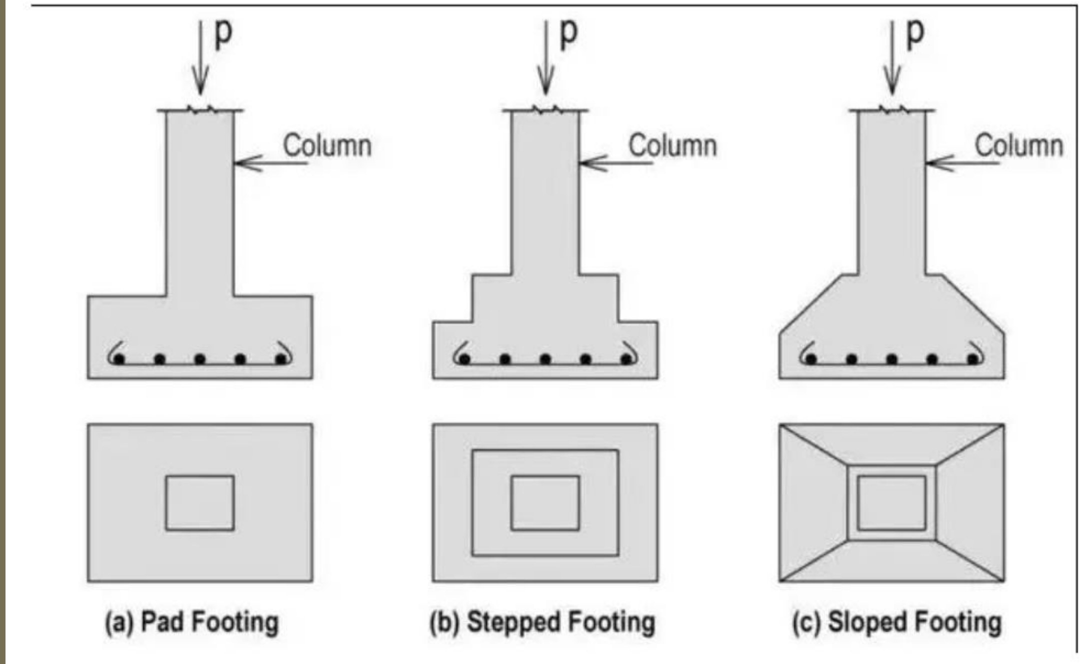
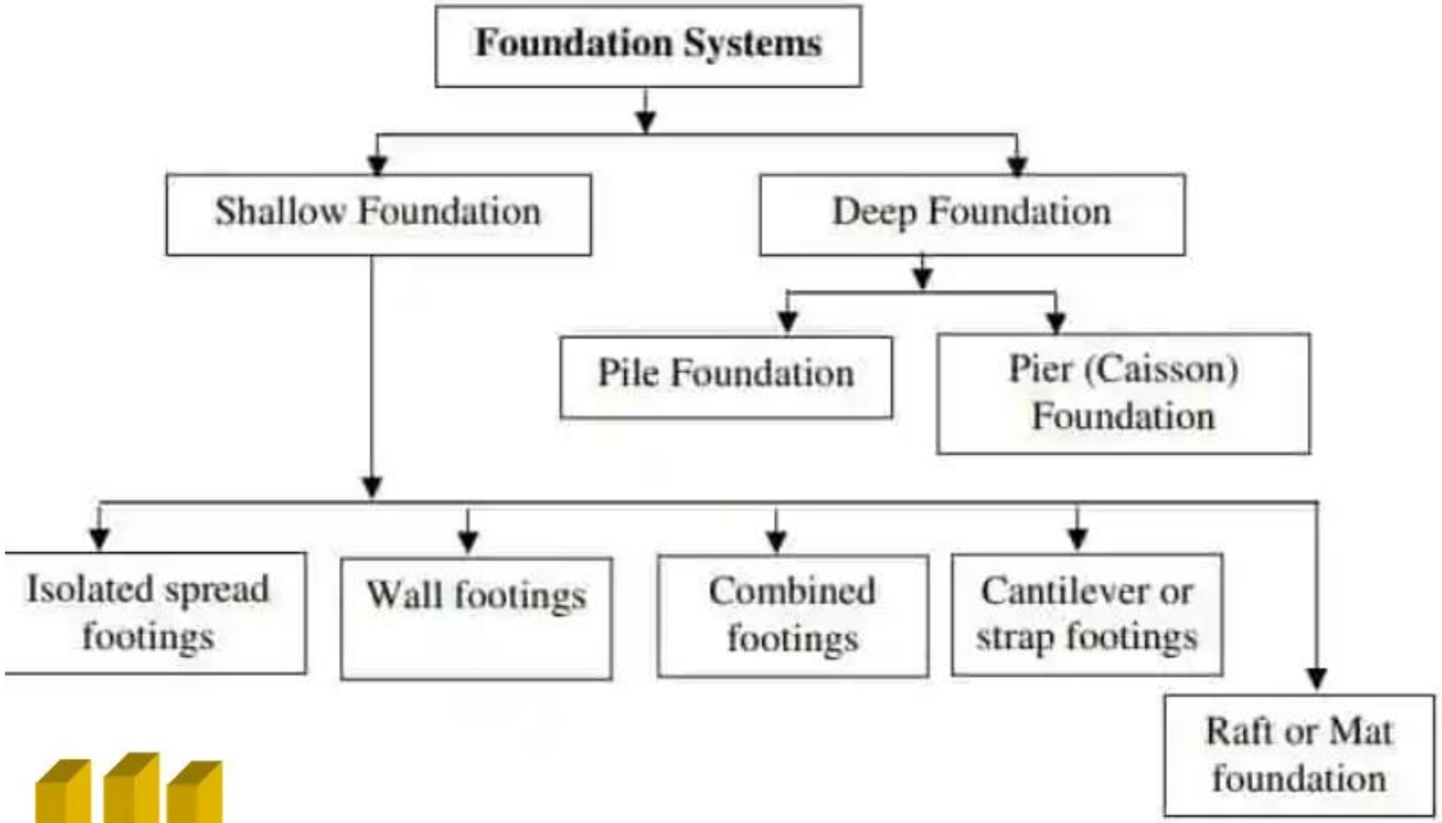
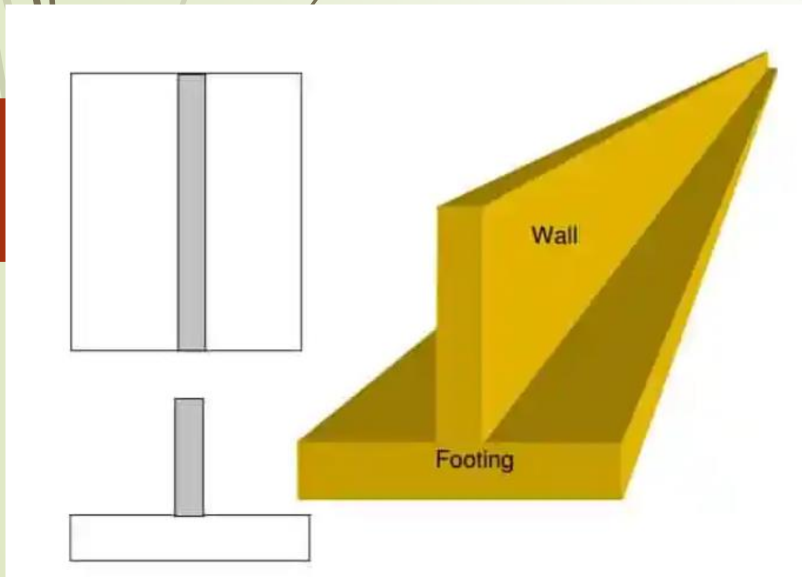
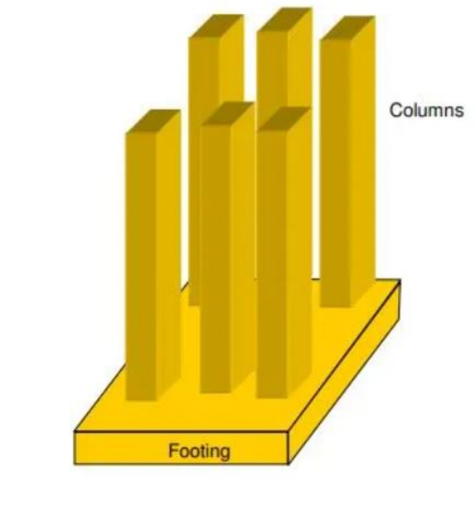
DAY 08



