L - 01

LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **I - SOIL CLASSIFICATION AND COMPACTION**

Date of Lecture:

Topic of Lecture: Nature of Soil

Introduction:

- Soils are one of Earth's essential natural resources.
- Soil is a mixture of organic matter, minerals, gases, liquids, and organisms.
- Earth's body of soil, called the pedosphere.
- Soil is produced by the weathering of solid rocks.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Weathering
- Denudation of rocks
- Transportation
- Deposition of rocks

Detailed content of the Lecture:

Soil:

Soil is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. Earth's body of soil, called the pedosphere.

Soil has four important functions:

- as a medium for plant growth
- as a means of water storage, supply and purification
- as a modifier of Earth's atmosphere
- as a habitat for organisms

Soil consists of a solid phase of minerals and organic matter (the soil matrix), as well as a porous phase that holds gases (the soil atmosphere) and water (the soil solution). The primary mechanism of soil creation is the weathering of rock. All rock types (igneous rock, metamorphic rock and sedimentary rock) may be broken down into small particles to create soil. It continually undergoes development by way of numerous physical, chemical and biological processes, which include weathering with associated erosion.

The weathering of parent material takes the form of physical weathering (disintegration), chemical weathering (decomposition) and chemical transformation. Given its complexity and strong internal connectedness, soil ecologists regard soil as an ecosystem.

Soil includes matter in all three states:

- Solid
- Liquid
- Gas

Because the matter in these states is constantly changing and interacting through chemical and physical processes, soil is a very dynamic layer.

Soil Mechanics:

Soil mechanics is a branch of soil physics and applied mechanics that describes the behavior of soils. Soil mechanics is used to analyze the deformations of and flow of fluids within natural and man-made structures that are supported on or made of soil, or structures that are buried in soils. Principles of soil mechanics are also used in related disciplines such as engineering geology, geophysical engineering, coastal engineering, agricultural engineering and hydrology and soil physics.

Foundation Engineering:

Foundation engineering is the application of soil mechanics and rock mechanics (Geotechnical engineering) in the design of foundation elements of structures.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mB3O6hQAoZA

https://www.youtube.com/watch?v=ZuofAC9rq58

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 01 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 05 to 13)

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L - 02

LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **I - SOIL CLASSIFICATION AND COMPACTION**

Date of Lecture:

Topic of Lecture: Phase relationships

Introduction:

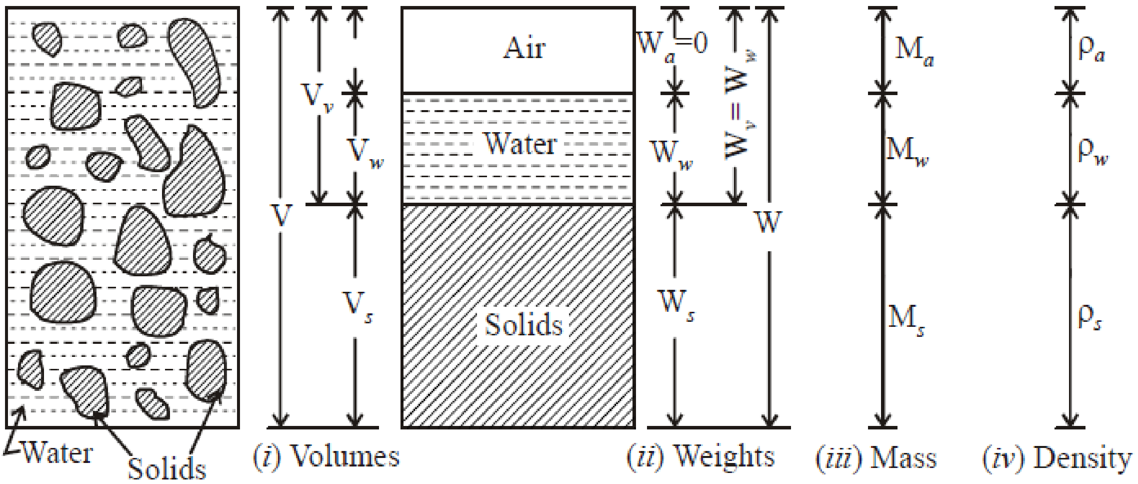
- Soil mass is generally referred to as three-phase system because it consists of solid particles, liquid, and gas.
- For many civil engineering purposes, the liquid may be considered to be water and the gas as air with the exception geo environmental, and oil and gas applications.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Soil
- Air
- Water
- Solids

Detailed content of the Lecture:

In a mass of soil, there are three physical components solid, water and air. A phase relationship diagram is normally used to represent the relationship as shown in Fig



(a) Element of Natural soil

(b) Element separated into three phases

Specific gravity:

It is the ratio of the unit weight of soil solids to that of water

Inter-Relationships in Terms of Densities

(i) $\rho_d = \dfrac{G \cdot \rho_w}{1+e}$

(ii) $\rho_d = (1-n)G \cdot \rho_w$

(iii) $\rho_{sat} = G \cdot \rho_w (1-n) + \rho_w \cdot n$

(iv) $\rho' = \dfrac{(G-1)\rho_w}{1+e}$

(v) $\rho' = \rho_d - (1-n)\rho_w$

(vi) $\rho_d = \dfrac{G\rho_w}{1+\dfrac{wG}{s}}$

(vii) $e = \dfrac{G \cdot \rho_w}{\rho_d} - 1$

(viii) $\rho_{sat} = \dfrac{(G+e)\rho_w}{1+e}$

(ix) $\rho = \dfrac{(G+es)\rho_w}{1+e}$

(x) $\rho = \rho_d + s(\rho_{sat} - \rho_d)$

(xi) $\rho_d = \dfrac{\rho}{1+w}$

(xii) $\rho_d = \dfrac{(1-na)G \cdot \rho_w}{1+wG}$

Relationships:

Soil mass is generally a three-phase system. It consists of:

(i) Solid particles,

(ii) Liquid,

(iii) Gas.

For all practical purposes, the liquid may be considered to be water (although in some cases, the water may contain some dissolved salts) and the gas as air.

The phase system may be expressed in SI units either in terms of mass-volume or weight-volume relationships.

The interrelationships of the different phases are important since they help to define the condition or the physical make-up of the soil.

Water content:

The water content w, also called the moisture content, is defined as the ratio of weight of water

W_w to the weight of solids (Ws or W_d) in a given mass of soil.

Inter-relationship between density and unit weight: In order to convert the density (g/cm^3) into unit weight (kN/m^3) multiply the former by 9.81.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=DtKheQcL2BU

https://www.youtube.com/watch?v=wRgMOcwOGIY

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 09 to 10)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 27 to 56)

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L - 03

LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **I - SOIL CLASSIFICATION AND COMPACTION**

Date of Lecture:

Topic of Lecture: Soil classification for engineering purposes

Introduction:

- To arrange various types of soils into groups according to their engineering or agricultural properties and various other characteristics

Prerequisite knowledge for Complete understanding and learning of Topic:

- Types of soil.
- Characteristics of soils
- Phase Relationship
- Specific Gravity

Detailed content of the Lecture:

Classifications

For general engineering purposes soils may be classified by the following systems:

1. Particle Size Classification,
2. Textural Classification,
3. Highway Research Board (HRB) Classification,
4. Indian Standard (IS) Classification System,
5. Unified Soil (US) Classification.

1. Particle Size Classification

There are various grain size classification in use, but the more commonly used systems are:

(i) U.S.Bureau of soil and public road administration (PRA) system of united states

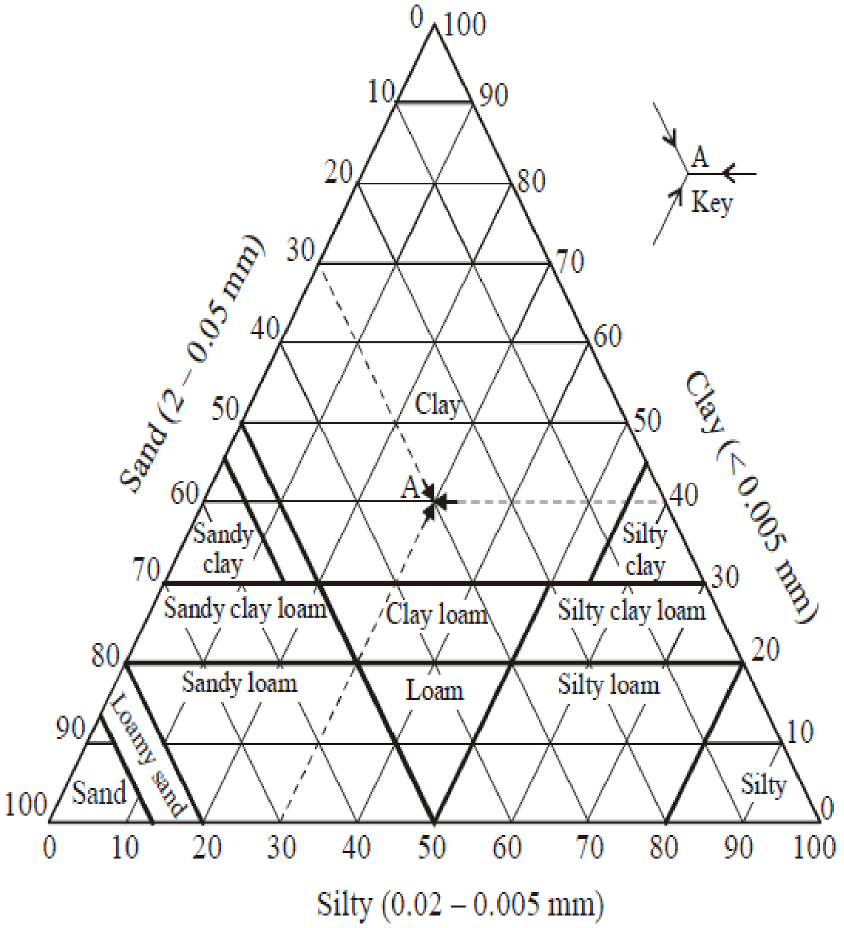
(ii) International soil classification, proposed at the international soil congress at Washington, D.C in 1927

(iii) The M.I.T classification proposed by Prof Gilboy of Mass Achusetts Institute of Technology as a simplification of the Bureau of soil classification

(iv) Indian Standard Classification (IS : 1948–1970) based on the M.I.T system

2. Textural Classification

Soil classification of composite solids exclusively based on the particle size distribution is known as textural classification



Textural classification chart (Adapted from U.S. Public Roads

3. Highway Research Board (HBR) Classification

This system is mostly used for pavement construction soils are divided into 7 primary groups, designated as A-1, A-2, …. A-7

4. Bureau of Indian Standard (BIS) Classification System (IS : 1498 – 1970)

This Indian standard was published 1959 to provided a common basis for soil classification. This Indian standard (First Revision) was adopted by the Indian Standard Institution on 19 December 1970, after the draft finalized by the soil engineering sectional committee had been approved by the civil engineering division council.

5. Bureau of Indian Standard (BIS) Classification System (IS : 1498 – 1970)

This Indian standard was published 1959 to provided a common basis for soil classification.

This Indian standard (First Revision) was adopted by the Indian Standard Institution on 19 December 1970, after the draft finalized by the soil engineering sectional committee had been approved by the civil engineering division council.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=5k_xT5Ebm7Q https://www.youtube.com/watch?v=i9Q3hjFaAPI
Important Books / Journals for further learning including the page nos.: 1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 111 to 132) 2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 59 to 106)

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L - 04

LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEO TECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **I - SOIL CLASSIFICATION AND COMPACTION**

Date of Lecture:

Topic of Lecture: Index properties of soils

Introduction:

- ✓ The water content w, also called the moisture content, is defined as the ratio of weight of water to the weight of solids in a given mass of soil.
- ✓ The density of soil is defined as the mass of the soil per unit volume.
- ✓ The specific gravity of soil is defined as the ratio of the unit weight of soil solids to that of water.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Water Content
- ✓ Specific gravity
- ✓ Density
- ✓ Soil Phase

Detailed content of the Lecture:

The properties of soil such as;

(i) Water content,

(ii) Specific gravity,

(iii) Particle size distribution,

(iv) Consistency limits,

(v) In-situ density and density index (Field density).

Are known as "Index properties"

1.Water Content

The water content of a soil sample can be determined by the following methods:-

(i) Oven Drying Method,

(ii) Sand Bath Method,

(iii) Alcohol Method,

(iv) Calcium Carbide Method,

(v) Pycnometer Method,

(vi) Radiation Method,

(vii) Torsion Balance Method.

2.Specific Gravity

The specific gravity of soil solids is determined by

i) 50 ml density bottle method,

ii) 500 ml flask method,

iii) Pycnometer method.

The flask or pycnometer method is used only for coarse grained soils. The density bottle method is the standard method used in the laboratory because it is the most accurate method and suitable for all types of soils.

Particle Size Distribution

The particle size distribution (or) particle size analysis meant the separation of a soil into it's different size fraction. It is also known as mechanical analysis.

The mechanical analysis is done by two stages;

(i) Sieve analysis

(ii) Sedimentation analysis

Consistency of Soils

In 1911, the Swedish agriculturist Atterberg divided the entire range from liquid to solid state into following four stages.

(i) The liquid state

(ii) The plastic state

(iii) The semi-solid state

(iv) The solid state

Field Density Method: (Insitu Density, Voids Ratio, and Density Index)

The field density of a natural soil deposit or compacted soil can be determined by the following methods:

1. Sand Replacement Method,

2. Core Cutter Method,

3. Water Displacement Method,

4. Rubber Balloon Method,

5. Submerged Mass Density Method.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=tqJw4VbGSR4

https://www.youtube.com/watch?v=G8hYn8YtAbc

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 37 to 109)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 59 to 106)

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L - 05

LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : **GEO TECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **I - SOIL CLASSIFICATION AND COMPACTION**

Date of Lecture:

Topic of Lecture: IS -Classification system

Introduction:

- This Indian standard was published 1959 to provided a common basis for soil classification.
- This Indian standard (First Revision) was adopted by the Indian Standard Institution on 19 December 1970, after the draft finalized by the soil engineering sectional committee had been approved by the civil engineering division council

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Classification System of soil
- ✓ Types of soils
- ✓ Index Properties of Soil
- ✓ Soil Phase Relationship

Detailed content of the Lecture:

Divisions:

Soils shall be broadly divided into three divisions as:

(i) Coarse-grained soils,

(ii) Fine-grained soils,

(iii) Highly organic soils and other miscellaneous soil materials.

(i) Coarse-grained soils:

In these soils, more than half the total material by weight larger than 75 micron IS sieve size

(ii) Fine-grained soils:

In these soils, more than half of the material by weight is smaller than 75 micron IS sieve size.

(iii) Highly organic soils and other miscellaneous soil materials:

These soils contain large percentages of fibrous organic matter, such as peat, and particles of decomposed vegetation. In addition, certain soils containing shells, concretions, cinders, and other non-soil materials in sufficient quantities are also grouped in this division.

Subdivisions:

The first two divisions shall be further divided as:

(i) Coarse-grained soils

(ii) Fine-grained soils

(i) Coarse-grained soils:

The coarse-grained soils shall be divided into two subdivisions namely:

(a) Gravels – In these soils, more than half the coarse fraction (+ 75 micro) is larger than 4.75 mm IS Sieve size. This subdivision includes gravels and gravelly soils.

(b) Sands – In these soils, more than half the coarse fraction (+ 75 micron) is smaller than 4.75 mm IS sieve size. This subdivision includes sands and sandy soils.

(ii) Fine-grained soils:

(a) Silts and clays of low compressibility – having a liquid limit less than 35 (represented by symbol L),

(b) Silts and clays of medium compressibility – having a liquid limit greater than 35 and less than 50 (represented by symbol I), and

(c) Silts and clays of high compressibility – having a liquid limit greater than 50 (represented by symbol H).

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=C7Z2zqkttTQ

https://www.youtube.com/watch?v=AfwIYX4vXmE

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 120 to 131)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 113 to 131)

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L - 06

LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : GEO TECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I - SOIL CLASSIFICATION AND COMPACTION

Date of Lecture:

Topic of Lecture: Soil compaction

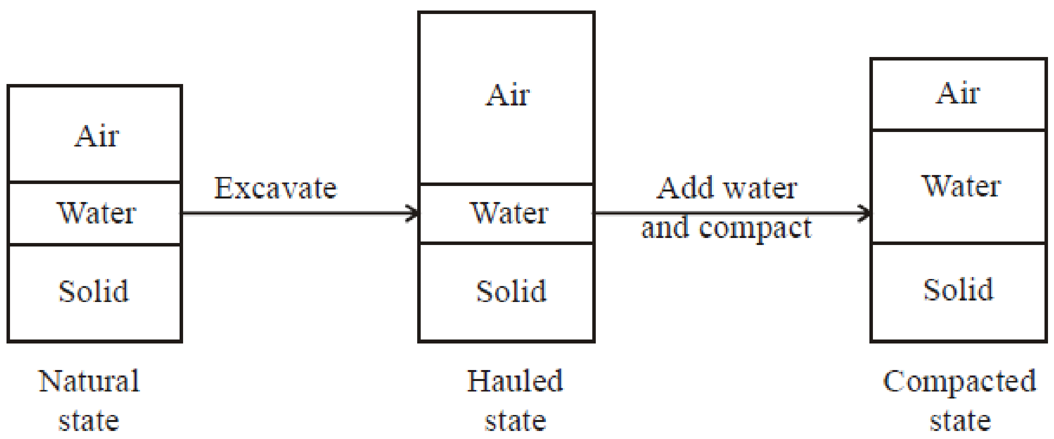
Introduction:

- ✓ Compaction is a process by which the soil particles are artificially arranged and packed together into a closer state of contact by mechanical means in order to decrease the porosity (or voids ratio) of the soil and thus increase it's dry density compaction is achieved by reduction in the volume of air, solid and water are virtually in compressible.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Density
- ✓ Water Content
- ✓ Liquid Limit
- ✓ Plastic Limit

Detailed content of the Lecture:



Three phase diagrams showing the changes in soil when it's move from natural location to compacted fill

Objectives of Compaction

Compaction can be applied to improve the properties of an existing soil or in the process of placing fill. The main objectives are to:

(i) Increase shear strength and therefore bearing capacity.

(ii) Increase stiffness and therefore reduced future settlement.

(iii) Decrease voids ratio, compressibility and so permeability, thus reducing potential frost heave.

(iv) Change in swelling and shrinkage characteristics

Difference between compaction and consolidation

S.No	Compaction	Consolidation
1.	Compaction is the process by which soil particles are packed more closely together by mechanical means	Consolidation is the process by which soil particles are packed more closely together under the application of static loading
2.	It is achieved through reduction of air voids	It is achieved through gradual drainage of water from soil pores
3.	It is a rapid process	It is a gradual process. In some soils it takes many years
4.	It is an artificial process	It is natural process
5.	It is mainly used for sandy soil	It is mainly used for clayey soil
6.	Proper compaction of soil is achieved at optimum moisture content	Consolidation is strictly applicable for saturated or nearly saturated clays or soils with low permeability

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=C87nXs_6z-I

https://www.youtube.com/watch?v=qq09VuGYE1E

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 407 to 423)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 113 to 131)

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L - 07

LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : GEO TECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I - SOIL CLASSIFICATION AND COMPACTION

Date of Lecture:

Topic of Lecture: Comparison of Laboratory and Field Compaction Methods

Introduction:

- ✓ Some of the usual compaction tests used in the laboratory to determine water –density relationships of soils

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Water Content
- ✓ Density
- ✓ Liquid Limit
- ✓ Plastic Limit

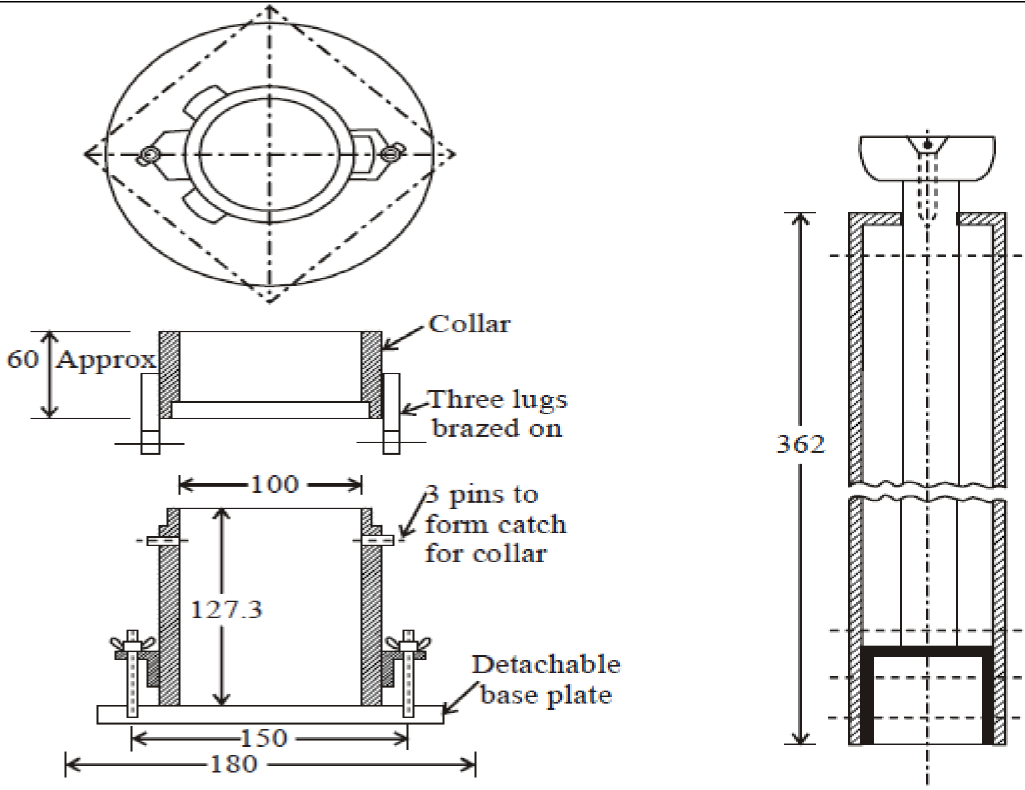
Detailed content of the Lecture:

- ✓ Some of the usual compaction tests used in the laboratory to determine water density relationships of soils are:

1. Standard Proctor Test
2. Modified Proctor Test
3. Harvard Miniature Compaction Test
4. Abbot Compaction Test
5. Jodhpur-Mini Compaction Test
6. The Dietert Test

1. Standard Proctor Test:

The standard protector compaction test was developed by R.R.Proctor in 1933, for the construction of earth fill dams in the state of California.



Equivalent for standard proctor test

2. Modified Proctor Test

Higher compaction is needed for heavier transport and military aircraft.

This test was standardized by the American Association of State Highway Officials and is known as "AASHO test".

3. Hardware Miniature Compaction Test:

In this test, the soil is compacted by kneading action of a cylindrical tamping foot of 0.5 inch (12.7 mm) in diameter.

