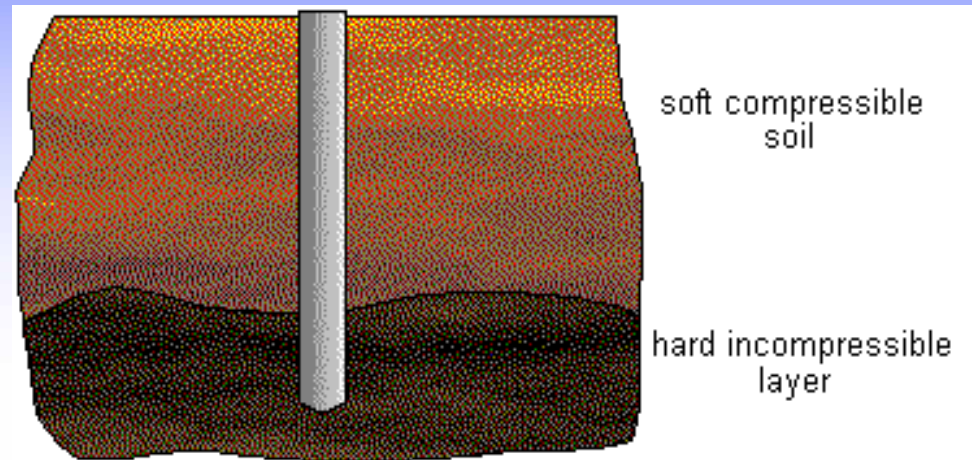


PILES

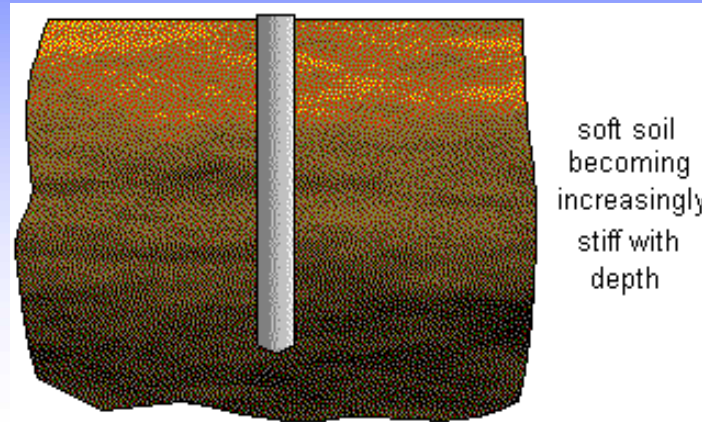
Long, slender members that **transmit foundation loads** through soil strata of low bearing capacity or through water to deeper soil or rock strata having a high bearing capacity.

End bearing piles



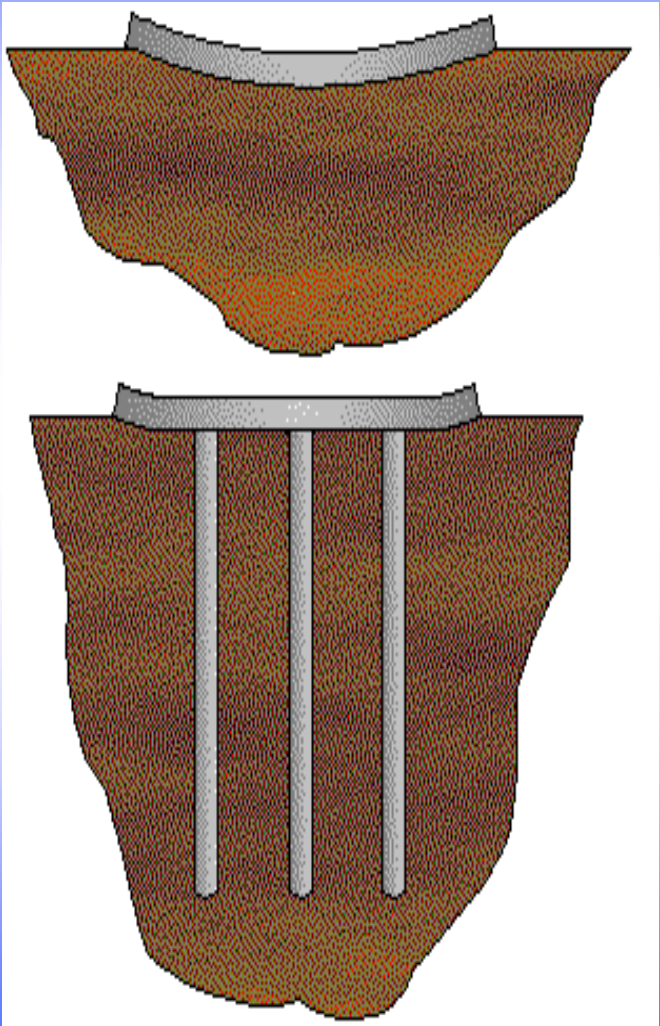
End bearing piles are those which terminate in hard, relatively impenetrable material such as **rock or very dense sand and gravel.**

Friction piles



- Friction piles obtain a greater part of their carrying capacity by skin friction or adhesion. This tends to occur when piles do not reach an impenetrable stratum but are driven for some distance into a penetrable soil.

