

Combined Footings

Geometry, Load Distribution, and Structural Design

Combined footings support two or more columns on a common reinforced concrete foundation. They are commonly used where property boundaries prevent concentric isolated footings, adjacent foundations would overlap, or substantial column loads must be supported within a restricted footprint.

The design must satisfy two related requirements: distribute loads within the soil's allowable bearing pressure and provide sufficient structural capacity to resist bending and shear. Footing geometry establishes the load distribution; thickness and reinforcement provide the required resistance.

The initial footing area is determined from service loads and allowable soil pressure. For two columns, the required area is

$$A_{\text{req}} = \frac{P_1 + P_2}{q_{\text{allow,net}}} \quad (1)$$

Here, A_{req} is the required footing area; P_1 and P_2 are the service column loads; and $q_{\text{allow,net}}$ is the net allowable soil bearing pressure.

The applied loads and allowable pressure must be evaluated on a consistent net basis, with foundation weight and overburden accounted for according to the geotechnical bearing-pressure definition.

Providing adequate area is only the first step. The footing must also be proportioned to control eccentricity between the applied load and the supporting area. For two vertical column loads, the resultant acts at

$$\bar{x} = \frac{P_1 x_1 + P_2 x_2}{P_1 + P_2} \quad (2)$$

The distances to the columns, x_1 and x_2 , and the distance to the resultant are measured from a common reference point.

Under the idealized uniform-pressure model, the centroid of the footing area coincides with this resultant. An offset introduces an eccentric moment and produces nonuniform bearing pressure. Since relative column loads can change between load combinations, centroid alignment must be evaluated for the relevant loading conditions.

A **rectangular combined footing** provides a constant-width base beneath the columns. Taking the reference point at one end of the footing, centroid alignment establishes the length:

$$L = 2\bar{x} \quad (3)$$

The required width then follows from

$$B = \frac{A_{\text{req}}}{L} \quad (4)$$

Here, L and B are the footing length and width. These relationships establish preliminary dimensions. The resulting footprint must also accommodate column locations, edge clearances, and property boundaries.

A **trapezoidal combined footing** provides greater flexibility by varying the width along its length. For end widths B_1 and B_2 , the footing area is

$$A = \frac{(B_1 + B_2)L}{2} \quad (5)$$

The centroid, measured from the end having width B_1 , is

$$\bar{x}_A = \frac{L(B_1 + 2B_2)}{3(B_1 + B_2)} \quad (6)$$

The end widths are selected to provide the required area while aligning the footing centroid with the load resultant. This approach is useful when unequal column loads or site constraints make a rectangular layout impractical.

A **strap footing** uses two separate pads connected by a reinforced concrete beam. The strap transfers moment and shear associated with an eccentric exterior column, allowing the exterior and interior footings to act together.

This arrangement can be economical when columns are widely spaced and the soil does not require a continuous bearing area between them. In the conventional analysis, the strap receives no supporting soil reaction; the construction details must reflect that assumption.

Structural analysis combines concentrated column loads with distributed soil reactions. For a rectangular footing with an aligned vertical resultant, the uniform bearing pressure is

$$q = \frac{P_1 + P_2}{BL} \quad (7)$$

The corresponding upward load per unit length is

$$w = qB \quad (8)$$

Here, q is a pressure, such as kips per square foot, and w is a line load, such as kips per foot. For strength analysis, the corresponding factored loads and reactions are used.

The downward column forces and upward soil reactions establish the longitudinal shear-force and bending-moment diagrams. Because the direction of bending can change along the footing, reinforcement may be required at both the top and bottom. Transverse bending must also be evaluated to establish reinforcement across the footing width.

The structural design then addresses four principal checks:

1. **One-way shear.** The footing acts as a wide beam, and its effective depth must provide adequate shear resistance at the applicable critical sections.
2. **Punching shear.** Each column is checked for localized shear around its critical perimeter. Edge columns require particular attention because the available perimeter is reduced.
3. **Flexure.** Longitudinal and transverse reinforcement are determined from the governing moments, together with applicable minimum reinforcement requirements.
4. **Anchorage and detailing.** Development length, concrete cover, bar spacing, reinforcement continuity, and termination locations must support the assumed load-transfer mechanism.

Service-level bearing checks and structural strength checks serve different purposes. Allowable soil pressure is assessed using the appropriate service loading, while factored actions determine reinforced concrete strength demands. Factored contact pressures should not be directly compared with a service-level allowable bearing pressure.

Settlement also requires separate evaluation. Uniform nominal contact pressure does not guarantee uniform settlement, particularly where soil stiffness varies across the footprint.

Constructability should influence the final reinforcement arrangement. Continuous longitudinal bars can simplify fabrication and placement, even where the moment diagram permits some bars to terminate. Strap dimensions must provide sufficient stiffness and space for reinforcement, anchorage, and concrete placement. These decisions connect the analytical design to a foundation that can be constructed as intended.