.3.2].

$$\gamma_v = 1 - \frac{1}{1 + \frac{2}{3} \sqrt{\frac{b_1}{b_2}}} \quad 55.15$$

When the column is located at the center of the footing, the constant J is given by Eq. 55.16 [ACI 318 R11.12.6.2].

$$J = \left(\frac{db_1^3}{6} \right) \left(1 + \left(\frac{d}{b_1} \right)^2 + 3 \left(\frac{b_2}{b_1} \right) \right) \quad 55.16$$

The nominal concrete shear stress for punching shear is given by Eq. 55.17.

$$v_c = (2 + y) \sqrt{f'_c} \quad 55.17$$

$$y = \min \{ 2, 4/\beta_c, 40d/b_o \} \quad 55.18$$

$$\beta_c = \frac{\text{column long side}}{\text{column short side}} \quad 55.19$$

$$b_o = \frac{A_p}{d} = 2(b_1 + b_2) \quad 55.20$$

Determining the footing thickness is accomplished through trial and error. First, obtain the required depth for punching shear using the following procedure.

- step 1: Assume a value of d .
- step 2: Compute b_1 and b_2 .
- step 3: Evaluate A_p , J , and γ_v .
- step 4: Compute R .
- step 5: Compute v_u .
- step 6: Calculate v_c .
- step 7: If $v_u \geq \phi v_c$, increase d and repeat from step 2.