G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY

Accredited by NAAC with 'A' Grade of UGC, Approved by AICTE, New Delhi

Permanently Affiliated to JNTUA, Ananthapuramu

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Nandikotkur Road, Venkayapalli, Kurnool – 518452

Department of Civil Engineering

Bridge Course

On

Geotechnical Engineering-II

By

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Course Description:

This course covers a wide range of problems in Civil Engineering. It includes topics such as: foundations for different types of buildings and bridges, excavations, slopes and retaining walls. This course builds on the material introduced in Geotechnical Engineering 1 and develops concepts and models for analysis and design of engineering projects involving soils in a natural or compacted state.

Objectives/Learning Outcomes/Capability Development

This course contributes to the following Program Learning Outcomes

1. In-depth understanding of specialist bodies of knowledge within the engineering discipline.
2. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline
3. Application of established engineering methods to complex engineering problem solving.
4. Fluent application of engineering techniques, tools and resources.

On completion of this course you should be able to:

1. Analyze the role of a geotechnical engineer in civil engineering projects
2. Describe laboratory consolidation tests and interpret the test data for obtaining the consolidation settlement of fine grained soils.
3. Determine the shear strength of soils under drained and undrained conditions using laboratory shear tests
4. Discriminate types of retaining walls and calculate lateral earth pressures using Rankine’s and Coulomb’s methods.
5. Estimate the stability of slopes considering various drivers (such as seepage, gravity, etc) which provoke slope failure
6. Apply established engineering practices to design foundations considering strength, long and short-term settlement, deformation and safety.

Pre-requisite

The required prior study for this course is Geotechnical Engineering-I.

Unit-1: Soil Exploration

Definition of Soil:

Soil is the relatively loose mass of mineral and organic materials and sediments found above the bedrock, which can be relatively easily broken down into its constituent mineral or organic particles.

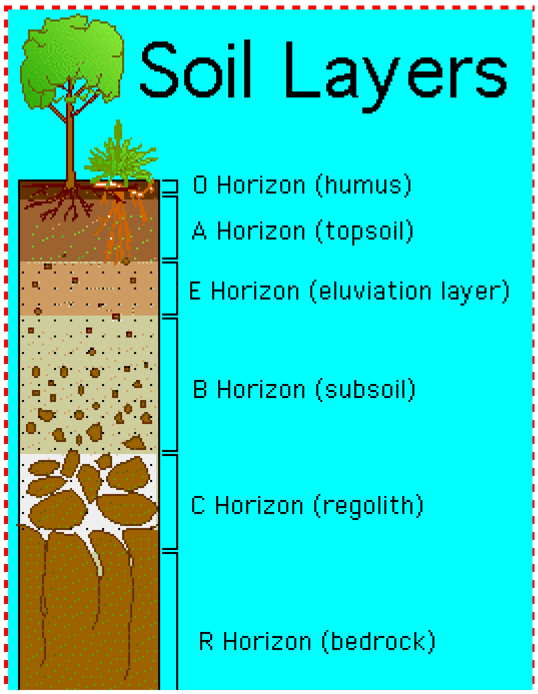


Fig.1 Soil Layers

Soil consists of layers of minerals constituents of variable thickness, which differ from the parent materials in the morphological, physical, chemical and mineralogical characteristics, as shown in Fig. 1. It is thus a natural product of weathering of rocks and decomposition of organic matter. It is an accumulation of individual particles that are bonded together by mechanical or attractive means, the strength of the bonds being a small fraction of the mineral particles. The particles may range from colloidal size to small boulders. Soil can also be referred to as regolith, or loose rock material.

O Horizon - The top, organic layer of soil, made up mostly of leaf litter and humus (decomposed organic matter).

A Horizon - The layer called topsoil; it is found below the O horizon and above the E horizon. Seeds germinate and plant roots grow in this dark-colored layer. It is made up of humus (decomposed organic matter) mixed with mineral particles.