Types of Isolated Spread Footing

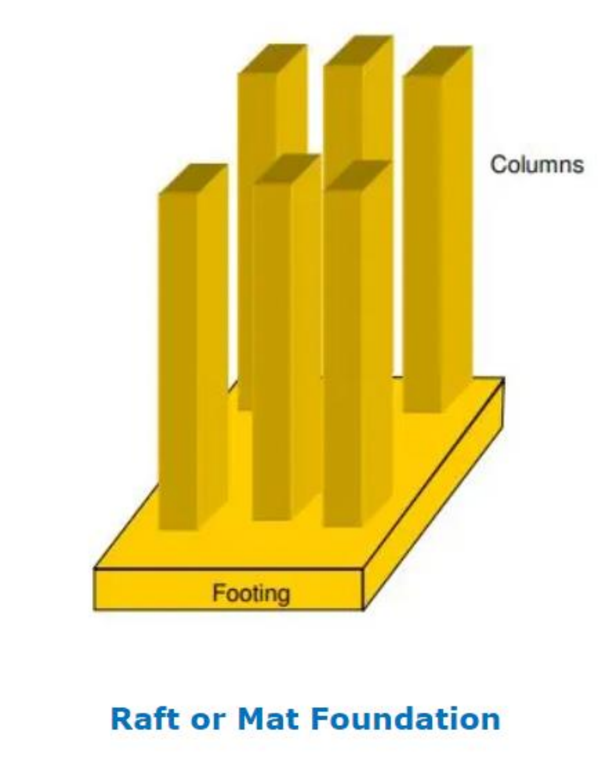


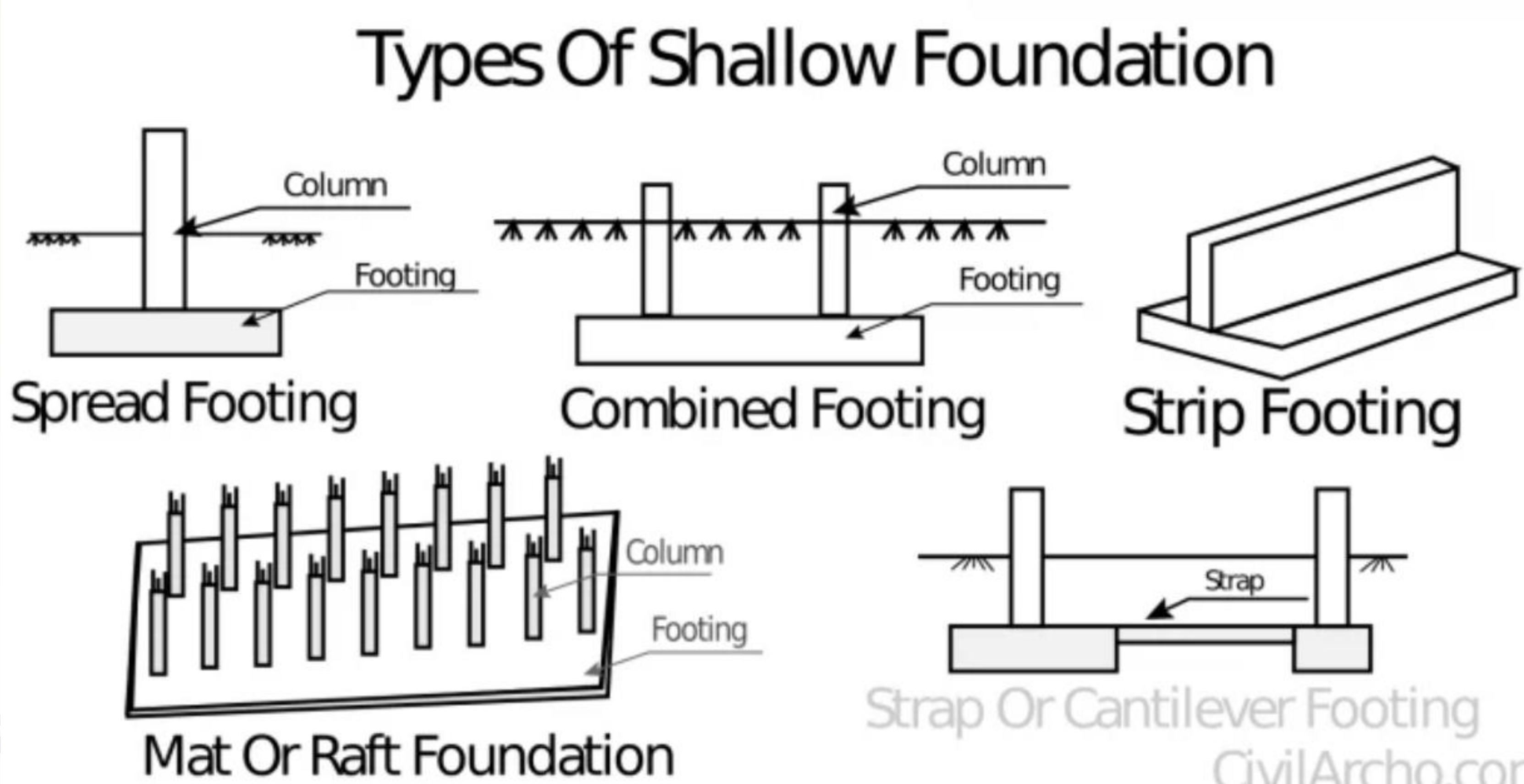




Raft or Mat Foundation

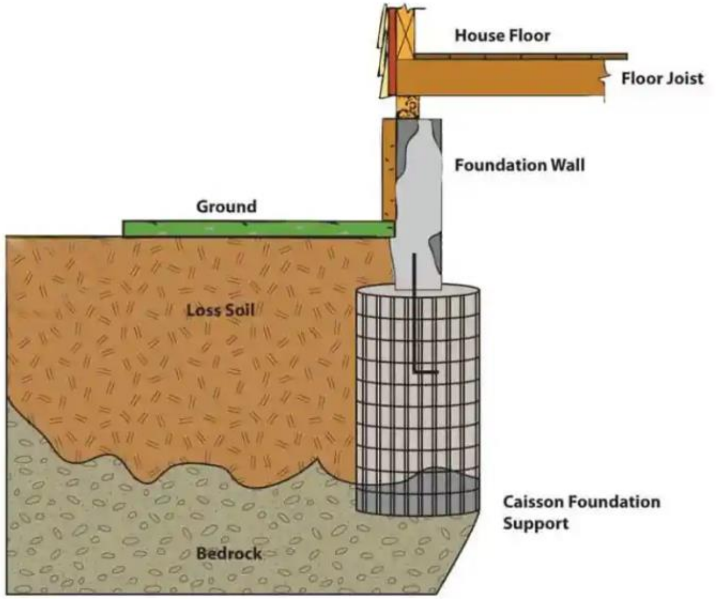
- **Isolated footing**: - below a column
- **Strip foundation**: The foundation whose length is considerably greater than its width is called strip or continuous foundation.
- **Combined foundation**: It supports two columns, and is provided when two columns are such closely spaced that their individual column footing overlap, or when the **property line is close to one column** and spread footing will be eccentrically loaded when kept entirely within the property line. It can be either rectangular or trapezoidal in plan.



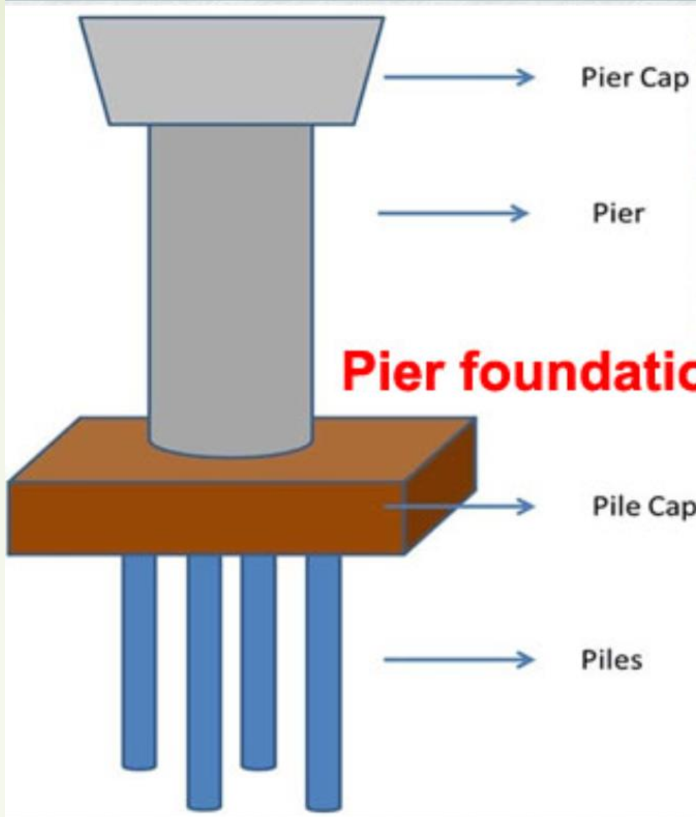


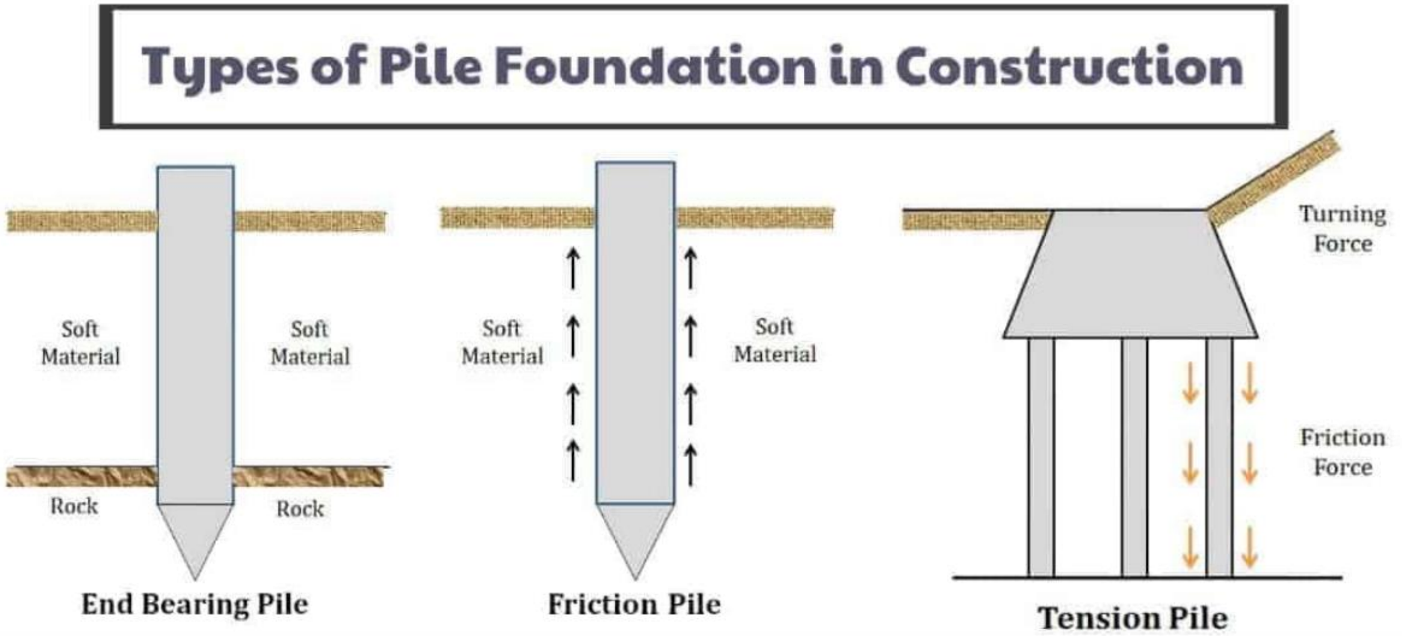
- **Strap foundation**: When two or more isolated footings connected by a beam (called strap) it is called strap foundation. The strap acts as connecting beam and doesn't take any soil reaction. Strap is designed as rigid beam. A strap footing is more economical than a combined footing when the allowable soil pressure is relatively high and the distance between the column is large.
- **Mat foundation**: It is large footing which covers the entire area below a structure and supports the arrangements of all column and wall. It is required when the allowable soil pressure is low or where the columns and walls are so close that individual footing would overlap or nearly touch each other **(Area of footings is more than 50% of total covered area)**. They are useful in reducing **differential settlement** in non-homogenous soil or when there is **large variation of load on individual columns**. **Hence, it can be used when structure is heavy and water table is near the base of the structure**.