Settlement reducing piles

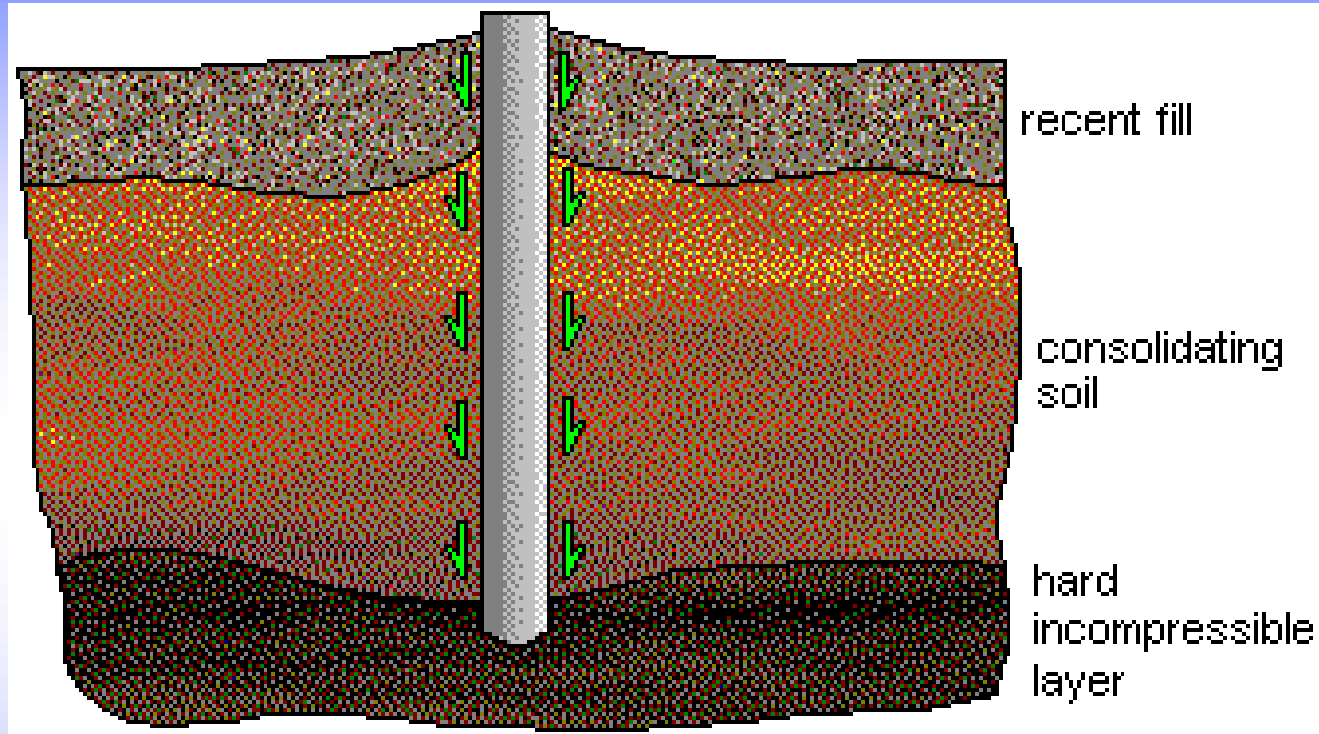


Settlement reducing piles are usually incorporated beneath the central part of a raft foundation in order to **reduce differential settlement** to an acceptable level. Such piles act to reinforce the soil beneath the raft and **help to prevent dishing of the raft in the centre.**

Tension piles

- Structures such as tall chimneys, transmission towers and jetties can be subject to **large overturning moments** and so piles are often used **to resist the resulting uplift forces at the foundations**. In such cases the resulting forces are transmitted to the soil along the embedded length of the pile.

Piles in fill



- Piles that pass through layers of moderately- to poorly-compacted fill will be affected by **negative skin friction**, which produces a downward drag along the pile shaft and therefore an additional load on the pile. This occurs as the fill consolidates under its own weight.

TYPES OF PILES

- Steel piles
- Concrete piles
- Timber piles (wood piles)

Steel piles

- Steel piles **withstand driving pressure well** and very **reliable end bearing members**.
- Pipe piles are normally, not necessarily filled with concrete after driving.
- **Strength, relative ease of splicing and economy** are some of the advantages cited in the selection.
- **Corrosion** (salt, acid, moisture and oxygen) > **restricted use for marine installations**.

Steel piles



Concrete piles

- Much more resistance against corrosive elements
- Concrete is available in most parts of the world than steel.
- Concrete piles may be pre-cast or cast-in place.



Concrete piles for deep foundations.

Pre-cast concrete piles

Formed, cast to specified lengths and shapes and cured at pre casting stations before driven in to the ground.

Their **shape and length are regulated at the prefab site.**
Usually came in **square, octagonal or circular cross-section.**

The diameter and the length of the piles are mostly **governed by handling stresses.**

Limited to **less than 25 m in length and 0.5 m in diameter.**

Some times it is **required to cut off and splice** to adjust for different length. Where part of pile is above ground level, the pile may serve as column.

Cast-In-Place Concrete Piles

- Made at the construction site
- Steel shell is grounded to the soil to act as container to allow the concrete filled in it
- Not contribute load capacity to the pile

Timber piles (wood piles)

- Timber piles are frequently used as **cohesion piles** and for **piling** under embankments.
- Made from **tree trunks** with the **branches and bark removed**.
- Normally wood piles are **installed by driving**. Typically the pile has a natural taper with top cross-section of twice or more than that of the bottom.
- To avoid splitting in the wood, wood piles are sometimes **driven with steel bands** tied at the top or at the bottom end





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Piles may be classified based on a number of criteria, e.g. material, shape, function, method of installation and mode of load transfer, etc.

CLASSIFICATION OF PILES

a - Classification of piles based on material:

b - Classification of piles based on shape:

c - Classification of piles based on their function:

d- Classification of piles based on mode of load transfer:

e - Classification of piles based on method of installation

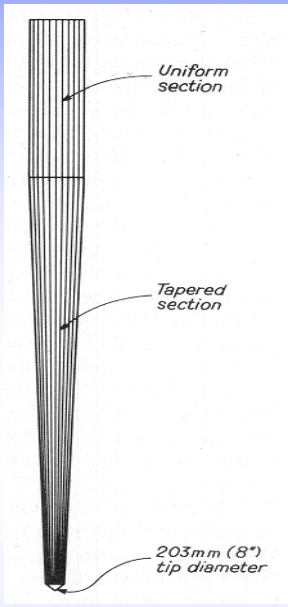
a - Classification of piles based on material:

- 1. Concrete piles:**
- 2. Steel piles:**
- 3. Timber piles:**
- 4. Composite piles:**

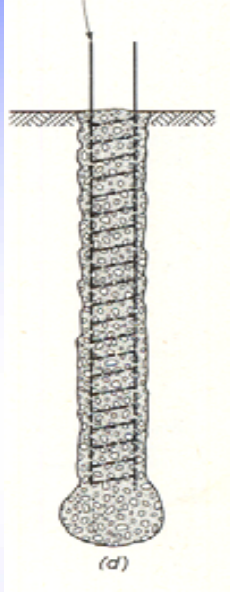
b - Classification of piles based on shape:

There may a large variety of piles based on shape, some are given below.

