Foundation Types Selection

Civil Engineering
Construction & Graphics

Lecture # 32

Engr. Shad Muhammad
Lecturer
Department of Civil Engineering
COMSATS University Islamabad, Sahiwal Campus.

Lecture # 31 _ Soil Investigations, Problems, and Compaction (Summary)
Table of Content

- Typical Geotechnical Section Activities
- Geotechnical Investigations
- Office Review
- Boring and In Situ Test Frequency
- Field Investigations
- Subsurface Soil Investigations
- Surface Soil Investigations
- Above Ground Indicators of Soil Conditions
- Soil Classifications
- Soil Groups
- Soil Problems
- Sumps and Ditches for Dewatering of Excavations
  - Suitability
  - Use of Sumps and Ditches in Cofferdams
  - Advantages of Sumps and Ditches
  - Disadvantages of Open Sump and Ditches
- Compaction of Soil

Lecture # 32 _ Foundation Types Selection
Table of Content

- Types of Foundations Based on Soil Investigation
- Role of Foundation
- Foundation Types
  - Spread Footings
  - Drilled Piers or Caissons
  - Pile Foundations
  - Mat Foundations
- Types of Soil Excavation Tools and Machines in Construction
  - Hand tools for Soil Excavation
  - Machinery Tools for Soil Excavation
- Methods of Soil Exploration
- Soil samples and sampling for Boring Method of Soil Exploration
- Types of Excavation Supports
- Selection of Foundations Based on Different Types of Soil

Foundation Types Selection
Types of Foundations Based on Soil Investigation

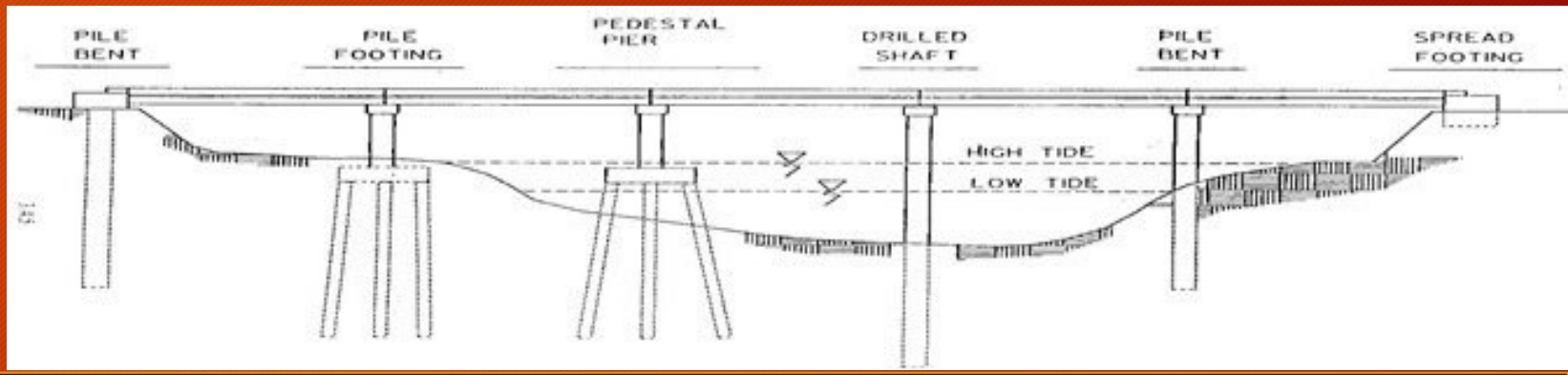
- ✓ For most of the **fine grained soils (containing silt and clays)** it might be sufficient to use **simple spread footings**, it is largely depending on the magnitude of the load. The location of the foundations in relation to the soil (need to be aware of foundation walls and hydrostatic pressure as moisture is present in the soil).
- ✓ If the soil is poor and structure loads are relatively heavy, then alternate methods are required.
- ✓ **Pile foundations** might be required in some cases where **fine cohesive silt and clay soil is present.** (CH, OH).
- ✓ Sometimes it might be desirable and economically feasible to over excavate / remove such soils that are not of good bearing capacity; can remove, compact, and fill back or **import other engineered soil.**

Foundation Types Selection
Types of Foundations Based on Soil Investigation

- ✓ The geotechnical engineer based on borings will recommend suitable foundations systems or alternative solutions, also **bearing capacity, minimum depths, and special design or construction procedures might be established.**
- ✓ Safe bearing capacity of soil equals to the **ultimate bearing capacity divided by a safety factor (usually 2-4).**
- ✓ Ultimate bearing capacity is defined as the **maximum unit pressure a soil can sustain without permitting large amounts of settlements.**
- ✓ Bedrock has the highest safe bearing capacity.
- ✓ **Well graded gravel and sand** that are confined and drained have a safe **bearing capacity of 3,000 – 12,000 psf. Silts and clays** have lower safe bearing capacity of **1,000 – 4,000 psf.**

Foundation Types Selection
Types of Foundations Based on Soil Investigation
Role of Foundation

- ✓ Transfer the building load to the ground.
- ✓ Anchor building against wind and seismic load.
- ✓ Isolate building from frost heaving.
- ✓ Isolate building from expansive soils.
- ✓ Holds building up from moisture.
- ✓ Provide living spaces (basement, storage).
- ✓ Houses mechanical systems.

