Design of Deep Foundations

Deep Foundation

A deep foundation is used to carry and transfer the applied load to the bearing ground located at some depth below ground surface. The main components of the deep foundation are the **pile cap** and the **piles**.

- Piles are long and slender members which transfer the load to a deeper soil or rock of high bearing capacity avoiding shallow soils of low bearing capacity.
- The main types of materials used for piles are wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to the pile cap.

When to use pile foundations:

1- The soil immediately beneath the structure is weak or unstable i.e.:
  - the soil does not have adequate bearing capacity,
  - the magnitude of the estimated settlement is not acceptable
  - expansive or collapsible soils.

2- When a cost estimate indicates that a pile foundation is cheaper than any other compared foundation or ground improvement.

3- Piles are a convenient method when foundation must penetrate through water such as those for a pier or when the soil is subjected to scour.

4- Piles are sometimes used to resist horizontal loads. This type of situation is generally encountered in the construction of earth-retaining structures and foundations of tall structures that are subjected to high wind or to earthquake forces.

5- Piles can also be used to resist uplift forces. The foundations of some structures such as offshore platforms, transmission towers, and basement mats below the water table are subjected to uplift forces.

Classification of piles

Piles are classified according to pile material, their effect on the soil, and load transmission

1- Type of material:

• Timber:

- Have been used for thousands of years and still used for many applications.
- Cannot withstand high driving stress
- Can stay undamaged indefinitely if they are surrounded by saturated soils. However, they are subjected to attack from marine organisms and insects.

• **Steel:**

- Usually pipe piles or steel H-section piles.
- Steel piles can penetrate hard layers such as dense gravel and soft rock because of their small cross-sectional area combined with their high strength.
- They can be easily cut off or joined by welding.
- If the pile is driven into a soil with low pH value, then there is a risk of corrosion. Tar coating, epoxy coating, or cathodic protection can be employed against corrosion. The speed of corrosion is 0.2-0.5 mm/year and, in design, this value can be taken as 1mm/year.
- In many cases, the pipe piles are filled with concrete after they have been driven.
- Disadvantages: high level of noise during driving, corrosion, may be damaged or deflected during driving

• **Concrete:**

- Precast or cast in place (CIP) piles
- Reinforcement is needed to resist the vertical load, the bending moment developed during pickup and transportation, and the bending moment due to a lateral load.

2- Effect on the soil:

- Driven piles:

- Driven piles are considered to be **<u>displacement</u>** piles. In the process of driving the pile into the ground, soil is moved radially as the pile shaft enters the ground. There may also be a component of movement of the soil in the vertical direction.
- Precast concrete piles usually of square, triangle, circle or octagonal section.
- Reinforcement is necessary within the pile to help withstand both handling and driving stresses.
- Precast piles can be prestressed and are becoming more popular than the ordinary pre cast as less reinforcement is required.

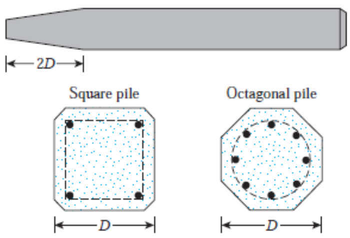


Figure 11.3 Precast piles with ordinary reinforcement

From Das (2011)

- Drilled shafts:

- Drilled shafts are generally considered to be **non-displacement** piles (**Replacement piles**).
- A hole is formed by boring or excavation and then it filled with concrete. A reinforcement cage is placed prior to concreting.
- The diameter of the shaft can be as high as 15 ft.
- Other commonly used names to identify drilled shafts are:
  A. Bored piles
  B. Cast in place (CIP) piles
  C. Drilled piers
  D. Caissons
- A bell can be constructed at the bottom to increase the capacity. Piles with a bell at the bottom are known as belled piers or underreamed piers.

-CIP piles can be cased or uncased. Sidewall failure and difficulty of keeping the hole open are very common problems. Steel casing would prevent the sidewalls from falling. Slurry can also be used during drilling. Basically, two types of slurry are used.