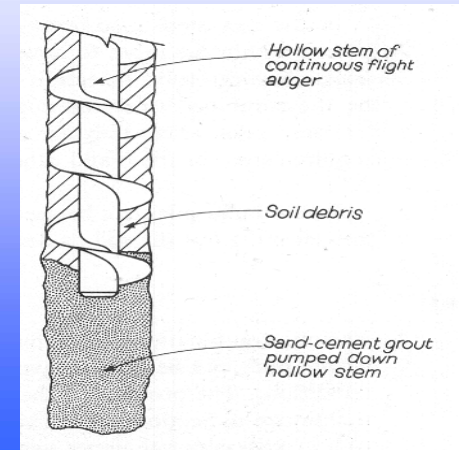
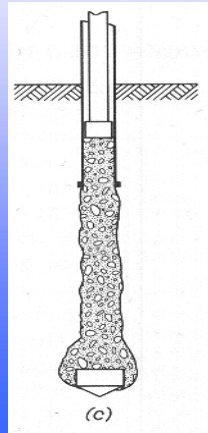
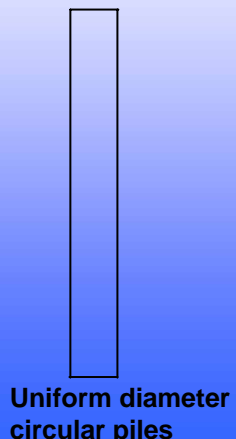
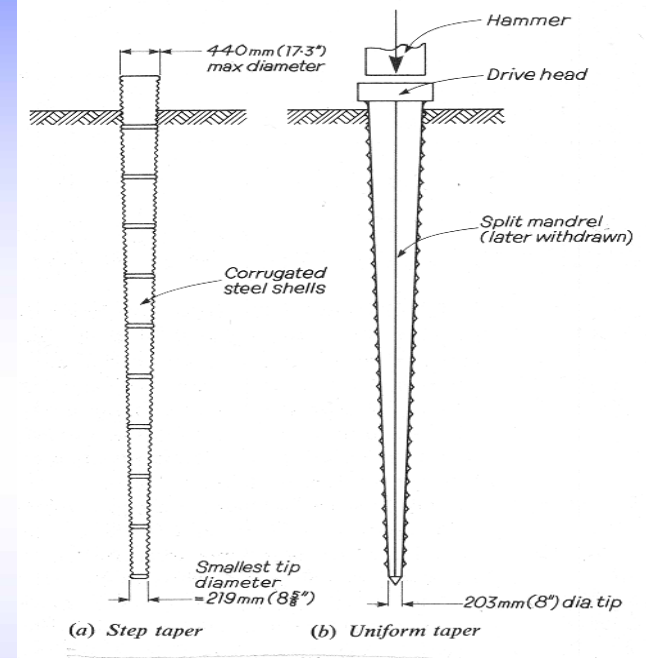
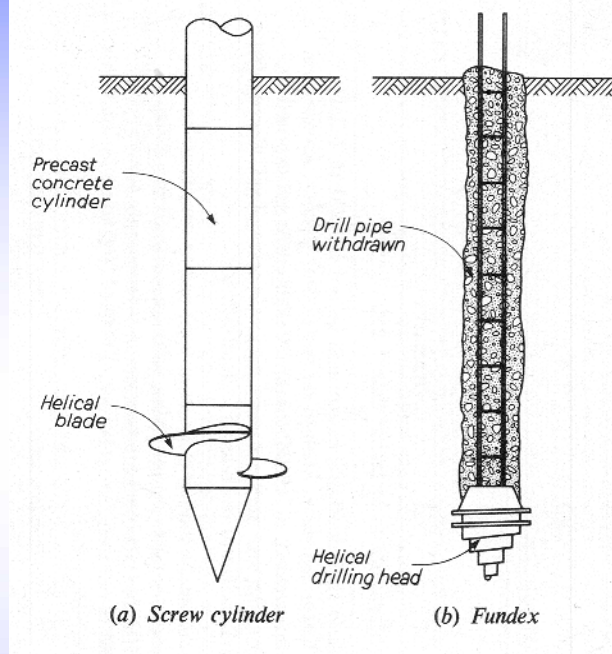
1. Uniform diameter circular piles,
2. Uniform taper piles,
3. Step taper piles
4. Pedestal piles,
5. Under-reamed piles,
6. H-shaped steel piles
7. Precast-concrete square piles,
8. Precast-concrete octagonal piles