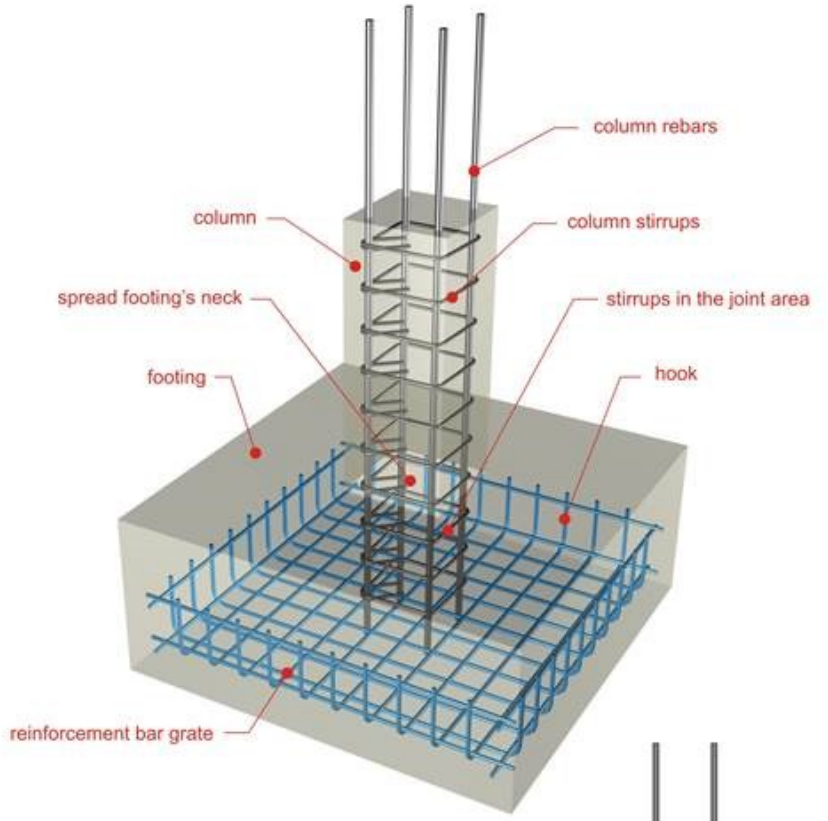


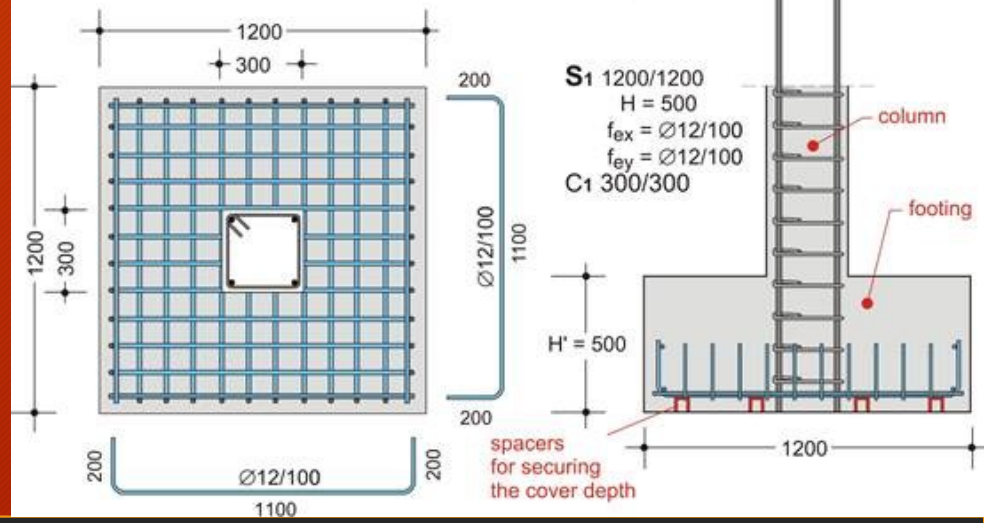
Foundation Types Selection
Types of Foundations Based on Soil Investigation
Foundation Types: Spread Footings

- ✓ Foundation configurations are: **Slab on Grade, Crawl Space, and Basement.**
- ✓ It is used for most buildings where the **loads are light and / or there are strong shallow soils.**
- ✓ At columns there are **single spot square pads** where bearing walls have an elongation form. These are almost always reinforced. These footing deliver the load directly to the supporting soils.
- ✓ Area of spread footing is obtained by dividing the applied force by the soils safe bearing capacity (f=P/A). Generally **suitable for low rise buildings (1-4 Stories).**
- ✓ **Requires firm soil conditions** that are capable of supporting the building on the area of the spread footings. When needed, **footings at columns can be connected together with grade beams to provide more lateral stability in earthquakes.**

Foundation Types Selection
Types of Foundations Based on Soil Investigation
Foundation Types: Spread Footings

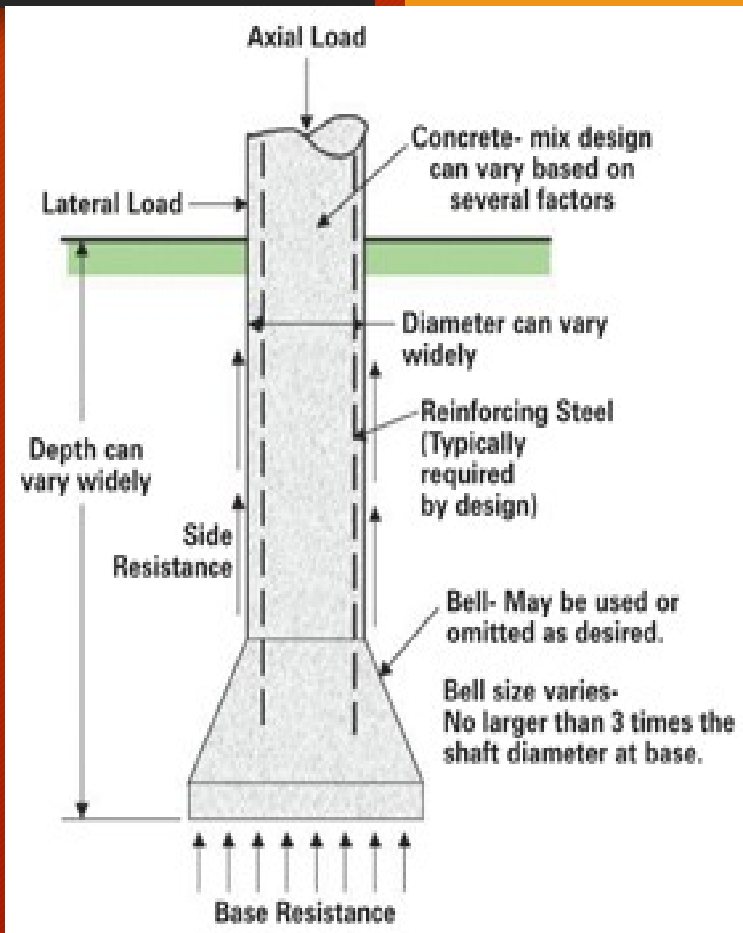
- ✓ These are **most widely used** because they are **most economical.**
- ✓ **Depth of footings should be below the topsoil, and frost line, on compacted fill or firm native soil.**
- ✓ Spread footings should be **above the water table.**
- ✓ Concrete spread footings are at least as thick as the width of the stem.
- ✓ As the weight of the building increases in relation to the bearing capacity or depth of good bearing soil, the footing needs to expand in size or different systems need to be used.





Foundation Types Selection
Types of Foundations Based on Soil Investigation
Foundation Types: Drilled Piers or Caissons

- ✓ **For expansive soils** with low to medium loads, or high loads with rock not too far down, drilled caissons (piers) and grade beams can be used.
- ✓ The caissons might be **straight or belled out at bottom to spread the load.**
- ✓ The **grade beam** is designed to **span across the piers and transfer the loads over to a column foundation.**
- ✓ Caissons deliver the load to soil of stronger capacity which is located not too far down.



Foundation Types Selection
Types of Foundations Based on Soil Investigation
Foundation Types: Pile Foundations

- ✓ **For expansive soils or soils that are compressive** with heavy loads where deep soils can not take the building load and where soil of better capacity if found deep below.
- ✓ There are two types of piles
  1. Friction piles – used where there is **no reasonable bearing stratum** and they **rely on resistance from skin of pile against the soil.**
  2. End bearing – which **transfer directly to soil of good bearing capacity.**
- ✓ The bearing capacity of the piles depends on the structural strength of the pile itself or the strength of the soil, whichever is less.
- ✓ Piles can be wood, steel, reinforced concrete, or cast in place concrete piles.