Pile Foundation



Caisson Foundation





- **Pile foundation**: Piles are further classified as:
  - ✓ On the basis of material [Steel, Concrete, Timber, Composite Piles]
  - ✓ On the basis of load transfer [End bearing, friction and combined piles]
- **Pier foundation:** It is a deep and cylindrical foundation large diameter that transfer large superimposed load to a firm stratum below by means of bearing.
- **Cassion foundation**: It is type foundation in a shape of hollow prismatic box which is built above the ground level and then sunk to required depth as a single unit. Its types are open Cassion, pneumatic Cassion and floating Cassion

Factors affecting choice of foundation:

- Location and depth criteria
- Bearing capacity criteria
- Settlement criteria
- Function and load carried by structure
- Subsurface condition
- Service life
- Environmental considerations
- Need of client

61. A raft foundation is preferred for:
    a. Columns of industrial buildings
    b. Load bearing walls of multistoried buildings
    c. Columns of a building which are closely spaced
    d. None
62. When the area of all the footings covers more than 50% of the total area of the structure, then the foundation that is preferrable is:
    a. Isolated foundation
    b. Combined footings
    c. Raft foundation
    d. None of these
63. Shallow footing is one whose depth is:
    a. Always equal to width
    b. Less than the width
    c. More than the width
    d. None of the above

CCBAB

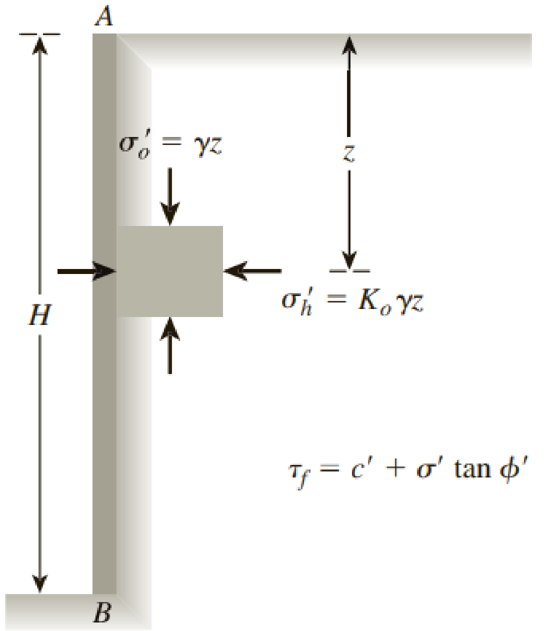
64. Which of the following, is a type of shallow footing?

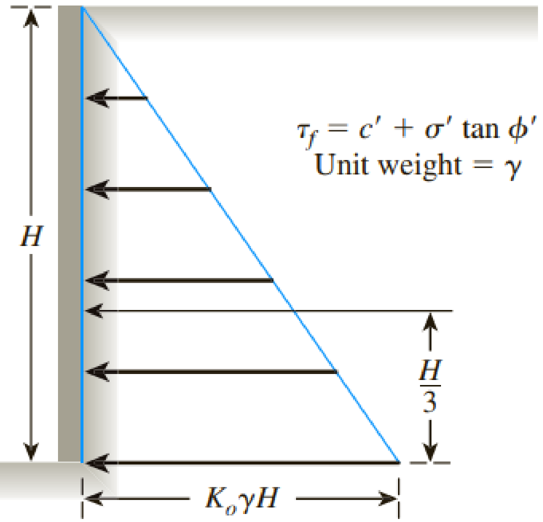
    a. Spread footing b. Pile foundation c. Pier Foundation d. Well Foundation

65. When do strap footings are used in foundation?

    a) To transfer load of an isolated column
    b) Distance between the columns are long
    c) Two column loads are unequal
    d) All of the mentioned

Earth Pressure Theories





Rankine Theory	Coulomb Theory
It is based on ideal conditions of semi-infinite soil.	Need not be such an ideal condition.
The face of the wall in contact with the backfill is smooth.	Wall friction is allowed on the face of the wall.
Yielding about a base point is necessary for both active and passive states to develop.	Yielding should ensure only a critical condition for a soil wedge to slide (or) torn off from the rest of the soil mass.
Potential sliding surfaces are planes making angle of $(45 - \frac{\phi}{2})$ with the direction of major principal stress.	Potential sliding surface are planes which make some angle with horizontal and dependent on angle of shearing resistance and angle of wall friction.

i) Earth pressure at rest:

The lateral pressure exerted by the soil when the retaining wall has **no movement relative** to the backfill, is called earth pressure at rest. This case occurs when the **retaining wall is firmly fixed at its top and is not allowed to move in lateral direction**. This condition is also called **"Elastic equilibrium condition"**, as no part of the soil mass has failed.

The lateral earth pressure intensity p_0 at any depth (h) in a soil is given by,

$$p_0 = K_0 \gamma h$$

Where, γ is the unit weight of soil, K_0 is the coefficient of earth pressure at rest.

$$K_0 = 1 - \sin\phi = \frac{\mu}{1-\mu}, \mu \text{ is Poisson's ratio.}$$

Total earth pressure P $= \frac{1}{2} k_0 \Upsilon H^2$, which acts at distance 2H/3 from top. Where, H is the height of retaining wall.

ii. Active earth pressure:

The lateral pressure exerted by the soil when the **retaining wall tends to move away** from backfill due to excessive pressure of retained soil is called active earth pressure. It is the **minimum earth pressure** exerted by soil on the retaining wall. When a retaining wall moves away from the backfill, there will be stretching of the soil mass and the active state of earth pressure exists and it is a state of plastic equilibrium.

Total active earth pressure

$$P_a = \frac{1}{2}\, k_a \Upsilon H^2,$$ which acts at distance 2H/3 from top.

$$K_a = \frac{1-\sin\emptyset}{1+\sin\emptyset} = \tan^2 (45 - \emptyset/2)$$

iii. Passive earth pressure:

The lateral earth pressure exerted by soil when the **retaining wall moves towards the backfill** due to any natural cause, is known as passive earth pressure. The value of earth pressure at rest is higher than the active earth pressure but less than the passive earth pressure.

