Building Construction

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Structure—Component Parts and Functions

Framed Structures:

- Roof loads accepted by beams transferred to columns.
- Load of roof covering plus any snow and wind loads transferred to roof slab.
- Loads accepted by roof slab transferred to beams.
- Edge beam acts as a main beam.
- Main and edge beam loads transferred to columns.
- Total roof loads transmitted down columns.
- Live and loads of floor transferred to main and secondary beams.
- Secondary beam loads transferred to main beams.
- Total column loads transferred to foundation.
- Total on foundation transferred to subsoil.
Foundation construction
Pad foundations

- Pad foundations can be used to carry point loads or can be designed so that the loads of the walls and the buildings are transferred through ground beams that rest on pad foundations.
- The area of this type of foundation depends on the load on the foundation and the bearing and shear strength of the subsoil, and its thickness on the strength of the foundation material.
- Pad foundations are often used in combination with ground beams. The ground beams can be used to transfer continuous loads imposed by brickwork or infill cladding panels to the reinforced or mass filled concrete pad foundations.
Walls raised off concrete ground beams

Oversite concrete

Piers support ground beams

Pad foundations support piers
• A blinding layer of weak concrete some 50mm thick is spread and levelled in the bed of the excavation to provide a firm working base.
• Two-way spanning, steel reinforcing rods are placed on and wired to spacers to provide cover of concrete below reinforcement.
50 to 75 mm thick blinding layer of ash, coarse sand or a lean mix concrete

centrally placed reinforced concrete column or isolated brick pier

reinforced concrete base

NB. ideal plan shape for the base is a square

area of base to be such that the unit load per m² does not exceed bearing capacity of the subsoil

ISOLATED PAD
• **Strip foundations**
  • Strip foundations consist of a continuous strip, usually of steel reinforced concrete, formed centrally under loadbearing walls.
  • The strip of concrete may well need to be no wider than the thickness of the wall.
  • A continuous strip foundation of concrete is the most economic form of foundation for small buildings on compact soils.
  • The width of a concrete strip foundation depends on the bearing capacity of the subsoil and the load on the foundations
• **Stepping strip foundations**

• Where strip foundations are used on sloping sites it may be necessary to step the foundation (Figure 3.8). In order to step the foundation, the full thickness of the upper foundation should overlap twice the height of the step (thickness of upper foundation), or 300mm, whichever is greater.

• consideration should also be given to the brickwork and blockwork that will be built on top of the foundation
Minimum overlap $L = \text{twice height of step or } 300 \text{ mm whichever is greater}$

The step ($S$) should not be greater than the foundation depth ($T$).

Figure 3.8 Stepped strip foundations.
• **Short bored pile foundations**

• Where the subsoil is of firm, shrinkable clay, which is subject to volume change due to deep rooted vegetation for some depth below the surface and where the subsoil is of soft, or uncertain bearing capacity for a few metres below the surface, it may be economic and satisfactory to use a system of short bored piles as a foundation (Figure 3.16)
• The piles that are excavated to a depth of 4 m below the surface are termed short bore,
• Short bored piles are generally from 2 to 4 m long and from 250 to 350mm diameter.
• A reinforced concrete ground beam is then cast over the piles.
Figure 3.16  Short bored pile foundation (worm’s eye view).
Combined foundations

• The foundations of adjacent columns are combined when a column is so close to the boundary of the site that a separate foundation would be eccentrically loaded.

• Combined foundations may also be used to resist uplift, overturning and opposing forces.

• If the existing and new foundations were erected next to each other, the combined force of the existing building and new structure may overstress the ground.
columns or piers placed so that their centre of gravity coincides with that of the base

reinforced concrete base

blinding

COMBINED PAD
Figure 3.27  Asymmetrical combined base foundation.
Figure 3.28  (a) Rectangular combined base foundation. (b) Trapezoidal combined base foundation.
• Where the subsoil under the wall of an adjoining building is comparatively sound and the load on columns next to the existing wall is moderate, it may be acceptable to use an asymmetrical combined base foundation such as that illustrated in Figure 3.27.

• A rectangular, combined base is used where the columns next to the boundary are less heavily loaded than those distant from the boundary, as illustrated in Figure 3.28a.
The load from heavily loaded columns next to the boundary can be more widely spread than that from less heavily loaded internal columns by the use of a trapezoidal, reinforced concrete, combined base illustrated in Figure 3.28b.
Raft foundations

- A raft foundation is a continuous slab of concrete usually covering an area equal to or greater than the base of a building or structure to provide support for walls or lightly loaded columns and serve as a base for the ground floor.
- The word raft is used in the sense that the slab of concrete floats on the surface as a raft does on water. Raft foundations are used for lightly loaded structures on soils with poor bearing capacity and where variations in soil conditions necessitate a considerable spread of loads.
- Beam and raft and cellular raft foundations are used for more heavily loaded structures, where the beams or cells of a raft are used to provide wide spread of loads.
The three types of reinforced concrete raft foundations are:

1. **Solid slab raft**
2. **Beam and slab raft**
Solid slab raft foundation

• solid reinforced concrete slab generally of uniform thickness (Figure 3.29a), cast on subsoils of poor or variable bearing capacity, so that the loads from walls or columns of lightly loaded structures are spread over the whole area of the building.