• Polymer-based fluids
• Bentonite-based fluids

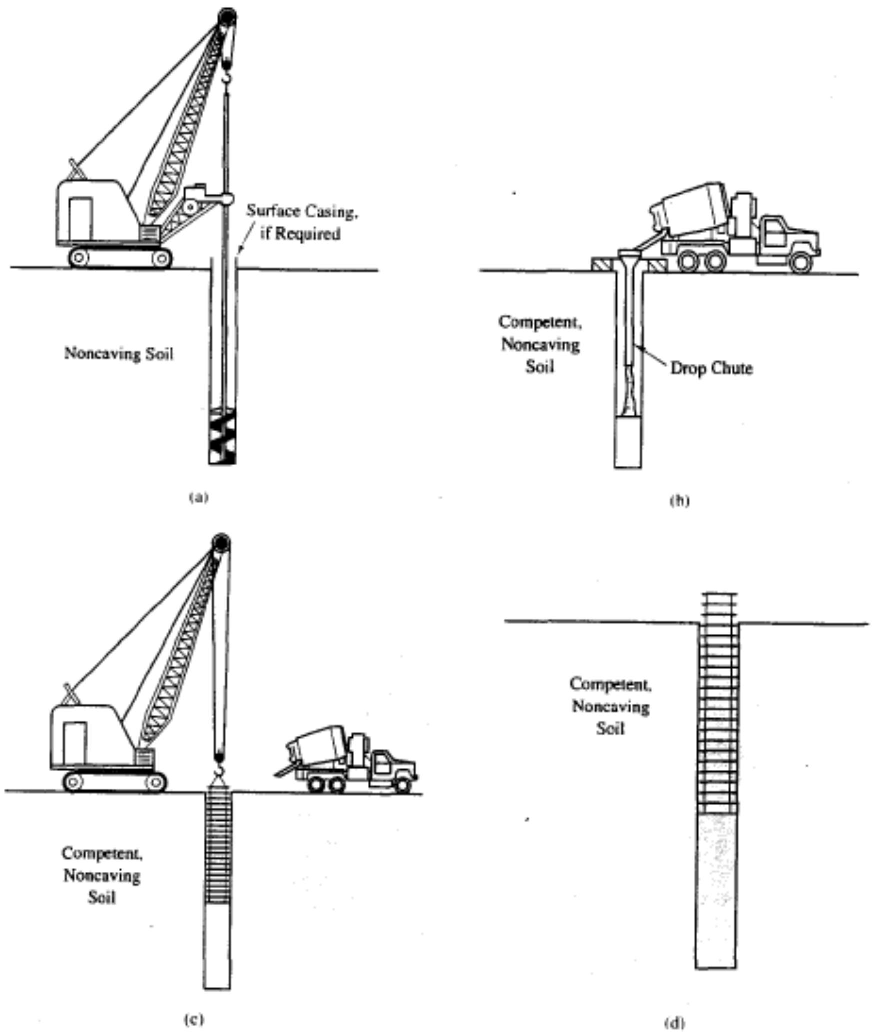
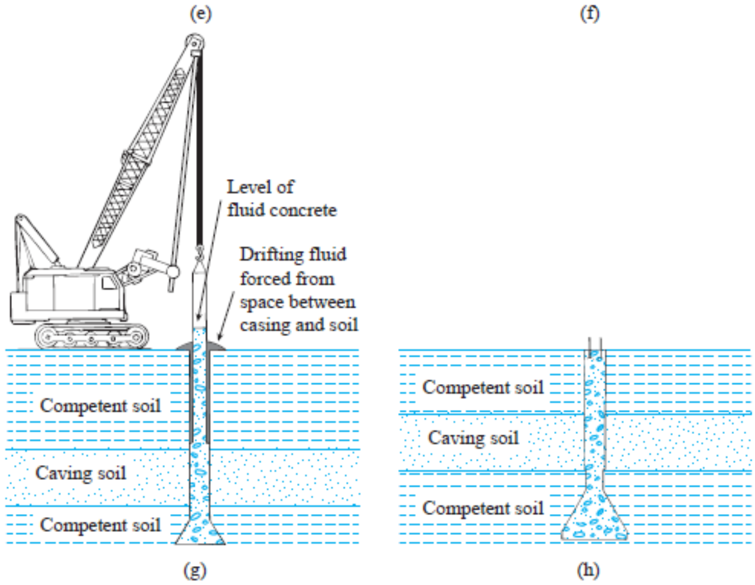