E Horizon - This eluviations (leaching) layer is light in color; this layer is beneath the A Horizon and above the B Horizon. It is made up mostly of sand and silt, having lost most of its minerals and clay as water drips through the soil (in the process of eluviations).

B Horizon - Also called the subsoil - this layer is beneath the E Horizon and above the C Horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives from layers above it when mineralized water drips from the soil above.

C Horizon - Also called regolith: the layer beneath the B Horizon and above the R Horizon. It consists of slightly broken-up bedrock. Plant roots do not penetrate into this layer; very little organic material is found in this layer.

R Horizon - The unweathered rock (bedrock) layer that is beneath all the other layers

Soil Formation:

Soil formation is the process by which soil is created. The formation of soil happens over a very long period of time. Soil is formed from the weathering of rocks and minerals.

Weathering:

Physical weathering

It involves the breakdown of rocks and soils through direct contact with atmospheric conditions, such as heat, water, ice and pressure, without any change in chemical condition. The soil formed due to physical weathering will be cohesion less (sand and gravel).

In summary, the physical agencies causing mechanical weathering of rocks are;

(i) Daily and seasonal temperature changes.

(ii) Flowing water, glaciers and wind, which produce impact and abrasive action on rock.

(iii) Splitting action of ice.

(iv) Growth of roots of plants in rock fissures and to a minor degree burrowing activities of small animals like earthworms.

Chemical weathering

Chemical weathering changes the composition of rocks by decomposing the parent minerals, transforming them into new compounds such as clay silica particles, carbonates and iron oxides.

The decomposition of rock is the result of the following reactions;

(i) Oxidation

(ii) Carbonation

(iii) Hydration

(iv) Leaching

Unit-2: Earth Slope Stability

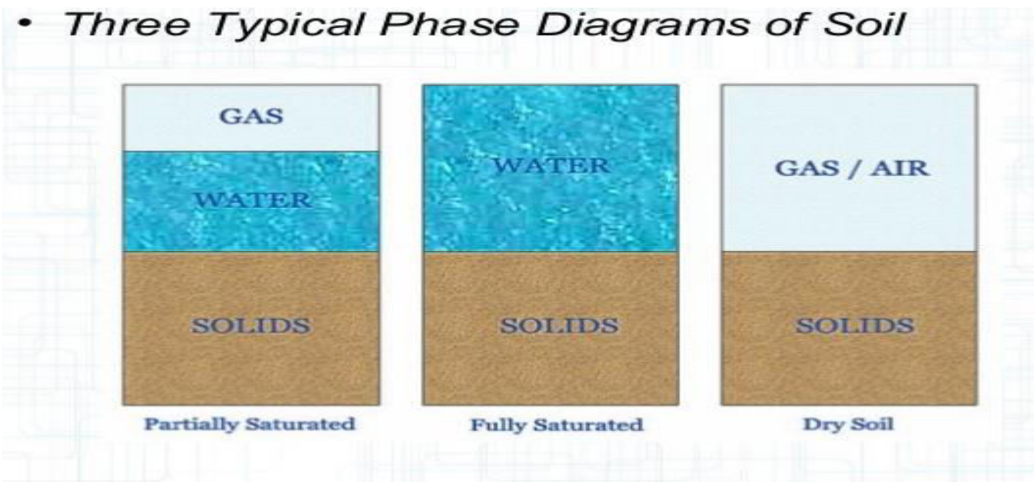
SOME USEFUL TERMS AND ASSOCIATED SYMBOLS

SYMBOL	DEFINITION	DIMENSION
e	Void Ratio	-
LL or WL	Liquid Limit	-
Ms	Mass of Solids	M
Mw	Mass of Water	M
n	Porosity	-
PI or IP	Plasticity Index	-
PL or WP	Plastic Limit	-
Sr	Degree Of Saturation	-
SL or WS	Shrinkage Limit	-
Va	Volume of Air	L3
Vs	Volume of Solids	L3
Vv	Volume of Voids	L3
W	Water Content	-
ρd	Dry Density	M/L3

