Pile Foundations

1. Outlines

① The first problem is to determine whether on not pile must be used for the given site foundations. - economical efficiency

② Selection of pile types

- by material types
- by method of placement

③ Computation of the ultimate load for the pile-soil system

④ Settlement analysis (the mechanism of load transfer accuring between pile and soil must be understood.)

⑤ Behavior of group piles

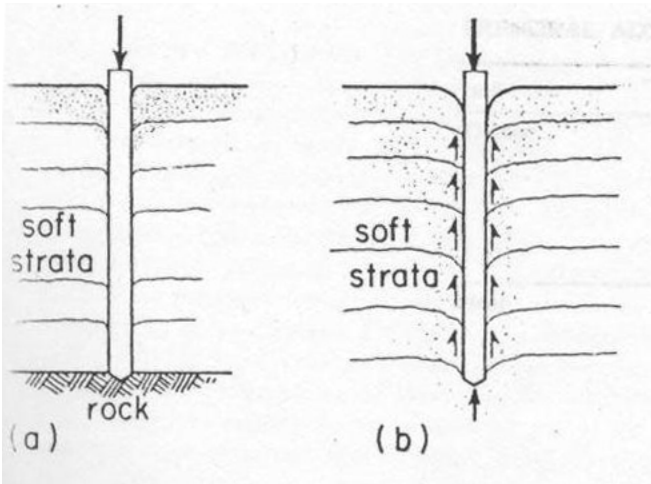
⑥ Construction problem at pile driving

⑦ Test piles - full scale

2. Introduction

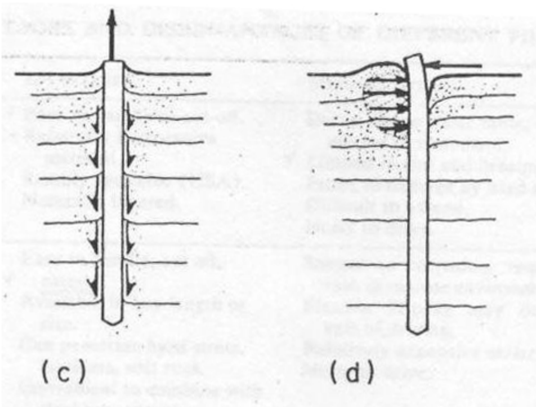
: When the pile foundations are needed ?

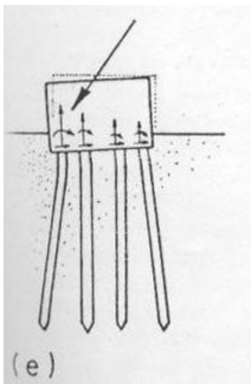
① the upper soil are too weak or too compressible to support the structural load.



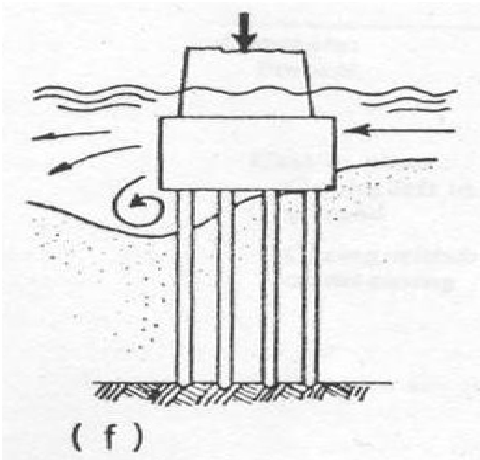
< end bearing pile > < friction piles >

② footings can't transmit inclined, horizontal, or uplift forces & overturing moment.