Total passive earth pressure

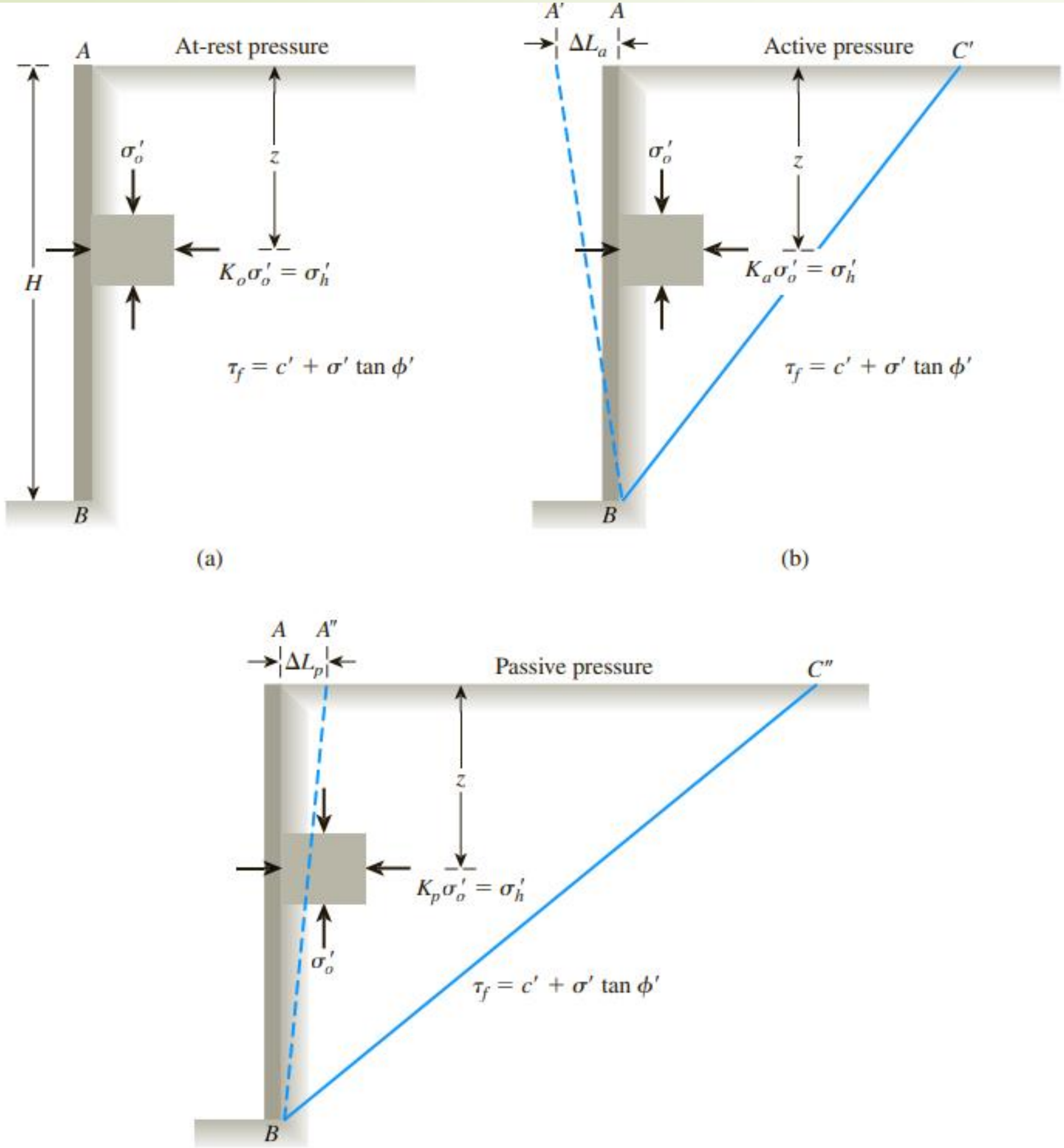
$$P_p = \frac{1}{2}\, k_a \Upsilon H^2,$$ which acts at distance 2H/3 from top.

Where, K_p is the coefficient of passive earth pressure

$$\mathbf{K_p = \frac{1+\sin\emptyset}{1-\sin\emptyset} = \tan^2 (45 + \phi/2)}$$

The relation among coefficient of earth pressure is $k_p > k_0 > k_a$

Active and passive earth pressures are the limiting condition and represents the state of plastic equilibrium. A state of plastic equilibrium exists in a soil mass when every part of it is just on the point of failing in shear i.e., they are just on the verge of failure



