12.5.5 Mat Foundations

Mat foundations may be specified for sites with uniform but poor soils extending to a considerable depth. A situation like this usually calls for deep foundations—piles, for example—unless the loads are so light that, when distributed over a large area, they result in acceptably small soil-bearing pressures. A light pre-engineered building with multispan rigid frames and flexible walls often qualifies. Mat foundations are considered cost-effective if the sum of the individual column footing areas would cover more than one-half of the total building footprint. The biggest economy is achieved when the top of the mat is at the floor level, making a slab-on-grade unnecessary.

A special kind of mat foundation occasionally encountered in low-rise buildings with basements is a so-called floating mat. A floating mat is located well below the surface, usually at the basement level, and is designed not to exert any more pressure on soil than there had been prior to excavation. Even some very weak soils (excluding peat and organics, of course) might be able to support a floating mat.

A rigorous design of mat foundations considers mat stiffness, edge conditions, and variability of column loads. Most accepted methods follow the model of a slab on elastic foundation subjected to concentrated loads and bending moments. One source of information on mat design is the report of ACI Committee 436.[10] Another excellent method of mat analysis, complete with formulas and charts, can be found in Ref. 4. In addition, several computer programs dealing with mat design are available.

For buildings of modest size and orderly layout, it might be possible to simply locate the geometrical center of the mat at the centroid of all the column vertical loads and to assume soil pressure under the mat to be uniform.[2] This approach can run into problems if the soil properties are variable enough to cause significant local variations in pressure, the only safeguard against which is a generous and conservative factor of safety used in the design. In fact, good practice is to provide more reinforcement than required by analysis and to specify the same reinforcement at the top and bottom of the mat.[11] Local stiffening of the mat might be needed to span over any known isolated areas of unsuitable material.

In mat foundations, outward-acting horizontal column reactions are canceled out within the mat, while inward-acting reactions are resisted by mat-to-soil friction. Wind uplift is rarely a problem because of a large mass of concrete involved. With proper design, differential settlements between various columns are minimized. These advantages of mat foundations are counterbalanced by disadvantages which include design complexity, a need for heavy reinforcing, difficulties in accommodating deep pits and trenches, and, in northern climates, potential damage from frost heave for mats located at grade. Indeed, according to Section 1806.1 of the BOCA Code,[2] mat foundations are to be carried down to a level below the frost line. This presents a problem for at-grade mats. Some engineers feel that deepening the mat edges to below the frost line adequately meets this requirement.

12.5.6 Pile Foundations

Pile foundations are commonly utilized for weak and unsuitable soils underlain by good material. Piles made of wood, precast concrete, steel pipe, and steel H shapes are hammer-driven into the ground; concrete piles can also be cast in place.

Pile engineering is a complex subject well beyond the scope of this book; whenever piles are involved, geotechnical engineering assistance is a must. Our main interest is primarily in the way piles resist lateral loads and uplift.

Piles supporting building columns are normally installed in groups of three or more, regardless of the column loading. The "tripod" is stable even if the piles are not driven with perfect precision—common driving tolerances can easily result in a pile 3 in or more away from the planned position—and the column ends up being eccentric to the centroid of the pile group. One- and two-pile groups require other methods of relieving unplanned eccentricities such as rigid pilecap grade beams.

A pile acts as a laterally braced column that extends through weak into suitable soil. Column loads are transferred into soil by end bearing, skin friction, or both. Friction piles offer a superior uplift resistance as well as comparable compression and tension capacities, if tension transfer is provided for by proper splices and tension reinforcing. (Some engineers restrict the pile's tension capacity to two-thirds of that in compression.) End-bearing piles, on the other hand, can offer only their own weight against uplift forces. Uplift capacity of the piles resisting loads by a combination of skin friction and end bearing is computed as the pile's friction capacity plus the pile weight; it can also be determined by testing.

Piles resist lateral loads by bending. A simple common model assumes a cantilever-type behavior with a point of fixity some distance below the surface (Fig. 12.22*a*); the stiffer the pile and the soil, the smaller the depth to fixity. A more sophisticated model assumes piles to behave as beams on elastic foundations. However calculated, lateral resistance of vertical piles often ends up being 5 to 10 kips per pile. One problem with either approach is that the piles must undergo substantial displacements at their tops in order to engage the bending mechanism; such movements might prove damaging to buildings with brittle finishes. For major lateral loads, battered piles may be appropriate (Fig. 12.22*b*).

Most earthquake codes require pilecaps to be interconnected by ties capable of transmitting tension or compression forces equal to 10 percent of the column loading. This bracing can be provided by reinforced slab on grade or by tie beams attached to foundation walls or grade beams, allowing for load transfer to the elements with substantial surface areas and passive-resistance capacities. Passive pressure on piles themselves is commonly neglected because of their small contact area and disturbance of soil during pile driving.

Pile installation is difficult to conduct next to existing buildings. Another limitation of pile foundations is cost: Building codes often require load tests for piles with capacities over 40 tons, often adding a considerable enough expense to make other solutions worthwhile.

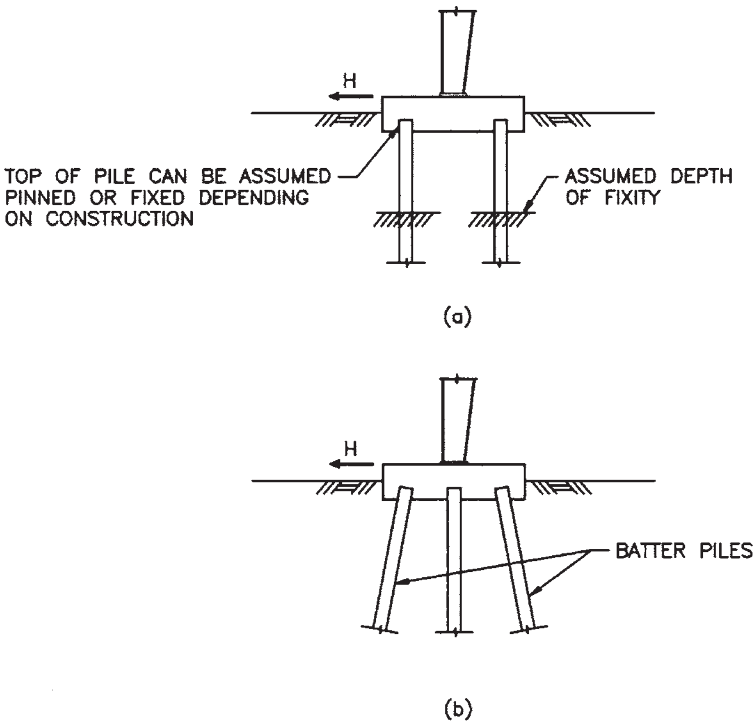

FIGURE 12.22 Lateral-load resistance of pile foundations: (*a*) vertical piles for moderate lateral loads; (*b*) batter piles for major loads.