4. Abbot Compaction Test:

The apparatus consists of a

(i) Metal cylinder of 5.2 cm in internal diameter.

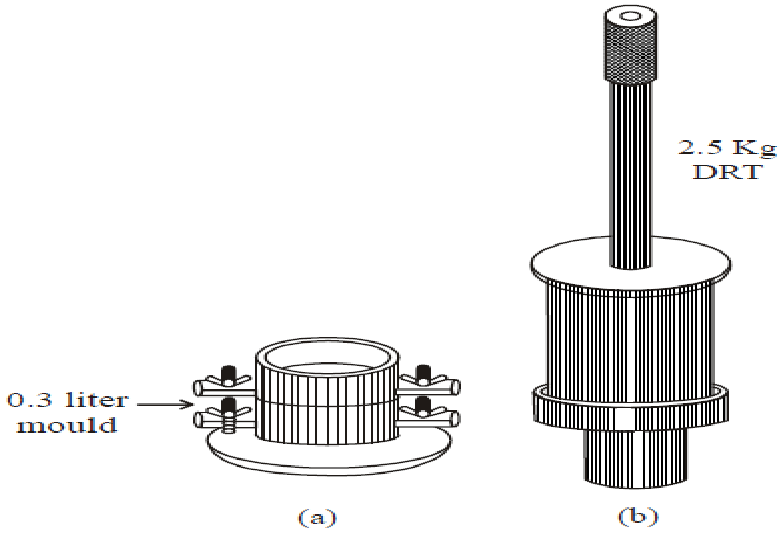
(ii) Effective height of 40 cm clamped to the base.

5. Jodhpur Mini-Compactor Test:

The Jodhpur mini-compactor consists of:

(i) The compaction mould having an internal diameter of 79.8 mm (cross-sectional area of 50 cm2) and internal height of 60 mm and a capacity of 0.3 litre.

(ii) A dynamic ramming tool (called the 2.5 kg DRT) consisting of a 2.5 kg drop weight, which freely slides down a stem through a height of 25 cm and falls over a foot, 50 mm in diameter and 75 mm in height.



Jodhpur mini-compactor

6. The Dietert Test:

The apparatus consists of a 2 inch diameter mould supported on a metal base by two stage.

i.The soil is compacted by means of a piston on which a cylindrical weight of 18 Ib falls through a height of 2 inch.

ii.The weight is operated by means of a cam.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=A-QHtLjvf8A

https://www.youtube.com/watch?v=ylLk5KsUQQc

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 407 to 421)

   Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 113 to 155)

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L 08

LECTURE HANDOUTS

CIVIL

IV/ II

Course Name with Code : **GEO TECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **I - SOIL CLASSIFICATION AND COMPACTION**

Date of Lecture:

Topic of Lecture: Field Compaction Methods

Introduction:

- ✓ The following types of equipments are used in the field for compacting embankments, sub-grades road base, etc.

(a) Rollers,

(b) Rammers (by Impact),

(c) Vibrators.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Embankments
- ✓ Sub-Grades Road Base
- ✓ Classification Of Soils
- ✓ Index Properties

Detailed content of the Lecture:

(a) Rollers:

The rolling equipment are of five types:

- ➢ Smooth Wheel Rollers
- ➢ Pneumatic Typed Rollers
- ➢ Sheep Foot Rollers
- ➢ Tamping Foot Rollers
- ➢ Vibratory Rollers

(i) Smooth Wheel Rollers:

- ✓ Smooth wheel rollers are usually self-propelled and are equipped with a clutch type reversing gear so that they can be operated back and front without turning.

(ii) Pneumatic Type Rollers:

- ✓ The pneumatic type rollers range in size from the smaller wobble-wheel-rollers to the very heavy rollers.
- ✓ A common form of pneumatic roller consists of a box or plat form mounted between two axles, the rear of which has one more wheel than the front, the wheel mounted on the front axle being arranged to track in between these mounted on the rear axle.

(iii) Sheep Foot Rollers:

- ✓ The sheep foot rollers consists of hollow cylindrical steel drum on which projecting foot are mounted.

(iv) Tamping Foot Rollers:

- ✓ Tamping foot rollers are very similar to sharp foot rollers with a difference that they use large foot with a corresponding smaller contact pressure.
- ✓ They can be operated at a faster speed, but cannot compact soil to a great depth.

(v) Vibratory Rollers:

- ✓ Vibratory rollers are similar to smooth wheel rollers with an addition of a vibrating mechanism.
- ✓ These rollers compact soils by pressure, kneading, and vibration.

(b) Rammers:

Rammers are used for compacting soils in relative small areas where rollers cannot be operated such as compacting trenches, slopes, etc.

Rammers for compacting soil comprise of:

(i) Pneumatic Rammers,

(ii) Internal Combustion

Type Rammer

a.Hand Operated Rammers,

b.Mechanical Rammers

(c) Vibrators:

- ✓ Vibrators are used for compacting sandy and gravelly soils.
- ✓ These compact the soil by use of vibration vibratory compaction equipment utilizes eccentric weights or some other device to induce strong vibrations into the soil.
- ✓ Vibration produced by vibrators typically has frequency of 1000–3500 cycles per minute.

- ✓ If a vibrating unit is mounted on a roller, then it is called as vibratory roller.
- ✓ Plate type vibrators are also available in the market.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Q69a_LiqC3s

https://www.youtube.com/watch?v=Qo8lyITgZu0

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 412 to 426)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 113 to 131)

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L - 09

LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : GEO TECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I - SOIL CLASSIFICATION AND COMPACTION

Date of Lecture:

Topic of Lecture: Factors influencing compaction

Introduction:

- ✓ There are many factors which influence the degree of compaction in the field. Some are compactor dependent and some depend. On the soil being compacted.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Compaction
- ✓ Consolidation
- ✓ Compaction Methods
- ✓ Permeability

Detailed content of the Lecture:

The factors which affect the degree of compaction are given below:-

(i) Water Content

At low water content, the soil is stiff and offers more resistance to compaction. As the water content is increased, the soil particles get lubricated.

The soil mass becomes more workable and the particles have closer packing.

(ii) Amount of Compaction

The effect of increasing the compactive energy results in an increase in the maximum dry density and decrease in the optimum water content

(iii) Type of Soil

Well graded coarse-grained soils attain a much higher density and lower optimum water content than fine-grained soils which requires more water for lubrication because of the greater specific surface.

(iv) Method of Soil Compaction

The dry density achieved depends not only open the amount of compactive effort, but also on the method of compaction.

(v) Compactive Effort (or) Compactive Energy

The term compactive effort or compactive energy simply means type of equipment of machinery used for compaction. Greeter the compactive effort, greater will be the compaction.

(vi) Layer Thickness or Thickness of Lift

Degree of compaction is inversely proportional to the layer thickness, i.e, for a given compactive energy, thicker layer will be less compacted as compared to thin layer.

The reason is for thicker foil layer, the energy input per unit weight is less.

(vii) Number of Roller Passes

It is obvious that density increases as the number of roller passes increases. But there are two important things we have to remember such as;

1. After certain number of roller passes, there is no further increase in density.
2. More number of roller passes means more cost of the project.

(viii) Contact Pressure

Contact pressure depends on the weight of the roller wheel and the contact area.

In case of pneumatic roller, the type inflation pressure also determines the contact pressure in addition to wheel load. A higher contact pressure increases the dry density and lowers the optimum moisture content.

(ix) Speed of Rolling

There are two important things we have to consider such as;

 First, the greater the speed of rolling, the more length of embankment can be compacted in one day.

 Second, at greater speed there is likely to be insufficient time for the desired deformations to take place and more passes may be required to achieve the required compaction.

(x) Length of Foot

The basic requirement for the length of foot is that is be at least as long as the thickness of lift being compacted. The minimum length is 18 inch and capable of exerting upwards of 1000 psi.

(xi) Shape of Foot

The feet of sheep foot rollers are manufactures in many shapes. This is true both for the face of the foot and for the foot shank. There may be some advantage to a particular shaped foot or foot shank with respect to ease of cleaning, rate of water etc.

(xii) Spacing of Foot

The ratio of the total foot area to the area of an imaginary drum with a diameter equal to the distance between the extremities of diametrically opposed foot on the actual drum.

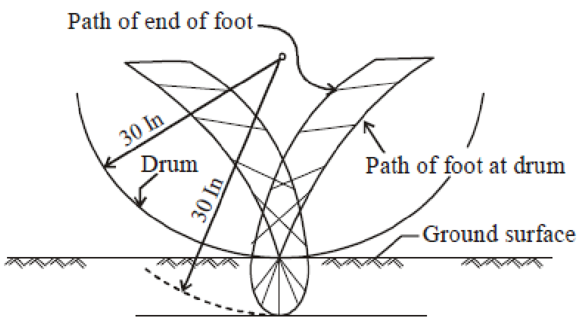
(xiii) Distribution of Roller Weight

However it is probable that the load will be carried on at least 3 or 4 rows of feet when one row of feet is penetrating the full length and the actual foot pressures may be roughly one-third or onequarter of the normal pressures.

(xiv) Effect of Passes

The number of passes has a considerable effect on the soil density obtained and has received a moderate amount of attention.

(xv) Rolling Radius



Rolling radius

(xvi) Addition of Admixtures

Line and calcium chloride are commonly used with clays and soil containing organic matter sodium carbonate and sodium sulphate has also been tried. Fly ash as an additive.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mB3O6hQAoZA

https://www.youtube.com/watch?v=AGMTmuXVz20

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 414 to 417)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 113 to 131)

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L 10

LECTURE HANDOUTS

CIVIL | **II / IV**

Course Name with Code : **GEO TECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Soil water and types

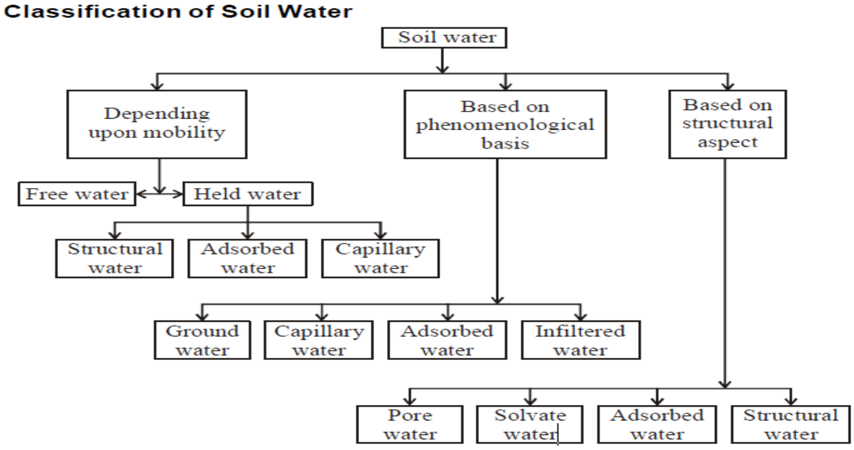
Introduction:

- The water present in the voids of soil mass is called **"Soil Water"**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Permeability
- Capillarity

Detailed content of the Lecture:



(i) Free Water (or) Gravitational Water

Water that is free to move through a soil mass under the influence of gravity is known as Free Water.

(ii) Held Water

Held water is the water that is held within a soil mass by soil particles.

It is not free to move under the influence of gravitation forces.

iii) Structural Water

Structural water is the water chemically combined in the crystal structure of the soil particle.

It cannot be removed without breaking the structure of soil particles.

(iv) Adsorbed Water

Adsorbed water is the water, in which is held by fine-grained soil particles due to electrochemical forces of adhesion.

It can be nearly removed by oven drying (usually at 105–110oC), but on exposed to atmosphere the adsorbed layer is again formed due to moisture present in the atmosphere.

(v) Ground Water

It is subsurface water that fills the voids continuously and is subjected to no forces other than gravity.

(vi) Infiltered Water

It is that portion of surface precipitation which soaks into ground, moving downwards through air-containing zones. It is subjected to capillary forces.

(vii) Pore Water

Pore water which is essentially free of strong soil attractive forces.

Types of pore water

(a) Capillary water

(b) Gravitational water

(viii) Solvate water

It is that water, which forms a hydration shell (presumably not more than 200 molecules thick) around soil grains.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mg6UoXcBkyA

https://www.youtube.com/watch?v=tUeOhlFSGcY

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 147 to 150)
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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Capillary stress

Introduction:

Capillary water is the water which is held in a soil mass due to capillary forces.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Surface tension of water,
- Pressure in water in relation to atmospheric pressure,
- Confirmation of soil pores.

Detailed content of the Lecture:

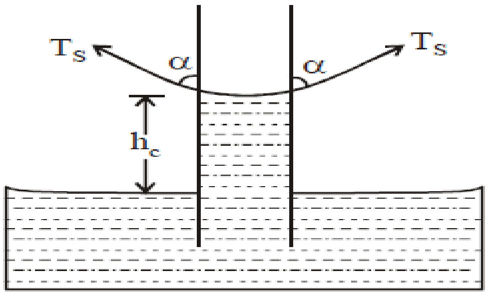
Capillary Action (or) Capillarity

It is the phenomenon of movement of water in the interstices of a soil due to capillary forces.

Capillary Rise

It is a phenomenon of raising of liquid surface in a small tube compared to the adjacent normal liquid level.

Derivation of Expression for Maximum Capillary Rise



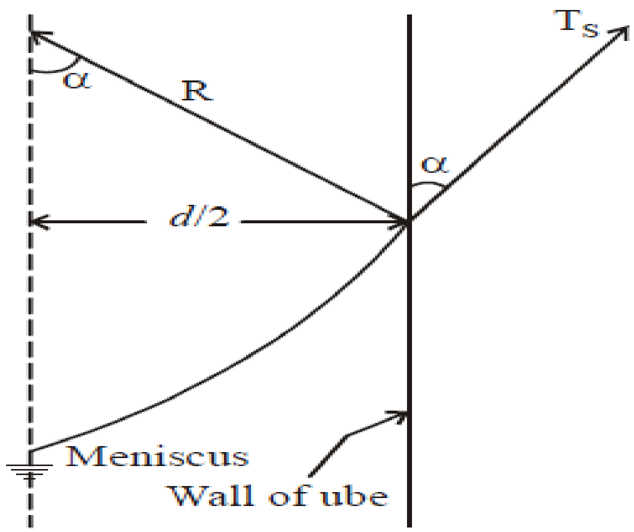
Capillary rise

Capillary Fall

It is a phenomenon of falling of liquid surface in a small tube compared to the adjacent normal liquid level.

Capillary Tension

The tensile stress caused in water is called as the capillary tension.



Relationship between R and d

Contact Pressure

Because of the tension in the contact capillary water, the two particles tend to press against each other giving rise to a force known as "Contact Pressure" factors affecting contact pressure;

(a) Particle size,

(b) Density of packing,

(c) Angle of contact,

(d) Water content.

Factors Affecting Soil Suction

Following are some of the factors influencing soil suction:-

(i) Particle size of soil,

(ii) Water content,

(iii) Plasticity index of soil,

(iv) History of drying and wetting,

(v) Soil structure,

(vi) Temperature,

(vii) Denseness of soil,

(viii) Angle of contact,

(ix) Dissolved salts in pore water.

STATIC PRESSURE IN WATER

The water pressure is called hydrostatic pressure. It is defined as the pressure exerted by a static fluid dependent on the depth of the fluid, the density of the fluid and the acceleration due to gravity.

- The total mass,
- The surface area,
- The shape of the liquid.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=QghuiEOoBCk

https://www.youtube.com/watch?v=AjQ7LWyUkRQ

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 150 to 156)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 219 to 234)

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LECTURE HANDOUTS

CIVIL | **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Permeability measurement in the laboratory

Introduction:

- A material having continuous voids is called "Permeable".
- Permeability is defined as the property of a porous material which permits the passage or seepage of water (or other fluids) through its inter connecting voids.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Seepage
- Darcy's Law
- Permeability

Detailed content of the Lecture:

Seepage

The slow movement of free of gravitational water (or other fluids) through a porous medium is called "seepage or percolation.

Darcy's law

According to Darcy's law (1956), for a laminar flow conditions the velocity of flow (V) is directly proportional to the hydraulic gradient (*i*).

Discharge Velocity (or) Theoretical Velocity

The velocity of flow of water (V) through soil mass is obtained from Darcy's law assuming that the flow takes place through the total cross-sectional area (A) of soil mass perpendicular to the direction of flow.

This velocity is referred to as discharge velocity or theoretical velocity. Thus, discharge velocity, $V = q/A$.

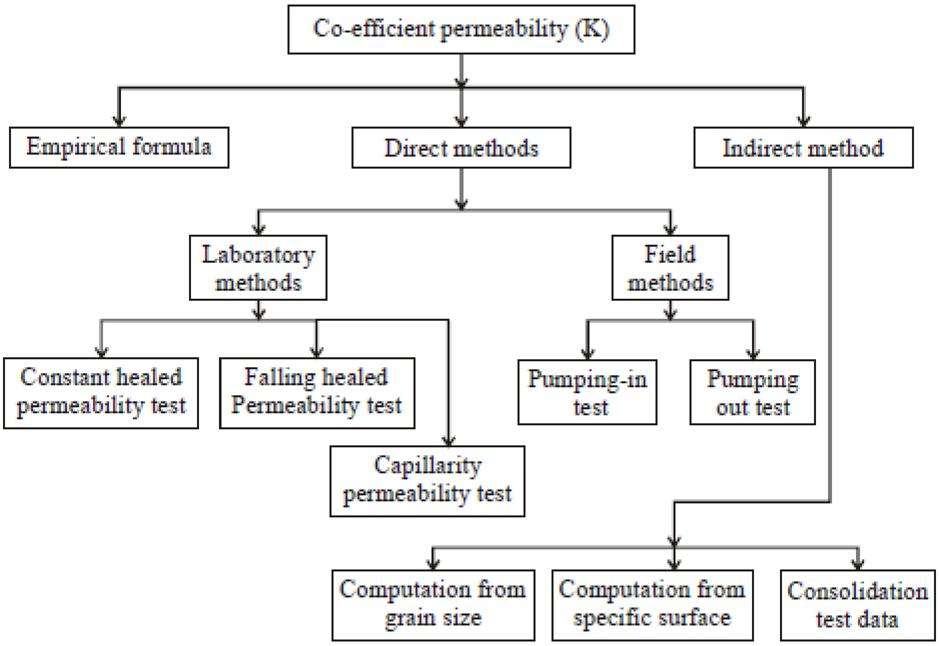
Co-Efficient of Percolation

The constant of proportionality K_p between V_s and i is referred as **"Co-efficient of Percolation".**

Validity of Darcy's Law

According to experimental investigations of francher, Lewis and Barnes (1933) flow through sands will be laminary and Darcy's law valid so long as the Reynolds number expressed in the form shown below is less than or equal to unity.

Determination of Co-Efficient of Permeability



Empirical Methods

Permeability can also be computed from several empirical formulae given below

(i) Jaky's Formula

Jaky (1944) found that a fair estimate of the order of magnitude of *k* can be obtained for all soils from the formula.

$$k = 100\,D_m^{\;2}$$

Direct Methods

It can be divided into the following two methods:-

(a) Laboratory Methods,

(b) Field Methods.

(a) Laboratory Methods

Permeability can be determined in the laboratory by direct measurement with the help of permeameters, by allowing under;

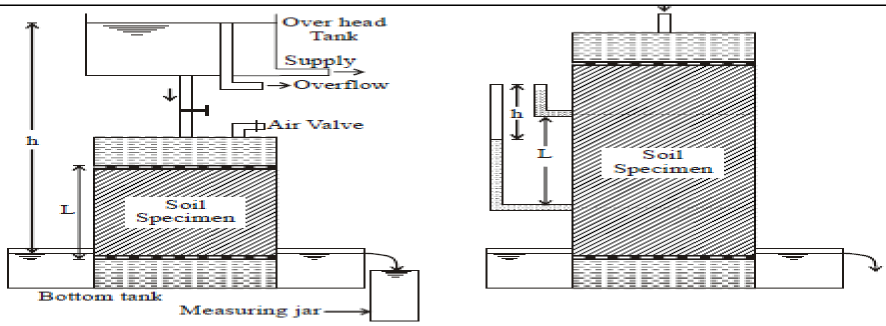
(i) Constant head permeability test

(ii) Falling (or) variable head

(iii) Capillarity test.

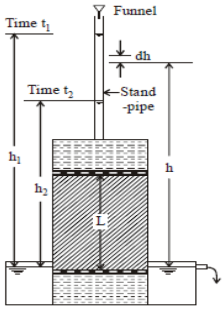
Constant head permeability test

The diagrammatic representation of constant head permeability test.



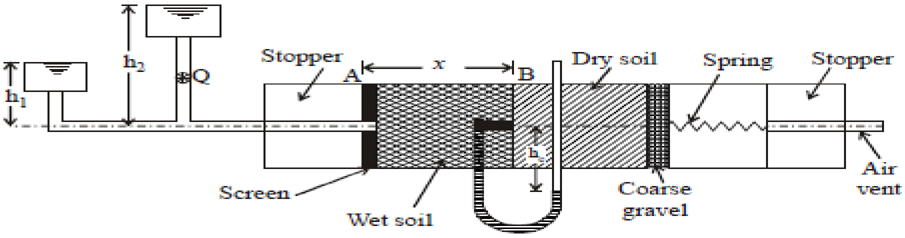
(ii) Variable head or falling head permeability test

The diagrammatical representation of a falling head test arrangement.



(iii) Capillarity permeability test

The capillarity permeability test or the horizontal capillarity test is used to determine the co-efficient of permeability *k* as well as the capillary height hc of the soil sample.



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=Eur_qpTKzrA

https://www.youtube.com/watch?v=B3gvVN29u8E

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 188 to 189)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 137 to 155)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Permeability measurement in the field

Introduction:

- There are two types of field tests for determining the co-efficient of permeability;
  (i) Pumping-in tests
  (ii) Pumping-out tests

Prerequisite knowledge for Complete understanding and learning of Topic:

- Constant water level method (In-open-end pipe)
- Packer method (In section of borehole).

Detailed content of the Lecture:

(i) Pumping-in tests

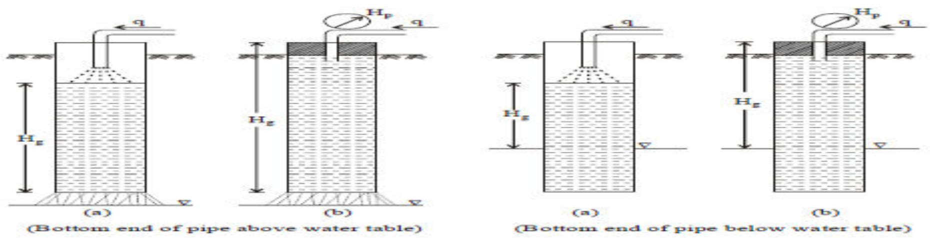
The two methods devised by U.S. Bureau of reclamation are;

(i) Constant water level method (In-open-end pipe)

(ii) Packer method (In section of borehole).