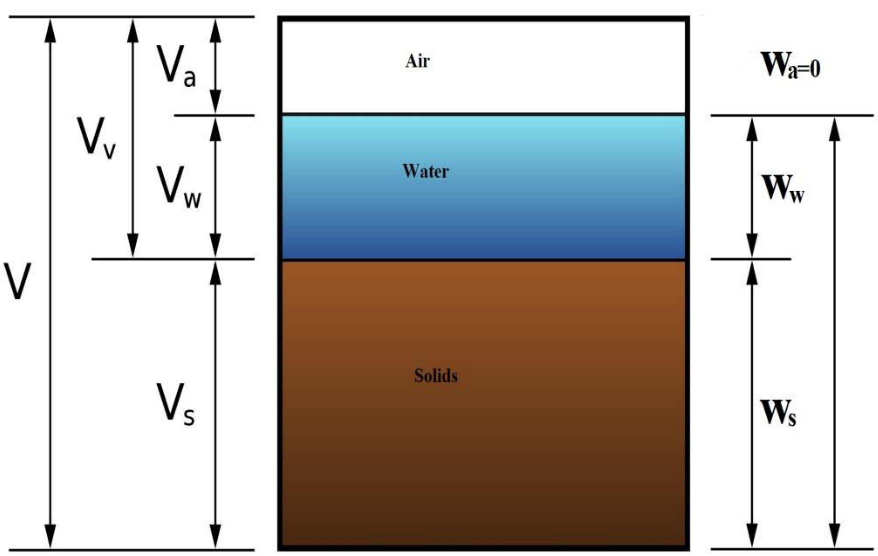
ρs	Density of Solids	M L3
ρsat	Saturated Density	M/L3
ρw	Density of Water	M/L3
ρ	Bulk Density	M/L3

Phase Relationship:

Phase diagram:



Three Typical Phase Diagrams of Soil



Phase diagram of soil mass

Void ratio (e):

This is the ratio of the volume of voids to the volume of the solids;

$$e = \frac{Vv}{Vs}$$

Moisture content (Water content) (w):

Is the ratio of mass of water to mass of solids;

$$w = \frac{Mw}{Ms}$$

Porosity (n):

This is the ratio of the volume of voids to the total volume;

$$n = \frac{Vv}{V} = \frac{Vv}{Vv+Vs} = \frac{e}{1+e}$$

Relative Density (Specific Gravity) (Gs):

The relative density (specific gravity) of soil particles is the ratio of the density of solids to the density of water. It is a measure of heaviness of material.

$$Gs = \frac{\rho s}{\rho w}$$

Degree of Saturation (Sr):

It is the ratio of the volume of water to the volume of voids usually expressed as a percentage.

$$Sr = \frac{Vw}{Vv}$$

Density of Solids (ρs):

It is the ratio of the mass of the solids to the volume of the solids.

$$\rho s = \frac{Ms}{Vs}$$

Bulk Density (ρ):

It is the ratio of the total mass of soil to the total volume of the soil.

$$\rho = \frac{M}{V}$$

Saturated Density (ρsat):

The saturated density ρsat is the bulk density of a soil mass when fully saturated.

For saturated soil, Sr = 1,

$$\rho sat = \frac{\rho w(Gs + e_{\mathrm{r}})}{1 + e}$$

Dry Density (ρd):

It is the mass of soil solids per unit of total volume of a dry soil mass. For completely dry soil, Sr = 0,

$$\rho sat = \frac{\rho w. Gs}{1 + e}$$

Dry Unit Weight (γdry):

It is defined as the weight of solids per unit weight of the solids. This is the same as the bulk unit of a dry soil with force units.

$$\gamma \mathrm{d} = \frac{\mathrm{Ws}}{\mathrm{V}}$$

Submerged Unit Weight (γsub):

Where the in situ soil is saturated with water, the particles are subjected to an all round thrust. The submerged unit weight is given by difference in the unit weight of a saturated weight of soil and the unit weight of water.