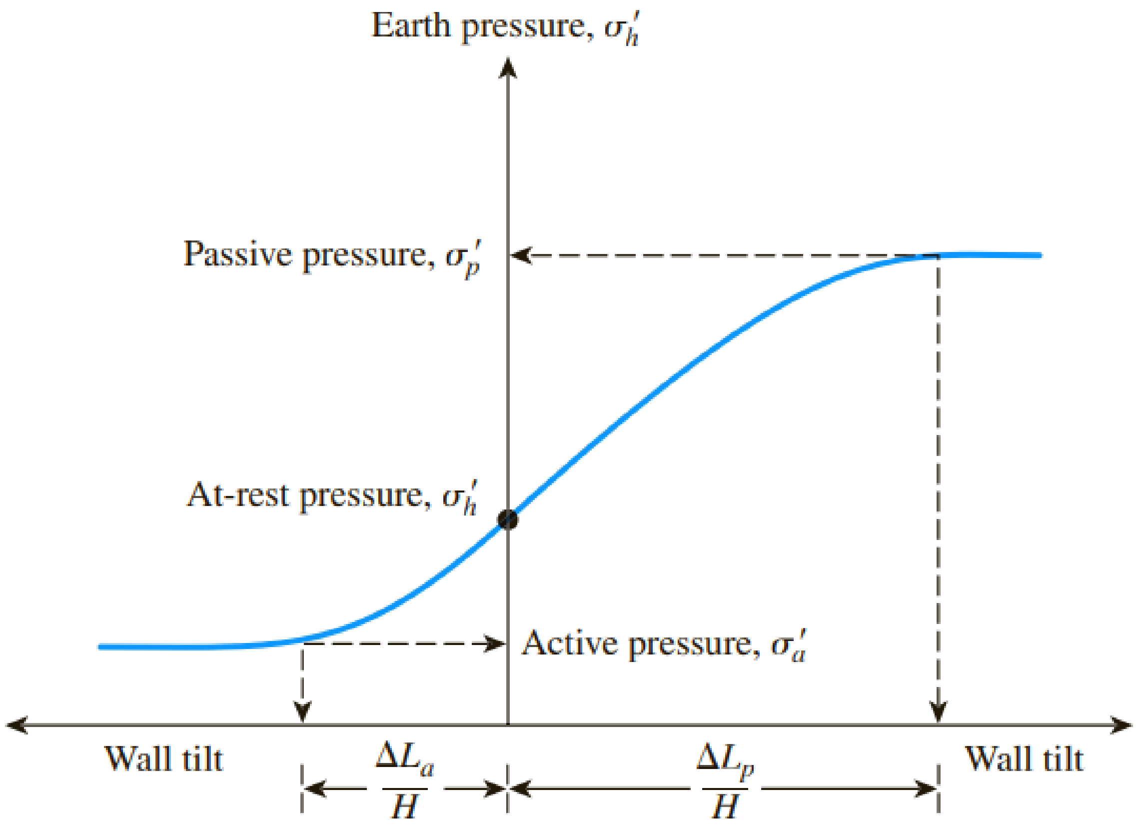
Therefore, $P_a = 0$,

$$K_a\gamma Z - 2c'\sqrt{K_a} = 0$$

$$Z_c = \frac{2c'\sqrt{K_a}}{K_a\gamma} = \frac{2c'}{\gamma\sqrt{K_a}}$$

The above depth is known as the depth of tensile crack (Z_c).

The critical depth of vertical cut is 2 × Z_c $= \frac{4c}{\gamma\sqrt{ka}} = H$



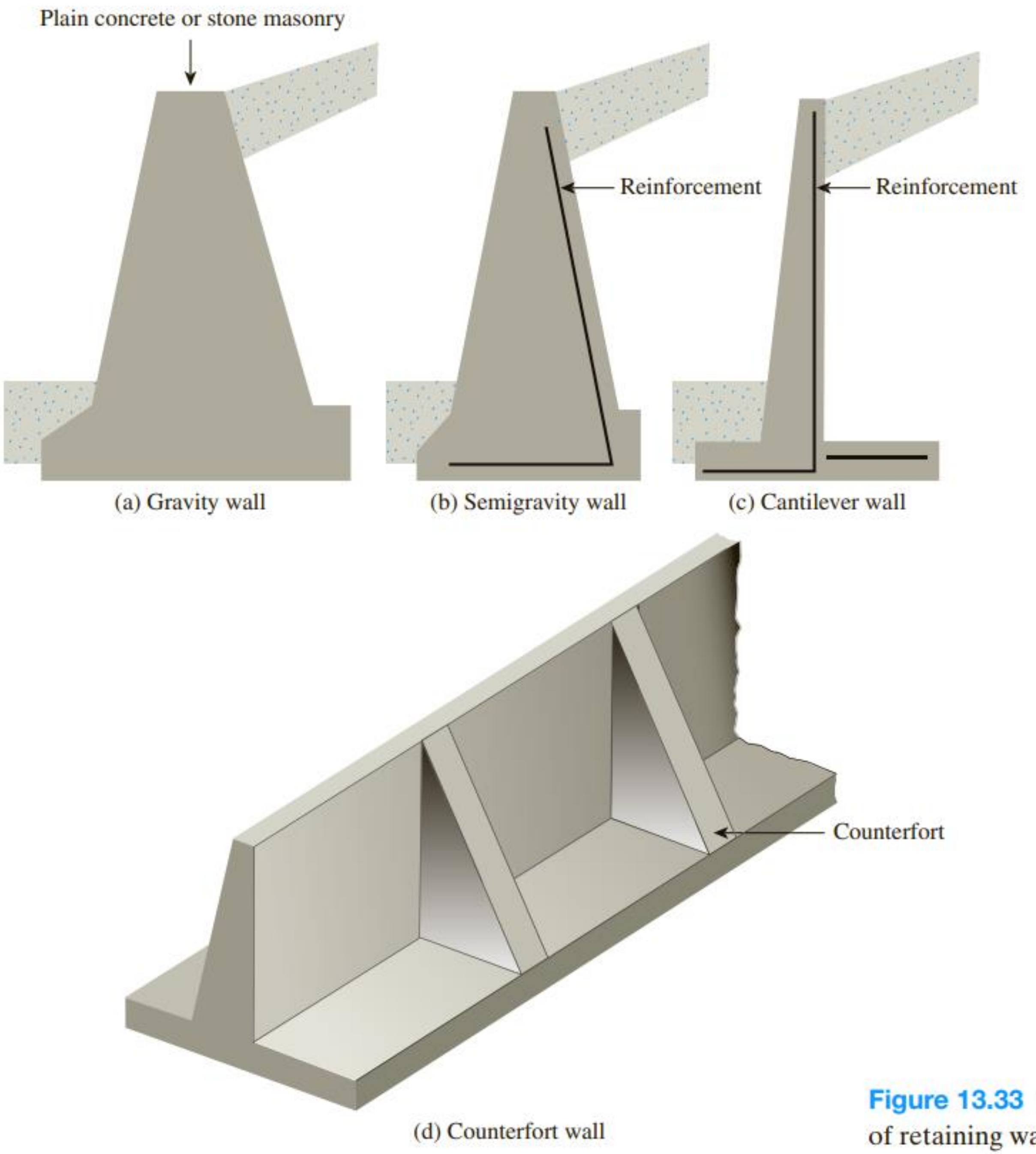


Figure 13.33 Types of retaining walls

Stability of analysis of retaining walls

i) Factor of safety against Sliding

$$FoS = \frac{\mu V}{H} (\geq 1.5\ for\ no\ sliding)$$

Where, μ is the coefficient of friction between base of wall and soil

V= Resisting force

H= Driving force

i) FOS against overturning

$$FoS = \frac{\sum M_R}{\sum M_O} (\geq 1.5\ for\ cohesionless\ \&\ \geq 2.0\ for\ cohesive\ soil)$$

i) FOS against bearing failure

$$FoS = \frac{q_{na}}{q_{max}} (\geq 3)$$

Where, q_{na} = allowable bearing pressure

q_{max}= maximum stress = $\frac{V}{b}\left[1 + \frac{6e}{b}\right]$, b is the base width and e is eccentricity.

iv) For no tension

$$Minimum\ pressure\ (q_{min}) = \frac{V}{b}\left[1 - \frac{6e}{b}\right]$$

So, when $e > b/6$, negative pressure (tension) is developed at the heel. Hence, for no tension to be developed eccentricity must be less than b/6.