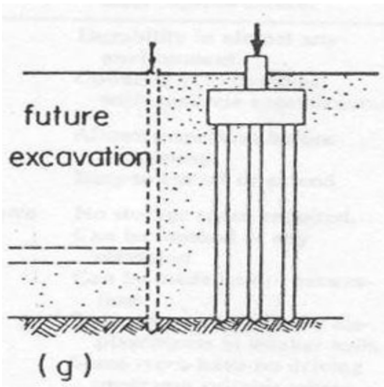




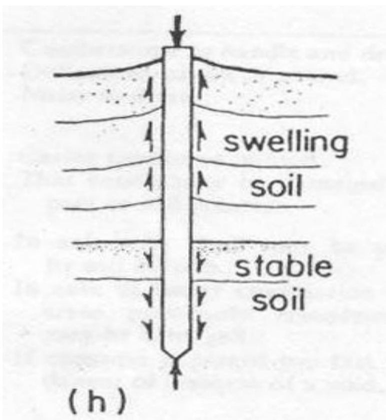
③ scour around footing could cause erosion, in spite of the presence of strong, incompressible strata at shallow depth



④ further excavation may be adjacent to the structure



⑤ expansive soil



3. Selection of pile types

1) by the material type : wood, steel, concrete or composite piles

TABLE 1

PRINCIPAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT PILE TYPES

PILE TYPE	ADVANTAGES	DISADVANTAGES
Timber	Easy to handle or cut-off. Relatively inexpensive material. Readily available (USA). Naturally tapered.	Decay above water table, especially in marine environment. Limited in size and bearing capacity. Prone to damage by hard driving. Difficult to extend. Noisy to drive.
Steel	Easy to handle, cut off, extend. Available in any length or size. Can penetrate hard strata, boulders, soft rock. Convenient to combine with steel superstructure.	Subject to corrosion, require protection in marine environment. Flexible H-piles may deviate from axis of driving. Relatively expensive material. Noisy to drive.
Concrete: Precast	Durability in almost any environment. Convenient to combine with concrete superstructure.	Cumbersome to handle and drive. Difficult to cut off or extend. Noisy to drive.
Cast-in-place: Casing left in ground	Allows inspection before concreting. Easy to cut off or extend.	Casing cannot be re-used. Thin casing may be damaged by impact or soil pressure.
Casing withdrawn or no casing	No storage space required. Can be finished at any elevation. Can be made before excavation. Some types allow larger displacements in weaker soils. Some types have no driving operation suitable where noise and vibration are prohibited (downtown).	In soft soils shaft may be squeezed by soil cave-in. In case of heavy compaction of concrete previously completed piles may be damaged. If concrete is placed too fast there is danger of creation of a void.

2) by the method of the placement of pile into the ground

displacement pile - up to passive conditions around the pile shaft ($K_0 \leq K < K_p$)
- driven / jacked / vibrated pile

non-displacement pile - near to active conditions around the pile shaft ($K_a \leq K < K_0$)
- CIP / bored pile

① displacement piles

- piles are placed by driven / jacked / vibrated
- the displacement of the surround soil by pile driving cause some increase in lateral ground stress and possibly densifies the soils. (for loose soils)
- close-end pipe pile or full-section piles / driven : high displacement pile
- open-end pipe pile or H-pile / jacked or vibrated : low displacement pile

② non-displacement pile

- are driven prefabricated or cast in a hole created by removing an equal volume of soil from the ground
- usually done by augering (drilling, rotary boring) or grabbing (percussion boring) under protection of a casing or drilling mud.
- their placement causes som relif of lateral stresses. → develop less friction than displacement pile of the same size and shape