Uniform taper piles

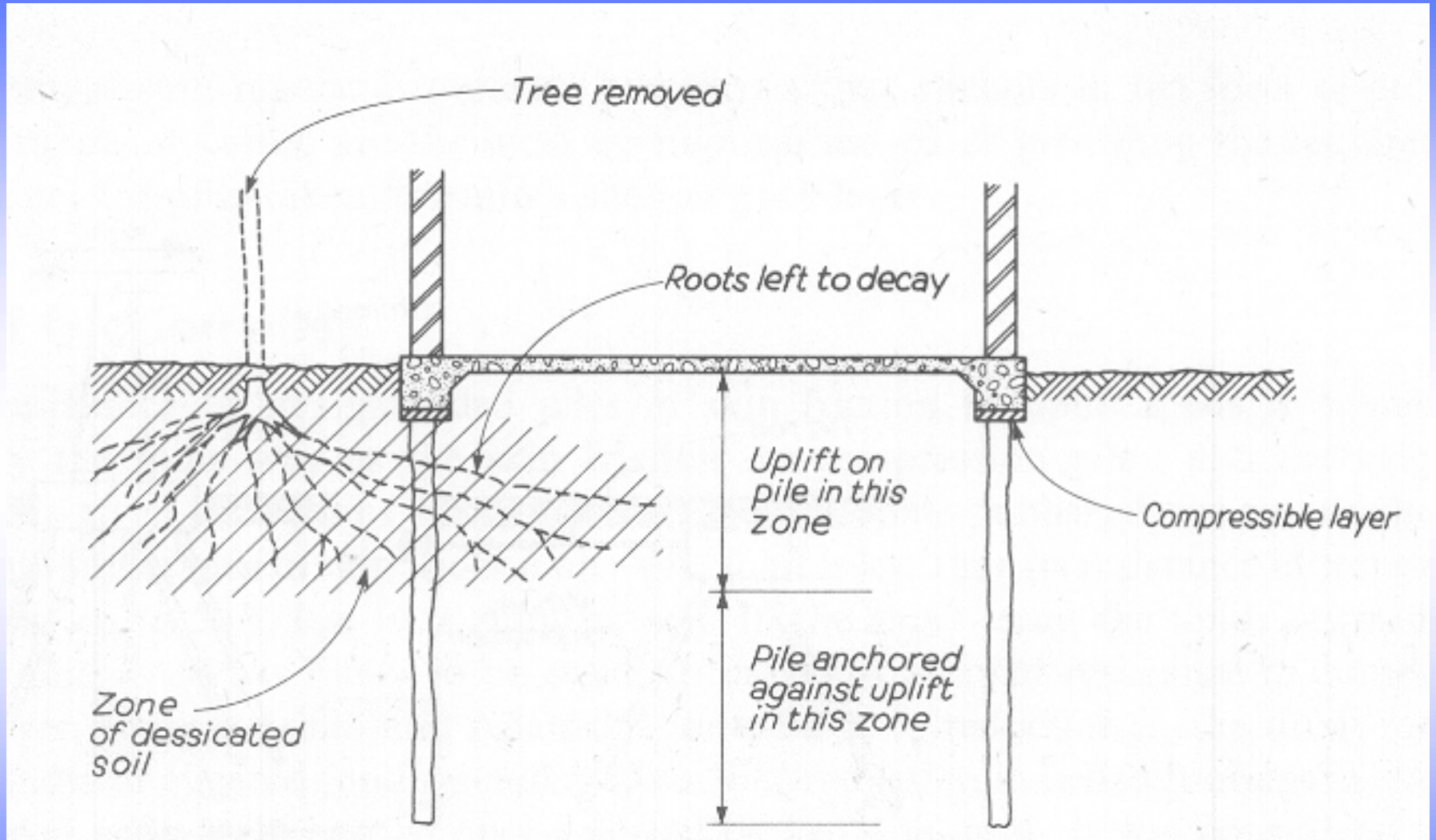


Pedestal piles

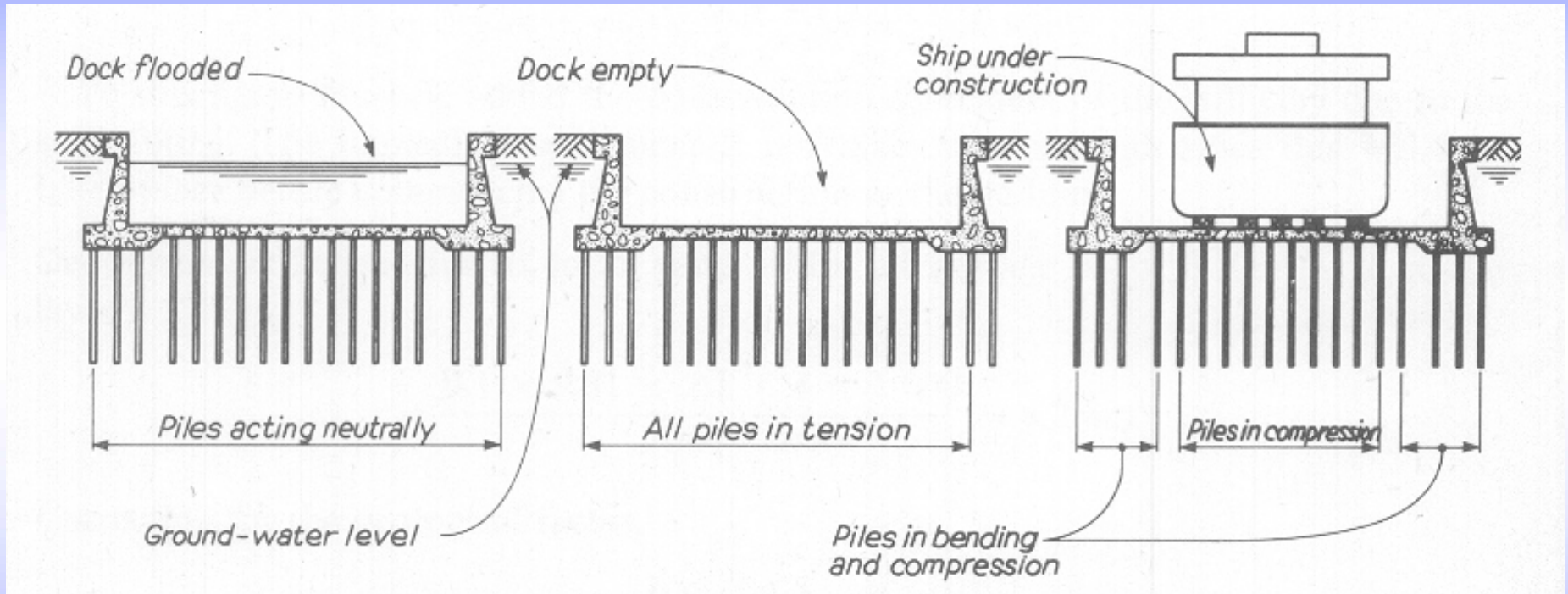


c - Classification of piles based on their function:

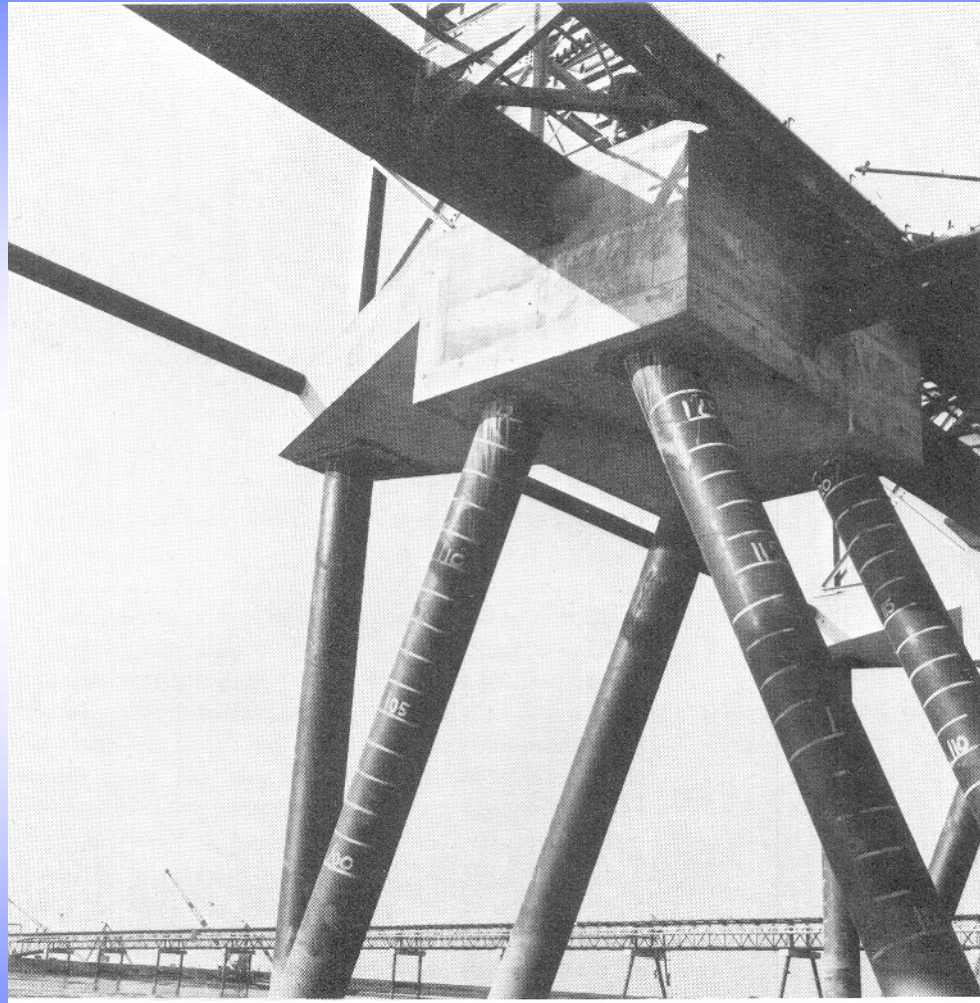
- 1. Compaction piles-**
To compact granular soils, thus increasing their bearing capacity.
- 2. Tension or uplift piles-**
To anchor down the structures subjected to uplift due to hydrostatic pressure or overturning moment
- 3. Anchor piles-**
Used to provide anchorage against horizontal pull from sheet piling walls or other pulling forces.
- 4. Fender or dolphin piles-**
Used to protect water-front structures against impact from ships or other floating objects.
- 5. Batter or racking piles-**
Used to resist large horizontal or inclined forces.



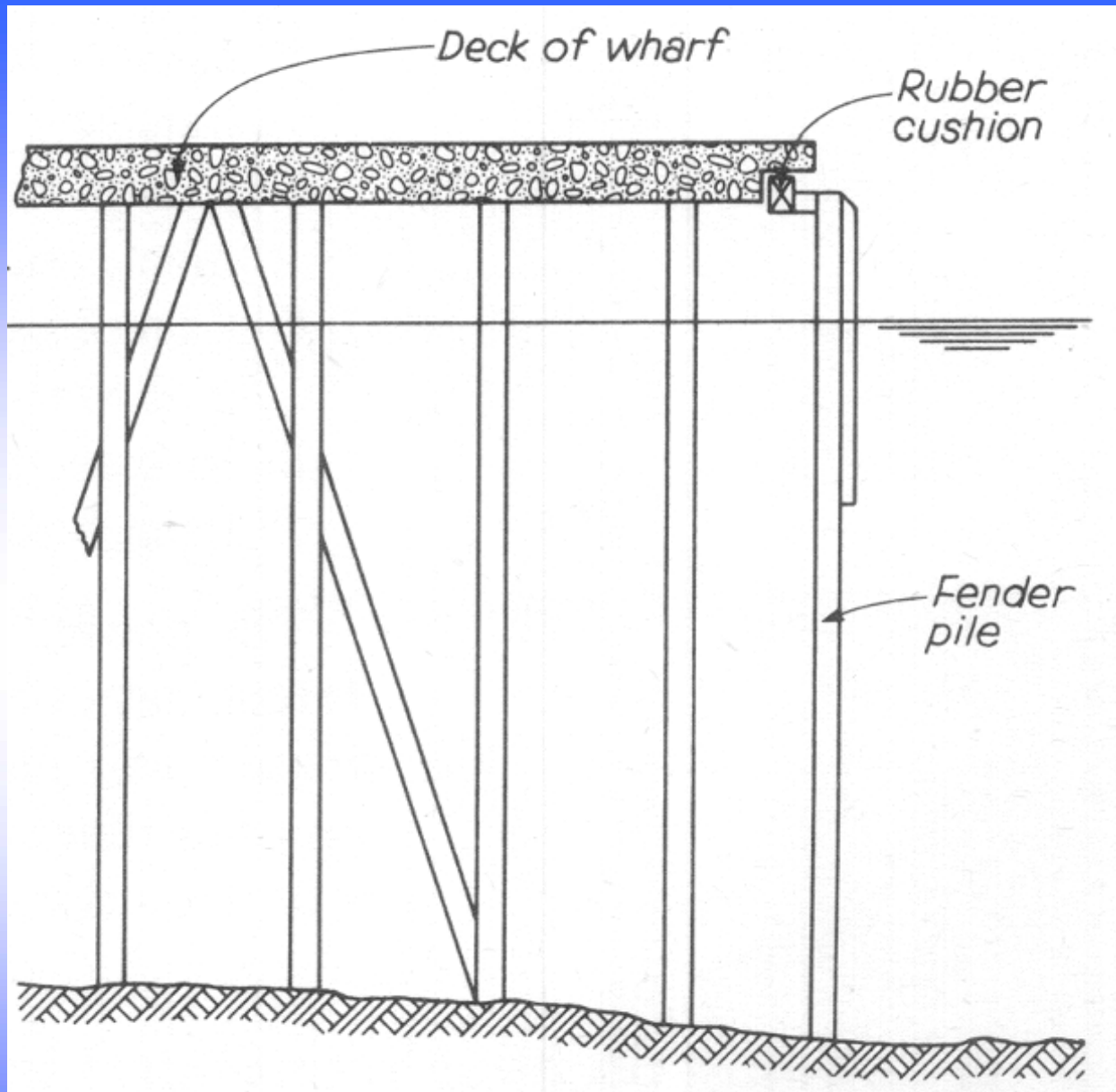
Uplift of pile due to swelling of soil
after removal of mature tree