Foundation Types Selection

Types of Foundations Based on Soil Investigation

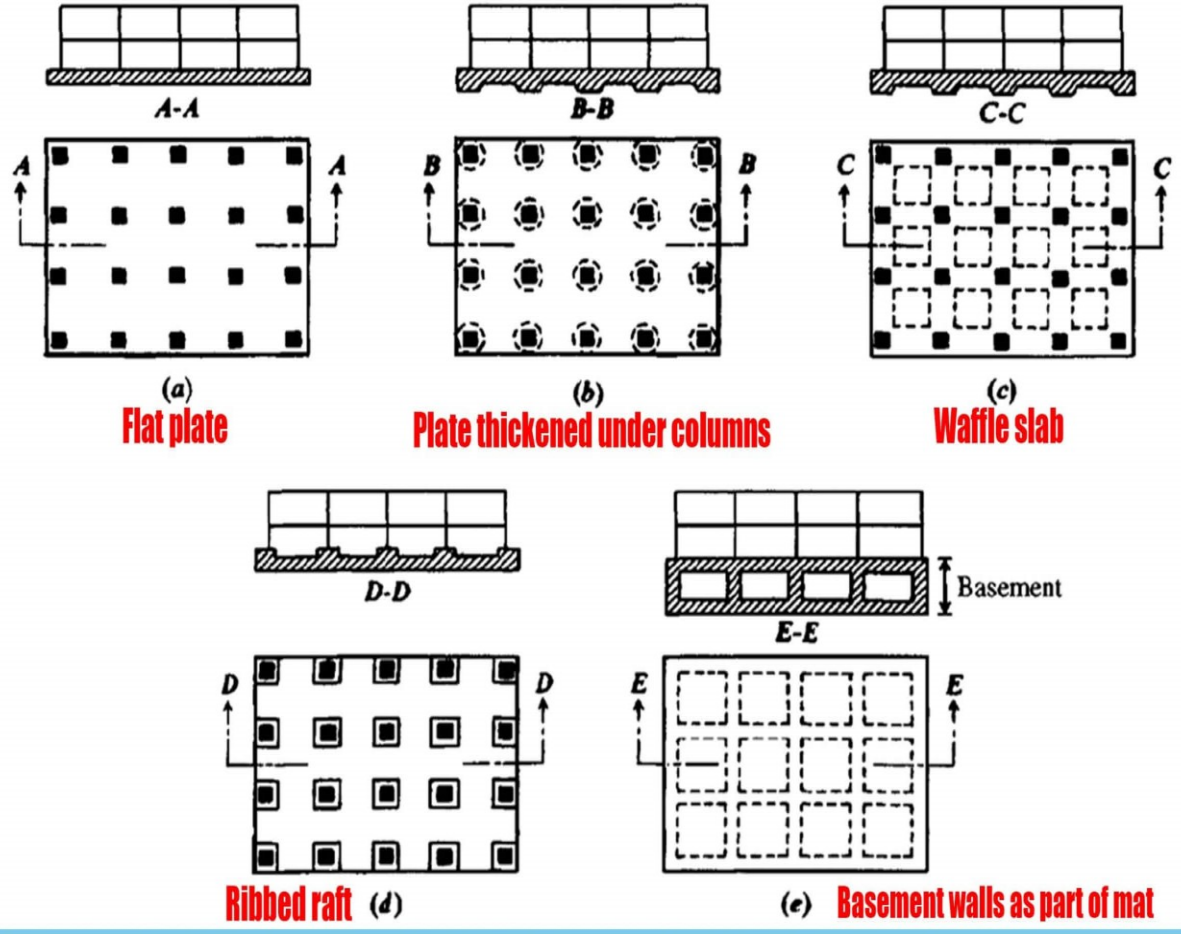
Foundation Types: Pile Foundations

- ✓ Cast in place piles are composed of hole drilled in earth and then filled with concrete, it is used for light loads on soft ground and where drilling will not cause collapse. Friction type, obtained from shaft perimeter and surrounding earth.

Foundation Types Selection
Types of Foundations Based on Soil Investigation
Foundation Types: Mat Foundations

- ✓ **Reinforced concrete raft or mats** can be **used for small light load buildings on very weak or expansive soils such as clays.**
- ✓ They are **often post tensioned concrete.**
- ✓ They allow the building to float on or in the soil like a raft.
- ✓ It can be used for **buildings that are 10-20 stories tall** where it **provides resistance against overturning.**
- ✓ It can be used where soil requires such a **large bearing area** and the footing might be spread to the extant that it becomes more economical to pour one large slab (thick), more economical – **less forms.**
- ✓ It is used in lieu of driving piles because can be less expensive and less obtrusive (i.e. less impact on surrounding areas).
- ✓ Usually used over expansive clays, silts to let foundation settle without great differences.

Foundation Types Selection
Types of Foundations Based on Soil Investigation
Foundation Types: Mat Foundations



Foundation Types Selection
General Summary of Soil Investigation and Types of Foundation

- ✓ Ranking of Soil for foundations: (from best to unsuitable):
  - Sand & Gravel – Best
  - Medium & Hard Clays – Good
  - Silts & Soft Clays – Poor
  - Organic Silt and Clays – Undesirable
  - Peat – Unsuitable

- ✓ The **greater the PI – Plasticity Index, Cohesiveness the greater the potential for shrinkage and swelling** usually characteristic of clay like soils.

Foundation Types Selection
General Summary of Soil Investigation and Types of Foundation

- ✓ **Non-cohesive soils** are **granular soils consisting of gravel and sands.**
- ✓ **Cohesive soils** are **silts and clays, and also organic.**
- ✓ Differential settlements in concrete foundations should be limited to ¼ to ½" maximum.
- ✓ Generally cost of foundations are 5% of total construction cost.
- ✓ Most economical where safe bearing capacity is at least 3000 psf – Spread Footings.
- ✓ Piles are most expensive, 2 or 3 times the price than Spread Footings.

Foundation Types Selection
Types of Soil Excavation Tools and Machines in Construction

- ✓ There are different types of soil excavation tools and machines used in construction.
- ✓ Excavation of soil is necessary in construction point of view and it should be done by hand tools or machineries based on the area of the land or depth of excavation.
- ✓ By the process of excavation, the land is cleaned from tree roots, strums, organic impurities etc., which should harm to the foundation.
- ✓ Now a days, for the soil excavation there are so many equipment's are there and these are classified into two types.

    1. Hand tools
    2. Machineries

Foundation Types Selection
Hand tools for Soil Excavation
Spade

- ✓ Spade is a tool which consists metal plate having sharp edges, the plate is attached to long handle which is generally made up of wood.
- ✓ Because of its sharp edges the soil can be dig easily. The metal plate having less curvature in the spade so, we cannot lift the soil by spade.

Foundation Types Selection
Hand tools for Soil Excavation
Shovel

- ✓ Shovel is tool which is used for the purpose of lifting of excavated soil.
- ✓ It is also similar to spade the difference between spade and shovel is the difference in leading edge.
- ✓ The curvature of metal plate of shovel is generally higher when compared to spade so we can hold the soil easily and lifted it.
- ✓ Shovel can also be used for digging purpose in case of soft soils, sand etc.

Foundation Types Selection
Hand tools for Soil Excavation
Hoe

- ✓ Hoe is an excavating tool which consists a metal plate attached to a long handle with acute angle.
- ✓ The plate having sharp edge is used to excavate the soil.
- ✓ For small work of excavation it is widely preferred tool.
- ✓ Sometimes metal plate is replaced by fork type plate.

Foundation Types Selection
Hand tools for Soil Excavation
Trowel

- ✓ Trowel is hand sized tool which is generally used to dig the small trenches in soil or to remove the shallow roots in soil.

Foundation Types Selection
Hand tools for Soil Excavation
Rake

- ✓ Rake is a tools which is having a horizontal rod having metal teeth and is used to remove the small layers of soil.

Foundation Types Selection
Hand tools for Soil Excavation
Pick axe

- ✓ Pick axe consists hard spike attached perpendicular to handle.
- ✓ They are used for excavating small trenches in soil.
- ✓ Pick axe can cut the soil even if the soil is of hard type.
- ✓ The metal spike is pointed on one side and wide blade is provided on the other side.

Foundation Types Selection
Hand tools for Soil Excavation
Mattock

- ✓ This looks like pickaxe.
- ✓ But serious digging is not possible with mattock.
- ✓ Generally it is used as lifting tool because of its curve shapes metal at its bottom.

