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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L - 01

LECTURE HANDOUTS

CIVIL

V / III

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Methods of exploration

Introduction:

Soil investigation and soil explorations are conducted for the purpose of site investigation to get clear information about the soil properties and hydrological conditions at the site.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Basics of soil mechanics
- ✓ Site investigation
- ✓ Soil properties
- ✓ Soil mechanics

Detailed content of the Lecture:

Purpose of Soil Exploration

The purpose of site exploration is to get detailed information about

- ✓ Order of occurrences and extent of soil and rock strata.
- ✓ Nature and engineering properties of of the soil and rock formation.
- ✓ Location of groundwater and its variation.

Methods of Soil Exploration

Different methods of soil exploration for study of soil profiles are:

1. Open excavation
2. Borings
3. Subsurface soundings
4. Geographical methods

1. **Open Excavation**

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

2. **Boring Method**

   Soil samples can be lifted from deeper depths by drilling bore holes by using mechanical devices called samplers.The process consists of

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

Methods of boring

(i) Auger boring
(ii) Auger and Shell boring
(iii) Wash boring
(iv) Percussion boring
(v) Rotary boring (Mud rotary drilling)

3. **Subsurface Sounding Tests**

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

   - ✓ Standard Penetration Test (SPT)
   - ✓ Cone penetration test or Dutch cone test

4. **Geographical Methods of Soil Exploration**

   (i) Electrical resistivity method

   This method is based on the measurement and recording of changes in the mean resistivity or apparent specific resistance of various soils. The test is done by driving four metal spikes to act as electrodes into the ground along a straight line at equal distances. This is shown in the figure. Direct voltage is applied between the two outer potentiometer electrodes and then mean for the potential drop between the inner electrodes is calculated.

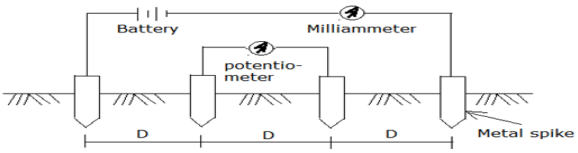
   Mean resistivity (ohm-cm) $\rho = 2\pi DR$

   Where D= distance between the electrodes (cm)

E= potential drop between outer electrodes (volts)

I= current flowing between outer electrodes (amperes)

R= resistance (ohms) = (E/I)



Resistivity mapping: This method is used to find out the horizontal changes in the sub soil, the electrodes kept at a constant spacing, are moved as a group along the line of tests.

Resistivity sounding: This method is used to study the vertical changes; the electrode system is expanded, about a fixed central point by increasing the spacing gradually from an initial small value to a distance roughly equal to the depth of exploration desired.

(ii) Seismic refraction method

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

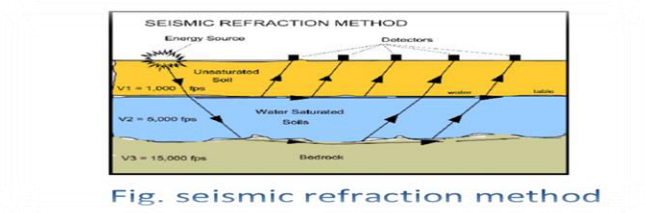


Fig. seismic refraction method

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

https://www.youtube.com/watch?v=HDAll-JmCy8

https://www.youtube.com/watch?v=50rT6FJa9gI

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 862 to 872)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 74 to 77)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Boring Technology

Introduction:

- ✓ Boring methods are widely used for subsurface investigations to collect samples, in almost all types of soil, for visual inspection or laboratory testing.
- ✓ There are several boring techniques like auger boring, auger and shell boring, wash boring, percussion drilling and rotary drilling, that are employed to collect disturbed and undisturbed samples of soils.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Site investigation
- ✓ Methods of exploration
- ✓ Test on soil

Detailed content of the Lecture:

These boring methods are selected based on the soil types, the efficiency of boring technique, types of soil sample (disturbed or undisturbed), and the availability of facility and accuracy by which soil and groundwater variations can be determined.

Methods of boring

1. Auger boring
2. Auger and Shell boring
3. Wash boring
4. Percussion boring
5. Rotary boring (Mud rotary drilling)

1. **Auger Boring**

It is a simple and cost-effective boring technique which can be used for almost all types of soil apart from gravelly soil and rocks. This technique encounters difficulty in gravelly soil and special drilling bits are needed for rocks.Auger boring is used to collect disturbed soil specimen. It collects the soil sample from a maximum practical depth of nearly 35m based on the available time and equipment type.