Figure 11.27 Drilled shaft construction in competent soils using the dry method: (a) Drilling the shaft; (b) Starting to place the concrete; (c) Placing the reinforcing steel cage; and (d) Finishing the concrete placement (Reese and O'Neill, 1988).

From Coduto (2001)



Belled piers (from Das, 2011)

3- Load transmission and functional behavior:

- **Point bearing piles**
  - These piles transfer their load to a firm stratum located at a considerable depth below the base of the structure and they derive most of their carrying capacity from the penetration resistance of the soil at the toe of the pile.
  - The pile behaves as an ordinary column and should be designed as such.
  - Even in weak soil a pile will not fail by buckling and this effect needs only be considered if part of the pile is unsupported, i.e. if it is in either air or water.
  - The depth of the pile is influenced by the results of the site investigation and soil tests.

- **Friction piles**
  - Carrying capacity is derived mainly from skin friction of the soil in contact with the shaft of the pile when no layer of rock or strong soil is present at a reasonable depth at a site.
  - The lengths of friction piles depend on the applied load, the pile size, and the shear strength of the soil.

Sometimes, the soil surrounding the pile may adhere to the surface of the pile and causes "Negative Skin Friction" on the pile. This, sometimes have considerable effect on the capacity of the pile. Negative skin friction is caused by the drainage of the ground water and consolidation of the soil.

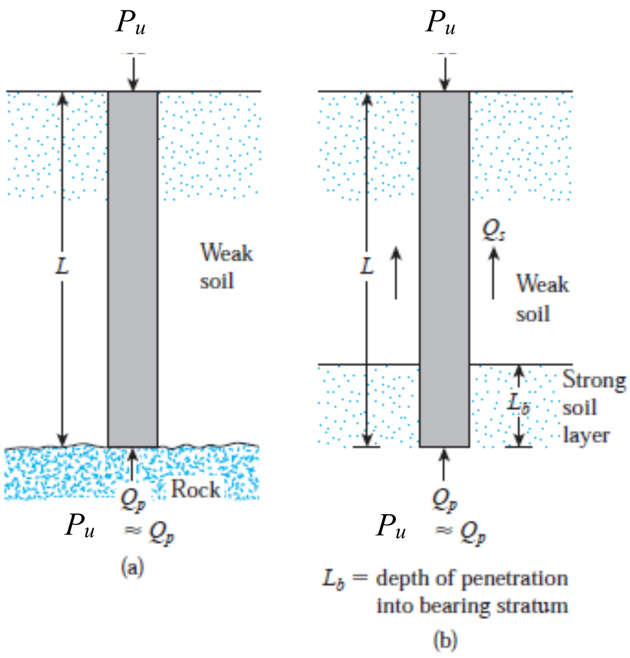


Figure 11.6 (a) and (b) Point bearing piles; (c) friction piles

From Das (2011)

$$P_u = Q_P + Q_S$$

$$P_u = q_P . A + \sum_{i=1}^{n} (f_{Si} . A_{si})$$

Q_P= load carried at the pile tip
Q_S= load carried by skin friction developed at the side of the pile (caused by shearing resistance between the soil and the pile)
q_p= unit tip resistance (point resistance)
A= area of pile tip
f_S= unit skin friction (friction or adhesion resistance). In clay, skin friction is also used to refer to adhesion.
A_s= surface area of the pile= perimeter * layer thickness =p*Hi

$$P_{all} = \frac{P_u}{FS} = \frac{q_P . A + \sum_{i=1}^{n} (f_{Si} . A_{si})}{FS}$$

P_{all} = allowable load capacity of the pile
FS= factor of safety=3