(i) Constant water level method

An open-end pipe is sunk into the desired depth and the soil is taken out of the pipe till its bottom end. The test is also conducted for borehole with the pipe casing extending to the desired depth. Water is pumped into the pipe and the rate of flow (q) is adjusted to maintain water level constant in the pipe. In the case of soils of low permeability additional pressure head (H_p) is required to be added to the gravity head (H_g) in order to maintain constant rate of flow.



(ii) Packer method

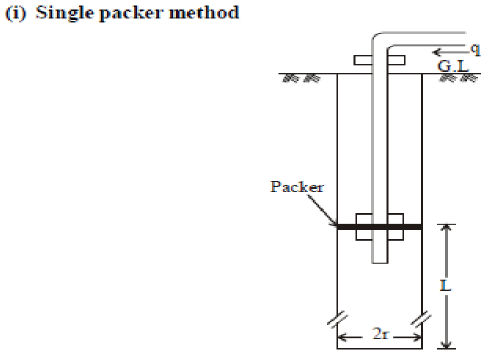
A packer is an expandable cylindrical rubber sleeve. Packers are used as a means of sealing of a section of borehole.

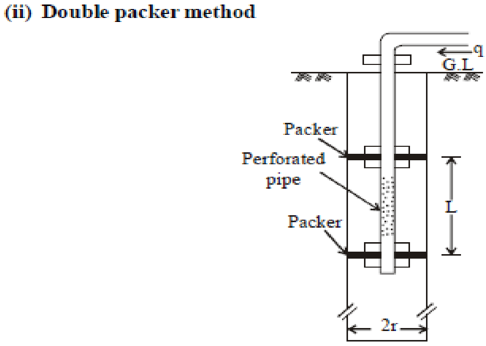
Types of packer methods

They are two types of packer methods are used in practices;

(i) Single packer method

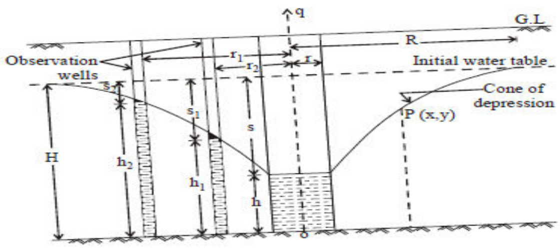
(ii) Double packer method





(a) Pumping-out test in unconfined aquifer

If the aquifer overlies an impervious stratum and the water table is free to fluctuate is called 'unconfined aquifer'.



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mB3O6hQAoZA

https://www.youtube.com/watch?v=-bYptlimsdI

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 185 to 195)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 137 to 155)

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LECTURE HANDOUTS

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CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Factors influencing permeability of soils

Introduction:

- In the case of stratified or layered soil deposits, each layer may be;

  (i) Homogeneous and

  (ii) Isotropic

But, when we consider flow through the entire deposite, the average permeability of deposit will vary with the direction of flow relative to the bedding plane.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Homogeneous soils
- Isotropic soils

Detailed content of the Lecture:

Factors Affecting Permeability

From Darcy's law

$$q = k\, i\, A$$

We get

$$k = D_s^2 \cdot \frac{\gamma_w}{\eta} \cdot \frac{e^3}{He} \cdot C$$

Thus factors affecting permeability are;

(i) Particle size
(ii) Properties of pore fluid
(iii) Void ratio
(iv) Soil fabric and soil stratification
(v) Degree of saturation
(vi) Presence of foreign matter
(vii) Adsorbed water

(i) Effect of Particle Size

It is found that permeability varies approximately as the square of the grain size.

According to Allen Hazen (1911) the permeability of sands can be estimated using the following equation

$$k = CD_{10}^2$$

Where; k = Co-efficient of permeability

D_{10} = Effective size (cm)

C = Constant, which may be taken as 100

ect of Properties of Pore Fluid

It can be shown that permeability is directly proportional to the unit weight of pore fluid and inversely proportional to its viscosity. Therefore we can write

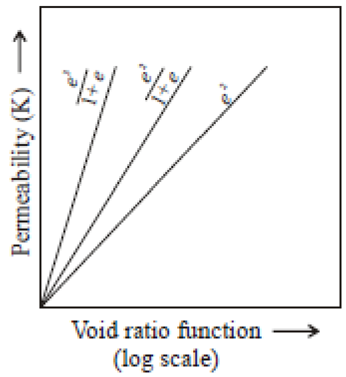
$$\frac{k_1}{k_2} = \frac{\gamma_{w1}}{\gamma_{w2}} \frac{\eta_2}{\eta_1}$$

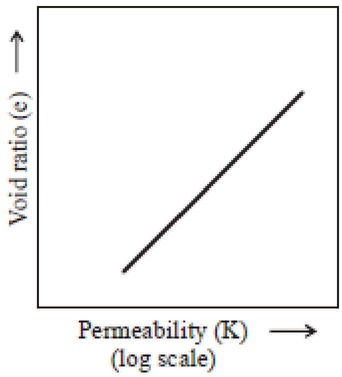
Where subscripts 1 and 2 all used to refer to quantities at temperature T_1 and T_2 respectively. As the variation in viscosity with temperature is much greater compared to that of unit weight of water is approximated as

$$\frac{k_1}{k_2} = \frac{\eta_2}{\eta_1}$$

(iii) Effect of Void Ratio

It has been found that a plot of void ratio on natured scale against permeability on logarithmic scale is approximately a straight line for both coarse-grained soils and finegrained soils.





(iv) Effect of Soil Fabric and Stratification

The effect of structural arrangement of particle on permeability can be founded by determining permeability of undisturbed and disturbed soil samples.

The effect of change in structural arrangement of particles on permeability is more than case of fine-grained soil.

(v) Effect of Degree of Saturation

In partly saturated soils the entrapped air greatly reduce the permeability test is always conducted one a fully saturated soil specimen.

The water used may contain dissolved air.

The use of air free water is not warranted as the percolating water in the field may contain dissolved gases.

(vi) Effect of Present of Foreign Matter

Organic foreign matter if present in soil mass may be carried by flowing water towards critical flow channel and may chock them up, causing reduction in permeability.

(vii) Effect of Absorbed Water

The absorbed water which is held by soil particles is not free to move and therefore reduce the effective pore space available for the flow of free water. According to casagrande the void ratio may be taken approximately as (e – 0.1) and permeability assumed to be proportional to the square of the net void ratio.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=lAOFl5dzIyU

https://www.youtube.com/watch?v=uUCump-lD-k

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 183 to 185)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 155 to 160)

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L - 15

LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Seepage

Introduction:

- The slow movement of free of gravitational water (or other fluids) through a porous medium is called "seepage or percolation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Darcy's law
- Discharge Velocity
- Actual Velocity

Detailed content of the Lecture:

Darcy's law

According to Darcy's law (1956), for a laminar flow conditions the velocity of slow (V) is directly proportional to the hydraulic gradient (i).

$$V \alpha i$$

The constant of proportionality k between v and i is called "Darcy's co-efficient of permeability"

$$V = ki$$

Where;

k = Co-efficient of permeability

i = Hydraulic gradient.

V = Velocity of flow average discharge velocity

When;

$i = 1$

We have

$$V = k$$

$\therefore$ The co-efficient of permeability can also defined as the velocity of flow through soil under unit hydraulic gradient and has same unit as the velocity. It is usually expressed in mm/sec, m/hr, m/day.

Further,

$$q = AV = Aki$$

Where;

q = Rate of flow or discharge per unit time.

A = Total cross-sectional area of soil mass perpendicular to the direction of flow.

If the soil sample subjected to differential head of water the discharge per unit timers given by;

$$q = k\frac{h_1 - h_2}{L}A$$

Where;

$(h_1 - h_2)$ = Differential head of water

L = Length of soil sample.

Discharge Velocity (or) Theoretical Velocity

The velocity of flow of water (V) through soil mass is obtained from Darcy's law assuming that the flow takes place through the total cross-sectional area (A) of soil mass perpendicular to the direction of flow.

This velocity is referred to as discharge velocity or theoretical velocity.

Thus, discharge velocity,

$$V = q/A.$$

Seepage Velocity (or) Actual Velocity

It is defined as the rate of discharge of percolating water per unit cross-sectional area of voids perpendicular to the direction of flow.

Thus, seepage velocity, $V_s = q/A_v$

$$\therefore q = V_s \cdot A_v \qquad \left[\text{Since } \frac{A_v}{A} = \frac{V_v}{V} = n\right]$$

$$V_s = V \cdot \frac{A}{A_v}$$

$$= V \cdot \frac{1}{n}$$

$$\therefore V_s = \frac{V}{n}$$

Where;

A_v = Area of voids

n = Porosity of soil mass

Validity of Darcy's Law

(i) According to experimental investigations of francher, Lewis and Barnes (1933) flow through sands will be laminary and Darcy's law valid so long as the Reynolds number expressed in the form shown below is less than or equal to unity.

$$\frac{V \cdot D_a \cdot \rho_w}{\eta g} \leq 1$$

Where;

V = Velocity of flow in cm/sec

D_a = Diameter of average

η = Viscosity of water (g sec/cm^2)

g = Acceleration due to gravity (cm/sec^2)

ρ_w = Density of water (g/ml)

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=UbPcW6vXbOg

https://www.youtube.com/watch?v=ZzO-e5XKAY0

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 223 to 225)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 197 to 215)

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LECTURE HANDOUTS

CIVIL **II/ IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture: 23/01/2020

Topic of Lecture: Introduction to flow nets

Introduction:

- A flownet is a graphical representation of two-dimensional steady-state groundwater flow through aquifers.

A Flownet comprised of:

(i) Flow lines

(ii) Equipotential lines

Prerequisite knowledge for Complete understanding and learning of Topic:

- Seepage
- FlowLines
- Equipotential Lines

Detailed content of the Lecture:

Applications (or) Uses of Flownet

A flownet can be used to determines

(i) Quantity of seepage,

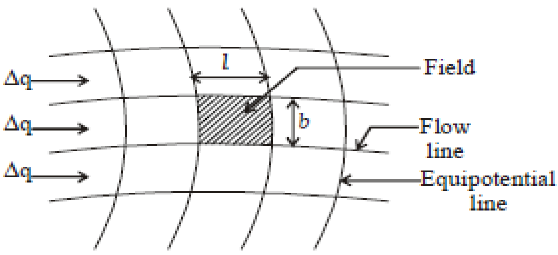
(ii) Seepage pressure at a point,

(iii) Hydrostatic pressure at a point,

(iv) Exit gradient.

(i) Determinations of Quantity of Seepage

Let us consider a portion of a flownet as shown in Fig.2.25.



(ii) Determination of Seepage Pressure

The seepage pressure at a point p_s is given by

$$p_s = h \cdot \gamma_w$$

Where;

h = Total head at that point = $(H - n \cdot \Delta h)$.

H = Total head causing flow.

n = Number of potential drops upto the point under consideration.

Δh = Potential drop per field = $\frac{H}{N_d}$

(iii) Determination of Hydrostatic Pressure at a Point:

(a) Hydrostatic Head (h_w)

The hydrostatic head at a point is given by;

$$h_w = h - z$$

Where;

h = Total head at that point = $(H - n \cdot \Delta h)$.

n = Number of potential drops upto that point.

Δh = Potential drop per field = $\frac{H}{N_d}$.

z = Datum head at that point.

The value of z will be

(i) Positive (+ve), when the point is above the datum.

(ii) Negative (– ve), when the point is below the datum.

Flow Channel : The space between any two adjacent flow lines is called flow channel.

Field : The space enclosed between two adjacent flow lines and two successive equipotential lines is called as field.

Velocity Potential (ϕ)

It is defined as a sealer function of space and time such that it's derivation with respect to any direction gives the fluid velocity in that directions.

We have;

$$\phi = k\,h$$

$$\therefore \frac{\partial \phi}{\partial x} = k \cdot \frac{\partial h}{\partial x} = k\,i_x = V_x \text{ and}$$

$$\frac{\partial \phi}{\partial y} = k \cdot \frac{\partial h}{\partial y} = k\,i_x = V_y$$

The velocity potential function is given by:

$$\phi = \int \frac{\partial \Psi}{\partial y} dy - \frac{\partial \Psi}{\partial x} dy$$

Methods of Construction of Flownet

The flownet can be constructed by the following methods:-

(i) Graphical Method,

(ii) Electrical Analogy,

(iii) Analytical - Method - Relaxation method,

(iv) Sand Model Method,

(v) Capillary Flow Analogy Method.

(i) Graphical Method

The graphical method of flownet construction first given by forchheimer (1930) is based on trail sketching. The hydraulic boundary conditions have a great effect on the general shape of the flownet and hence must be examined before sketching is started. Casegrande (1937) gave the following excellent hints the beginner in flownet sketching.

(ii) Electrical Analogy

The Darcy's law governing the flow of water through soil is analogous to Ohm's law governing the flow of electric current through conductors.

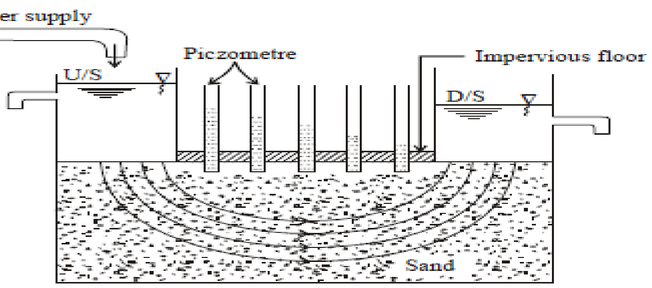
iii) Analytical Method-Relaxation Method

The analytical method of drawing flownet is based on the solution of the Laplace equation in of potential ϕ can be written in finite different form as;

$$\phi_1 + \phi_2 + \phi_3 + \phi_4 - 4\phi_0 = 0$$

(iv) Sand Model Method

Fig.2.31 shows a sand model constructed to steady flow through pervious foundation below the impervious floor of a weir.



(v) Capillary Flow Analogy Method

This method is based on the principle that capillary flow between two closely spaced parallel plates follows a law analogous to two dimensional flows through soils.

The setup consists of two small tanks interconnected through two parallel glass plates with a capillary space of constant width between them.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=MgKMWZOIy2w

https://www.youtube.com/watch?v=tnZWJ6pRkk8

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 232 to 234)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 197 to 215)

Course Teacher

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LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : GEOTECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II - SOIL WATER AND PERMEABILITY

Date of Lecture:

Topic of Lecture: Simple problems

Introduction:

For solving simple problems the following input data are required, such as permeability of soil, height of sheet pile wall and height of upstream and down streams side, etc.,

Prerequisite knowledge for Complete understanding and learning of Topic:

- Permeability of soil
- Sheet pile

Detailed content of the Lecture:

A soil stratum with permeability $k = 5 \times 10^{-7}$ cm/sec overlies an impermeable stratum. The impermeable stratum lies at a depth of 18 m below the ground surface (surface of soil stratum). A sheet pile wall penetrates 8 m into the permeable soil stratum. Water stands to a height of 9 m on upstream side and 1.5 m on downstream side, above the surface of soil stratum. Sketch the flownet and determine;

(i) Quantity of seepage

(ii) The seepage pressure at a point p located 8 m below surface of soil stratum and 4 m away from the sheet pile wall on it is upstream side.

(iii) The pore pressure at a point p.

(iv) The maximum exit gradient.

Solution:

(iii) Pore pressure (u)

Hydrostatic head at p, $h_w = h - z = 5.16 - (-9.5)$

$h_w = 14.66$ m

$\therefore$ Pore pressure at p, $u = h_w \cdot \gamma_w = (14.66 \times 9.81)$

$u = 143.81$ kN/m^2

(iv) Maximum exit gradient (i_e)

Average length of exit field adjustment to sheet pile wall $l_e = 2.6$ m

$$\text{Maximum exit gradient, } (i_e) = \frac{\Delta h}{l_e} = \frac{0.9375}{2.8} = 0.33$$

In the flownet

(a) Boundary flow lines : BC, DE and JK

(b) Boundary equipotential lines : AB and EF.

From the flownet, we have;

No of flow channels, $N_f = 4$

No of potential drops, $N_d = 8$

(i) Quantity of seepage (q)

Head causing flow, $H = q - 1.5 = 7.5$ m

$$\therefore \text{ Quantity of seepage, } q = k \cdot H \cdot \frac{N_f}{N_d}$$

$$= 5 \times 10^{-9} (7.5) \cdot \left(\frac{4}{8}\right)$$

$$q = 18.75 \times 10^{-9} \text{ m}^3\text{/sec per metre length}$$

(ii) Seepage pressure (p_s)

Potential drop per filed, (Δh)

$$\Delta h = \frac{H}{N_d} = \frac{7.5}{8}$$

$$\Delta h = 0.9375 \text{ m}$$

Number of potential drops upto point p, $n = 2.5$

$$\therefore \text{ Total heat at point } p,\ h = (H \ \ n \cdot \Delta h)$$

$$= (7.5 \ \ (2.5 \times 0.9375))$$

$$h = 5.16 \text{ m}$$

$$\text{Seepage pressure at } p,\ p_s = h \cdot \gamma_w$$

$$= (5.16 \times 9.81)$$

$$p_s = 50.62 \text{ kN/m}^2$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=put77fWj1k0

https://www.youtube.com/watch?v=tnZWJ6pRkk8

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 244 to 249)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 133 to 155)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **II - SOIL WATER AND PERMEABILITY**

Date of Lecture:

Topic of Lecture: Effective stress concept in soil

Introduction:

- Pressure is transmitted through a soil mass by soil particles through their points of contact is called effective stress.
- It is effective in decreasing the void ratio and increasing shear strength.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Pore pressure
- Total stress
- Neutral pressure

Detailed content of the Lecture:

i) Pore pressure (or) pore water pressure (or) neutral pressure (*u*):

The pressure transmitted by pore water in a soil mass is called pore pressure, Pore pressure at any point in – soil mass,

$u = hw \square w$

Where,

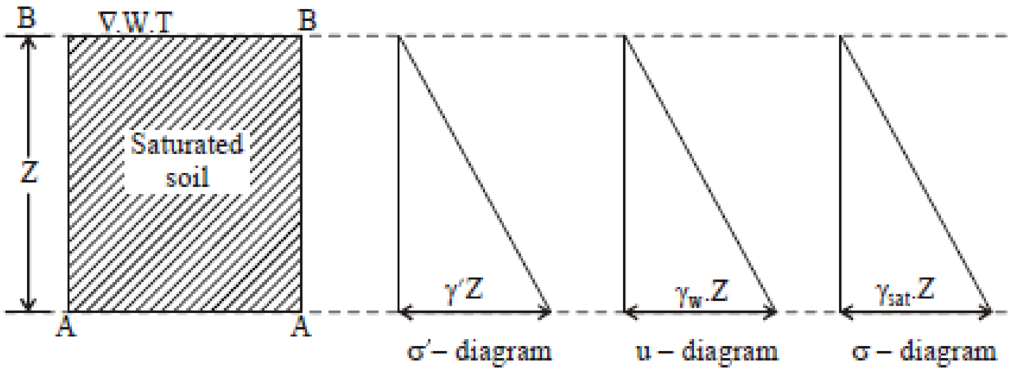
hw = Piezometric head at that point

(ii) Total stress

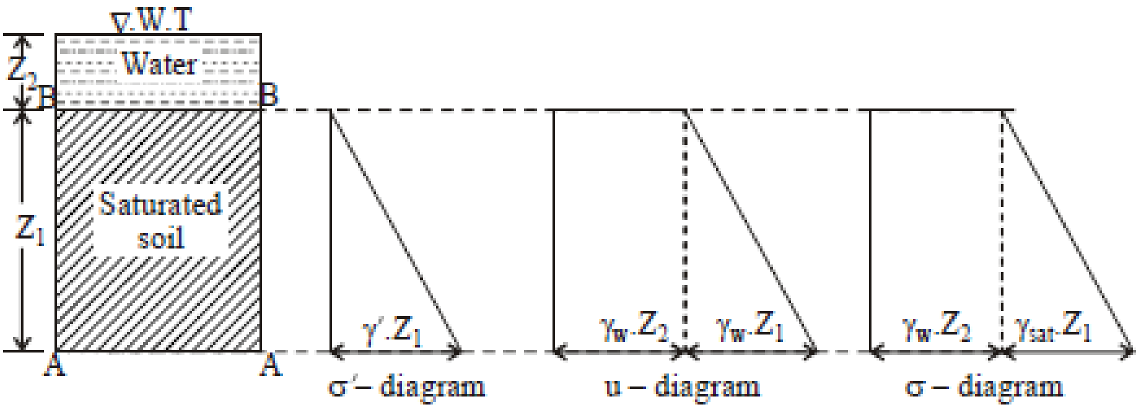
The total stress at any point is the sum effective stress and pore pressure

$$\therefore \boxed{\sigma = \sigma' + u}$$

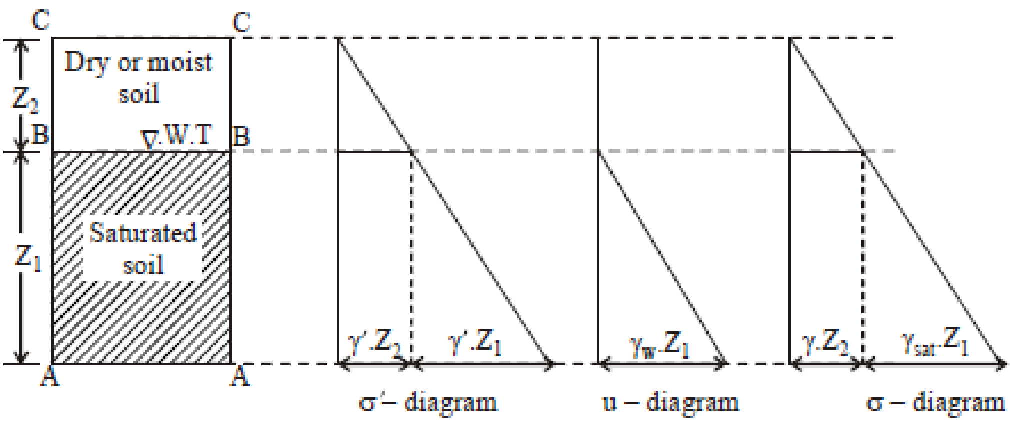
Submerged Soil Mass with Water Table at the Surface



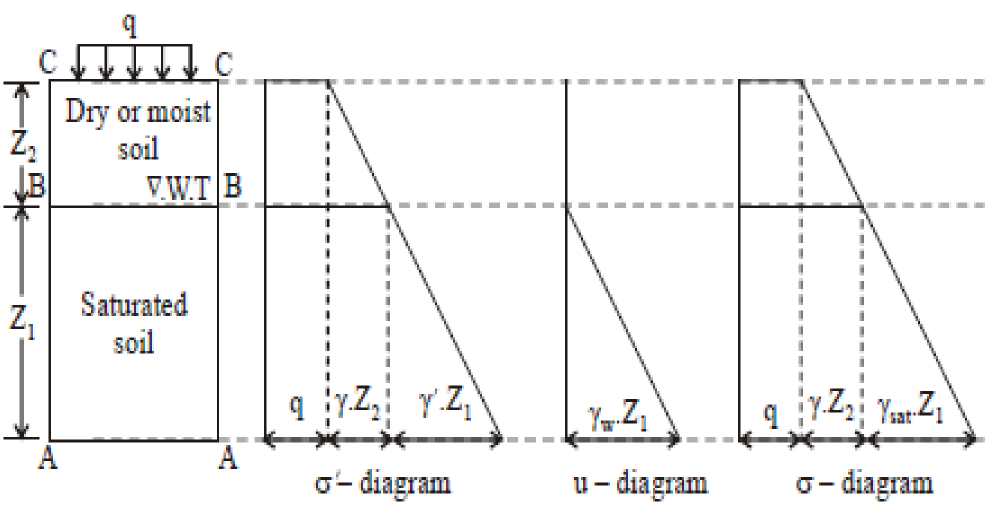
Submerged Soil Mass with Water Table Above the Surface



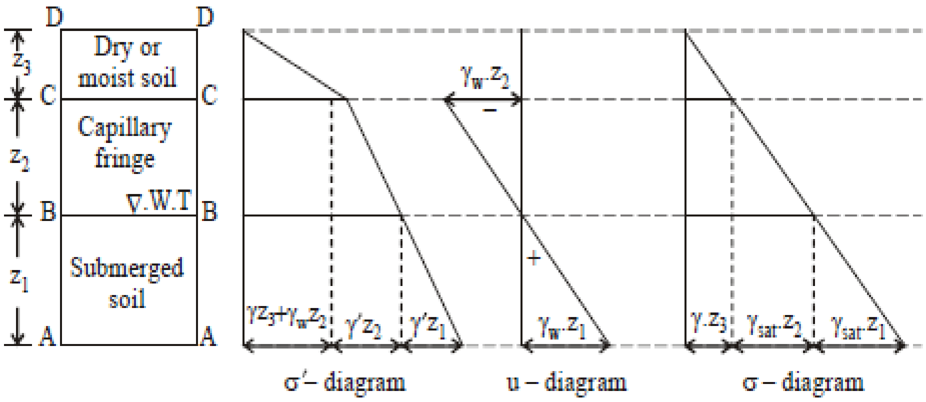
Partially Submerged Soil Mass



Partially Submerged Soil Mass with Surcharge



Soil Mass with Capillary Fringe



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=jg0fyum6LQQ

https://www.youtube.com/watch?v=jbo6HckLkJk

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 163 to 176)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 197 to 215)

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Course Name with Code : GEOTECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT

Date of Lecture:

Topic of Lecture: Boussinesq theory -Assumptions

Introduction:

- Stress in a soil is caused by the first (or) both of the self-weight of the soil and the structural loads applied at or below the surface.
- The theory of elasticity which gives primarily the interrelationships of stress gives strains (Timoshenko and Goodier 1951) has been the basics for the determination of stresses in a soil-mass.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Point Load
- Concentrated Load
- Stress

Detailed content of the Lecture:

Assumption Made in Boussinesq's Analysis

The following assumptions are made by Boussinesq in obtained the solution:

(i) The soil-mass is an elastic medium for which E is constant.