66. The earth pressure at rest is defined as the lateral pressure exerted by soil:
    a. When it is at rest.
    b. When the retaining wall has no movement relative to the back fill
    c. When the retaining wall tends to move away from the backfill
    d. When the retaining wall moves into the soil
67. The active earth pressure of a soil is defined as the lateral pressure exerted by soil:
    a. When it is at rest.
    b. When the retaining wall has no movement relative to the back fill
    c. When the retaining wall tends to move away from the backfill
    d. When the retaining wall moves into the soil
68. The lateral earth pressure exerted by the soil when the retaining wall moves into the backfill is known as:
    a. Earth pressure at rest
    b. Active earth pressure
    c. Passive earth pressure
    d. Total earth pressure
69. The coefficient of active earth pressure for cohesionless granular soils is given by:
    a. $\frac{1-\sin\phi}{1+\sin\phi}$
    b. $\frac{1+\sin\phi}{1-\sin\phi}$
    c. $\frac{1-\cos\phi}{1+\cos\phi}$
    d. $\frac{1+\cos\phi}{1-\cos\phi}$
70. The coefficient of passive earth pressure for cohesionless granular soils is given by: (options same as above)

BCCAB

CADDB

71. Compared to dry backfill, submerged back fill will exert:
   a. Same earth pressure
   b. Less earth pressure
   c. More earth pressure
   d. Difficult to tell

72. Factor of safety against sliding shall be:
   a. At least 1.5 b. More than 3.0 c. Between 2.5 and 3.0 d. Equal to 1.0

73. The structure which derives its stability due to self-weight is:
   a. Sheet pile wall
   b. Bulk head
   c. Cantilever retaining wall
   d. Masonry retaining wall

74. Select the incorrect statement:
   a. Sheet piles and retaining walls can be installed for increasing the stability of soil slopes
   b. Translational failures may occur along slopes of layered materials
   c. For increasing the stability of a slope, densification can be done in case of cohesionless soils
   d. Proper drainage along a slope reduces the stability of a soil slope

75. Factor of safety of slopes is defined as:

   a. $F.S = \frac{Total\ Stress}{Effective\ Stress}$

   b. $F.S = \frac{Resisting\ Moment}{Overturning\ Moment}$

   c. $F.S = \frac{Overturning\ Moment}{Resisting\ Moment}$

   d. $F.S = \frac{Shear\ Stress}{Normal\ Stress}$

ADBB

76. A Retaining wall is 10 m high and the soil retained has angle of internal friction of 35 degrees and unit weight 19 kN/m^3. Using Rankine's theory, the total active thrust will be

a. 257 kN

b. 217 kN

c. 157 kN

d. 111 kN

77. A wall 6 m high has a smooth vertical back and retained sand as a backfill that is submerged. The sand has saturated unit weight of 20 kN/m^3 and friction angle 30 degrees. The total active earth pressure is

a. 90 kN/m

b. 60 kN/m

c. 120 kN/m

d. None of these

78. If poisons ratio of a soil is 0.4, its coefficient of earth pressure at rest is:

a. 0.5

b. 0.7

c. 0.3

d. 1.0

79. While making the vertical excavation in soft saturated clay, soil caved in at a depth of 4 m. If the unit weight of soil is 20000 N/m^3, what is the cohesion of the soil?

a. 10 kN/m^2 b. 20 kN/m^2 C. 40 kN/m^2 D. 26.67 kN/m^2

$\phi = 0$ for soft clay, γ = 20 kN/m^3, H = 4 m

$$k_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$

$$k_a = \frac{1 - \sin 0}{1 + \sin 0} = 1$$

$$H_c = \frac{4 \times c}{\gamma \times \sqrt{K_a}}$$

$$4 = \frac{4 \times c}{20 \times 1}$$

c = 20 kN/m^2

Given,

H = 6 m

γ_{sat} = 20 kN/m^3

γ_w = 9.81 kN/m^3

γ_{sub} = 20 - 9.81 = 10.19 kN/m^3

ϕ = 30°

∴ From (3)

$K_a = \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ} = \frac{1}{3}$

$p_a = K_a \gamma_{sub} H + \gamma_w H$

$\Rightarrow p_a = \frac{1}{3} \times 10.19 \times 6 + 9.81 \times 6 =$ **79.24 kN/m^2 (Active lateral earth pressure at bottom)**

∴ from (2)

$P_a = \frac{1}{2} \times 79.24 \times 6 = 237.72$ kN/m (Total active earth pressure)

Soil exploration

- **Test pits (or) Trenches:** In these methods, soil can be inspected in their natural condition on pit of **size $1.2\ m \times 1.2\ m$ [IS Code**]. Shallow **pits upto a depth of 3 m** can be made without providing any lateral support. For deeper pits, lateral support in the form of sheeting and bracing are provided. **For depths greater than 6 m, bore holes are more economical than test pits**.

- **Drifts and Shafts**: Drifts **are tunnels driven in horizontal direction** to find the nature of the soil strata. Drift should have the **minimum clear dimensions of 1.5 m width and 2.0 m height in hard rock. Shafts are large size vertical holes** driven into the ground to find the nature of the soil strata. Minimum diameter of such holes should be **2.4 m.**

Boring:

- **Auger Boring:** An auger is a device that is used for advancing a bore hole into the ground. Types are **hand augers [upto depth of 3-6m)** and **mechanical augers (upto depth 12 m).**

- **Auger and Shell Boring:** The sides of the bore hole cannot remain unsupported; the soil is prevented from falling with the help of casing (or) shell. Casings may be used for sandy soils (or) stiff clays.

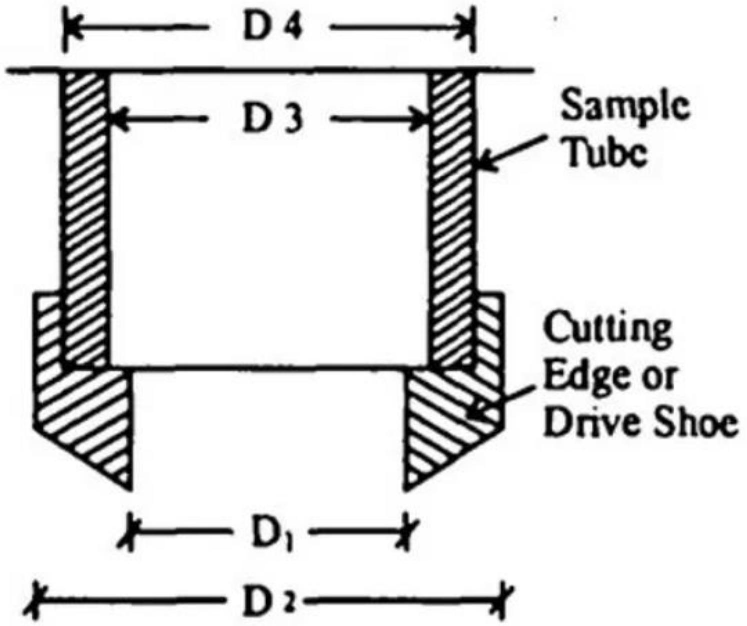
- **Wash Boring:** It is a simple method used for making holes in all types of soil **except** those which are mixed with **gravel and boulders**. This method used for exploration <u>**below the ground water table**</u>. This method is slow for stiff soils and coarse-grained soils.