Foundation Types Selection
Machinery Tools for Soil Excavation
Tracked Excavator

- ✓ This is also called as track hoe. It consists of cabinet and long arm.
- ✓ Long arm again consists of 2 parts. The first part which is closure to cabinet is called as Boom and the other part is called as Dipper-stick.
- ✓ Digging bucket is attached to the end of dipper.
- ✓ This entire system can rotate 360 degrees.
- ✓ In this case Vehicle is moved by traction, so we can use this equipment in mines, forestry, pipeline industries etc.
- ✓ The function of excavator is done by hydraulic fluid so, it is also called as hydraulic excavators.

Foundation Types Selection
Machinery Tools for Soil Excavation
Wheeled Excavator

- ✓ This whole arrangement is similar to the tracked excavator except that the movement of vehicle is done by wheels.
- ✓ It can move quickly when compared to tracked excavator but it is not suitable for uneven grounds or hilly areas because of slippery nature.
- ✓ So these are generally used for road constructions etc..

Foundation Types Selection
Machinery Tools for Soil Excavation
Back Hoe Excavator

- ✓ In case of back hoe excavator, the hoe arrangement is on back side and loader bucket is arranged in front of the vehicle.
- ✓ So two operations digging and loading or lifting is done by hoe and loader.
- ✓ This is widely used equipment nowadays because of its small size and versatility.
- ✓ This is moved with the help of wheels. so, moving from one workstation to another is quickly done.

Foundation Types Selection
Machinery Tools for Soil Excavation
Bulldozer

- ✓ Bulldozer consists of hard steel plate with sharp edge at its front.
- ✓ This sharp edge is helps the plate to cut the soil and for excavation.
- ✓ The metal plate can be raised and lowered with the help of hydraulic arms.
- ✓ The bulldozers are available in both tracked and wheeled form.
- ✓ These are widely used for the works of soil excavations, weak rock strata removal, lifting of soil etc.

Foundation Types Selection
Machinery Tools for Soil Excavation
Dragline Excavators

- ✓ Dragline excavators consists large length boom.
- ✓ A cable is hanged from the top of the boom and digging bucket is suspended to the cable.
- ✓ Generally dragline excavators are used for larger depth excavations like port construction, under water sediment removal etc.
- ✓ These are heavy equipment with greater economy.

Foundation Types Selection
Machinery Tools for Soil Excavation
Trenchers

- ✓ Trenchers are the equipment's used to dig trenches in the ground.
- ✓ These are also available in many sizes based on our requirement.
- ✓ The trenches dug are generally used for drainage purpose, pipeline laying, cable laying.
- ✓ The trenchers are generally available in two types.
  1. **Chain trenchers**
  2. **Wheeled trenchers**

Foundation Types Selection
Machinery Tools for Soil Excavation
Trenchers: Chain Trenchers

- ✓ Chain trencher consists of a fixed arm called boom around which digging chain is arranged. The chain is very hard and consists sharp tooth. Whenever it is driven into ground the chain rotates around boom with rapid force and cuts the ground. By adjusting the angle of the boom we can manage the depth to be excavated. It cuts the soil with hard strata which cannot excavate by bucket type excavator. In case of smaller chain trenchers wheeled vehicles are available and for larger chain trenchers are available in tracked form.

Foundation Types Selection
Machinery Tools for Soil Excavation
Trenchers: Wheeled trenchers

- ✓ In case of wheeled trencher, toothed metal wheel is used as trenching tool. This equipment is available in both tracked and wheeled form of vehicles. When compared to chain trencher the wheeled trencher can cut harder soil strata. It is also used to cut pavement surface while road repair works. Economically also wheeled trencher is better than the chain trencher.

Foundation Types Selection
Methods of Soil Investigation and Soil Exploration and their Details

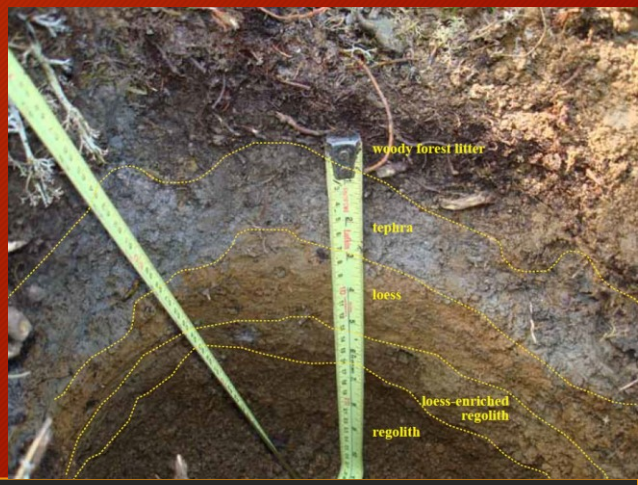
- ✓ Soil investigation and soil explorations are conducted for the purpose of site investigation to get clear information about the soil properties and hydrological conditions at the site.
- ✓ Site Reconnaissance
- ✓ Site reconnaissance is the inspection of the site and study of topography to get a proper information about the soil and groundwater condition.
- ✓ Purpose of Soil Exploration
  1. Order of occurrences and extent of soil and rock strata.
  2. Nature and engineering properties of of the soil and rock formation.
  3. Location of groundwater and its variation.

Foundation Types Selection
Methods of Soil Investigation and Soil Exploration and their Details
Methods of Soil Exploration

1. Open Excavation
2. Borings
3. Subsurface Soundings
4. Geographical Methods

Foundation Types Selection
Methods of Soil Exploration
1. Open Excavation

- ✓ A pit, eventually, can be excavated for exploring shallower depths, say of the order of 2 to 5 m, or so.
- ✓ Such a pit can be easily excavated at the proposed construction site, if the soil has a bit of cohesion, and the soil samples can be lifted from such different depths, besides making the easy visualization and examination of the different strata.
- ✓ Even undisturbed soil samples can be lifted from such a pit by a process called chunk sampling.



Foundation Types Selection
Methods of Soil Exploration
2. Boring Method

- ✓ Soil samples can be lifted from deeper depths by drilling bore holes by using mechanical devices called samplers.

- ✓ The process consists of
  - ✓ **Drilling a hole and visually examining the cuttings coming out from different depths**
  - ✓ **Lifting the soil samples from different depths by using mechanical devices called samplers.**

Foundation Types Selection
Methods of Soil Exploration
2. Boring Method: 1. Auger Boring

- ✓ This is simplest method of boring a hole by hand drilling.
- ✓ These can be used for shallower depths generally confined to depths of about 5 m or so.
- ✓ In cohesive and other soft soils above water table, augers may be used.