(ii) The soil-mass is homogeneous, that is, all it's constituent parts or elements are similar and it has identical properties at every point in it in identical directions.

(iii) The soil-mass is isotropic, that is, it has identical properties in all directions through any point of it.

(iv) The soil-mass is semi-infinite in extent that is, it extends infinitely in all directions below a level surface.

(v) The self-weight of the soil is ignored.

(vi) The soil is initially unstressed.

(vii) The change in volume of the soil upon application of the load on it is neglected.

(viii) The top surface of the medium is free of shear stress and is subjected to only the point load at a specified location.

(ix) The continuity of stress is considered to exist in the medium.

(x) The stresses are distributed symmetrically with respect to z-axis.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mB3O6hQAoZA

https://www.youtube.com/watch?v=JcvIPXAKelQ

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 296 to 298)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 237 to 238)

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LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : GEOTECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT

Date of Lecture:

Topic of Lecture: Point load - circular load - rectangular load

Introduction:

- Boussinesq (1885) has given the solution of the problem of stress distribution in soil due to a point load (single concentrated vertical load) acting at the soil surface with the aid of the theory of elasticity.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Point Load
- Vertical Load

Detailed content of the Lecture:

The determination of vertical stresses at any point in a soil-mass due to external vertical loadings are of great significance in the prediction of settlement of the following:

(i) Building,

(ii) Bridges,

(iii) Embankment and many other structures.

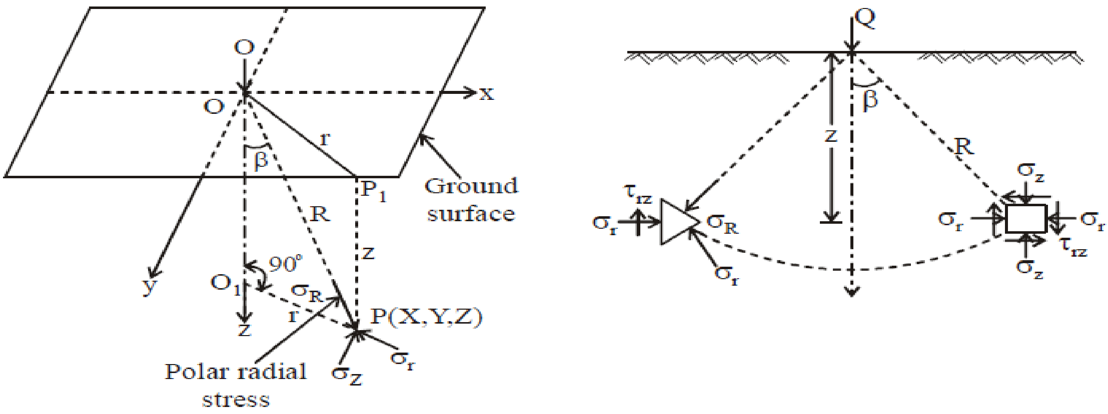
Let a point load Q act at the ground surface at a point O which may be taken

as the origin of the x, y and z axes

Let us find the stress components at a point P in the soil-mass having coordinates

x, y and z or having a radial horizontal distance r and vertical distance z

From the point O.



(a) (b)

1. Vertical Normal Stress Distribution Diagrams

By means of Boussinesq's equation, the following vertical normal stress distributions diagrams can be prepared.

(i) Isobar diagram (or) Stress Isobar diagram.

(ii) Vertical normal stress distribution on a horizontal plane.

(iii) Vertical normal stress distribution on a vertical plane.

1.1 Isobar Diagram (or) Stress Isobar Diagram

Stress Isobar or Isobar is a curve connecting all the points below the soil surface at which the vertical normal stress is the same.

In other words, an isobar is a contour of equal vertical normal stress. An isobar is a spatial curved surface of the shape of a bulb, because the vertical normal stress at all points in a horizontal plane at equal radial distance from the load is the same. The vertical normal stress at every point on the surface of the pressure bulb is the same.

The zone in a loaded soil-mass bounded by an isobar of given vertical normal stress is called the "Pressure Bulb".

1.2 Construction of an Isobar

Suppose an isobar of □*z* = 0.2 Q (or 20% of Q) per unit area is to be plotted.

W.K.T

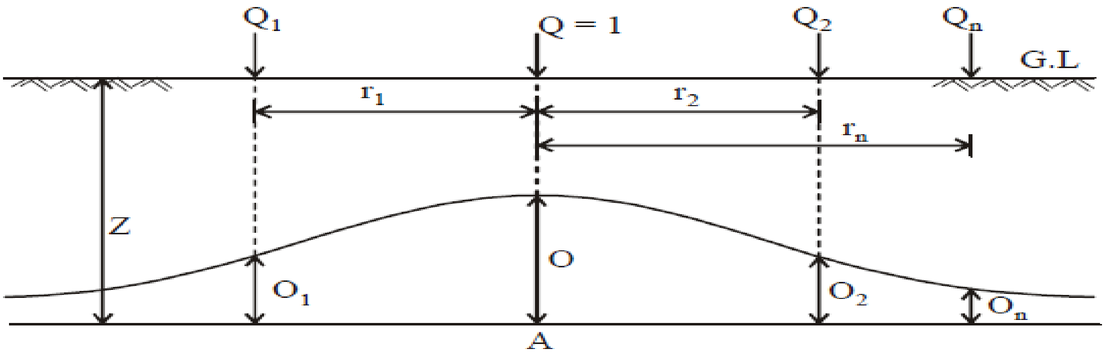
$$\sigma_z = K_B \cdot \frac{Q}{z^2}$$

$$K_B = \frac{\sigma_z \cdot z^2}{Q} = \frac{0.2Q \cdot z^2}{Q} = 0.2\,z^2$$

1.3 Vertical Normal Stress Distribution on a Horizontal Plane

The vertical pressure distribution on any horizontal plane at a depth *z* below the ground surface due to a concentrated load is given by

$$\sigma_z = K_B \cdot \frac{Q}{z^2}$$



If such a diagram is plotted for unit load (Q = 1) is called "Influence Diagram" for point below the axis.

Such a diagram is helpful for computing the vertical stress □*z* at A due to a number of concentrated loads Q1, Q2, Q3 ... Q*n* etc. Situated at radial distances *r*1, *r*2, *r*3 ... *rn* from the vertical axis through point A.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mB3O6hQAoZA

https://www.youtube.com/watch?v=kbXpCmJ6GkE

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 399 to 312)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 244 to 271)

Course Teacher

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT**

Date of Lecture:

Topic of Lecture: 2:1 distribution method - equivalent point load

Introduction:

- This is an approximate method of calculating the vertical stress at any point due to any loaded area.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Vertical Stress
- Point Load
- Horizontal Stress

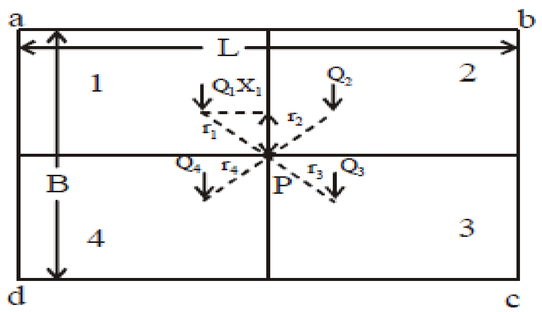
Detailed content of the Lecture:

Principle

The entire area is divided into a number of small area units and the total distributed load over a unit area is replaced by a point load of the same magnitude acting at the centroid of the area unit. The vertical stress at point *p* below the depth *z* is given by

$$\sigma_z = \frac{1}{z^2}[Q_1 K_{B1} + Q_2 K_{B2} + \ldots + Q_n K_{Bn}]$$

Where K_B = Boussinesq influence factor $= \frac{3}{2\pi}\left[\frac{1}{1+\left(\frac{r}{z}\right)^2}\right]^{\frac{5}{2}}$



If all the point loads are of equal magnitude Q'

$$\therefore \qquad \sigma_z = \frac{Q'}{z^2} \sum K_B$$

Where

$\sum K_B$ = Sum of the individual influence factors for the various area units.

The accuracy of the result can be increased by increasing the number of area units and thus decreasing the size of each area unit.

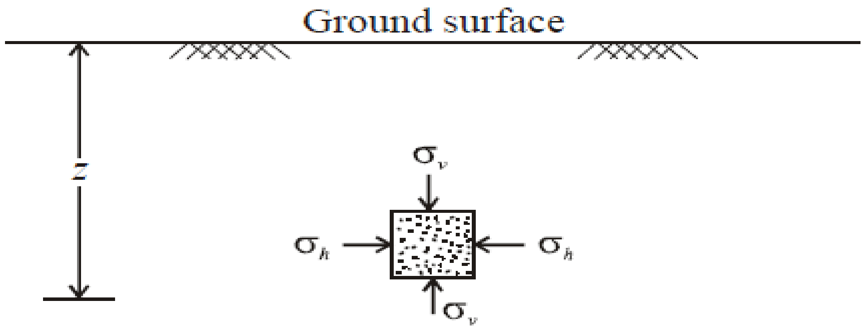
The error involved can be limited to 3 % if the length of each unit is kept less than one-third the depth at which vertical stress is required.

STRESS DISTRIBUTION IN HOMOGENEOUS SOIL MEDIUM

Any change in total vertical stress *v* may also result in a change of total

horizontal stress *n* on the same soil element. There is no simple relationship between

horizontal and vertical stress



In a homogeneous soil, the total vertical stress σ_v on an element with distance z from the surface is determined by the weight of the overlying soil and can be calculated by:

$$\sigma_v = \rho_b (1 + w_m) g \cdot z$$

Where;

ρ_b = Bulk density of soil

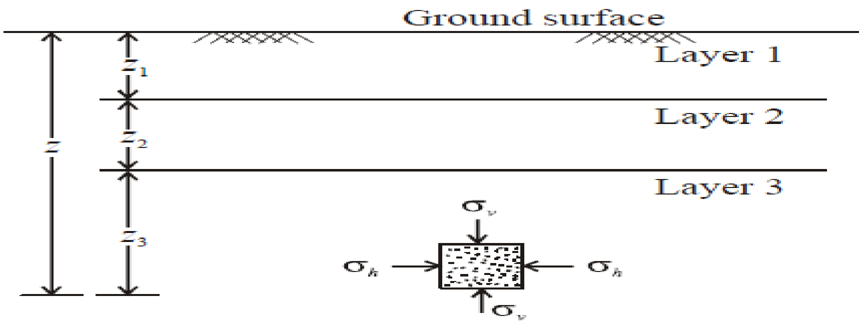
w_m = Gravimetric water content

g = Gravity constant the typical values of ρ_b are 1000–1800 kg m^3

STRESS DISTRIBUTION IN ISOTROPIC SOIL MEDIUM

The total vertical stress *v* at depth *z* is the sum of the weight of the soil in

each layer above



Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=mB3O6hQAoZA https://www.youtube.com/watch?v=Ki-iRyqxwOo
Important Books / Journals for further learning including the page nos.: 1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 299 to 312) 2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 237 to 238)

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MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT**

Date of Lecture:

Topic of Lecture: Use of newmarks influence chart

Introduction:

- A more accurate method of determining the vertical stress at any point under

a uniformly loaded area of any shape is with the help of influence chart or influence diagram originally suggested by Newmark (1942).

Prerequisite knowledge for Complete understanding and learning of Topic:

- Soil Settlement
- Vertical Pressure

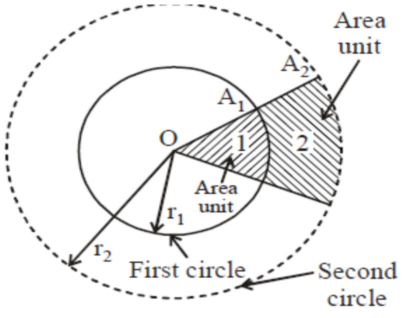
Detailed content of the Lecture:

Principle of Newmark's Chart

A chart consists of a number of concentric circles divided into area units by radiating lines such that vertical stress at a given depth below the centre of circles due to load on each area unit is same.

Construction of Newmark's Chart

Let a uniformly loaded circular area of radius $r1$(cm) be divided into 20 sectors



If q is the intensity of loading and σ_z is the vertical pressure at a depth z below the centre of the area, each unit such as $OA_1 B_1$ exerts a pressure equal to $\frac{\sigma_z}{20}$ at the centre.

Hence

$$\frac{\sigma_z}{20} = \frac{q}{20}\left[1 - \left\{\frac{1}{1 + \left(\frac{r_1}{z}\right)^2}\right\}^{3/2}\right] = i_f \cdot q$$

Where i_f = influence value = $\frac{q}{20}\left[1 - \left\{\frac{1}{1 + \left(\frac{r_1}{z}\right)^2}\right\}^{3/2}\right]$

If i_f be made equal to an arbitary fixed value say 0.005, we have

$$\frac{q}{20}\left[1 - \left\{\frac{1}{1 + \left(\frac{r_1}{z}\right)^2}\right\}^{\frac{3}{2}}\right] = 0.005q \quad \dots (1)$$

Use of Newmark's Influence Chart

- To use the chart for determining the vertical stress at any point under the loaded area.
- The plan of the loaded area is first drawn on a tracing paper to such a scale that the length AB (= 5 cm) drawn on the chart represents the depth to the point at which pressure is required.

Examples:

If the pressure is to be found at a depth of 5 m, the scale of plan will be 5 cm = 5m (or) 1 cm = 1 m. The plan of the loaded area is then so placed over the chart that the point below which pressure is required coincides with the centre of the chart.

- The point below which pressure is required may lie within or outside the loaded area.

Advantages of Newmark's Influence Chart

(i) It can be used for loaded area of any shape.

(ii) It is relatively rapid.

Points to be Considered

While using Newmark's chart the following points should be noted:

(i) The fractions of the area units should be counted and properly accounted for.

(ii) If the plan of the loaded area extends beyond the circle, it may be assumed to approach the 10th circle for the purpose of counting the area units.

(iii) The point p at which the vertical normal stress is required to be determined may be anywhere within or outside the loaded area.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=mB3O6hQAoZA

https://www.youtube.com/watch?v=XqFfP-oIxu8

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 312 to 315)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 271 to 274)

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LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : GEOTECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT

Date of Lecture:

Topic of Lecture: Components of settlement

Introduction:

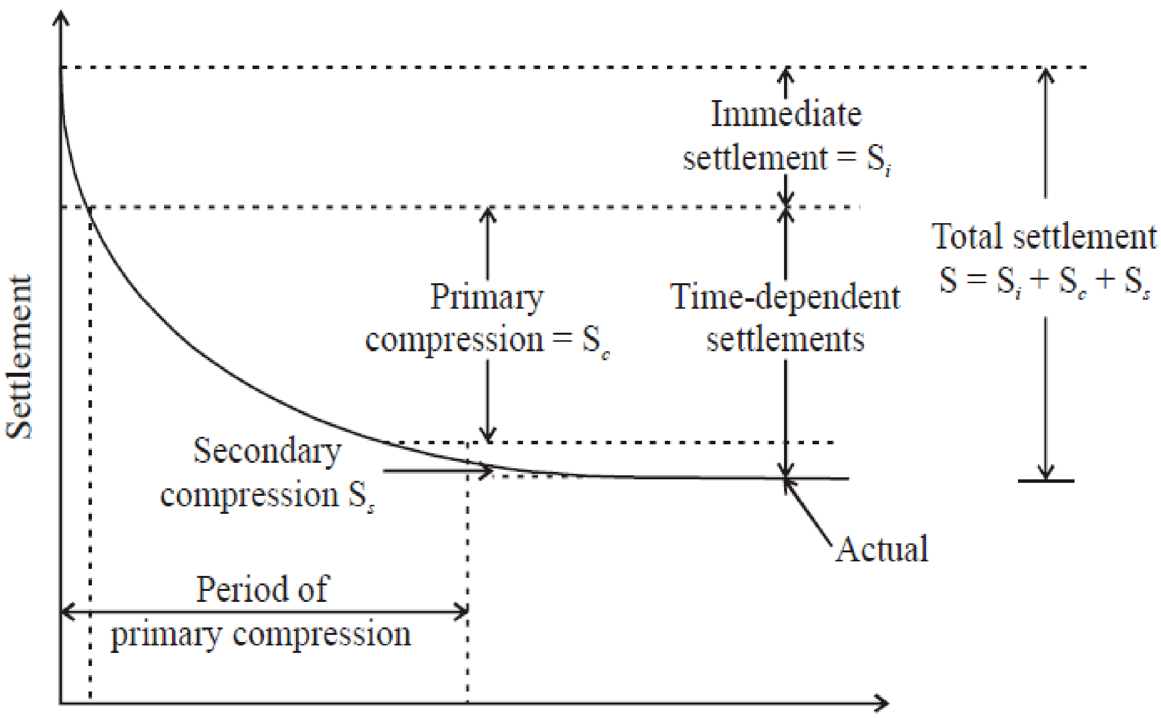
- It is defined as the decrease in elevation experienced on or within a soil as a result of compression

Prerequisite knowledge for Complete understanding and learning of Topic:

- Immediate settlement
- Stress

Detailed content of the Lecture:

Types (or) Components of Settlement



The total settlement can be divided into the following two groups:

(i) Immediate settlement

(ii) Time-dependent settlement

(a) Settlement due to consolidation

(b) Settlement due to secondary compression or creep.

Immediate Settlement (S*i*)

Immediate settlement (S*i*) is the change in shape or distortion of the soil caused by the applied stress.

Computation of Immediate Settlement

(a) For Cohesive Soil

Immediate settlement in cohesive soil may be estimated by using elastic theory, particularly for saturated clays, clay shales and most rocks

$$S_i = q_o B \frac{1-\mu^2}{E_s} m I_S I_E$$

(b) For Cohesionless Soil:

Calculation of immediate settlement in cohesionless soil is complicated by a non-linear stiffness that depends on the state of stress.

(i) Empirical methods:

The most widely used is Schleicher's method. In this method the settlement at the corner of rectangular loaded area at the surface of a semi-infinite medium of a homogeneous and isotropic soil mass

$$S_i = q \cdot B \cdot (1-\mu^2) \frac{I_S}{E}$$

(ii) Semi-empirical methods:

Jambu, Bjerrum and Kjeernsli (1956) have suggest the equation to compute the average immediate settlement under a flexible compressible foundation is saturated undrained clays

$$S_i = \mu_0 \cdot \mu_1 \cdot \frac{q \cdot B}{E_S}$$

Primary Consolidation Settlement (SC)

It occurs in cohesive (or) compressible soil during dissipation of excess pore fluid pressure and it is controlled by the gradual expulsion of fluid from voids in the soil loading to the associated compression of the soil skeletion.

- Primary consolidation settlement is normally insignificant in cohesionless soil and occurs rapidly because these soils have relatively large permeabilities.
- Primary consolidation takes substantial time in cohesive soils because they have relatively low permeabilities.
- Time for consolidation increases with thickness of the soil layer squared and is inversely

related to the co-efficient of permeability of the soil.

 Consolidation settlement are time dependent and take months to years to develop.

 The principal settlement for most projects occurs in 3–10 years.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=AjQ7LWyUkRQ

https://www.youtube.com/watch?v=0M4TIorI1gk

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 344 to 346)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 283 to 285)

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MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT**

Date of Lecture:

Topic of Lecture: Immediate and consolidation settlement

Introduction:

- Immediate settlement (S_i) is the change in shape or distortion of the soil caused by the applied stress.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Cohesive soil
- Cohesionless soil

Detailed content of the Lecture:

Computation of Primary Consolidation Settlement

Primary consolidation settlement determined from results of one-dimensional consolidation tests also includes some immediate settlement.