• Concrete rafts are reinforced with mild steel rods to provide tensile strength against the upward or negative bending and resistance to shear stress due to the loads from walls or columns that are raised off the raft. For additional strength under the load of walls, rafts are commonly cast with downstand edge beams, as illustrated in Figure 3.29b, and downstand beams under loadbearing internal walls.

• The solid slab raft foundation illustrated in Figure 3.29c is cast with a wide toe to the beam under external walls so that the concrete does not show above ground solely for appearance sake.
Typical Raft Foundation Types -

RC column

75 mm high kicker

binders

main bars

column starter bars

75 mm thick blinding

main bars

distribution bars

SOLID SLAB RAFT

reinforced concrete raft of uniform thickness over whole area - simple to design and construct but can be wasteful in amount of concrete used
Solid slab raft foundation
Reinforcement runs in both directions

Reinforced concrete raft
40–50 concrete blinding seals surface and provides level platform to fabricate the reinforcement matt and cages
Well-compacted hardcore

Figure 3.29  (a) Solid slab raft foundation. (b) Solid slab raft foundation with downstand beam. (c) Raft foundation with extended toe to carry brickwork.
(b) Downstand beams or edge thickenings can be used to add rigidity and stability to the raft foundation. Where brick or block walls sit on the raft, the extra load can be accommodated by a beam within the raft.

Reinforcement cages are constructed to act as beams within the raft foundation.

Reinforced concrete raft
40–50 concrete blinding seals surface and provides level platform to fabricate the reinforcement matt and cages.
Toe cast into the slab to carry brickwork cladding; hides the concrete raft below the ground

Edge beam and reinforcement extended to carry brickwork cladding
• To provide a level bed for the concrete, a layer of blinding is spread either on a hardcore bed or directly on levelled soil to a thickness of 50mm. The purpose of the blinding is to provide a level bed, which will prevent wet concrete running through it.

• The necessary reinforcement is placed and supported

• (with concrete spacers) to provide the necessary cover and the concrete spread, consolidated and finished level
Beam and slab raft foundation

- As a foundation to support the heavier loads of walls or columns, a solid slab raft would require considerable thickness. To make the most economical use of reinforced concrete in a raft foundation supporting heavier loads, it is usual practice to form a beam and slab raft.
- This raft consists of upstand or downstand beams that take the loads of walls or columns and spread them to the monolithically cast slab, which bears on natural subsoil.
- Figure 3.31 is an illustration of an upstand beam raft and Figure 3.32 shows a section through a downstand beam raft.
Figure 3.31  Reinforced concrete beam and slab raft.
Figure 3.32  Beam and slab raft with downstand beams.
Pile foundations

• The word ‘pile’ is used to describe columns, usually of reinforced concrete, driven into or cast in the ground in order to carry foundation loads to some deep underlying firm stratum or to transmit loads to the subsoil by the friction of their surfaces in contact with the subsoil (see Figure 3.37).
• The main function of a pile is to transmit loads to lower levels of ground by a combination of friction along their sides and end bearing at the pile point or base.

• Piles that transfer loads mainly by friction to clays and silts are termed friction piles, and those that mainly transfer loads by end bearing to compact gravel, hard clay or rock are termed end-bearing piles (Figure 3.37).
Typical Examples -

**Two Pile Cap**
- Pile spacing
- Main bars
- Dist. bars

**Three Pile Cap**
- Pile spacing
- Main bars
- Distribution bars

**Five Pile Cap**
- Pile spacing
- Main bars

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Elevation of Pile Cap and Beam
- 75mm blinding
- Piles
- Main bars
End-bearing piles used to transfer loads through soft silts, clays and made-up ground. The surrounding strata offers little resistance to the piles. The bulk of the load is transferred to the sound loadbearing strata at the end of the pile.

Friction and end-bearing pile

Friction forces develop between the surface of the shaft of the pile and the surrounding strata. In most soils, the resistance to the piles increases as the pile settles. As with all foundations, a small amount of settlement will occur.

Displacement piles cause the surrounding soil to compress and thus increases friction. Continuous helical bored piles make use of this principle.

Figure 3.37 End-bearing and friction piles.
Figure 3.38  Pile foundations and pile caps.
• Four or more piles may be used to support columns of framed structures. The columns are connected to a reinforced concrete pile cap connected to the pile, as illustrated in Figure 3.38. Piles may be classified by their effect on the subsoil as displacement piles or non-displacement piles.
• Displacement piles are driven, forced or cut (by an auger) into the ground to displace subsoil. The strata are penetrated.

• No soil is removed during the operation. Solid concrete or steel piles and piles formed inside tubes which are driven into the ground and which are closed at their lower end by a shoe or plug, which may either be left in place or extruded to form an enlarged toe, are all forms of displacement pile.
• Non-displacement piles are formed by boring or other methods of excavation that do not substantially displace subsoil. Sometimes the borehole is lined with a casing or tube that is either left in place or extracted as the hole is filled.