- **Percussion Drilling:** This method is used for making **holes in rocks**, boulders and other hard strata. For this method, a **heavy drill bit is driven into the ground by repeated blows**.

- **Rotary Drilling:** In this method, the bore hole is advanced by a **rotating drill rod**. It is driven by a rotary drive mechanism by the application of downward pressure. This method is generally used to obtain the **rock core samples**.

Soil sampling and Samplers

- **Disturbed Samples:** Disturbed samples can be used to determine the index properties of the soil, such as grain size, plasticity characteristics, specific gravity.
- **Undisturbed Samples:** Undisturbed samples are used to determine the engineering properties of the soil, such as compressibility, shear strength, and permeability.



Inside Clearance (C_i)

$$C_i = \frac{D_3 - D_1}{D_1} \times 100$$

For undisturbed sample, inside clearance should be between 0.5 to 3 %

Outside Clearance (C_o)

$$C_i = \frac{D_2 - D_4}{D_4} \times 100$$

- For undisturbed sample, inside clearance should be between 0 to 2 %.

- **Area ratio** $(A_r) A_r = \frac{Maximum\ cross\ sectional\ area\ of\ the\ cutting\ edge}{Area\ of\ the\ soil\ sample} \times 100 = \frac{D_2^2 - D_1^2}{D_1^2} \times 100$

For obtaining good quality undisturbed samples, the area ratio should be 10% or less.

- **Recovery ratio (L_r)**

  $L_r = \frac{Length\ of\ the\ sample\ within\ the\ tube}{Depth\ of\ the\ penetration\ of\ sampling\ tube}$ L_r**=1,** represents good recovery where L_r**>1** represents swelling of the soil.

- Split spoon sampler which is used for SPT test gives disturbed samples. Shelby tube are used for undisturbed sampling.
- Cutting angle should be within 20^0

Planning of soil exploration includes:

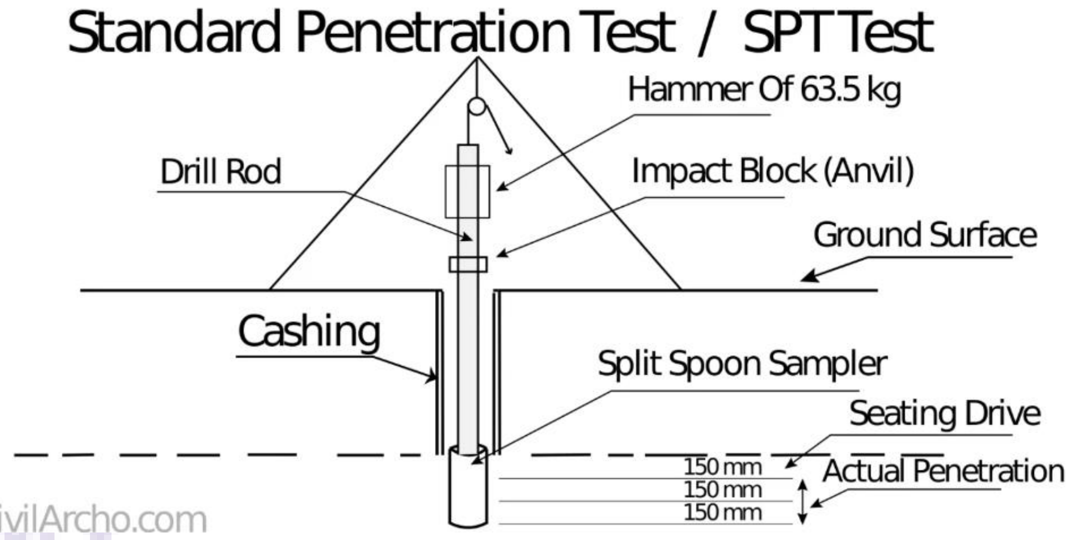
- The cost of the site investigation generally varies between **0.05 to 0.2% of the total cost** of the entire structure. In some unusual conditions, the cost may be even upto 1%.
- The depth of exploration required at a particular site depends upon the **degree of variation of the subsurface data** in the horizontal and vertical directions. The depth of exploration is governed by the depth of the **influence zone**.
- The depth upto which the stress increment due to superimposed loads **can produce significant settlement and shear stresses** is known as the **significant depth**.
- The depth of the exploration should be at least upto the significant depth. Significant depth is generally taken as the depth at which the **vertical stress is 20% of the load intensity**.
- According to this, the depth of exploration should be:
    - at about 1.5 times the width of square footing
    - 3.0 times the width of strip footing.
    - at least 1.5 times the width of the entire loaded area (raft).
    - at least 1.5 times the width of the pile group (below the tip of pile).
- In **case of multi-storeyed buildings**,
    - (Sowers and Sowers, 1970), $\boldsymbol{D = C(S^{0.7})}$ where D = depth of exploration (m), C = constant, which is equal to 3 for light steel buildings and narrow concrete buildings. It is equal to 6 for heavy steel buildings and wide concrete buildings, S = number of storeys.
- In case of road cuts, it is taken at least equal to the width of the cut.
- In case of road fills, the minimum depth of boring is **2 m below the ground surface** or equal to the height of the fill, whichever is greater.
- In case of gravity dams, the **minimum depth of boring is twice the height of the dam**.
- **Horizontal spacing:**
    - For small and less important buildings, even one bore hole or a trial pit in the centre may suffice. But for compact buildings, covering an area of about 0.4 hectares, there should be at least 5 bore holes, one at the center and four near the corners. For large, multi-storeyed buildings, the bore holes should be drilled at all the corners and also at important locations.

Standard Penetration Test (SPT):

The sampler is driven to the soil by drop hammer **63.5 kg** mass falling through **750 mm** and at a rate of **30 blows per minute**. The number of blows required to penetrate each 150 mm is counted for three penetrations. But the number of blows for first 150 mm is referred as **seating drive** and the number of **blows for last two 150 mm intervals** are recorded for standard penetration number (N). If the number of blows for 150mm **exceeds 50, it is taken as refusal** and the test is discontinued.

The obtained N value is further corrected for dilatancy and overburden to get corrected Standard penetration number (N_C)

- Used for cohesionless soil which can't be easily sampled.
- Used for determining the relative density and the angle of shearing resistance for cohesionless soil.
- Used for determining compressive strength of cohesive soil.



Overburden Pressure Correction

- The overburden correction in SPT is mainly required in the **cohesionless soil** or **granular soil**.

As we all know that **effective overburden pressure** or **confining pressure** increases when the depth increases.

$$N_1 = N_0\left(\frac{350}{70+\bar{\sigma}}\right)$$

The dilatancy correction or water table correction:

- is applied in the **fine sand** and **silt** when the water table is present. when the **water table** is **at** or **above** the **test level**, then the dilatancy or water table correction shall be applied.

$$N_2 = 15 + 1/2\,(N_1 - 15)$$