The equation for primary consolidation settlement of a normally consolidated soil can then be determined to be:

$$S_c = \frac{C_c}{1 + e_o} H \log\left(\frac{\sigma'_{zf}}{\sigma'_{zo}}\right)$$

Where

S_c = Settlement compression index. C_c = Compression index.

e_o = Initial voids ratio. H = Height of the compressible soil.

σ'_{zf} = Final vertical stress. σ'_{zo} = Initial vertical stress.

Secondary Compression Settlement

It is a form of soil creep which is largely controlled by the rate at which the skeleton of compressible soils, particularly clays, soil and peats can yield and compress. Secondary compression is often conveniently identified to follow primary consolidation when excess pore fluid pressure can no larger be measured however both processes may occurs simultaneously.

It occurs under constant effective stress due to continuous rearrangement of clay particles into a more stable configuration and predominates in highly plastic clays and organic clays.

Computation of Secondary Compression Settlement

Assumptions:

Assumptions about the behaviour of fine-grained soils in secondary compression:

(i) Compression index is independent of time (at least during the time span of interest).

(ii) Compression index is independent of the thickness of soil layers.

(iii) The ratio of C/C*c* is approximately constant for many geo-materials over the normal range of engineering stresses.

To determine the magnitude of secondary compression settlement under the final vertical stress

$$S_s = \frac{C_c}{1+e_o} H \log \frac{t}{t_p}$$

Where

C_c = Compression index = $\frac{\Delta e}{\Delta \log t}$.

e_o = Initial void ratio.

H = Height of the compressible soil.

t = Time of interest.

t_p = Time of the end of primary consolidation.

Secondary compression is a continuation of the voulme change that started during primary consolidation only, it usually occurs at a much slower rate.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=RZwglLbNrvI

https://www.youtube.com/watch?v=bOxwR-oEvTY

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 357 to 371)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 283 to 294)

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LECTURE HANDOUTS

CIVIL **II/ IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT**

Date of Lecture:

Topic of Lecture: Computation of rate of settlement

Introduction:

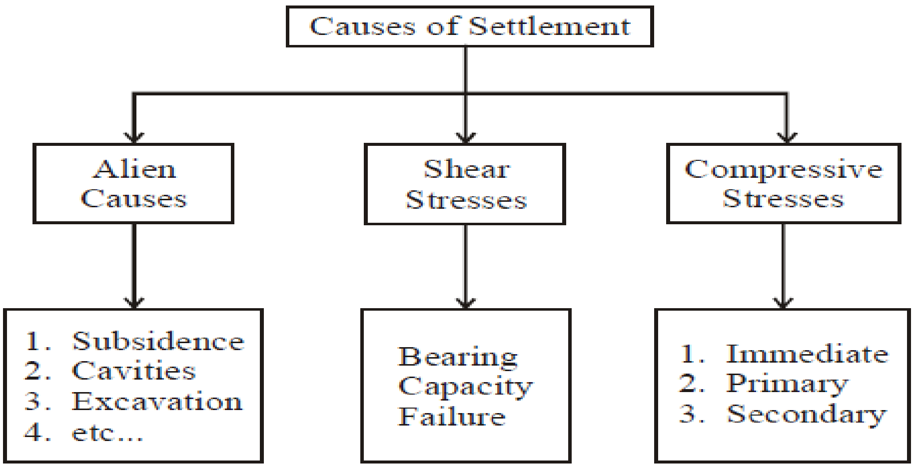
- Primary consolidation settlement determined from results of one-dimensional consolidation tests also includes some immediate settlement.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Compression index
- Vertical stress
- Void ratio

Detailed content of the Lecture:

Causes of Settlement



The settlement of a structure resting on soil may be caused two distinct kinds of action within the foundation soils are:

(i) Settlement Due to Shear Stress (Distortion Settlement).

(ii) Settlement Due to Compressive Stresses (Volumetric Settlement).

(i) Settlement Due to Shear Stress

In the case of applied load causing shearing stresses to develop within the soil-mass, which are greater than the shear strength of the material than the soil fails by sliding downward and laterally and the structure settle and may tip of vertical alignment.

(ii) Settlement Due to Compressive Stress

As a result of the applied load a compressive stress is transmitted to the soil
leading to compressive strain. Due to the compressive strain the structure settles this is important only if the settlement is excessive otherwise it is not dangerous.

Factors Influencing Settlement (or) Consolidation

The factors which affect the consolidation are:

(1) Thickness of Clay Layer,

(2) Number of Drainage Path,

(3) Co-efficient of Permeability,

(4) Co-efficient of Consolidation,

(5) Magnitude of the Consolidation Pressure and the Manner of it's Distribution Across the Thickness of Layer,

(6) Time Factor.

(1) Thickness of Clay Layer

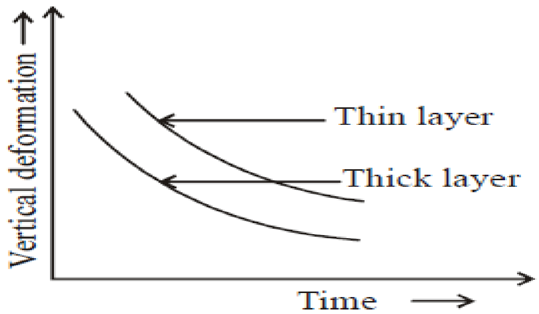
If the thickness is more the consolidation of the layer will be more due to self overburden pressure.

(2) Number of Drainage Paths

The drainage path represents the maximum distance which the water particles have to travel for reaching the free drainage layer. If the drainage path is more than the distance of travel of water particles are reduced proportionality and in turn water will come out of the soil layer causing consolidation. Hence more the drainage path, the more will be the consolidation.

(3) Coefficient of Permeability

If the co-efficient of permeability of the soil is more, water will come out of the soil pores more easily and hence consolidation will be more.



(4) Co-efficient of Consolidation

The co-efficient of consolidation is directly proportional to the degree of consolidation and hence if the co-efficient of consolidation is more the consolidation of soil will be more.

(5) Magnitude of the Consolidation Pressure and it's Distribution

Consolidation of the soil is greatly affected by the consolidation pressure and it's distribution. If the consolidation pressure is more and it is uniformly distributed over the area, the consolidation will be more.

(6) Time Factor:

From the equation of consolidation i.e., $T_v = \frac{C_v \cdot t}{d^2}$ clear that the co-efficient of consolidation (C_v) is directly porportional to the time factor (T_v). If the time factor is more consolidation will be more.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=YJNTlY98pJM

https://www.youtube.com/watch?v=0M4TIorI1gk

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 357 to 362)
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LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT**

Date of Lecture:

Topic of Lecture: √t and log t methods

Introduction:

- In the natural process of deposition, fine-grained soils, like silt and clay undergo the process of consolidation under their own weight of overburden pressure. A state of equilibrium is reached after an elapse of several years and the compression cases.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Consolidated Clay
- Over-Consolidated Clay

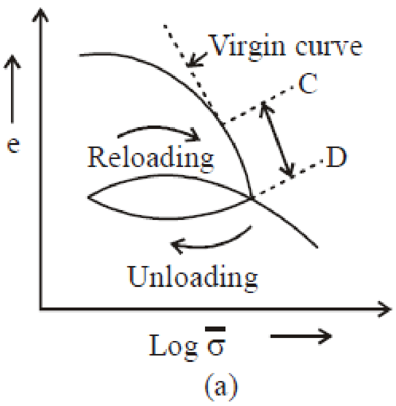
Detailed content of the Lecture:

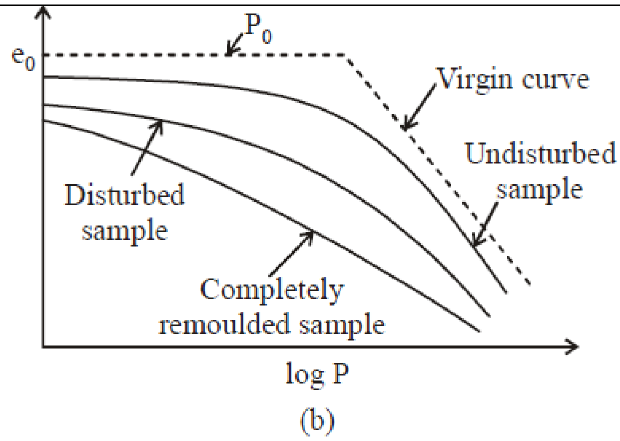
This process continues, season after season, and sometimes erosion or removal of overburden takes place, and sometimes the process of consolidation may continuously take place due to frequent deposition so it is evident that clay soil deposits exist in the field under different conditions and their stress history should be known.

(i) Normally Consolidated Clay (N-C Clays)

If the present effective overburden pressure in the deposit is the maximum pressure to which the deposit has ever been consolidated clay deposit. There is no reliable procedure available to predict the in-situ effective stress void ratio relationship.

A fluid *e*-P relationship has to be obtained from a carefully obtained undisturbed soil sample. Whatever the case with which the sampling operation is performed, there is bound to be some disturbance due to stress removal.





(ii) Over-Consolidated Clay (O-C clays)

A clay soil deposit that has been fully consolidated under a pressure P*c* in the past, larger than the present overburden pressure P*o*, is called an over-consolidated (Pre-consolidated or Pre-compressed) clay deposit. The ratio (P*c* – P*o*)/P*o* is called the over-consolidation ratio (OCR).

Over-Consolidation of clay may be caused by any or a combination of the following loads:

(i) Pressure due to overburden which have been removed.

(ii) Glacial ice sheets have since disappeared.

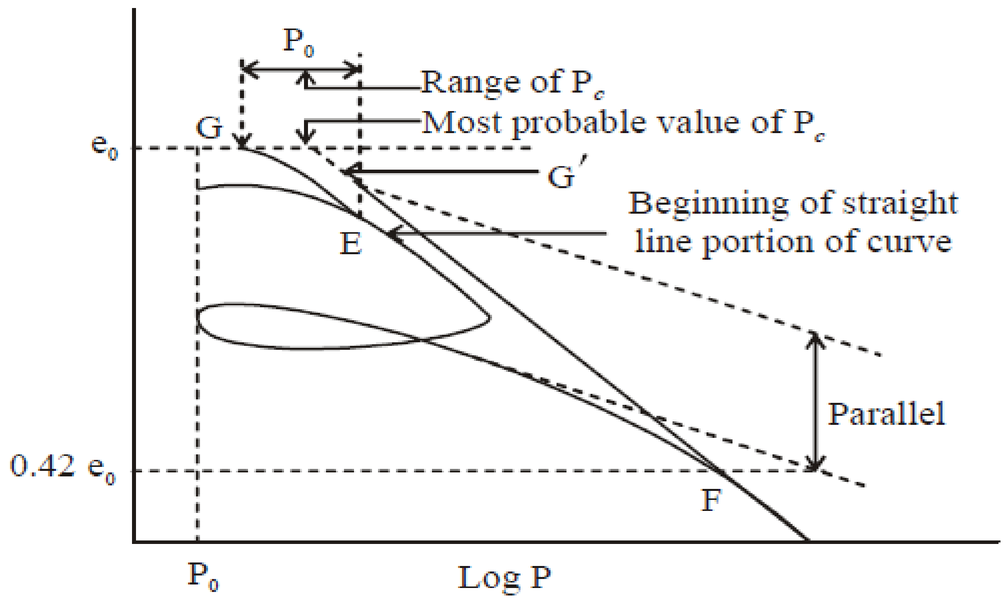
(iii) Sustained seepage forces.

(iv) Tectonic forces caused due to movements in earth's crush.

(v) Fluctuation of water table.

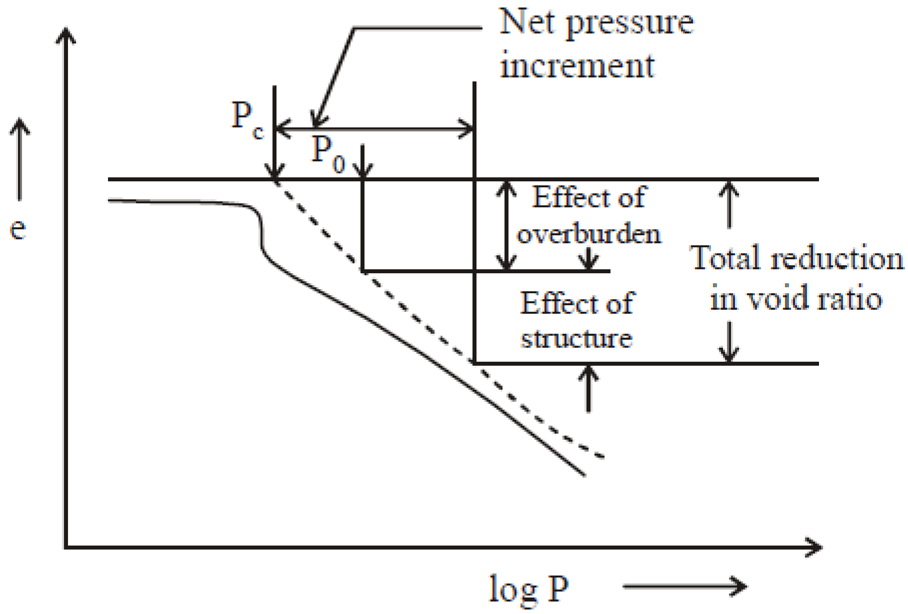
The in situ *e*-P relationship is radically changed by over-consolidation.

The in situ e-log P curve is obtained following the procedure given below



(iii) Under-Consolidated Clay (U-C clays)

Rapid natural deposition or deposits under recent fillings may not be fully consolidated under the present overburden pressure; such clay deposit is called Under- Consolidated Clay



Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=JdIwXPsEchY https://www.youtube.com/watch?v=ck2bgPilMMg
Important Books / Journals for further learning including the page nos.: 1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 355 to 371) 2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 283 to 294)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **III - EFFECTIVE STRESS DISTRIBUTION DUE TO APPLIED LOADS AND SETTLEMENT**

Date of Lecture:

Topic of Lecture: Factors influencing consolidation behavior of soils

Introduction:

- The laboratory consolidation test is conducted with an apparatus known as "Consolidometer"
- Loading frame and consolidation cell in which the specimen is kept.
- Porous stones are put on the top and bottom ends of the specimen.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Consolidation
- Voids Ratio
- Settlement

Detailed content of the Lecture:

Factors Influencing Settlement (or) Consolidation

The factors which affect the consolidation are:

(1) Thickness of Clay Layer,

(2) Number of Drainage Path,

(3) Co-efficient of Permeability,

(4) Co-efficient of Consolidation,

(5) Magnitude of the Consolidation Pressure and the Manner of it's Distribution Across the Thickness of Layer,

(6) Time Factor.

LABORATORY CONSOLIDATION TEST

The laboratory consolidation test is conducted with an apparatus known as "Consolidometer". It consists of:

(i) Loading frame and consolidation cell in which the specimen is kept.

(ii) Porous stones are put on the top and bottom ends of the specimen.

(iii) Ring cells.

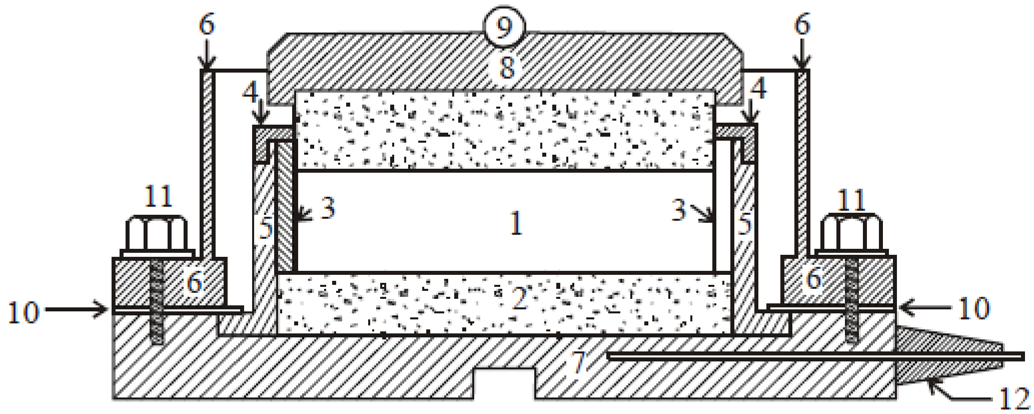
(a) Fixed ring cell.

(b) Floating ring cell.

(iv) Loading machine.

(v) Dial gauge.

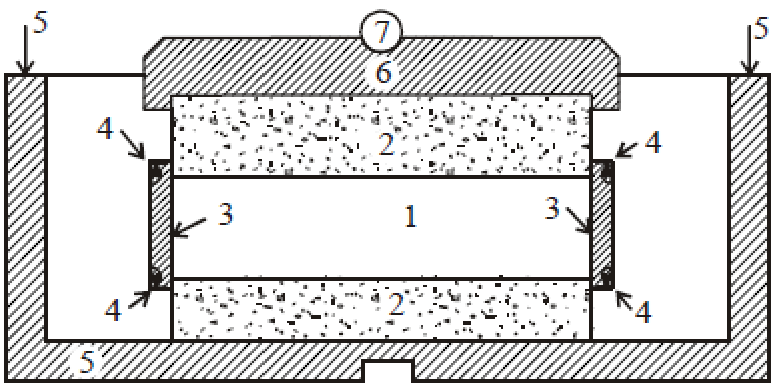
(a) Fixed ring cell:



1.	Soil specimen	2.	Porous stones	3.	Specimen ring
4.	Guide ring	5.	Outer ring	6.	Water jacket
7.	Base	8.	Pressure pad	9.	Pressure ball
10.	Rubber gasket	11.	Bolts	12.	Drain tube

(b) Floating ring cell:

In the floating ring cell, both top and bottom stones are free to compress the specimen the middle. However, the floating ring cell has the advantage of having smaller effects of friction between the specimen ring and the soil specimen.



1. Soil specimen
2. Porous stones
3. Specimen ring
4. Guide rings
5. Water jacket
6. Pressure pad
7. Pressure ball

(iv) Loading machine:

- The loading machine is usually capable of applying steady vertical pressure upto 800 or 1000 kN/m2 (kpa) to the soil specimen.

- During the test, the specimen is allowed to consolidate under a number of increments of vertical pressure such as 10, 20, 50, 100, 200, 400, 800, 1000 N/m^2 (kPa).

 Each pressure increment is maintained constant until the compression virtually cases, generally 24 hours.

(v) Dial gauge:

 The vertical compression of the specimen is measured by means of a dial gauge.

 Dial gauge readings are taken after the application of each pressure increment at the following total elapsed times : 0.25, 1.00, 2.25, 4.00, 6.25, 9.00, 12.25, 20.25, 25, 36, 49, 60 minutes and 2, 4, 8 and 24 hours.

 The dial gauge readings showing the final compression under each pressure increment are also recorded. After the completion of consolidation under the desired maximum vertical pressure, the specimen is unloaded and allowed to swell. The final reading corresponding to the completion of swelling is recorded and the specimen is taken out and dried to determine its water content and the weight of soil solids.

Use of Consolidation Test Data

The consolidation test data are used to determine the following:

1. Calculation of voids ratio,
2. Calculation of co-efficient of volume change,
3. Calculation of co-efficient of consolidation,
4. Calculation of co-efficient of permeability

Video Content / Details of website for further learning (if any):

youtube.com/watch?v=9XdU3AAQ014

https://www.youtube.com/watch?v=b-gKiMQFP3Q

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 414 to 417)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 283 to 322)

Course Teacher

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Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Shear strength of cohesive soils

Introduction:

- Shear strength of soil is one of the three engineering properties of soil, the other two being permeability and compressibility. Knowledge of shear strength is required in all engineering problems involving stability analysis such as in the design
- Shear strength of a soil may be defined as resistances deformation by shear stresses.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Stability
- Durability
- Shear Strength

Detailed content of the Lecture:

Shear strength of soil is one of the three engineering properties of soil, the other two being permeability and compressibility.

- Foundations of structures,
- Retaining walls,
- Stability of earth slopes, etc.

Development of Shear Strength

(i) The frictional resistance between the particles at their points of contact (combination of sliding friction and rolling friction).

(ii) The structural resistance to displacement because of interlocking of particles and cementation or adhesion between particles.

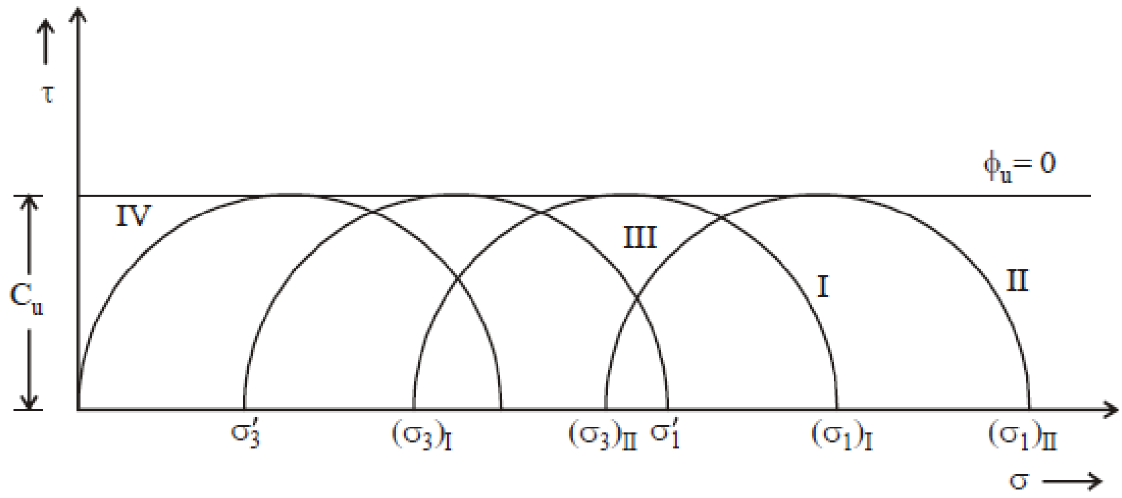
(iii) Cohesion (or) force of altraction between particles.