• Driven piles are those formed by driving a precast pile and those made by casting concrete in a hole formed by driving. Bored piles are those formed by casting concrete in a hole previously bored or drilled in the subsoil.
• **Driven piles – Concrete**

• Square, polygonal or round section reinforced concrete piles are cast in moulds in the manufacturer’s yard and are cured to develop maximum strength.

• The placing of the reinforcement and the mixing, placing, compaction and curing of the concrete can be accurately controlled to produce piles of uniform strength and cross section.

• The precast piles are often square section with chamfered edges, as illustrated in Figure 3.39
Piles are lifted into position, checked for plumb and driven into the ground until the required set is reached.

The exposed pile is then broken away and the reinforcement tied into the pile cap.
• The head of the pile is reinforced with helical binding wire; this helps prevent damage that would otherwise be caused by driving the pile into the ground.

• Once the pile is in place, the concrete at the top of the pile is removed to expose the main reinforcement. The helical reinforcement can be removed once the main reinforcement bars, which will be tied into the pile cap, are exposed.

• To connect the top of the precast pile to the reinforced concrete foundation, the top 300mm of the length of the pile is broken to expose reinforcement to which the reinforcement of the foundation is connected.
• Precast-driven piles are not in general used on sites in built-up areas. Difficulties are often experienced when attempting to move large precast piles through narrow streets; however, using smaller sections (Figure 3.42) can overcome this problem.

• Where vibration is excessive, or buildings and structures are sensitive to vibration, damage may be caused to adjacent buildings, structures and services.

• Driven piles are used as end-bearing piles in weak subsoils where they are driven to a firm underlying stratum
• Driven piles give little strength in bearing due to friction of their sides in contact with soil, particularly when the surrounding soil is clay.
Helical binding in head

Links

Lifting hole

Pressed steel forks

Reinforcement

Cover of concrete

Mild steel straps cast into cast iron shoe

Chilled cast iron shoe
Figure 3.42 Precast concrete pile segments (adapted from http://www.roger-bullivant.co.uk).
Driven cast-in-place piles

- Driven cast-in-place piles are of two types: the first has a permanent steel or concrete casing and the second uses a temporary casing. The purpose of driving and maintaining a permanent casing is to consolidate the subsoil around the pile casing by the action of driving.

- The lining is left in place to protect the concrete cast inside the lining against weak strata of subsoil that might otherwise fall into the pile excavation.
• Permanent casings also protect the green concrete (concrete which has not set) of the pile against static or running water that may erode the concrete.
Figure 3.45  Driven cast-in-place concrete pile with permanent casing.
Figure 3.46  Driven cast-in-place concrete pile without permanent casing.
Bored piles

- *Auger bored piles*. A hole is bored or drilled by means of earth drills (mechanically operated augers), which withdraw soil from the hole into which the pile is to be cast. Occasionally, it is necessary to lower or drive in steel lining tubes as the soil is taken out, to maintain the sides of the drilled hole. As the pile is cast, the lining tubes are gradually withdrawn.

- The mechanical rigs used to install the piles come in a range of sizes, from small units weighing just a few tonnes to large rigs exceeding 20m and weighing in excess of 50 tonnes (Photograph 3.5a and b).
Photograph 3.5  (a) CFA – thread of the auger extends along the full length of the shaft.  
(b) Piling rig without auger attached (http://www.roger-bullivant.co.uk).
Figure 3.50  (Continued)

Tracked excavator

Kelly bar rotates and the core barrel

The loose soil is trapped within the barrel

The barrel is removed from the excavated shaft and the granular non-cohesive soil is released
• Figure 3.49 illustrates the drilling and casting of a bored cast-in-place pile. Photograph 3.6a and b shows the piling rig and steel piling tubes used for the pile excavation.

• Soil is withdrawn from inside the lining tubes with a cylindrical clay cutter that is dropped into the hole, which bites into and holds the cohesive soil. The cutter is then withdrawn and the soil knocked out of it.
1. Steel tube driven in
2. Tubes driven in as shell takes out granular soil
3. At required depth, reinforcing cage is lowered into tubes
4. Concrete compacted in pile boring
5. Enlarged toe

Concrete placed in tubes and compacted by air pressure
Air line
Pressure cap
Starter bars
Concrete fills weak pockets of subsoil
Photograph 3.6  (a) A drop auger piling rig mounted on a tripod. (b) Cutting tube and lining tubes.
Pile caps and spacing of piles

• Piles may be used to support pad, strip or raft foundations. Commonly a group of piles is used to support a column or pier base. The load from the column or pier is transmitted to the piles through a reinforced concrete pile cap, which is cast over the piles.

• To provide structural continuity, the reinforcement of the piles is linked to the reinforcement of the pile caps through starter bars protruding from the top of the cast-in-place piles or through reinforcement exposed by breaking off the top concrete from precast piles.
Figure 3.54  Concrete pile cap arrangements.

Reinforced concrete pile cap arrangement with four piles; starter bars protrude from the pile reinforcement cage into the pile cap.

Double pile cap arrangement

Triple pile cap arrangement