Tension/compression piles beneath floor of ship building dock



Racking and vertical piles to resist lateral forces from berthing ships



Fender pile to resist impact force from berthing ships

d- Classification of piles based on mode of load transfer:

1. End-bearing or point-bearing piles.

These piles transfer loads through water or soft soil to a suitable bearing stratum by means of end bearing at the base of the piles.

2. Friction piles.

These piles transfer loads to the soil by means-of "skin friction" along the length of the piles.

3. Combined resistance piles.

These piles carry loads through end bearing at the base as well as skin resistance through the length of the piles.

e - Classification of piles based on method of installation

1. Displacement (or large-displacement) piles

These piles include solid or hollow-section piles with a closed end, which are driven or jacked into the ground and thus displace the soil. All types of driven and cast-in-situ piles come under this category.

2. Small-displacement piles

These piles are also driven or jacked into the ground but have a relatively small cross-sectional area. They include rolled steel H- or I-sections, and pipe or box sections driven with an open end such that the soil enters the hollow section. Screw piles that have a small-diameter shaft and a larger helical blade are also known as small-displacement piles.

3. Bored or non-displacement piles

These are formed by first drilling a borehole of the required size. Concrete is then placed into a cased or uncased hole, or the casing may be withdrawn as the concrete is placed. Preformed members of timber, concrete, or steel may be placed in drilled holes.

Types of piles in each of the above three categories are listed below.

Displacement piles (driven types)

1. Timber (round or square section, jointed or continuous).
2. Pre-cast concrete (solid or tubular section in continuous or jointed units).
3. Pre-stressed concrete (solid or tubular section).
4. Steel tube (driven with closed end).
5. Steel box (driven with closed end).
6. Fluted and tapered steel tube.
7. Jacked-down steel tube with closed end.
8. Jacked-down solid concrete cylinder.

Displacement piles (driven and cast-in-situ types)

- 1. Steel tube driven and withdrawn after placing concrete.**
- 2. Pre-cast concrete shell filled with concrete.**
- 3. Thin-walled steel shell driven by removable mandrel and then filled with concrete.**

Small-displacement piles

- 1. Pre-cast concrete (tubular section driven with open end).**
- 2. Pre-stressed concrete (tubular section driven with open end).**
- 3. Steel H-section.**
- 4. Steel tube section (driven with open end and soil removed as required).**
- 5. Steel box section (driven with open end and soil removed as required).**
- 6. Screw pile.**
- 7. Screw cylinder.**

Bored or non-displacement piles

- 1. Concrete placed in borehole (bored and cast-in-situ).**
- 2. Tubes placed in hole drilled as above and filled with concrete as necessary.**
- 3. Pre-cast concrete units placed in drilled hole.**
- 4. Cement mortar injected into drilled hole.**
- 5. Steel sections placed in drilled hole.**
- 6. Steel tube drilled down.**

Composite piles

A pile consisting of two or more types of piles along its length is known as a composite pile.

a. Composite piles based on material-A composite pile of a displacement type can thus be formed by jointing a timber section to a pre-cast concrete section, or a pre-cast concrete pile can have an H-section jointed to its lower end.

b. Composite piles based on method of installation-Composite piles consisting of more than one type can be formed by driving a steel or pre-cast concrete pile at the base of a drilled hole, or by driving a tube and then drilling out the soil and extending the drill hole to form a bored and cast-in-situ pile i.e., a part of length as a driven pile while the remaining part as a bored pile.

The selection of the appropriate type of pile or parts for composite pile from any of the above categories depends on the following three factors.

- a- The location and type of structure
- b- The ground conditions
- c- The durability

a- Location and type of structure

- ❖ **Marine Structures:** A displacement pile is the best choice for a marine structure.
- ❖ A solid precast/prestressed concrete pile can be used in shallow water,
- ❖ In deep water a solid pile becomes too heavy to handle and either a steel or precast concrete tubular pile is used.
- ❖ Steel tubular piles are preferred on H-sections for exposed marine conditions due to smaller drag forces from waves.
- ❖ Large-diameter steel tubes are also an economical solution for dealing with impact forces from waves and berthing ships.
- ❖ Timber piles are used for temporary works in shallow water.
- ❖ Bored and cast-in-situ piles can not be used for any marine or river structure since it is very problematic to make these piles in water. They can however be considered in a composite form of construction, say as a means of extending the penetration depth of a tubular pile driven through water and soft soil to a firm stratum (i.e., upper portion driven and cast-in-situ while the lower portion bored and cast-in-situ).
- ❖ **Ground Structures:** Any of the three main categories of piles can be used for structures on land. However the choice will depend on many factors e.g., loading intensity, soil conditions, environment etc.

- Bored and cast-in-situ piles are the cheapest type where unlined or only partly-lined holes can be drilled by rotary auger. These piles can be drilled in very large diameters and provided with enlarged bases, and thus are suitable to withstand high working loads from heavy buildings.
- Augered piles are also suitable where it is desired to avoid ground heave, noise and vibration, i.e. for piling in urban areas, particularly where stringent noise regulations are enforced.
- Driven and cast-in-situ piles are economical for land structures where light or moderate loads are to be carried, but the ground heave, noise and vibration associated with these types may make them unsuitable for some environments.
- Timber piles are suitable for light to moderate loadings in countries where timber is easily available.
- Steel or precast concrete driven piles are not economical as compared to driven or bored and cast-in-situ piles for land structures.
- Jacked steel tubes or concrete units are used for underpinning.

b- Ground conditions:

The ground conditions influence both the pile material and the method of installation.