SHEAR STRENGTH OF COHESIVE SOILS (CLAYS)

(a) For Fully Saturated Clays:

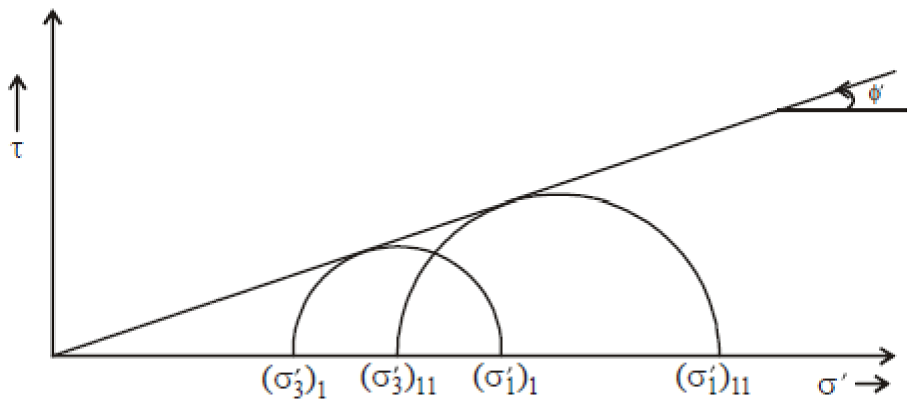
(i) Unconsolidated-Undrained Test (UU Test)

Drainage is not permitted throughout the test. In the case of direct shear test drainage is not permitted during the application of both normal stress and shear stress. When undrained tests are conducted on identical specimens of a fully saturated clay with different cell pressures, the Mohr's circles obtained will all be of same diameter



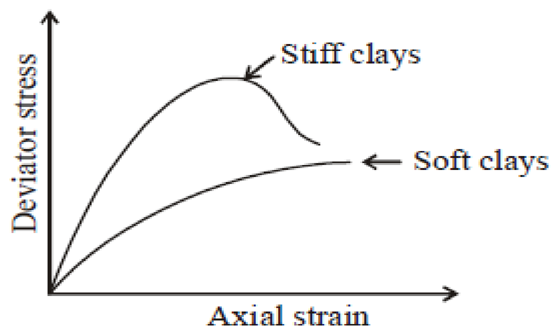
(ii) Consolidated-Undrained Test (CU Test):

In this type of shear test, the soil specimen is allowed to consolidate fully under initially applied stress and then sheared quickly without allowing dissipation of pore pressure.



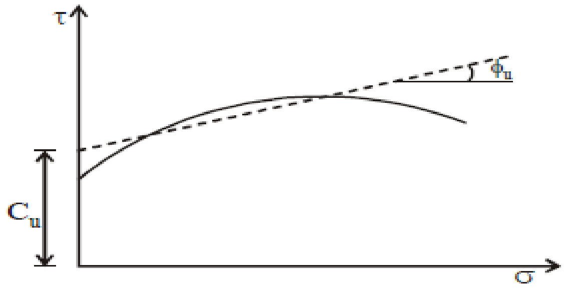
(iii) Consolidated Drained Test (CO Tests):

In this type of test, the drainage is allowed throughout test. The specimen is allowed to consolidate fully under the applied initial stress and then sheared at low rate of strain giving sufficient time for the pore water to drain out at all stages



(b) For Partially Saturated Clays and Composite Soils

The failure envelopes obtained by conducting shear tests on partially saturated clays and composite soils will be curved



Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=s5BX0mJFAus

https://www.youtube.com/watch?v=Bgso4L3ekr4

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 427 to 430)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 329 to 330)

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LECTURE HANDOUTS

CIVIL | **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Shear strength of cohesionless soils

Introduction:

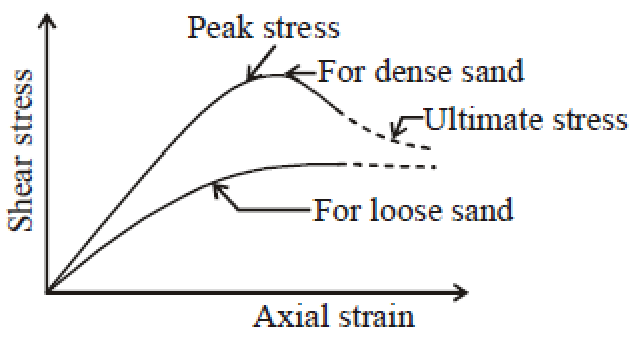
- The stress-strain and volume change characteristics is helpful for proper understanding of shear strength of cohesionless soils such as granular soils and non-plastic silts.
- The stress-strain relation for cohesionless soils. Can be easily obtained from direct shear test under drained conditions on saturation (or) dry specimen.

Prerequisite knowledge for Complete understanding and learning of Topic:

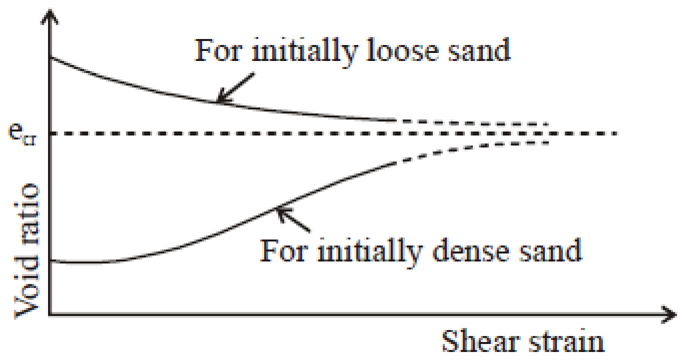
- Cohesionless Soil
- Axial Strain
- Shear Stress

Detailed content of the Lecture:

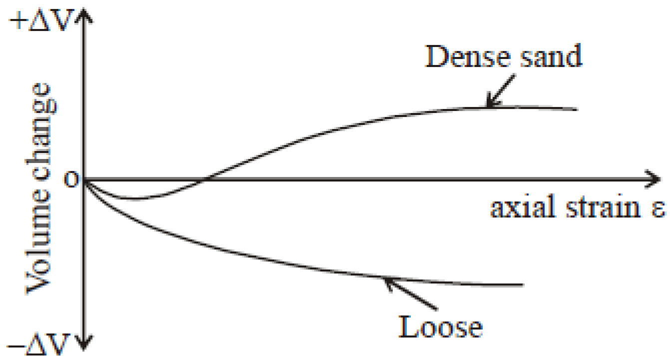
The stress-strain and volume change characteristics is helpful for proper understanding of shear strength of cohesionless soils such as granular soils and non-plastic silts.



The volume change characteristics during the shear test is best understood by examining change in void ratio with increasing strain. The void ratio is plotted against shear strain for both loose sand and dense sand

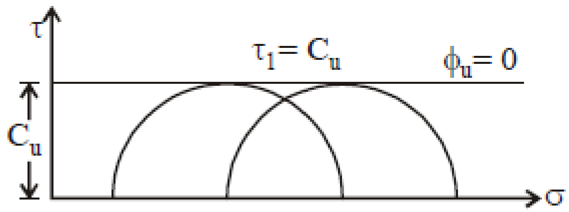


It is clear that dense sand expands and loose sand gets compressed during shear. At high strains the curves tend to approach each other. At sufficiently high strains both dense sand and loose sand may be through of as attaining the same void ratio at which there will be no further change in volume with increase in shear strain.



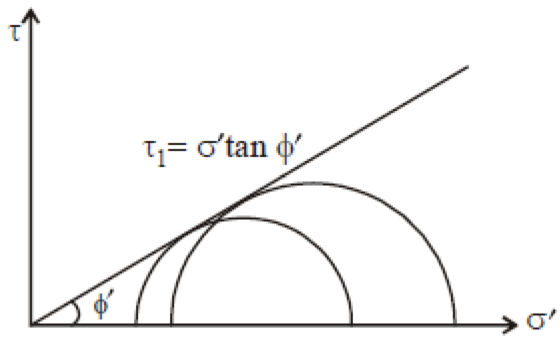
(i) Undrained Strength of Saturated Sands

In undrained triaxial tests are conducted on saturated sand specimens and volume remains essentiallyconstant.



(ii) Drained Strength of Saturated Sand

The drained shear strength of cohesionless soils



If drained tests are conducted on saturated sand specimens initially at the same density index. The failure envelope will be approximately a straight line passing through the origin of stresses with effective stresses being equal to the total stresses (C□ = 0).

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=5_2cF1SakeI

https://www.youtube.com/watch?v=bmpn5oNDvOs

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 427 to 430)
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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Mohr – Coulomb failure - assumptions

Introduction:

- This theory was first proposed by Coulomb (1776) and later generalized by Mohr.

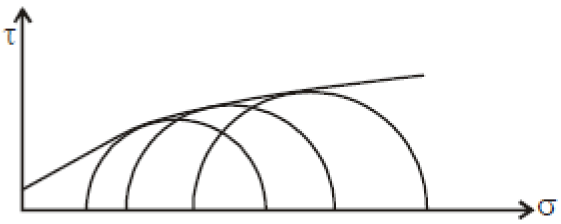
Prerequisite knowledge for Complete understanding and learning of Topic:

- Shear Stress
- Effective Stress
- Strength

Detailed content of the Lecture:

Mohr strength envelope:

If we plot shear stress at failure as orginate against normal stress as abscissa we obtain a curve called the Strength Envelope. The shear strength envelope will be tangential to any Mohr circle at failure



It can be represented by the equation

$$\tau_f = F(\sigma)$$

Coulomb Strength Envelope

Coulomb assumed the relation between □ *f* and □ to be linear and gave the following equation popularly known as coulomb equation

$$\tau_f = C + \sigma \tan\phi$$

Where;

C = Cohesion.

$\tan\phi$ = Slope of the strength envelop.

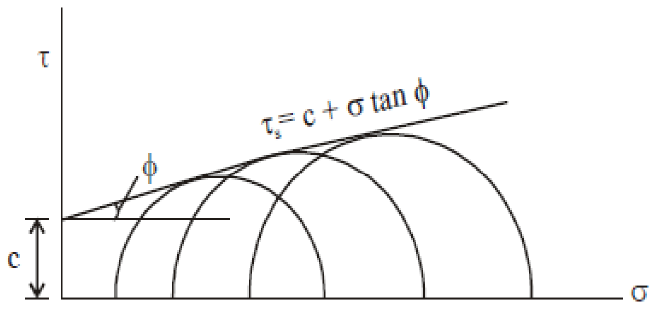
ϕ = Angle of internal friction.

C and ϕ are shear strength parameters and are variable for any soil depending on conditions of testing such as:

(a) Drainage conditions.

(b) Rate of strain.

The Coulomb failure (strength) envelope as shown in Fig.4.16.

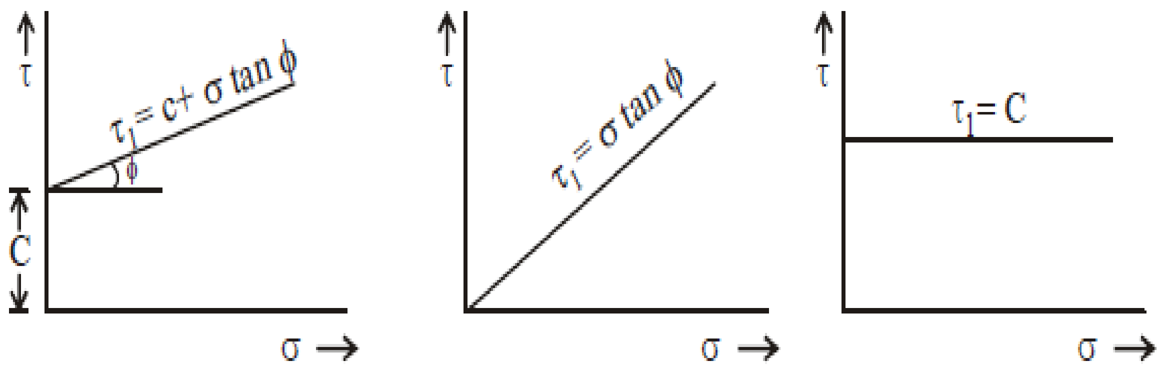


Based on values of shear strength parameters, soils can be described as

(i) Cohesive soil,

(ii) Cohesionless soil,

(iii) Purely cohesive soil.



Case $(i) c-\phi$ soil   Case $(ii) c-0$ Case $(iii)\ \phi = 0$

Terzaghi's Effective Stress Principle

According to Terzaghi, the shear strength of soil in the case of saturated soil is a function of effective normal stress on the potential failures.

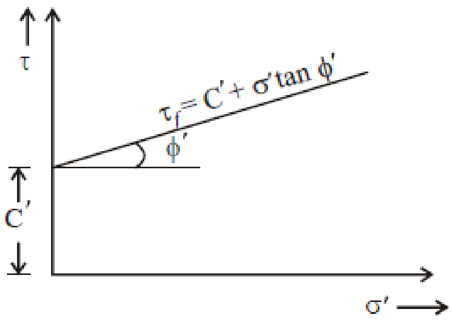


Figure 4.18 Effective strength parameters

The mohr strength envelope can be represented by the following equation:-

$$\tau_f = C' + \sigma' \tan \phi'$$

Where;

$\sigma' = (\sigma - u)$,

C' = Effecting cohesion,

ϕ' = Effecting angle of shearing resistance while C' and ϕ' are referred to as effective shear strength parameters.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=HUY8I6v6Ztk

https://www.youtube.com/watch?v=F8B6ll1j1aQ

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 430 to 432)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 339 to 341)

Course Teacher

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Measurement of shear strength

Introduction:

- Shear strength of soil is one of the three engineering properties of soil, the other two being permeability and compressibility.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Direct Shear Test
- Compression Test
- Torsion Test

Detailed content of the Lecture:

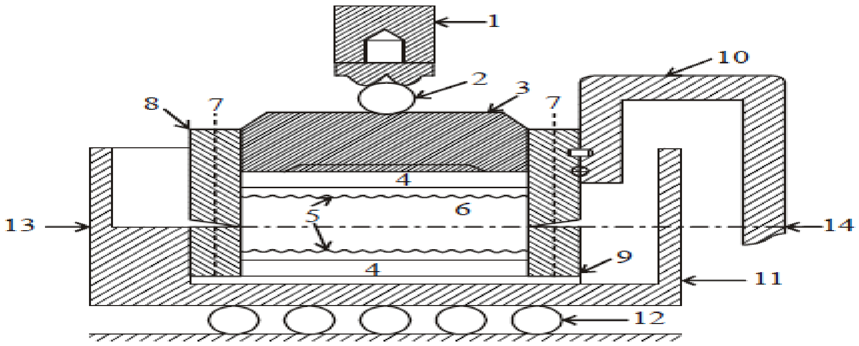
Direct Shear Test

The soil specimen used in the test is usually square in plan of size 60 mm × 60 mm and thickness about 20–25 mm. The direct shear test equipment estentially consists of:

(i) Shear box,

(ii) Loading yoke,

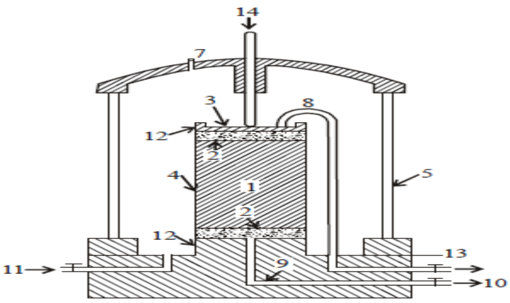
(iii) Geared jack.



1. Loading yoke
2. Steel ball
3. Loading pad
4. Porous stone
5. Metal grids
6. Soil specimen
7. Pins to fix two halves of shear box
8. Upper part of shear box
9. Lower part of shear box
10. U-arm
11. Container for shear box
12. Roller
13. Shear force (applied by jack)
14. Shear resistance (measure by proving dial gauge)

Triaxial Compression Test

It was first introduced in U.S.A by casagrande and Karl Terzaghi in 1936–1937. In the common solid cylindrical specimen test, the major principal stress σ_1 is applied in the vertical direction and the other two principal stresses σ_2 and σ_3 $(\sigma_2 = \sigma_3)$ are applied in the horizontal directions by the fluid pressure around the specimen.



1. Soil specimen
2. Porous disc
3. Top cap
4. Rubber membrane
5. Perspex cylinder
6. Loading ram
7. Air release value
9. Bottom drainage tube
10. Connections for drainage or pore pressure measurement
11. Cell fluid inlet
12. Rubber rings
13. Sealing ring
14. Axial load through

Unconfined Compression Test (UC Test)

The unconfined compression test (also designated as UC-test) is a special case of the triaxial compression test in which the soil sample is not confined laterally and the confining pressure is zero and hence this test is known as "Unconfined Compression Test".

Vane Shear Test

- The vane shear test is a quick test used either in the laboratory or in the field,

to determine the undrained shear strength of cohesive soils.

- However, the laboratory vane shear test apparatus is usually smaller in size as

compared to the field shear test apparatus.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=enqGoJMXQkk

https://www.youtube.com/watch?v=bmpn5oNDvOs

Important Books / Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 433 to 434)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 347 to 362)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Direct shear test

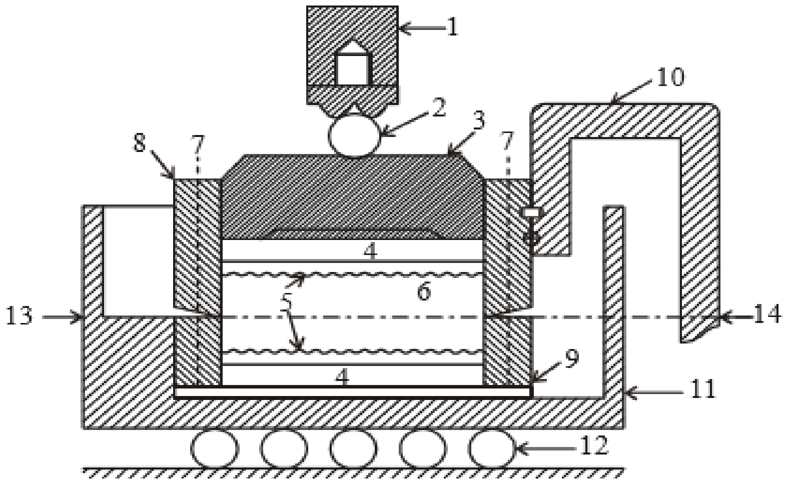
Introduction:

- Shear strength of soil is one of the three engineering properties of soil, the other two being permeability and compressibility.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Cohesive soils
- Non-cohesive soils
- Consolidated-undrained test
- Consolidated-drained test.

Direct shear test:

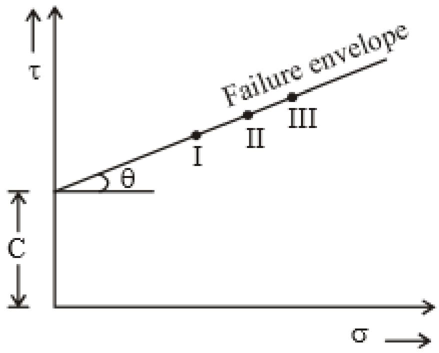


1. Loading yoke
2. Steel ball
3. Loading pad
4. Porous stone
5. Metal grids
6. Soil specimen
7. Pins to fix two halves of shear box
8. Upper part of shear box
9. Lower part of shear box
10. U-arm
11. Container for shear box
12. Roller
13. Shear force (applied by jack)
14. Shear resistance (measure by proving dial gauge)

Shear box with accessories

Principles:

- The soil specimen is placed in the shear box such that it gets sheared on a horizontal plane exactly at its mid-height.
- The specimen is sandwiched between a pair of metal grid plates and a pair of porous plates or porous plates.
- The grid plates provided with serrations are placed with serrations at right angles to direction of shearing to provide grip on the specimen.
- For conducting drained test perforated grid plates and porous stones are used.
- Because the matter in these states is constantly changing and interacting through chemical and physical processes, soil is a very dynamic layer.
- The shear stress is gradually increased until the specimen fails and there will be no transmission of shear force from lower half to top half of shear box.
- If test continues beyond 20% strain it is usuals to stop the test and define failure point corresponding to any desired level of strain upto 20%.



Plot of failure envelope

Preparation of specimen:

(a) For undisturbed specimen:

- The undisturbed specimen is prepared by pushing a cutting ring of size 10 cm in diameter and 2 cm in height in the undisturbed soil sample obtained from field.
- The square specimen of size 6 cm × 6 cm is then cut from the circular specimen so obtained.

(b) For remoulded specimen of cohesive soils:

- In order to obtain remoulded specimen of cohesive soil, the soil may be compacted to the required density and water content in a separate bigger mould.
- The sample is then extracted and trimmed to the required size.

(c) For non-cohesive soils:

- Non-cohesive soils may be tamped in the shear box it self with the base plate and grid plate or porous stone as required in place at the bottom of the box.
- In all the three cases, the water content and dry density of the soil compacted in the shear box should be determined.

Test procedures:

The shear box test should be done by the following three conditions of drainage:

- Undrained test
- Consolidated-Undrained Test
- Consolidated-drained test.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=bmpn5oNDvOs

https://www.youtube.com/watch?v=Bgso4L3ekr4

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 434 to 436)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 374 to 377)

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MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Triaxial compression test

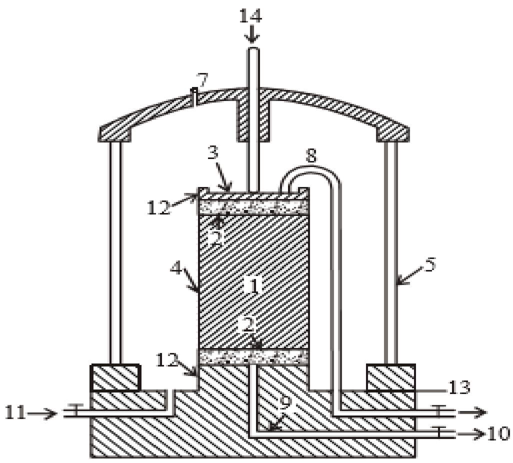
Introduction:

- It was first introduced in U.S.A by casagrande and Karl Terzaghi in 1936–1937.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Bishop's Pore pressure.
- Modified failure envelope.

Triaxial compression test:



1. Soil specimen
2. Porous disc
3. Top cap
4. Rubber membrane
5. Perspex cylinder
6. Loading ram
7. Air release value
9. Bottom drainage tube
10. Connections for drainage or pore pressure measurement
11. Cell fluid inlet
12. Rubber rings
13. Sealing ring
14. Axial load through

The triaxial cell

The test equipment essentially consists of:

- A high pressure cylindrical cell, made of Perspex or other transparent material fitted between the base and the top cap.
- There outlet connections are generally provided through the base

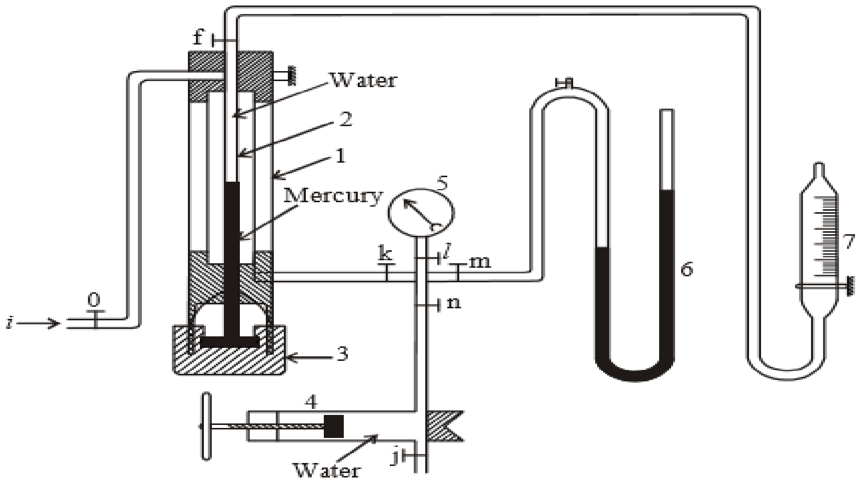
(i) Cell fluid inlet,

(ii) Pore water outlet from the bottom of the specimen,

(iii) Drainage outlet from the top of the specimen.