Slope stability is the potential of soil covered slopes to withstand and undergo movement. The field of slope stability encompasses static and dynamic stability of slopes of earth and rock-fill dams, slopes of other types of embankments, excavated slopes, and natural slopes in soil and soft rock.

Unit-3: Earth Pressure Theories

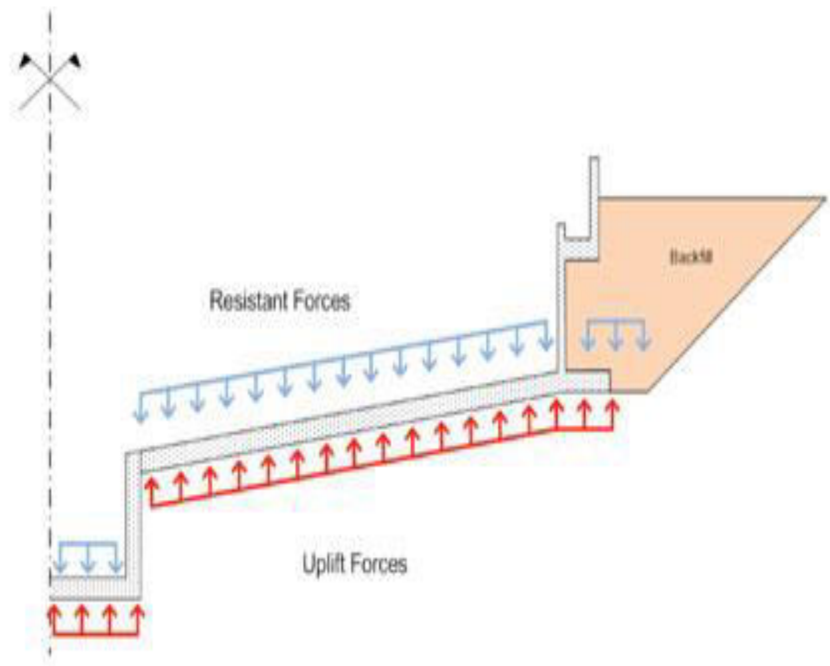
Earth pressure is the lateral pressure exerted by the soil on a shoring system. It is dependent on the soil structure and the interaction or movement with the retaining system. Due to many variables, shoring problems can be highly indeterminate. Therefore, it is essential that good engineering judgment be used.

Pore Water Pressure:

Pour water pressure (sometimes abbreviated to **pwp**) refers to the pressure of groundwater held within a soil or rock, in gaps between particles (pores).

Uplift Pressure:

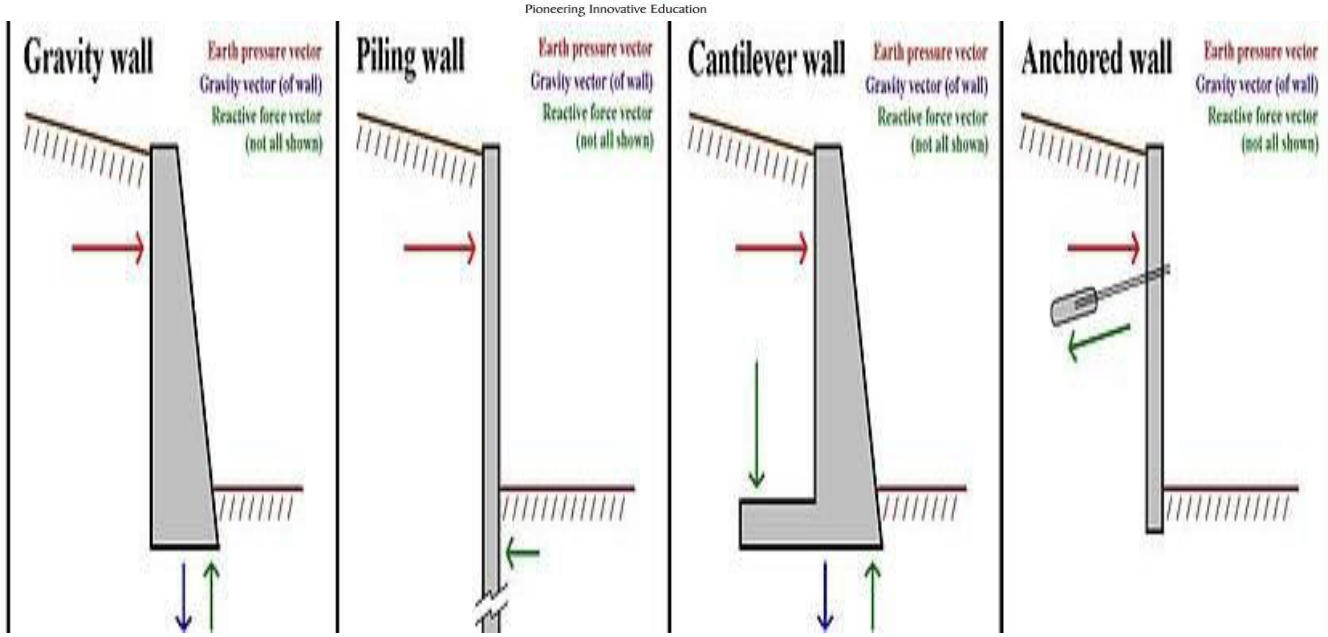
Uplift occurs when pore-water pressure under a structure or a low permeability confining layer becomes larger than the mean overburden pressure.



Uplift Pressure

Retaining Wall:

A retaining wall is a structure designed and constructed to resist the lateral pressure of soil, when there is a desired change in ground elevation that exceeds the angle of repose of the soil. A basementwall is thus one kind of retaining wall.



Principal planes and principal stresses:

The study of the stress distribution around a point in a continuous demonstrates that there are three orthogonal planes, called principal planes, where the stresses are normal and called the main stresses. They are designated by:

- $\sigma 1$ for the major principal stress,
- $\sigma 3$ for the minor principal stress,
- $\sigma 2$ for the intermediary principal stress.

The applications, in soil mechanics, can be reduced to:

- Plane problems (the intermediary principal stress $\sigma 2$ is perpendicular to the plane containing $\sigma 1$ and $\sigma 3$)
- Asymmetric (3D revolution) problems ($\sigma 2 = \sigma 3$ and a meridian contains $\sigma 1$ and $\sigma 3$).

It follows that the study of the distribution stresses in the $\sigma 1$-$\sigma 3$ plays an important role in soil mechanics and will be discussed below.

Mohr Circle:

The Mohr circle construction enables the stresses acting in different directions at a point on a plane to be determined, provided that the normal and shear stresses are known on any two orthogonal planes. The Mohr circle construction is very useful in Soil Mechanics as many practical situations can be approximated as plane strain problems.

The sign convention is different to that used in Structural Analysis because for soils it is conventional to take the compressive stresses as positive.

Sign convention:

- Compressive normal stresses are positive
- Anti-clockwise1 shear stresses are positive (from inside soil element)
- Angles measured anti-clockwise positive

Unit-4: Shallow Foundations

Types of foundation:

- Shallow foundations
    1. Pad foundations
    2. Strip foundations
    3. Raft foundations
- Deep Foundations
    1. Well Foundations
    2. Deep Foundations

Shallow foundations:

Shallow foundations are those founded near to the finished ground surface; generally where the founding depth (Df) is less than the width of the footing and less than 3m. These are not strict rules, but merely guidelines: basically, if surface loading or other surface conditions will affect the bearing capacity of a foundation it is 'shallow'. Shallow foundations (sometimes called 'spread footings') include pads ('isolated footings'), strip footings and rafts.

Shallows foundations are used when surface soils are sufficiently strong and stiff to support the imposed loads; they are generally unsuitable in weak or highly compressible soils, such as poorly-compacted fill, peat, recent lacustrine and alluvial deposits, etc.