- Auger-cast piles can be used in Firm/stiff cohesive soils, but augering is impossible in very soft clays, or in loose or water-bearing granular soils, for which driven or driven-and-cast in-situ piles are suitable.
- Piles with enlarged bases are possible only in firm to stiff or hard cohesive soils or in weak rocks.

- Driven & driven-and-cast-in-situ piles cannot be used in ground containing boulders or other massive obstructions, nor can they be used in soils subject to ground heave.
- Driven-and-cast-in-situ piles where tubes to be withdrawn, cannot be used for very deep penetrations because of the limitations of jointing and pulling out the driven tubes.

C- Durability:

Timber piles are very durable below ground-water level but are liable to decay above this level. In marine conditions softwoods and some hardwoods are attacked by wood-boring organisms.

Concrete piles are resistant to attack by aggressive substances in the soil, or in sea water or ground water. Weak, honeycombed concrete in cast-in-situ piles is liable to disintegration when aggressive substances are present in soils or in ground water.

Steel piles are liable to corrosion above the soil line and in disturbed ground, and they require cathodic protection if a long life is desired in marine structures.

FACTORS GOVERNING CHOICE OF TYPE OF PILE

The advantages and disadvantages of the various types of piles which affect the choice of pile for any particular foundation project;

1. Driven displacement piles

a. Advantages

- Material forming pile can be inspected for quality and soundness before driving.
- Not liable to 'squeezing' or 'necking'.
- Construction operations not affected by ground water.
- Projection above ground level advantageous to marine structures.
- Can be driven in very long lengths.
- Can be designed to withstand high bending and tensile stresses.

b. Disadvantages

- 1. Cannot readily be varied in length to suit varying level of bearing stratum.**
- 2. May break during driving, necessitating replacement piles.**
- 3. May suffer unseen damage which reduces carrying capacity.**
- 4. Uneconomical if cross-section is governed by stresses due to handling and driving rather than by compressive, tensile, or bending stresses caused by working conditions.**
- 5. Noise and vibration due to driving may be unacceptable.**
- 6. Displacement of soil during driving may lift adjacent piles or damage adjacent structures.**
- 7. End enlargements, if provided, destroy or reduce skin friction over shaft length.**
- 8. Cannot be driven in conditions of low headroom.**

2. Driven-and-cast-in-situ displacement piles

a. Advantages

- 1. Length can easily be adjusted to suit varying level of bearing stratum.**
- 2. Driving tube driven with closed end to exclude ground water.**
- 3. Enlarged base possible.**
- 4. Formation of enlarged base does not destroy or reduce shaft skin friction.**
- 5. Material in pile not governed by handling or driving stresses.**
- 6. Noise and vibration can be reduced in some types by driving with internal drop- hammer.**

b. Disadvantages

- 1. Concrete in shaft liable to be defective in soft squeezing soils or in conditions of artesian water flow where withdrawal-tube types are used.**
- 2. Concrete cannot be inspected after installation.**
- 3. Length of some types limited by capacity of piling rig to pull out driving tube.**
- 4. Displacement may damage fresh concrete in adjacent piles, or lift these piles, or damage adjacent structures.**
- 5. Noise and vibration due to driving may be unacceptable.**
- 6. Cannot be used in river or marine structures without special adaptation.**
- 7. Cannot be driven with very large diameters.**
- 8. End enlargements are of limited size in dense or very stiff soils.**
- 9. When light steel sleeves are used in conjunction with withdraw able driving tube, skin friction on shaft will be destroyed or reduced.**

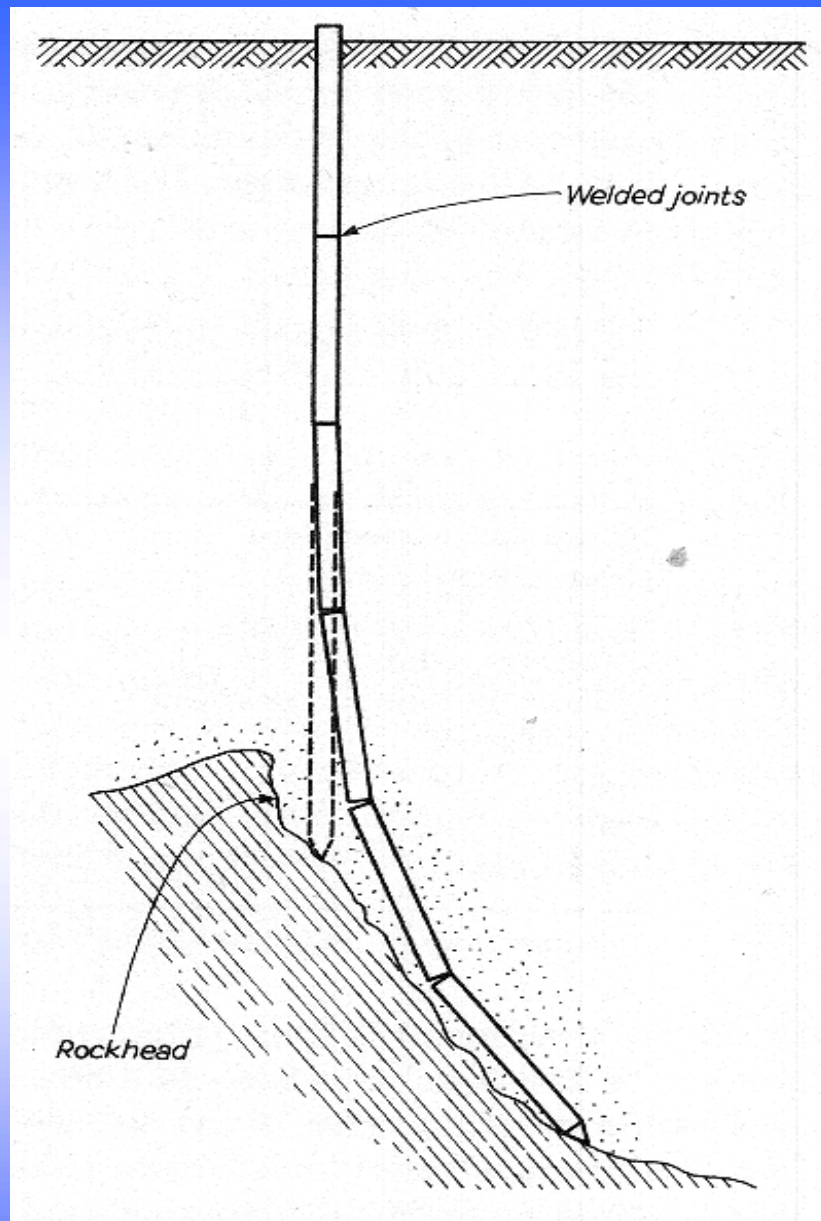
3. Bored and-cast-in situ (non-displacement piles)