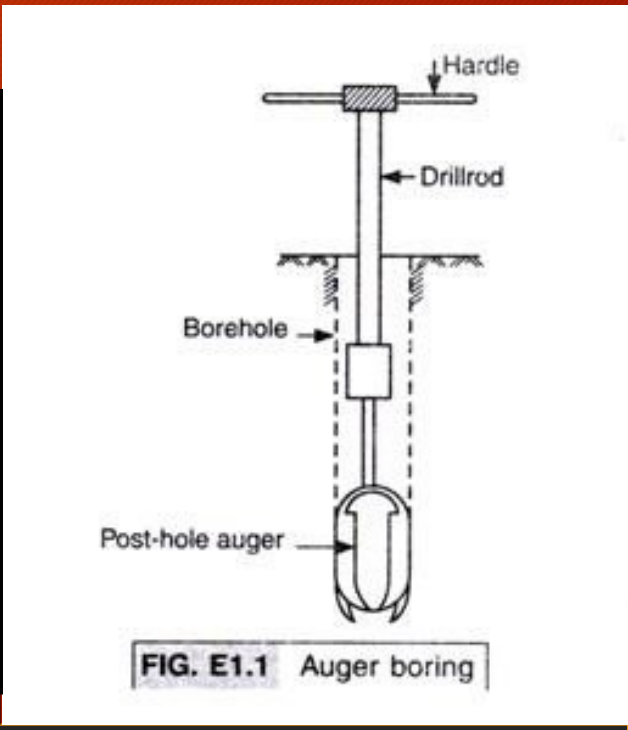


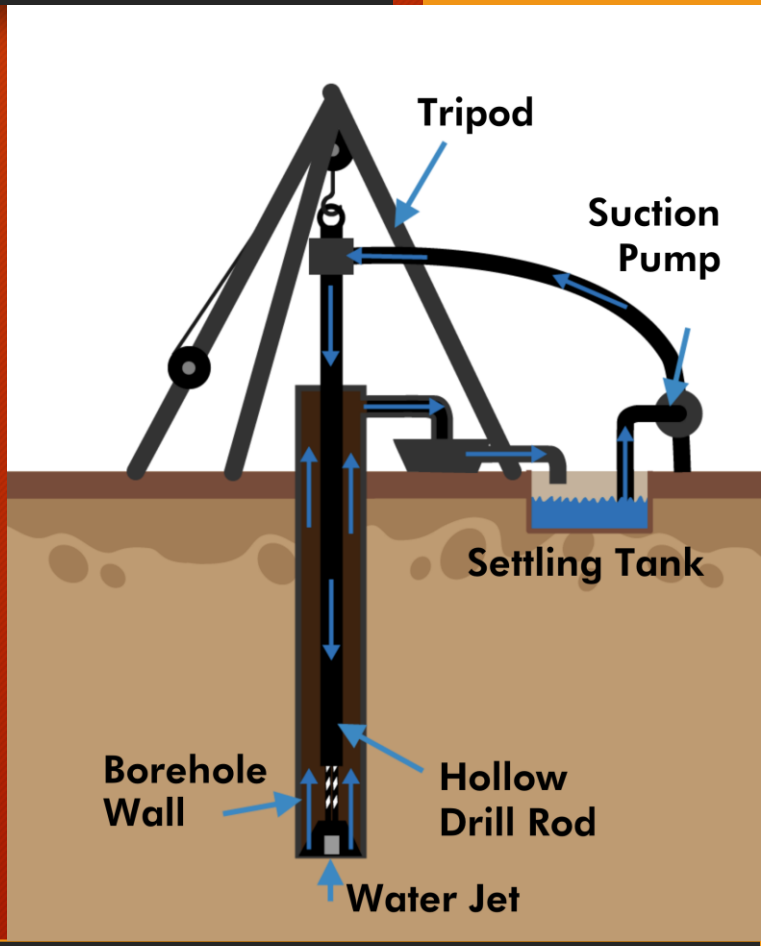
FIG. E1.1 Auger boring

Foundation Types Selection
Methods of Soil Exploration
2. Boring Method: 2. Auger and Shell Boring

- ✓ Augers are suitable for soft or stiff clays and very stiff and hard clays and sand pumps for sandy soils.
- ✓ Cylindrical augers and shells are used for making deep boring.
- ✓ Hand operated, mechanized ring are used for depths 25m, 50m respectively.

Foundation Types Selection
Methods of Soil Exploration
2. Boring Method: 3. Wash boring

- ✓ This is a simple and fastest method, used for making holes in all types of soils except boulders and rocks.

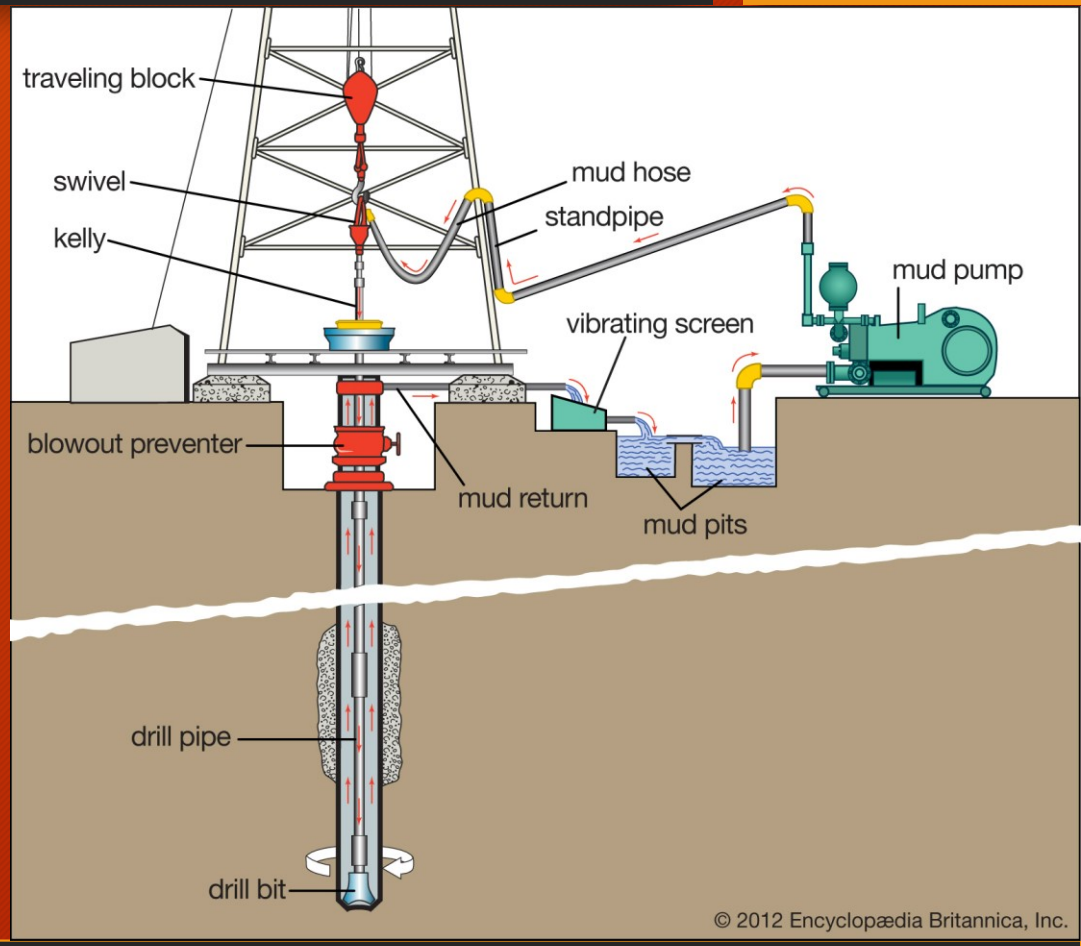


Foundation Types Selection
Methods of Soil Exploration
2. Boring Method: 4. Percussion Boring

- ✓ This method is used to make hole in all types of soils including boulders and rocks. Percussion drilling is employed when auger or wash boring is not possible in very stiff soil or rock. It also can be used in most soil types. Here the advancement of a hole is achieved by alternatively lifting and dropping a heavy cutting or hammering bit that is attached to a rope or cable that is lowered into an open hole or inside a temporary casing (casings are hollow cylindrical pipes used for borehole stability and to prevent the loss of drilling fluid through the boreholes). Usually a tripod is used to support the cable. The stroke of bit varies according to the ground condition. The major disadvantage of this method is that it is not possible to get good-quality undisturbed samples.