- A separate compressor is used to apply fluid pressure in the cell.
- Pore pressure developed in the specimen during the test can be measured with the help of a separate pore pressure measuring equipment such as Bishop's apparatus.
- The cylindrical specimen is enclosed in a rubber membrane.
- A stainless steel piston running through the centre of the top cap applies the vertical compressive load on the specimen under test.
- The load is applied through a proving ring, with the help of a mechanically operated load frame.

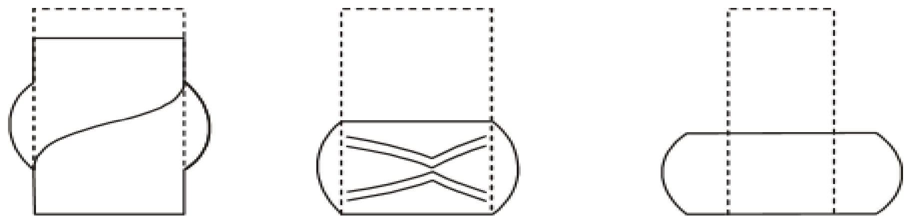
Measurement of pore pressure during test:



Bishop's pore pressure measuring apparatas

Types of failure of soil specimens in the triaxial compression test:

Depending upon the soil type and it's physical properties of a soil specimen can exhibit one of the three failure patterns as follows:



Failure patterns

(a) Brittle failure:

- Well-defined failure plane,
- Little lateral bulging.

(b) Semi-plastic failure:

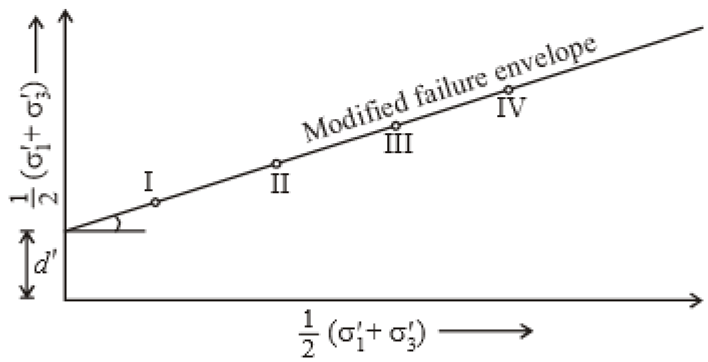
- Shear cones,
- Some lateral bulging.

(c) Plastic failure:

- Absence of failure plane,
- Excessive lateral bulging.

Modified failure envelope:

The modified procedure was introduced by Lambe and Whitman (1969) and provides a means for average scattered data when tests are conducted on a large number of samples with wide range of cell pressures as shown in Fig.4.29.



Modified failure envelope

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=KecOIID4kJg

https://www.youtube.com/watch?v=hq4UlLm8oIs

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 436 to 442)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 335 to 339)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: UCC and Vane shear tests

Introduction:

- The unconfined compression test (also designated as UC-test) is a special case of the triaxial compression test in which the soil sample is not confined laterally and the confining pressure is zero and hence this test is known as "Unconfined Compression Test".
- The vane shear test is a quick test used either in the laboratory or in the field, to determine the undrained shear strength of cohesive soils.

Prerequisite knowledge for Complete understanding and learning of Topic:

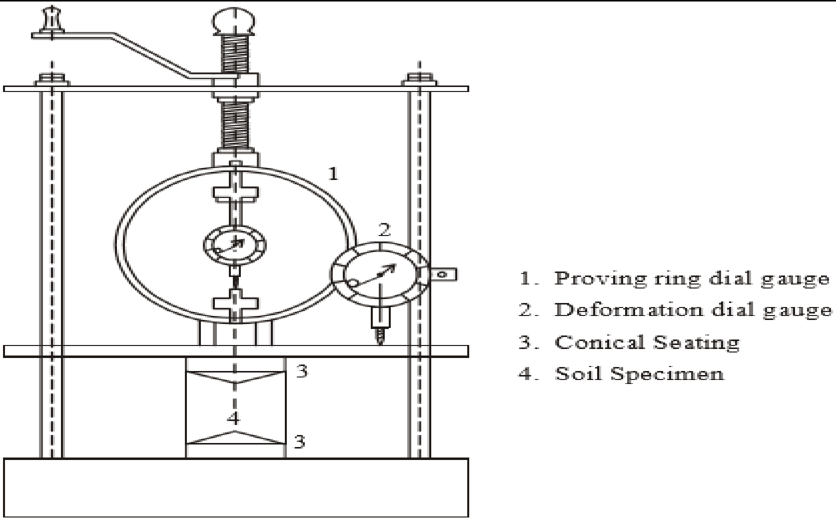
- Axial compressive force
- Shear strength
- Vane shear test.

Detailed content of the Lecture:

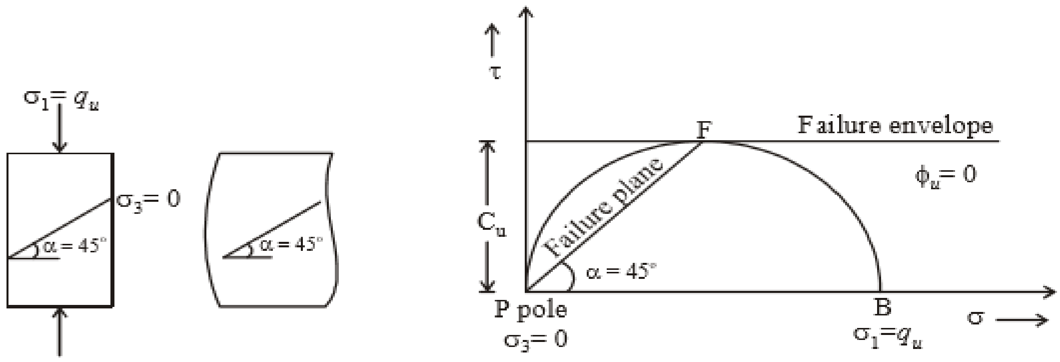
Unconfined Compression Test (UC Test):

The unconfined compression test is a quick test in which no drainage is allowed. The test is conducted on saturated clay and volume change is assumed to be zero.

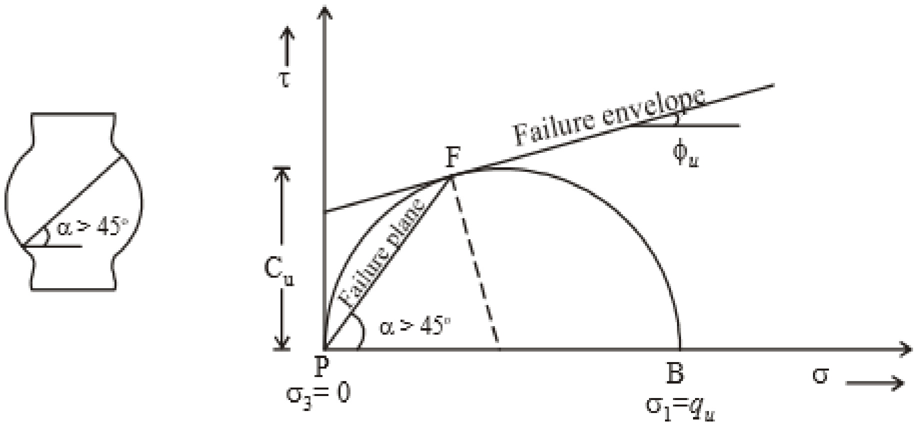
The undrained shear strength parameters obtained are denoted by C_u and ϕ_u. The test results are acceptable for soils having no friction or little friction. The angle α which the failure plane makes with the horizontal is measured after carefully sketching the failed specimen the failure envelopes for the two cases are shown in



Unconfined compression test apparatus



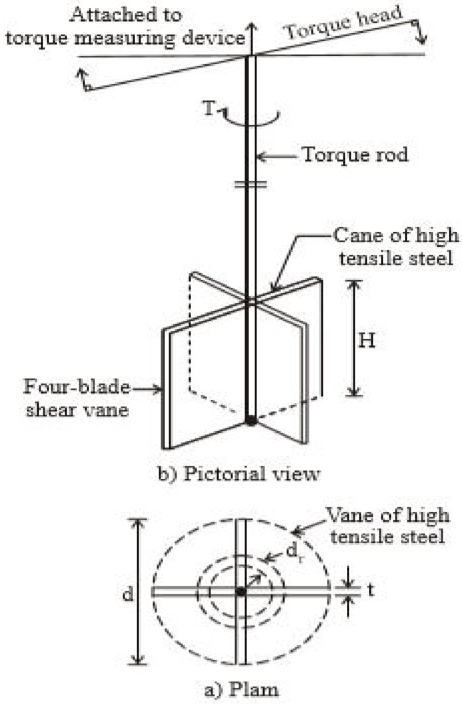
Unconfined compression test (ϕ_u = 0 soil)



Unconfined compression test (C – ϕ soil)

Vane Shear Test:

- The vane shear test is a quick test used either in the laboratory or in the field,to determine the undrained shear strength of cohesive soils.
- However, the laboratory vane shear test apparatus is usually smaller in size ascompared to the field shear test apparatus.



Vane shear test apparatus

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=M4TNKwuSnAk

https://www.youtube.com/watch?v=zJ-_NZnTd2U

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 442 to 452)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 374 to 380)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Pore pressure parameters

Introduction:

- A pore pressure parameters have been proposed by prof A.W. Skempton (1954) and it is defined as a dimensionless number that indicates the fraction of total stress increment that showup an excess pore pressure for the condition of no drainage.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Pore pressure
- Stress-strain curve
- Cell pressure

Detailed content of the Lecture:

SKEMPTON'S PORE PRESSURE PARAMETERS:

$$\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$$

Where A and B are called skempton's pore pressure parameters.

Determination of Parameters A and B

The parameter is experimentally determined in the laboratory by measuring the change in the pore pressure Δu_1 during the first stage of the test when the cell pressure is applied and change in the pore pressure Δu_2 when deviator stress is applied.

Then $\Delta u = \Delta u_1 + \Delta u_2$

Comparing Eqn.(3) and (4), we get

$$\Delta u_1 = B\Delta\sigma_3$$

$$\therefore \quad \boxed{B = \frac{\Delta u_1}{\Delta\sigma_3}} \quad \text{or} \quad \boxed{B = \frac{1}{1 + \frac{n \cdot C_v}{C_c}}}$$

and $\Delta u_2 = A \cdot B \cdot (\Delta\sigma_1 - \Delta\sigma_3) = \bar{A}(\Delta\sigma_1 - \Delta\sigma_3)$

$$\therefore \quad \bar{A} = A \cdot B = \frac{\Delta u_2}{\Delta\sigma_1 - \Delta\sigma_3}$$

Knowing B and $\bar{A}$, A direct way to determine A is from the equation:

$$\boxed{A = \frac{\Delta u - \Delta\sigma_3}{\Delta\sigma_1 - \Delta\sigma_3}}$$

For the usual undrained triaxial test,

$\Delta\sigma_3 = U$, when the deviator stress is applied

$$\therefore \quad \boxed{A = \frac{\Delta u}{\Delta\sigma_1}}$$

Factors Affecting A and B

(a) Fully saturated soil:

- In a fully saturated soil, the compressibility of water above(C_v) is very uch smaller than C_c.
- Then ratio is approximately zero.

$$\frac{C_v}{C_c}$$

Hence $\boxed{B = 1}$

(b) Dry soil:

✓ If the soil is perfectly dry $\frac{C_v}{C_c}$ approaches infinity, since compressibility of air is far greater than that of solids.

Hence $\boxed{B = 0}$

(c) Partially saturated soil:

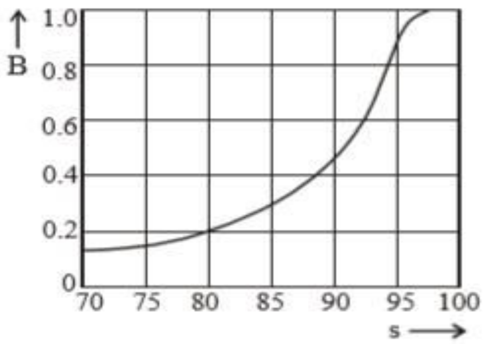
$$O < B < 1$$

At proctor's optimum water content and density, the values of B range typically from about 0.1 to 0.5. The variation of B with the degree of saturation

It's value also depends upon whether the total stresses are increasing or decreasing preconsolidation of test specimen tends to reduce considerably the parameter A.

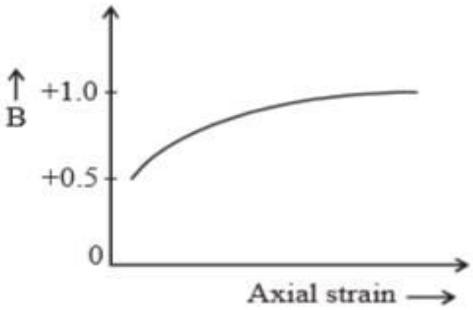
The other factors affecting the parameters A are:

- Type of shear,
- Sample disturbance,
- Environment during shear (such as temperature and nature of the fluid).



Variation of B with degree of saturation

For any given soil, the co-efficient A varies with the stresses and strain as shown



Stress-strain curve

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=RFdriAskimY

https://www.youtube.com/watch?v=WSgbNdQxBJE

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 372 to 374)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **IV - SHEAR STRENGTH**

Date of Lecture:

Topic of Lecture: Liquefaction

Introduction:

- Liquefaction takes place when loosely packed, water-logged sediments at or near the ground surface lose their strength in response to strong ground shaking. Liquefaction occurring beneath buildings and other structures can cause major damage during earthquakes.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Weathering or denudation of rocks.
- Transportation and deposition of rocks.

Detailed content of the Lecture:

Soil liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. Liquefaction and related phenomena have been responsible for tremendous amounts of damage in historical earthquakes around the world.

Liquefaction occurs in saturated soils, that is, soils in which the space between individual particles is completely filled with water. Prior to an earthquake, the water pressure is relatively low--the weight of the buried soil rests on the framework of grain contacts that comprise it. However, earthquake shaking can disrupt the structure, the soil particles no longer support all the weight, and the groundwater pressure begins to rise. The soil particles can move farther, and become entrained in the water--the soil flows. Liquefied soil will force open ground cracks in order to escape to the surface. The ejected material often results in flooding and may leave cavities in the soil.

Whether and where liquefaction will take place depends on many factors. These include the degree of saturation, the grain size distribution and consistency at a site, the strength, duration, and frequency content of the shaking and even the grain shape and depth of soil. There is much active research into the mechanisms of liquefaction, because its effects can be so severe yet its process remains imperfectly understood.

The following movies are of flooding and sandblows from the February 2011 Christchurch NZ, 6.3 earthquake:

The consequences to structures and utilities of earthquake-induced liquefaction include:

1) Non-uniform and differential settlement of structures often resulting in cracking.

2) Loss of bearing support

3) Flotation of buried structures such as sewer lines, tanks, and pipes.

4) Strong lateral forces against retaining structures such as seawalls.

5) Lateral spreading (limited lateral movement)

6) Lateral flows (extensive lateral movement)

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=9fPPLGXueCs

https://www.youtube.com/watch?v=lKpCX1LOOsI

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 354 to 355)

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CIVIL

II/IV

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture: Slope failure mechanisms

Introduction:

- An exposed ground surface that stands at an angle with the horizontal is called "Slope". Slopes are required in the construction of highway and railway embankments, earth dams, levees, and canals.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Intense rainfall.
- Slopes.
- Slope failure.

Detailed content of the Lecture:

Introduction:

An exposed ground surface that stands at an angle with the horizontal is called "Slope". Slopes are required in the construction of highway and railway embankments, earth dams, levees, and canals. Soil has four important functions:

SLOPE FAILURE TRIGGERING MECHANISMS:

The following are the slope failure triggering mechanisms:

- Intense rainfall,
- Water-level change,
- Seepage water flow,
- Volcanic eruption,
- Earthquake shaking,
- Human activity.

FACTORS AFFECTING THE STABILITY OF SLOPE:

The factors loading to instability can generally be classified as

(a) These causing increased stress,

(b) These causing a reduction in strength.

(a) These Causing Increased Stress The factors causing increased stress include:

- Increased unit weight of soil by wetting,
- Added external loads (moving loads, buildings, etc.),
- Steepened slopes either by excavation or by erosion,
- Shock load.

(b) These Causing a Reduction in Strength: The loss of strength may occur by;

- Vibration and earthquake,
- Increase in moisture content,
- Freezing and thawing action,
- Increase in pore pressure,
- Loss of cementing pressure.

CAUSES OF SLOPE FAILURE:

The various causes includes:-

(i) Erosion,

(ii) Steady seepage,

(iii) Sudden drawdown,

(iv) Rainfall,

(v) Earthquakes,

(vi) External loading,

(vii) Construction activities at the toe of the slope.

(i) Erosion:

The wind and flowing water causes erosion of top surface of slope and makes the slope steep and thereby increase the tangential component of driving force.

(ii) Steady seepage:

Seepage forces in the sloping direction add to gravity forces and make the slope susceptible to instability. The pore water pressure decrease the shear strength. This condition is critical for the downstream slope.

(iii) Sudden drawdown:

In this case there is reversal in the direction flow and results in instability of side slope. Due to sudden drawdown the shear stresses are more due to saturated unit weight while the shearing resistance decreased due to pore water pressure that does not dissipate quickly.

(iv) Rain fall:

Long period rain falls saturate, soften and erode soils. Water enters into existing cracks and may weaken underlying soil layers, leading to failure. Example:

- Mud slides.

(v) Earthquakes:

Earthquakes induce dynamic shear force in addition there is sudden buildup of pore water pressure that reduces available shear strength.

(vi) External loadings:

Additional loads placed on top of the slope increases the gravitational forces that may cause the slope to fail.

(vii) Construction activities at the toe of slope

Excavation at the bottom of the sloping surface will make the slopes steep and thereby increase the gravitational forces which may result in slope failure.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=oltBMly3ho0

https://www.youtube.com/watch?v=s87MHDA5evM

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 389 to 390)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture: Types of slopes

Introduction:

- An exposed ground surface that stands at an angle with the horizontal is called "Slope". Slopes are required in the construction of highway and railway embankments, earth dams, levees, and canals.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Natural slope
- Man-made slopes
- Extent

TYPES OF SLOPES:

(a) According to Basis Method of Construction Slopes can be:

(i) Natural slopes,

(ii) Man-made slopes.

(i) Natural slopes:

The slopes formed due to natural process and exist naturally are called Natural slopes. Natural slopes are those that exist in nature and are formed by natural causes.

Example:

- Slopes due to landslides

(ii) Man-made slopes:

The slopes formed by unnatural process. Artificial slopes are formed by humans as per requirements. **Examples:**

- Highway embankment,
- Railway embankment,
- River training works.

(b) According to Extent:

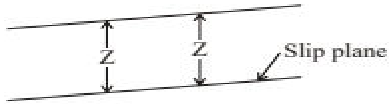
They are divided into two types:-

i) Infinite slopes

ii) Finite slopes

(i) Infinite slopes:

The slope extending infinitely or upto an extent whose boundaries are not well defined. For this type of slope the soil properties for all identical depths below the surface are same. So that the slip surface will be a plane parallel to the surface of the slope.



Infinite slopes

(ii) Finite slopes:

Finite slopes: The slope that is of limited extent is called finite slope. Slopes extending to infinity do not exist in nature. So that the slip surface is curved.

Finite slope

Examples:

- Slopes of embankments,
- Slopes of earth dams,
- Curs etc

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=8oDVvXo9WJM

https://www.youtube.com/watch?v=a-6YbkZJ5UY

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture: Infinite slopes

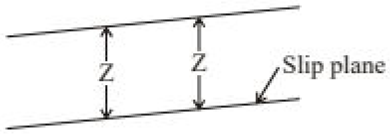
Introduction:

- The slope extending infinitely or upto an extent whose boundaries are not well defined. For this type of slope the soil properties for all identical depths below the surface are same. So that the slip surface will be a plane parallel to the surface of the slope.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Slip plane.
- Angle of slope.

Infinite slopes:



Infinite slopes

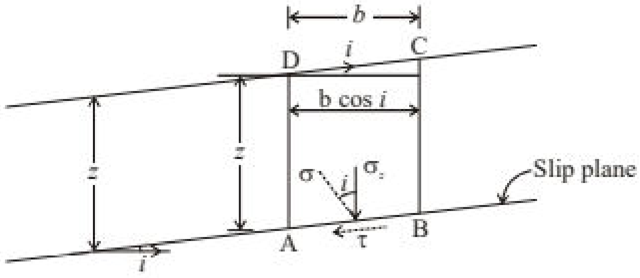
The slope extending infinitely or upto an extent whose boundaries are not well defined. For this type of slope the soil properties for all identical depths below the surface are same. So that the slip surface will be a plane parallel to the surface of the slope.

Stability Analysis of the Infinite Slopes

The limit equilibrium method is used for the analysis of the infinite slopes.

Stability analysis of an infinite slope can be made by considering the forces acting on a prism of soil which forms a part of the sliding mass. The factor of safety against sliding is determined for different trail slip planes in order to locate the critical slip plane for which the factor of safety will be specified minimum.