4. Computation of the ultimate load

1) Problem statement

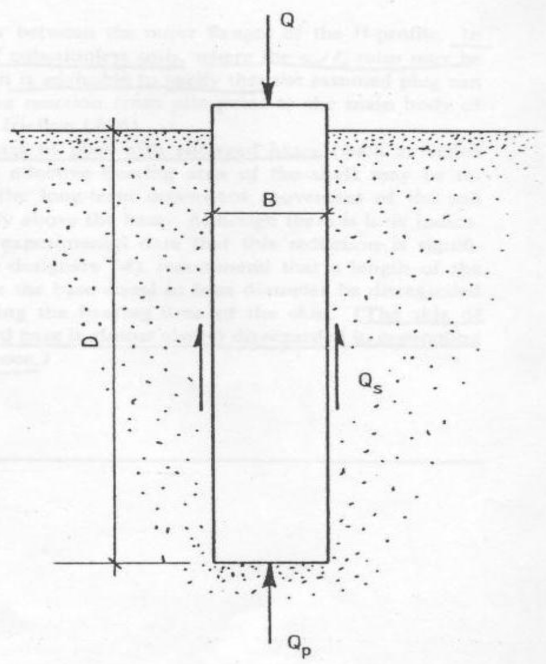


Figure 5. Basic problem of a deep foundation.

: A cylinder shaft of diameter B is placed to depth D inside a soil mass of known physical properties (c, Φ, ɣ). a static, vertical and central load Q is applied at the top and increased until a shear failure in the soil is produced. **<u>the problem is to determine the ultimate load</u>** Q_0 that this foundation can support.

2) Some distinct differences from shallow foundations

1. the bearing soils above and below foundation base are almost always disturbed.

2. piles are often designed in groups

3. load distribution in soil mass is not easily defined.

→ load-transfer problem

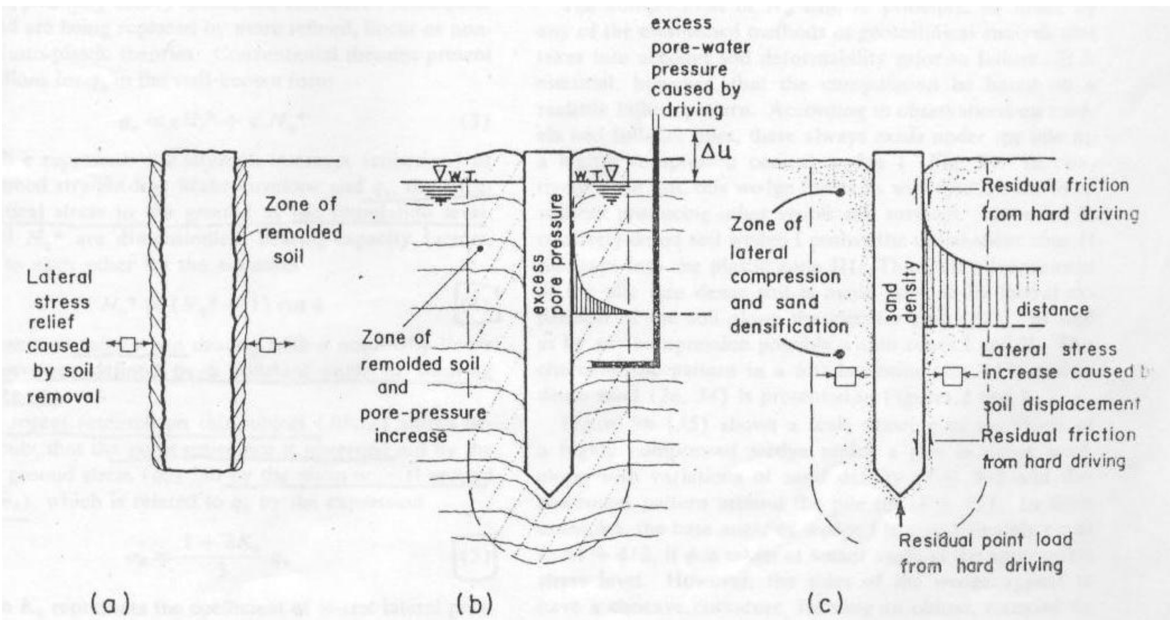


Figure 6. Effects of placement of pile into a soil mass.

3) For design, the ultimate load is separated into two components.