Foundation Types Selection
Methods of Soil Exploration
2. Boring Method: 5. Rotary Boring (Mud Rotary Drilling)

- ✓ This method is used to advance hole in rocks and soils.
- ✓ Rotating core barrels which are provided with commercial diamond bits or a steel bit with slots are used for rotary drilling.
- ✓ This method is used to obtain the rock cores, so this method is called as core boring or core drilling.



Foundation Types Selection

Soil samples and sampling for Boring Method of Soil Exploration

1. Disturbed sample

- ✓ In disturbed sampling, the natural structures of soils gets partly or fully modified or destroyed, although with suitable precaution the natural water content may be preserved.
- ✓ Disturbed sample can be obtained by direct excavations by auger and thick wall samplers.

Soil samples and sampling for Boring Method of Soil Exploration

2. Undisturbed sample

- ✓ In undisturbed sample, the natural structure and properties remain preserved.
- ✓ These samples are used to tests for shear, consolidation and permeability.

Soil samples and sampling for Boring Method of Soil Exploration

3. Non-representative Sample

- ✓ It consists of a mixture of soil from different soil strata.
- ✓ Size of the soil grains as well as the mineral constituents, might thus, have changed in such samples.
- ✓ Soil samples obtained from auger cuttings and settling in some well of wash borings, can be classified in this category.
- ✓ Such samples may help in determining the depths at which major changes may be occurring in subsurface soil strata.

Soil samples and sampling for Boring Method of Soil Exploration

3. Subsurface Sounding Tests

- ✓ These tests are carried out to measure the resistance to penetration of a sampling spoon, a cone or other shaped tools under dynamic or static loading.
- ✓ These tests are used for exploration of erratic solid profiles for finding depth to bedrock or stratum and to get approximate indication of the strength and other properties of soil.

Soil samples and sampling for Boring Method of Soil Exploration

3. Subsurface Sounding Tests

1. Standard Penetration Test (SPT)

- ✓ This test is carried out in a clean hole of diameter about 55 to 150mm. the sides of the holes are supported by casing or drilling mud.
- ✓ A split tube sampler with 50.8mm outer diameter, 38mm inner diameter is driven into the undisturbed soil, placed at the bottom of the hole under the blows of 65kg drive weight with 75cm free fall.

Soil samples and sampling for Boring Method of Soil Exploration

3. Subsurface Sounding Tests

2. Cone penetration test or Dutch cone test

- ✓ This type of test is carried out to get a continuous record of the resistance of the soil by penetrating steadily under static pressure, a cone with base of 10 sq.cm (3.6 cm in dia.) and an angle of 60 degree at the vortex.
- ✓ To find out the cone resistance, the cone alone is first forced down for a distance of 8cm and the maximum value of resistance is recorded.
- ✓ This test is very useful in finding bearing capacity of pits in cohesionless soil.
- ✓ Cone resistance qc (kg/sq.cm) is approximately equal to 10 times the penetration resistance N.

Soil samples and sampling for Boring Method of Soil Exploration

4. Geographical Methods of Soil Exploration

1. Electrical resistivity method

- ✓ This method is based on the measurement and recording of changes in the mean resistivity or apparent specific resistance of various soils.
- ✓ The test is done by driving four metal spikes to act as electrodes into the ground along a straight line at equal distances.

2. Seismic refraction method

- ✓ This method is very fast and reliable in establishing profiles of different strata, provided the deeper layers have increasingly greater density, higher velocities and greater thickness.

Foundation Types Selection
What Are Excavation Supports?

- ✓ In general, to construct a structure either above the ground or below the ground, excavation of soil is necessary in the ground.
- ✓ The excavation may be shallow or deep based on our requirement.
- ✓ But when deep cuts are made in soil, the soil from the sides of excavated area may collapse due to low stability.
- ✓ To prevent this and to make the cut accurate vertical we need some temporary earth retaining structures called excavation supports.
- ✓ The failure of soil cut arises when the limit of excavation exceeds its safe height limit and it depends upon unconfined compressive strength of soil and cohesion.

Foundation Types Selection
What Are Excavation Supports?

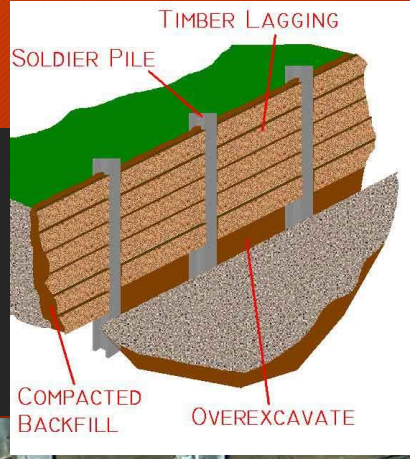
- ✓ Following table provides the safe height limit for different soil types based on their unconfined compressive strength and cohesion limits.
- ✓ Generally, there are two most commonly adopted methods of providing excavation supports:
  1. Soldier Pile and Lagging
  2. Soil Nailing

Soil type	Unconfined compressive strength (psf)	Cohesion (psf)	Safe height (ft)
Very soft	Less than 500	<250	<5
Soft	500-1000	250-500	5-10
Medium	1000-2000	500-1000	10-20
Stiff	2000-4000	1000-2000	20-40
Very stiff	4000-8000	2000-4000	40-80
Hard	>8000	>4000	>80

Foundation Types Selection
Types of Excavation Supports
Soldier Pile and Lagging

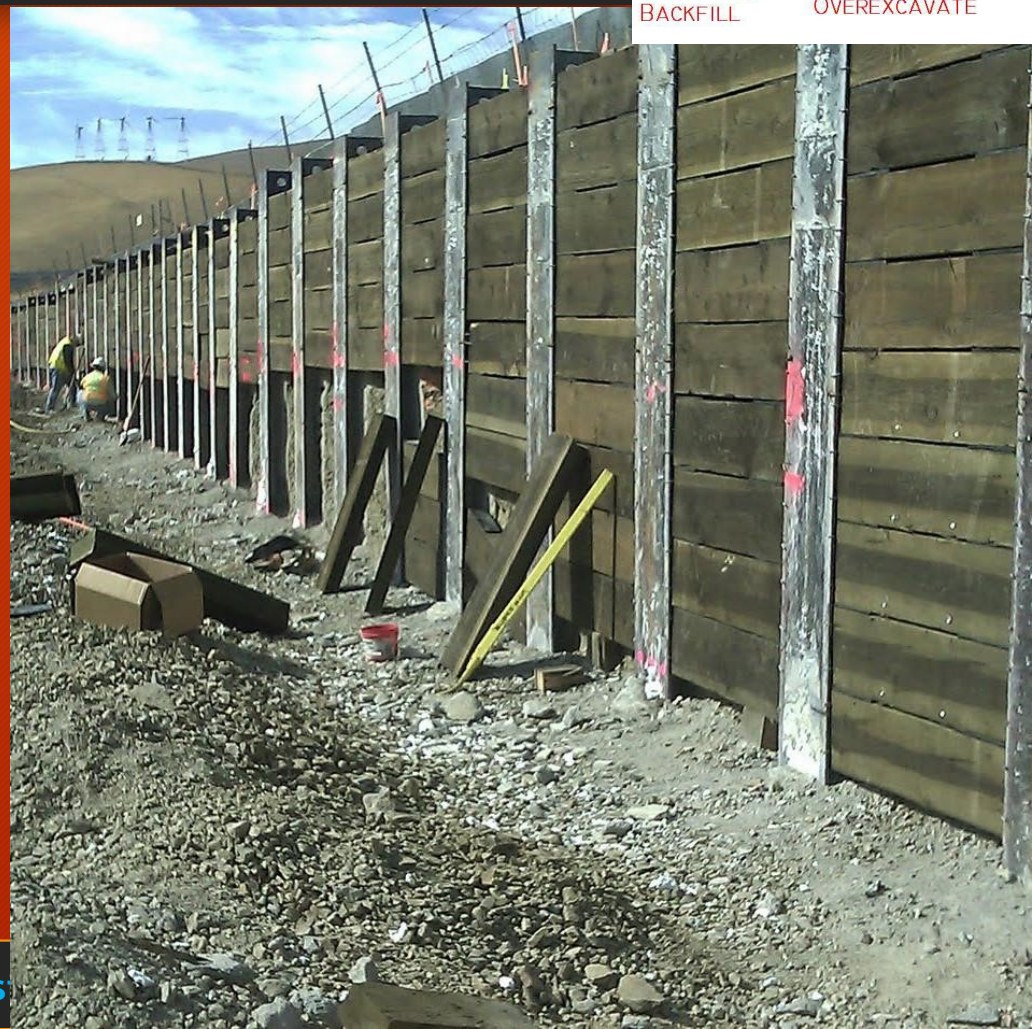
- ✓ Soldier Piles are nothing but **I-sections which consists web between two flanges.**
- ✓ These I-sections are **drilled into the ground around the periphery of an excavation.**
- ✓ The piles are driven to the point slightly **below the required excavation depth.**
- ✓ **Weak concrete is used for grouting of piles.**
- ✓ The spacing between every two adjacent piles is limited to 10 feet.
- ✓ After that exaction is done and the surrounded soil is well supported by the flanges of piles.
- ✓ In between the piles, wood lagging is used. The lagging consists long timber sheets or planks placed behind the front flanges of piles to support the soil between the piles.
- ✓ The timber is of 2 to 4 inches thickness, so, some manual excavation behind the front flange is needed. To offer strong bond between horizontal wood sheets and front flange, welded studs, clips etc. are used.