a. Advantages

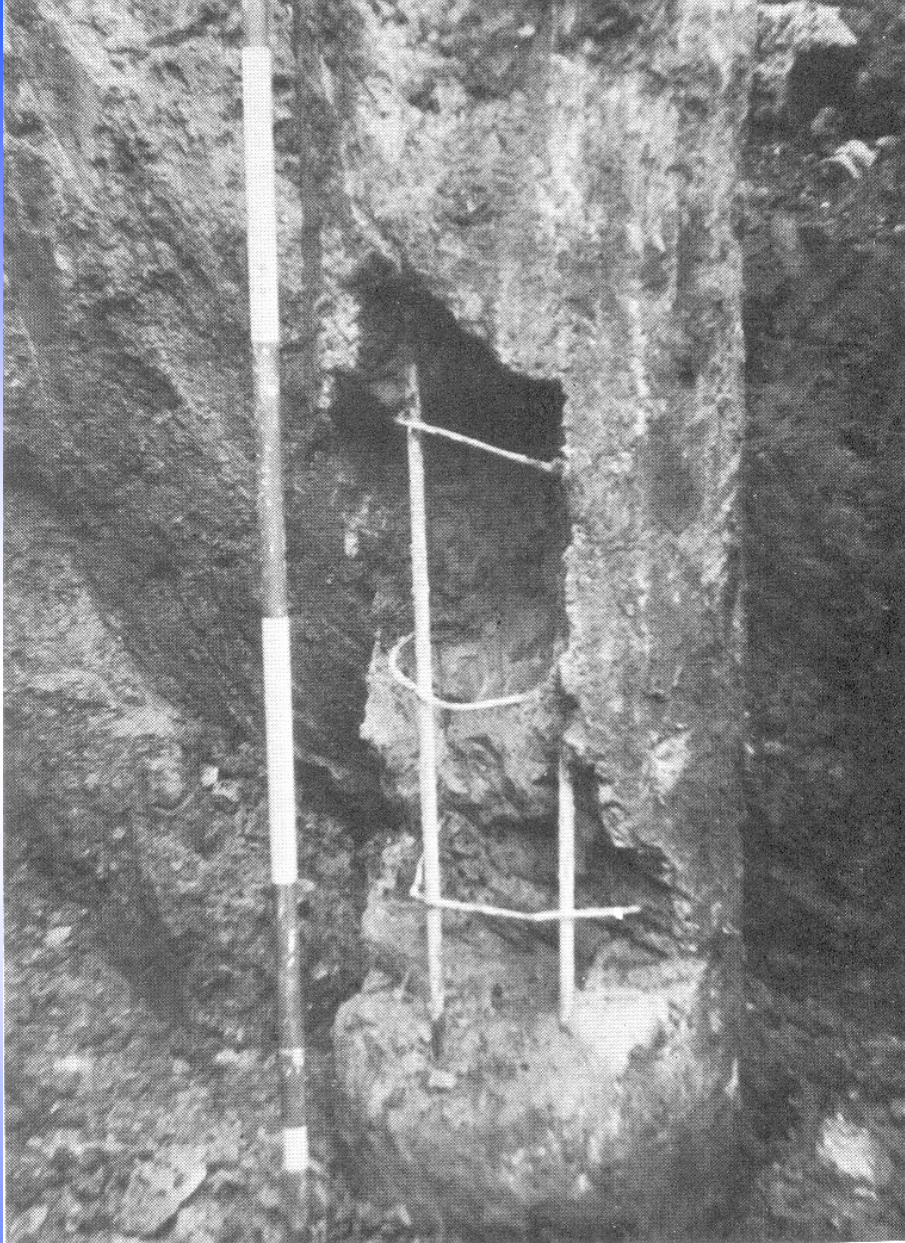
- 1. Length can readily be varied to suit variation in level of bearing stratum.**
- 2. Soil or rock removed during boring can be inspected for comparison with site investigation data.**
- 3. In-situ loading tests can be made in large-diameter pile boreholes, or penetration tests made in small boreholes.**
- 4. Very large [to 6m (20ft) diameter] bases can be formed in favourable ground.**
- 5. Drilling tools can break up boulders or other obstructions which cannot be penetrated by any form of displacement pile.**
- 6. Material forming pile is not governed by handling or driving stresses.**
- 7. Can be installed in very long lengths.**
- 8. Can be installed without appreciable noise or vibration.**
- 9. No ground heave.**
- 10. Can be installed in conditions of low headroom.**

b. Disadvantages

- 1. Concrete in shaft liable to squeezing or necking in soft soils where conventional types are used.**
- 2. Special techniques needed for concreting in water-bearing soils.**
- 3. Concrete cannot be inspected after installation.**
- 4. Enlarged bases cannot be formed in cohesion less soils.**
- 5. Cannot be extended above ground level without special adaptation.**
- 6. Low end-bearing resistance in cohesionless soils due to loosening by conventional drilling operations.**
- 7. Drilling a number of piles in group can cause loss of ground and settlement of adjacent structures.**



Unseen damage to driven piles



Effective shaft of bored pile due to collapse of bore after lifting casing



Effective shaft of bored pile due to washing out of cement of unset concrete