- the shaft (or skin) load (Q_s)
- the base (or point) load (Q_p)

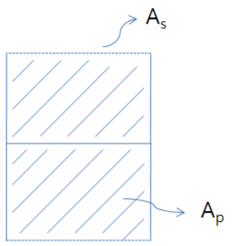
→ superimposed as follows, $Q_0 = Q_p + Q_s$

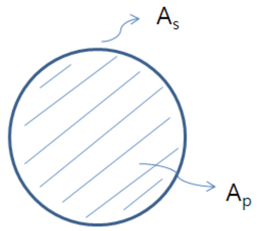
- $Q_p = q_0 A_p$
- $Q_s = f_s A_s$

where A_p, A_s : the areas of the base and shaft of piles

q_o, f_s : unit base and shaft resistance by the relative displacement of pile

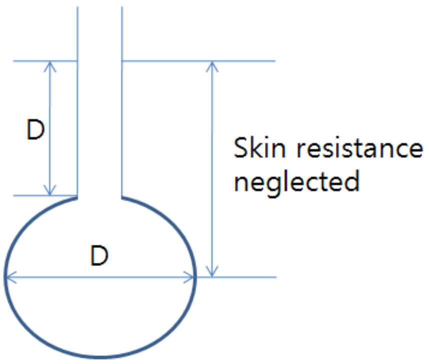
- H-pile & Open pipe pile





4) Special cases

- Enlarged base pile



- For normal situations, ok, if piles embedded shallow to the bearing layer, need to check the pugging status.

5) Point resistance (q_0)

$$q_o = cN_c^* + q_v N_q^*$$

$$N_c^* = (N_q^* - 1)\cot\Phi$$

$$N_q^* = (1 + \tan\Phi)e^{\pi\tan\Phi\tan^2(45^\circ + \Phi/2)}$$

Vesic's method

Based on the theory of expansion at cavities

$$q_0 = cN_c^* + \sigma_0 N_\sigma$$

$$\sigma_0 = \frac{3}{1+2K_0}q_v$$

σ_0' = mean normal effective stress at pile tip

$$= \frac{1+2K_o}{3}q$$

↑ vertical effective stress at pile tip

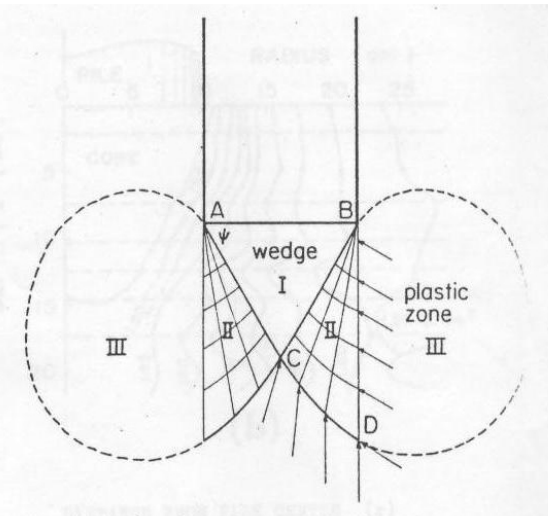


Figure 7. Assumed failure pattern under pile point.

I : zone of compression

II : radial zone

III : plastic zone

6) Skin resistance

$Q_s = f_s \cdot A_s$

$f_s = c_a + q_s \tan\delta$

where c_a : adhesion between soil and pile (neglected)

q_s : effective stress normal to pile shaft

δ : interface friction angle (Φ of remoulding soil)

for sand, $f_s = K_s \sigma_v' \tan\phi$

i> in bored pile or jetted pile : $K_s \leq K_0$

ii> in H or open pipe pile : $K_s \leq 1.5 K_0$

iii> short, driven, high-displacement pile : $K_s = K_p = \tan^2(45° + \frac{\phi}{2})$

iv> driven into NC soft-ti-firm clay : $K_s \geq K_0$

For NC clay (soft-to-firm)

in terms of the undrained strength

$f_s = \alpha s_u$

where α = f (soil condition, pile type⋯)

soft to firm ($s_u \leq 0.5$ tsf) : $\alpha \fallingdotseq 1$

OC : $\alpha = 0.45$

7) Determination of point and skin friction resistance from field test

→ CPT, SPT, PMT is used.