Foundation Types Selection
Types of Excavation Supports
Soldier Pile and Lagging

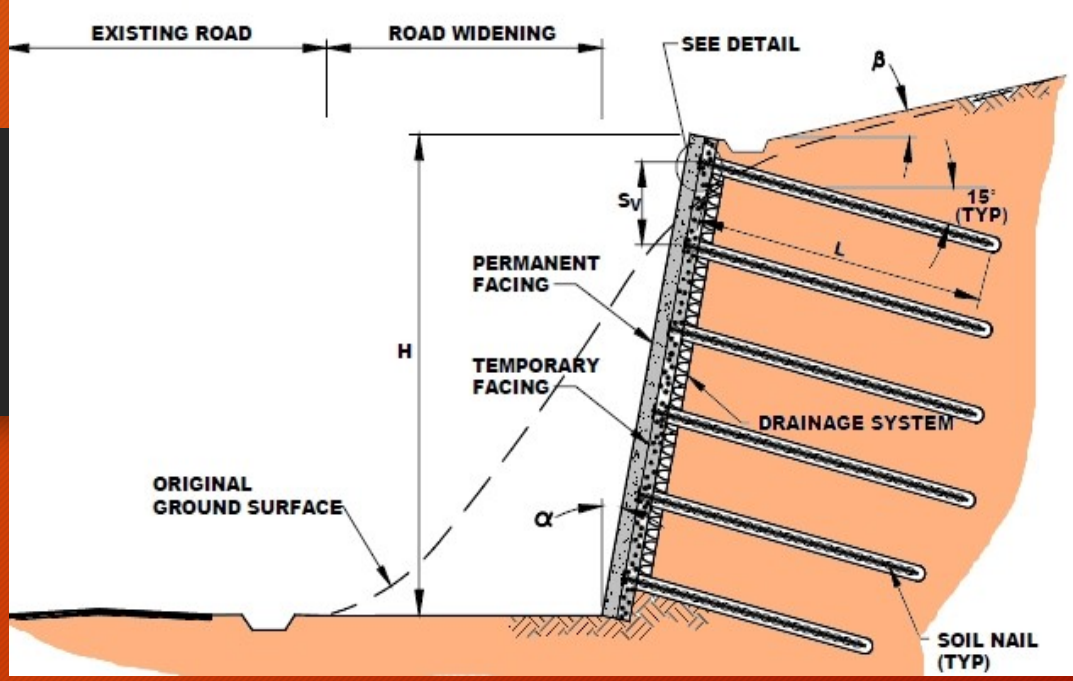


- ✓ For narrow cuts which have limited width and more depth, excavation bracings are provided in the form of struts. Struts are connecting member which connect the one side cut wall to another cut wall horizontally.

- ✓ To install struts, horizontal member called waler is arranged in front of wooden lagging. If the excavation is very wide, then inclined struts called rakers are used.



Foundation Types Selection
Types of Excavation Supports
Soil Nailing Method



- ✓ Soil nailing is another technique of protecting excavated ground.
- ✓ It is **economical and rapid process.**
- ✓ In this case, **soil is reinforced in situ to make it stable.**
- ✓ For soil nailing, firstly shallow cut is excavated and then the **cut is coated with shotcrete.** Shotcrete is nothing but concrete which is sprayed through pipes with some force. On the shotcrete area, soil nails are driller and grouted.
- ✓ The Group of nails installed on a grid holds the soil in a stable manner. The same process is repeated until the required depth is reached.

Foundation Types Selection
Types of Excavation Supports
Soil Nailing Method

- ✓ Soil nailing is more effective and easier if it is done with subsequent layers of installation.
- ✓ Even though it is rapid in construction it **needs skilled persons** to who are having knowledge on geo-technology and craftsmanship.
- ✓ Soil nailing should be more **effective above the ground water table.**
- ✓ Soil nailing is mostly **used for rail or road embankments, tunnel excavations, retaining structures for high rise buildings etc.**
- ✓ Soil nailing structures **provides good resistance against seismic activities and deflections** are also with in the tolerable limits.

Foundation Types Selection
Types of Excavation Supports
Soil Nailing Method

- ✓ Sometimes this excavation bracings or rakers may disturbs the field operations.
- ✓ To overcome this, **tie back system is developed**.
- ✓ In this case, **tie back bars or anchor bars are installed in the soil cut that is behind the excavation support.**
- ✓ So, these tie backs holds the excavation supports and they are grouted to the rock below the ground. From this lateral earth pressure is also prevented and the load from the structure is carried to rocks through this tie backs.
- ✓ The **angle of inclination of anchors** is decided based on the soil behavior and availability of hard stratum but In General **10 to 20-degree inclination is provided for anchors.**