Pad foundations:

Pad foundations are used to support an individual point load such as that due to a structural column. They may be circular, square or rectangular. They usually consist of a block or slab of uniform thickness, but they may be stepped or hunched if they are required to spread the load from a heavy column. Pad foundations are usually shallow, but deep pad foundations can also be used.

Strip foundations:

Strip foundations are used to support a line of loads, either due to a load-bearing wall, or if a line of columns need supporting where column positions are so close that individual pad foundations would be inappropriate.

Raft foundations:

Raft foundations are used to spread the load from a structure over a large area, normally the entire area of the structure. They are used when column loads or other structural loads are close together and individual pad foundations would interact.

A raft foundation normally consists of a concrete slab which extends over the entire loaded area. It may be stiffened by ribs or beams incorporated into the foundation.

Raft foundations have the advantage of reducing differential settlements as the concrete slab resists differential movements between loading positions. They are often needed on soft or loose soils with low bearing capacity as they can spread the loads over a larger area.

Deep foundations:

Deep foundations are those founding too deeply below the finished ground surface for their base bearing capacity to be affected by surface conditions, this is usually at depths >3 m below finished ground level. They include piles, piers and caissons or compensated foundations using deep basements and also deep pad or strip foundations. Deep foundations can be used to transfer the loading to deeper, more competent strata at depth if unsuitable soils are present near the surface.

Piles:

Piles are relatively long, slender members that transmit foundation loads through soil strata of low bearing capacity to deeper soil or rock strata having a high bearing capacity. They are used when for economic, constructional or soil condition considerations it is desirable to transmit loads to strata beyond the practical reach of shallow foundations. In addition to supporting structures, piles are also used to anchor structures against uplift forces and to assist structures in resisting lateral and overturning forces.

Piers:

Piers are foundations for carrying a heavy structural load which is constructed insitu in a deep excavation.

Caissons:

Caissons are a form of deep foundation which are constructed above ground level, then sunk to the required level by excavating or dredging material from within the caisson.

Compensated foundations:

Compensated foundations are deep foundations in which the relief of stress due to excavation is approximately balanced by the applied stress due to the foundation. The net stress applied is therefore very small. A compensated foundation normally comprises a deep basement.

Unit-5: Pile Foundations

Piles:

Piles are relatively long, slender members that transmit foundation loads through soil strata of low bearing capacity to deeper soil or rock strata having a high bearing capacity. They are used when for economic, constructional or soil condition considerations it is desirable to transmit loads to strata beyond the practical reach of shallow foundations. In addition to supporting structures, piles are also used to anchor structures against uplift forces and to assist structures in resisting lateral and overturning forces.

End bearing piles:

End bearing piles are those which terminate in hard, relatively impenetrable material such as rock or very dense sand and gravel. They derive most of their carrying capacity from the resistance of the stratum at the toe of the pile.

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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. The resisting force can be increased in the case of bored piles by under-reaming. In the design of tension piles the effect of radial contraction of the pile must be taken into account as this can cause about a 10% - 20% reduction in shaft resistance.

Laterally Loaded piles:

Almost all piled foundations are subjected to at least some degree of horizontal loading. The magnitude of the loads in relation to the applied vertical axial loading will generally be small and no additional design calculations will normally be necessary. However, in the case of wharves and jetties carrying the impact forces of berthing ships, piled foundations to bridge piers, trestles to overhead cranes, tall chimneys and retaining walls, the horizontal component is relatively large and may prove critical in design. Traditionally piles have been installed at an angle to the vertical in such cases, providing sufficient horizontal resistance by virtue of the component of axial capacity of the pile which acts horizontally. However the capacity of a vertical pile to resist loads applied normally to the axis, although significantly smaller than the axial capacity of that pile, may be sufficient to avoid the need for such 'raking' or 'battered' piles which are more expensive to install. When designing piles to take lateral forces it is therefore important to take this into account.

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.