Let a slip plane be at depth z below the surface of slope with i as the angle of slope. We consider a prism of soil ABCD with inclined width b, depth z, and of unit thickness to the plane of paper



Stability analysis of infinite slope

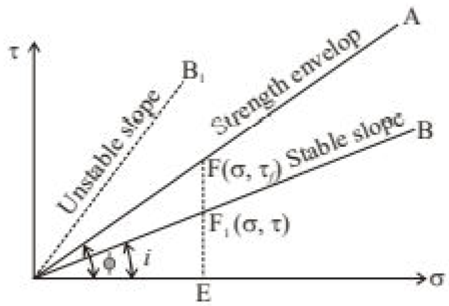
Vertical stress on plane AB,

$$\sigma_z = \frac{\text{Weight of prism ABCD}}{\text{Area of plane AB}} = \frac{(zb\cos i)\gamma}{b} = \gamma z \cos i$$

$\therefore$ Normal stress on slip plane, $\sigma = \sigma_z \cos i = \gamma_z \cos^2 i$

Shear stress on slip plane, $\tau = \sigma_z \sin i = \gamma_z \cos i \sin i$

Case (i) : Slope of cohesionless soil (C = 0):

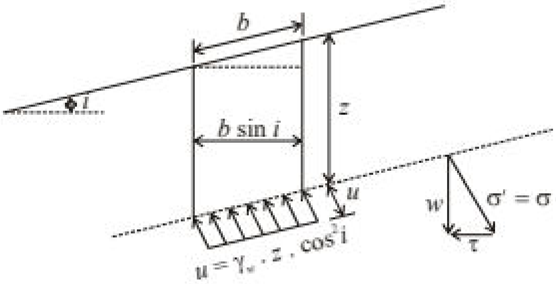


Failure condition for infinite slope of cohesionless soil

(a) In submerged slope:

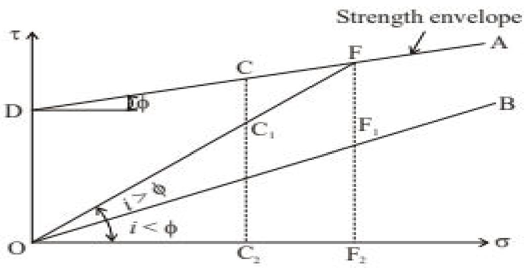
$$\boxed{F = \frac{\tan \phi}{\tan i}}$$

(b) In steady seepage along the slope:



Steady seepage along infinite slope

Case (ii): Cohesive soil (C – ϕ soil):



Failure condition of an infinite slope of cohesive soil

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=9goMsXW8VYQ

https://www.youtube.com/watch?v=bzsbJ73HZ_M

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 389 to 400)

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LECTURE HANDOUTS

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CIVIL

II/IV

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture: Finite slope

Introduction:

- The slope that is of limited extent is called finite slope. Slopes extending to infinity do not exist in nature. So that the slip surface is curved.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Finite slope
- Embankment
- Curs

Detailed content of the Lecture:

Finite slopes:

The slope that is of limited extent is called finite slope. Slopes extending to infinity do not exist in nature. So that the slip surface is curved.

Examples:

- Slopes of embankments,
- Slopes of earth dams,
- Curs etc.

Finite slope

Stability Analysis of Finite Slope

The slip surface in the case of a finite slope will be curved and is assumed to be arc of a circle or a logarithmic spiral in section for the purpose of stability analysis.

Types of Finite Slope Failures

Two basic types of failure of a finite slope may be occur:

(i) Slope failure,

(ii) Base failure.

(i) Slope Failure:

The term slope failure is sub-divided into the following two types:

(a) Face failure,

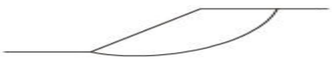
(b) Toe failure.

(a) Face failure:

Face failure

In the case of face failure the slip surface cuts the surface of slope above the toe. This type of failure condition occurs when a stratum relatively strong compared to the top layers occurs above the toe level.

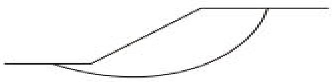
(b) Toe failure:



Toe failure

In the case of the toe failure the slip surface passes through the toe. This type of failure condition occurs when a stratum relatively strong compared to the top layers occurs at toe level.

(ii) Base Failure:



Base failure

In the case of base failure the slip surface passes below the toe. This type of failure condition occurs when a stratum relatively hard compared to the top layers occurs below the toe level.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=ksSLuVf8ifE

https://www.youtube.com/watch?v=9goMsXW8VYQ

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 389 to 400)

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LECTURE HANDOUTS

CIVIL | **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture: Total stress analysis for saturated clay

Introduction:

- Slope stability analysis is performed to assess the safe design of human-made (or) natural slopes and the equilibrium condition. Slope stability is the resistance of inclined surface to failure by sliding (or) collapsing.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Infinite slopes.
- Finite slopes.
- Cohesive soils.

Detailed content of the Lecture:

Objectives of Slope Stability Analysis:

- The main objectives of slope stability analysis are:-
- Finding endangered areas,
- Investigation of potential failure mechanisms,
- Determination of the slope sensitivity to different triggering mechanisms,
- Designing and optimal slopes with regard to safety,
- Reliability and economics,
- Designing possible remedial measures.

Types of Stability Analysis on Slopes:

The stability analysis could be split up into two categories:-

(i) Stability Analysis of Infinite Slopes,

(ii) Stability Analysis of Finite Slopes.

Stability Analysis of the Infinite Slopes

The limit equilibrium method is used for the analysis of the infinite slopes.

Stability analysis of an infinite slope can be made by considering the forces acting on a prism of soil which forms a part of the sliding mass. The factor of safety against sliding is determined for different trail slip planes in order to locate the critical slip plane for which the factor of safety will be specified minimum.

Let a slip plane be at depth z below the surface of slope with i as the angle of slope. We consider a prism of soil ABCD with inclined width b, depth z, and of unit thickness to the plane of paper

TYPES OF FAILURE SURFACES OR SLIP SURFACES

The rupture of a finite slope may take place along one of the following failure surfaces:-

(i) Planar Failure Surface,

(ii) Circular Failure Surface,

(iii) Non-circular Failure Surface.

(i) Planar Failure Surface

- It may commonly occur in a soil deposited or embankment with a specific plane of weakness.
- Excavation in stratified deposited quite often leads to a planar failure surface along a plane parallel to the strata.
- Similarly in composite earth dams with sloping cores, planes of weakness within the bank may consist of two or three planar surfaces.
- However, in most cases actual failure surfaces are curved.
- Collin observed that the rupture mass slide down a sliding surface in a definite pattern resembling that of a cycloid.
- Generally, the failure surfaces have arcs some what flatter at ends and sharper at the centre.

(ii) Circular Failure Surface

- Circular rupture surface was first proposed by Patterson (1916).
- Further field investigations by Swedish Geotechnical Commission justified circular arcs as close approximation of actual slip surface in homogeneous and isotropic soil conditions.
- For simple idealized problems, the assumption of a circular failure surface is sufficiently accurate.

(iii) Non-circular Failure Surface or Composite Failure Surface

It occurs in the following practical cases:-

(a) In homogeneous earth dams,

(b) In non-homogeneous earth dams.

(a) In homogeneous earth dams:

According to Bennett (1951). Non-circular slip surface may arise in homogeneous earth dams having one or more of the following:-

(i) Foundation of infinite depth,

(ii) Rigid boundary planes of maximum (or) zero shear,

(iii) Presence of relatively stronger (or) weaker layer.

(b) In non-homogeneous earth dams:

According to Morgenstern and Price (1965). Conditions for which non-circular slip surface may occur in non-homogeneous earth dams may occur are:-

(i) Presence of a soft layer in foundation.

(ii) Use of different type of soil or rock in the dam section with varying strength and pore pressure condition.

(iii) Use of drainage blankets to facilitate dissipation of pore pressure.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=e8WUMP6Rt94

https://www.youtube.com/watch?v=rUV8KHNGP64

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 527 to 538)

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MUTHAYAMMAL ENGINEERING COLLEGE
(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

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LECTURE HANDOUTS

CIVIL | **II/IV**

Course Name with Code : GEOTECHNICAL ENGINEERING - 19CEC08

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V - SLOPE STABILITY

Date of Lecture: 16/12/2019

Topic of Lecture: c -ϕ soil method of slices

Introduction:

- In order to find the centre of critical slip circle ordinarily a large number of trails are required.
- The number of trails may, however be reduced by using a method given by W. Fellenius in which the locus of the centre of the critical slip circle is located.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Factor of safety
- Directional angles
- Slope angle

Detailed content of the Lecture:

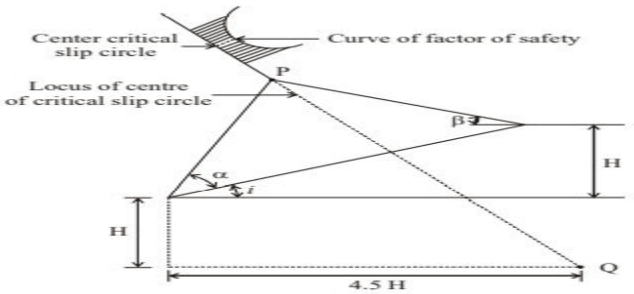
GUIDELINES FOR LOCATION CRITICAL SLOPE SURFACE IN COHESIVE AND C – ϕ SOIL:

- In order to find the centre of critical slip circle ordinarily a large number of trails are required.
- The number of trails may, however be reduced by using a method given by W. Fellenius in which the locus of the centre of the critical slip circle is located.
- According to Fellini's for slopes of homogeneous soils with one continuous inclination and bound by horizontal surfaces at top and bottom the centre of critical slip circle lies on a line QP
- The point Q has it's co-ordinates with respect to toe of the slope as H vertically downwards and 4.5 horizontally away from the toe.
- Where H is the height of the slope.
- According to Fellenius for purely cohesive soil (having angle of internal friction ϕ equal to zero) the centre of critical slip circle is located at point P.

- For C– ϕ soils (Both having cohesion and internal friction) the centre of critical slip circle lies above the point O on the line Q_p produced.
- Thus after drawing the line Q_p in order to find the centre of critical slip circle, a number of trail centres O1 , O2 , O3 , O4 etc., are selected above point P on the line QP produced.
- For the sake of convenience the trail centres may be equally spaced.
- From each of the selected trail centres slip circle is drawn and the factor of safety corresponding to each centre is calculated by the equation

$$F = \frac{M_R}{M_D} = \frac{C\hat{L} + \tan\phi \sum N}{\sum T}$$

- A smooth curve is drawn passing through the tops of the plotted ordinates representing the factors of safety



Fellenius method for locating centre of critical slip circle

- The lowest point on this curve is noted and its ordinate is drawn and measured which represents the factor of safety.
- Also the point where this ordinate meets the line produced, represents the centre of the critical slip circle.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=ksSLuVf8ifE&t=9s

https://www.youtube.com/watch?v=2wT2he6Numk

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 555 to 561)

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LECTURE HANDOUTS

CIVIL **II/IV**

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture: 16/12/2019

Topic of Lecture: Friction circle method

Introduction:

- In the friction circle method the slip surface is assumed to be cylindrical i.e., arc of a circle in section.
- The sliding soil-mass is assumed to be acted upon by three forces keeping it in equilibrium

Prerequisite knowledge for Complete understanding and learning of Topic:

- Friction circle
- Cohesive Force

Detailed content of the Lecture:

Friction Circle Method:

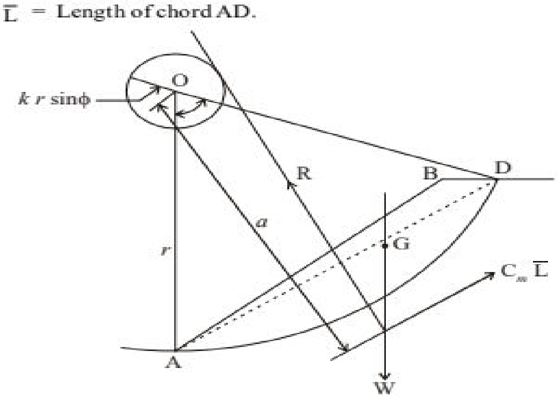
In the friction circle method the slip surface is assumed to be cylindrical i.e., arc of a circle in section. The sliding soil-mass is assumed to be acted upon by three forces keeping it in equilibrium

- The weight, W of the sliding soil-mass ABDA acting vertically through it'scentre of gravity

Where, $a = r \cdot \frac{\hat{L}}{\bar{L}}$

$\hat{L}$ = Length of arc AD

$\bar{L}$ = Length of chord AD.



Friction circle method

- The resultant reaction R passing through the point of intersection of the above two forces and tangential to the friction circle.

Test Procedures:

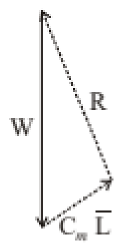
1. With centre O and radius r, the slip circle AD is constructed.
   - The friction circle is drawn with centre O and radius k r sin ϕ.
   - k is taken as 1 unless otherwise given.
2. A vertical line is drawn through centroid of section ABDA to get the line of action of weight W.
3. Chord AD is drawn. A line is drawn parallel to chord AD and at distance

$$a = r \cdot \frac{\hat{L}}{\overline{L}}$$

4. The length of arc AD,) L is computed using the equation:

$$\hat{L} = \frac{\pi r \cdot \delta}{180}$$

5. The length of chord AD, L is obtained by measurement.
6. Through the point of intersection of the line of action of W and force , $C_m \cdot \overline{L}$, a line is drawn tangential to the friction circle to get the line of action of resultant reaction R.
7. The weight W of the sliding soil-mass ABDA is computed and plotted to scale as



Sliding soil-mass

8. The factor of safety with respect to cohesion F c is given by:

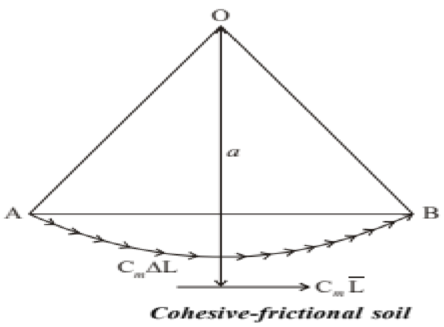
$$F_c = \frac{C}{C_m}$$

Where;

C = Cohesive strength (ultimate cohesion)

Cm = Mobilised cohesion.

Resultant cohesive force

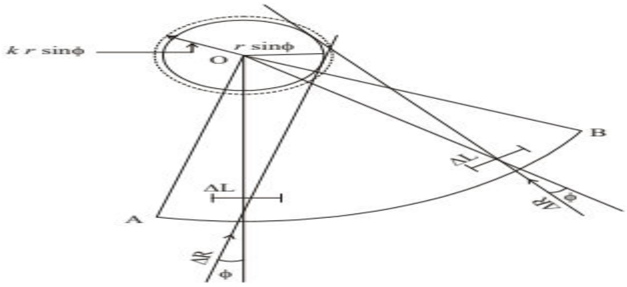


Cohesive-frictional soil

- The closing line of this force polygon is chord AB.
- Then chord AB will represent the resultant cohesive force in magnitude and direction.
- Let the resultant cohesive force acting parallel to chord AB, be at distance a from O.
- Taking moments about O and applying Varignon's theorem we get;

$$C_m \cdot \bar{L}(a) = \sum C_m \cdot \Delta L \cdot r$$
$$= C_m \cdot r \cdot \sum \Delta L$$
$$= C_m \cdot r \cdot \hat{L}$$
$$\boxed{\therefore\ a = \frac{\hat{L}}{\bar{L}} \cdot r}$$

Resultant reaction (R):



Resultant reaction

- The arc AB is assumed to consist of a number of elemental lengths ΔL.
- If can be shown that the resultant reaction R for the entire arc AB will be tangential to the circle of radius k r sinϕ drawn with centre O.
- This circle is called **"Friction Circle of Circle"**.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=IWUoK0Glfnc

https://www.youtube.com/watch?v=ttfT7-3M8js

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 544 to 551)

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LECTURE HANDOUTS

CIVIL

II/IV

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture: Use of stability number

Introduction:

- Slope stability analysis is performed to assess the safe design of human-made (or) natural slopes and the equilibrium condition. Slope stability is the resistance of inclined surface to failure by sliding (or) collapsing.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Taylor's stability number
- Friction circle
- Finite slopes

Detailed content of the Lecture:

TAYLOR STABILITY NUMBER:

Taylor stability number is a dimensionless quantity denoted by S_n and defined as:

$$S_n = \frac{C_m}{\gamma \cdot H}$$

Where

Cm = Mobilised cohesion on slip surface

γ = Unit weight of soil

H = Height of slope

Also $F_C = \frac{C}{C_m}$

So that $C_m = \frac{C}{F_c}$

Substitute C_m in Eqn. (1) we get

$$S_n = \frac{C}{F_c \cdot \gamma \cdot H}$$

Where

C =Unit ultimate cohesion

Further

$$F_C = F_H = \frac{H_c}{H}$$

So that $H = \frac{H_c}{F_c}$

Substitute H in Eqn. (2) weget

$$S_n = \frac{C}{\gamma \cdot H_c}$$

Where

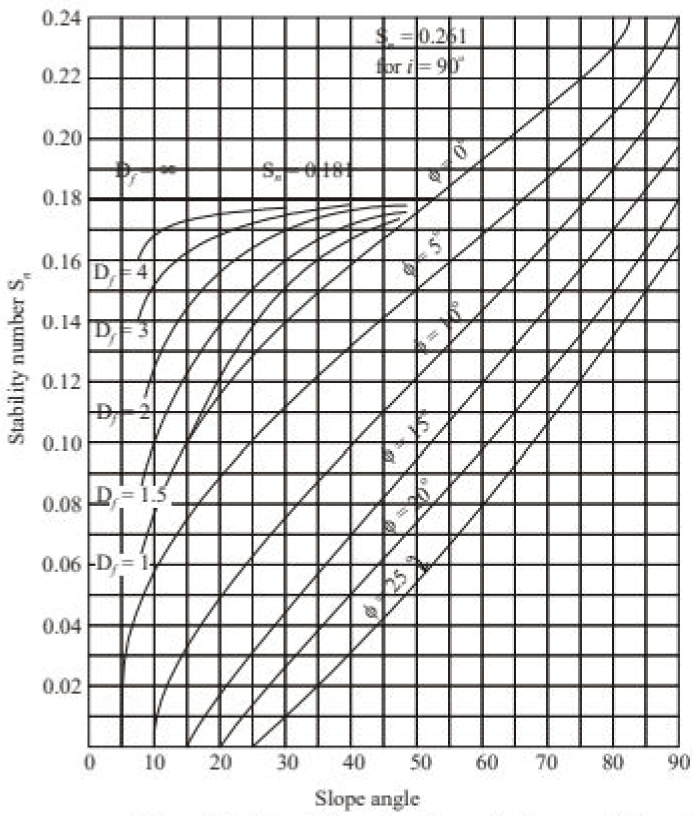
Hc = Critical height of slope

Using the friction circle method along with an a procedure, Taylor determined S_n for finite slopes presented the results

Taylor's stability number

i ↓ / φ →	0°	5°	10°	15°	20°	25°
90°	0.261	0.239	0.218	0.199	0.182	0.166
75°	0.219	0.195	0.173	0.152	0.134	0.117
60°	0.191	0.162	0.138	0.097	0.116	0.079
45°	(0.170)	0.136	0.108	0.062	0.083	0.044
30°	(0.156)	(0.110)	0.075	0.0625	0.046	0.009
15°	(0.145)	(0.068)	(0.023)	–	–	–

A chart from which one can obtain value of S_n for different values of slope angle i and angle of shearing resistance ϕ



Value of S_n for different values of slope angle i and angle of shearing resistance ϕ

Depth factor (D_f):

It is defined as the ratio of depth to hard strata below top of slope to the height of slope.

$$\text{Depth factor} = \frac{\text{Depth to hard strata below top of slope}}{\text{Height of slope}}$$

$$D_f = \frac{(H + D)}{H}$$

Values of S_n for slopes in cohesive soils ($\phi = 0$) with different depth factors

Slope angle in Degrees	Stability Number, δ_n				
	Depth Factor, D_f				
	1	1.5	2	3	∞
90	0.261	–	–	–	–
75	0.219	–	–	–	–
60	0.191	–	–	–	–
53	0.181	0.181	0.181	0.181	0.181
45	0.164	0.174	0.177	0.180	0.181
30	0.133	0.164	0.172	0.178	0.181
22.5	0.113	0.153	0.166	0.175	0.181
15	0.083	0.128	0.150	0.167	0.181
7.5	0.054	0.080	0.107	0.140	0.181

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=TDIw5hksRso

https://www.youtube.com/watch?v=aobbi-qe7JE

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 555 to 570)

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LECTURE HANDOUTS

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CIVIL

II/IV

Course Name with Code : **GEOTECHNICAL ENGINEERING - 19CEC08**

Course Teacher : **Mrs.R.SELVAPRIYA**

Unit : **V - SLOPE STABILITY**

Date of Lecture:

Topic of Lecture:Slope protection measures

Introduction:

- Slopes that are susceptible to sliding should be produced so that the area will be safe. Slopes which have failed recently are likely to fall under long term condition. Slopes have been protected by adopting some successful techniques.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Groundwater condition
- Type of soil in the slope
- Angle height and length of the slope

Detailed content of the Lecture:

SLOPE PROTECTION MEASURES:

Slopes that are susceptible to sliding should be produced so that the area will be safe. Slopes which have failed recently are likely to fall under long term condition. Slopes have been protected by adopting some successful techniques.

In general protection measures involves:-

(a) Reducing the mass or loading which contributes to sliding.

(b) Improving the shearing strength along the anticipated zone of failure.

(c) Providing certain materials which will provide resistance to movement.

The protective measure adopted depends on the different field conditions such as;

- Objective and extent of protection to be achieved.
- The type of soil in the slope.
- The geological structure of the slope.
- The volume or depth of the soil involving in sliding.
- The angle height and length of the slope.

- The groundwater condition.

(i) Requirements for Effective Slope Protection Method

A good slope protection measure having the following requirements are:-

- A slope protection method must be able to resist erosion, prevent fine-grained soil loss and facilitate adequate drainage.
- A surface water drainage system required to effectively control the rain water.

Methods:

The stability of slopes may be improved by adopting the following methods:

(i) Slopes flattening (or) benched.

(ii) Providing a berm.

(iii) Provide rock-fill blanket followed by a riprap.

(iv) Lowering the groundwater or intercepting the surface water.

(v) Use of driven (or) cast in-site piles.

(vi) Providing a retaining walls and sheet piles.

(vii) Provide a drainage.

(viii) Densification.

(ix) Consolidation.

(x) Grouting and injection.

(xi) Stabilization.

(xii) Plan for building design to aid slope stability.

(i) Slopes flattening (or) benched

- The slope due to which the tendency for soil mass to slide is reduced.
- The different techniques for reducing the weight of the moving mass.

(ii) Providing a berm

- When a base failure is anticipated, a beam may be provided wear the toe
- Providing a berm below the toe of the slope helps to increase the resistance to the movement of the soil from the slope.
- It is especially useful when there is a possibility of a bases failure.

(iii) Providing rock-fill blanket followed by a riprap

- If a zone wear the toe is susceptible to erosion, a protective rock-fill blanket followed by a riprap can be provided

(iv) Lowering the groundwater

- Shearing resistance of the soil is reduced due to high groundwater and excess pore-water pressure.
- This could be avoided by lowering the groundwater (or) intercepting the surface water.

(v) Densification

Densification by use of explosives vibro flotation. Etc helps in increasing the shear strength of cohesionless soil and thus increasing the stability.

(vi) Consolidation

Consolidation by surcharging elector-osmosis or other methods help in increasing the stability of slopes of cohesive soils.

(vii) Grouting and injection

Grouting and injection of cement or other compounds into specific zones help in increasing the stability of slopes.

(viii) Stabilization

Stabilization of the soil helps in increasing the stability of slopes.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=At0G2HEgVDo

https://www.youtube.com/watch?v=QnyufKaokak

Important Books/Journals for further learning including the page nos.:

1. Soil Mechanics and Foundations by Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 03 to 08)
2. Soil Mechanics and Foundation Engineering by V.N.S.Murthy, CBS Publishers & Distributors Pvt Ltd., Fifth Edition, 2013. (Page no – 420 to 424)

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