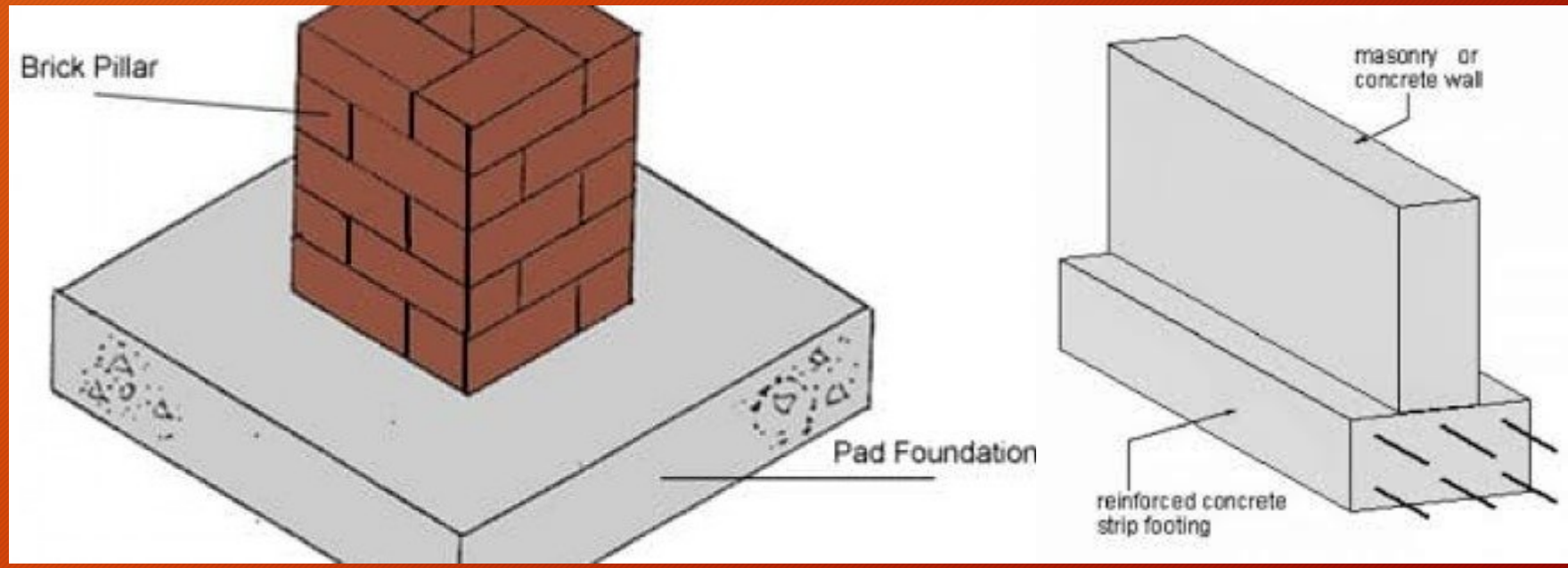
Foundation Types Selection
Selection of Foundations Based on Different Types of Soil

- ✓ Commonly, the selection of foundation type for a given structure is controlled by number of factors for example **soil type, past site usage, adjacent construction, size of development process, limitations.**
- ✓ Among these factors, **types of soil play significant role.**
- ✓ Foundations are recommended based on the different soil types which are provided below:
    1. **Rocks**
    2. **Uniform Firm and Stiff Clay**
    3. **Soft Clay**
    4. **Peat**

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
1. Rocks

- ✓ This category involves **rocks, hard sound chalk, sand and gravel, sand and gravel with little clay content, and dense silty sand.**

- ✓ Recommended foundation types
  - Strip foundation
  - Pad foundation
  - Raft foundation.



Foundation Types Selection

Selection of Foundations Based on Different Types of Soil

1. Rocks

- ✓ Minimum depth of 450mm shall be used for foundation if the area prone to frost so as to protect the foundation.
- ✓ Strip or trench base shall be **kept above groundwater table if possible.**
- ✓ Engineer shall be aware of running sand conditions.
- ✓ Sand slopes possibly eroded by surface water, so protect foundation by perimeter drainage.
- ✓ Weathered rock needs to be evaluated upon inspection.
- ✓ Engineer shall be aware of swallow holes in chalks.

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
2. Uniform Firm and Stiff Clay - Case I

- ✓ There are three cases which are discussed below:

1. Where the foundation is not close to vegetation or existing vegetation is not important.
   - ✓ Recommended foundations
     - Strip Foundation
     - Pad Foundation
     - Raft Foundation.

- Factors to be considered in this case are as follow:
  - Minimum depth to underside of foundation shall be 900mm.
  - When strip foundation is constructed in desiccated clay in dry soil, then the foundation shall be loaded with building prior to the return of rains.

Selection of Foundations Based on Different Types of Soil

2. Uniform Firm and Stiff Clay - Case II

2. Where trees, hedges, and shrubs are close to foundation location, or there is a plan to plant these trees near the structure in the future.
   - ✓ Recommended foundation
     - ✓ concrete piles supporting reinforced concrete ground beams and precast concrete floor
     - ✓ concrete piles carrying in situ concrete slab
     - ✓ specially designed trench fills in certain clay soil based on the foundation location relative to trees
     - ✓ Raft foundation

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
2. Uniform Firm and Stiff Clay

- ✓ Engineer should be aware that size and type of pile foundation is controlled by economic factors.
- ✓ When in situ concrete ground slab is utilized, avoid must be created under the slab if it is laid in dry weather in desiccated clay.
- ✓ If the distance between recently planted tree and foundation position is at least one to two times mature tree height, then it might be suitable to construct strip foundation.
- ✓ In few cases, reinforced trench fill could be employed. For example, in clay of low to medium shrinkage potential, or in perimeter zone of the tree root system.

Selection of Foundations Based on Different Types of Soil

2. Uniform Firm and Stiff Clay - Case III

3. Where trees are cut down shortly before the foundation construction begin
   - ✓ Recommended foundation
     - Reinforced concrete pile in previously tree root zone
     - Strip foundation
     - Raft foundation

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
2. Uniform Firm and Stiff Clay - Case III

- ✓ Piles shall be tied properly into suspended reinforced concrete slabs or ground beams.
- ✓ Sufficient length of slab shall be provided to withstand clay heave force. Added to that, top section of pile may be sleeved to decline friction and uplift.
- ✓ Special pile design may be needed for clay slopes greater than 1 in 10 because creep possibly occur.
- ✓ Consequently, lateral thrust and cantilever effect shall be taken into consideration in the pile design.
- ✓ In few cases, reinforced trench fill could be employed. For example, in clay of low to medium shrinkage potential, or in perimeter zone of the tree root system.

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
3. Soft Clay

- ✓ This category includes soft clay, soft silty clay, soft sandy clay, and soft silty sand.
  - ✓ Recommended foundations
    - Wide strip footing
    - Raft foundation
    - Pile to firmer strata below
    - For smaller projects use pier and beam foundation to firm strata
- ✓ Wide Strip Footing is used when bearing capacity is sufficient and predicted settlement is acceptable.
- ✓ Strip footing shall be reinforced based on the thickness and projection beyond wall face.
- ✓ Services entries to the buildings should be flexible.
- ✓ Frequently, Sub-soil can be improved using vibro treatment, and it would an economical solution if employed in conjunction with strip or raft foundation.

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
4. Peat

- ✓ Recommended foundation
  - Concrete piles extended to the firm soil layer below
  - For small projects, pad and beam foundation taken to firm strata below.
  - Raft foundation for the case where firm strata is not available at reasonable depth but there is hard surface crust with 3-4 m thick of suitable bearing capacity.

Foundation Types Selection
Selection of Foundations Based on Different Types of Soil
4. Peat

- ✓ Pile types include bored cast-in-place with temporary casing, driven cast in place, and driven precast concrete.
- ✓ Allow for peat consolidation drag on piles.
- ✓ Special high grade and protection is likely to be required in aggressive peats.
- ✓ If peat layer is shallow over firm layer of soil, dig it out and replace it with compacted fill. For this, use raft or reinforced wide spread foundation dependent on anticipated settlement.
- ✓ Frequently, Sub-soil can be improved using vibro-treatment, and it would an economical solution if employed in conjunction with strip or raft foundation.

Thank-you for Listening!

Abhi sarhe-ulfat ki manzil kahan ha …
Abhi tu TAQI ibtidaon ma gum hun …

Mufti Taqi Usmani