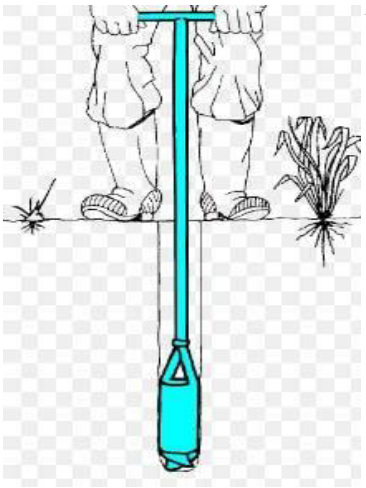
2. **Auger and Shell boring**

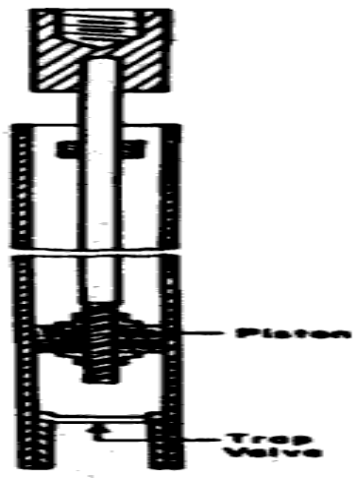
Cylindrical augers and shells with cutting edge or teeth at Iower end can be used for making deep borings. Hand operated rigs are used for depths upto 25 m and mechanised rigs up to 50 m. Augers are suitable for soft to stiff clays, shells for very stiff and hard clays, and shells or sand pumps for sandy soils. Small boulders, thin soft strata or rock or cemented gravel can be broken by chisel bits attached to drill rods. The hole usually requires a casing.

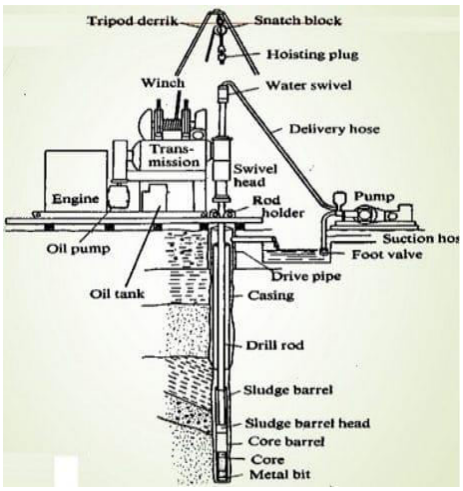
3. **Rotary Drilling**

Rotary drilling method of boring is suitable for all types of soil including rocks. It is used to take disturbed as well as undisturbed soil sample. So, it is specifically applicable for stiff soil layers. The practical depth of sampling is around 70m and greater depth based on the type of utilized equipment.

Generally, thin-walled tube samplers and various piston samplers are used to collect undisturbed soil specimen. The diameter of the undisturbed soil sample is around 100 mm and ranges from 150mm to 200mm for rocks.







Auger BoringAuger and Shell boringRotary Drilling

4. **Wash Boring**

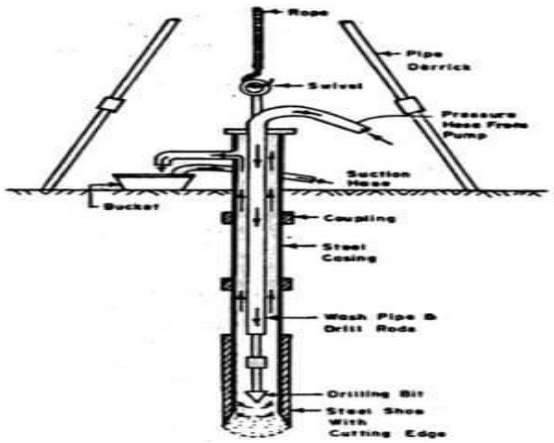
Wash boring method is used to collect disturbed and undisturbed samples in almost all types of soils except rocks. In this technique, portable, cheap, and limited equipment is used which is an advantage of wash boring. Similar to rotary drilling, thin-walled tube

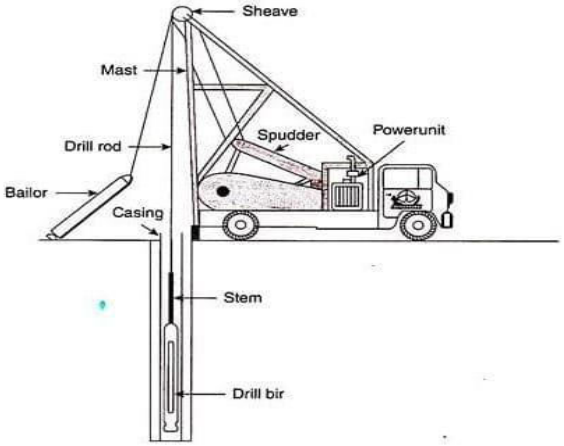
samplers and piston samplers are used to recover undisturbed soil samples with minimum 50 mm diameter and maximum 100 mm diameter.

5. Percussion Drilling

It is used for all types of soils and rocks including stiff soils and rocks. Percussion drilling is used to take disturbed and undisturbed specimen but the quality of undisturbed samples is not that good because of the heavy blows of the chisel.

Similar to rotary drilling and wash boring, the soil specimen can be taken from a depth of 70m and more based on the utilized equipment. The diameter of disturbed soil samples is about 100 mm and greater, and obtaining smaller diameter samples would be uneconomical.





Wash BoringPercussion Drilling

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

https://www.youtube.com/watch?v=50rT6FJa9gI

https://www.youtube.com/watch?v=HDAll-JmCy8

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 862 to 872)
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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Depth of boring

Introduction:

The depth of soil affected by the load transmitted by the foundation determines the required depth of boring in the overall process. The additional stresses imposed by the foundation to a depth of one and half times the total width of foundation is still found to be about 20% below the foundation base.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Site investigation
- ✓ Methods of exploration
- ✓ Methods of boring

Detailed content of the Lecture:

Significant Depth of Boring

Exploration should be carried to a depth up to which the increase in pressure due to structural loading is likely to cause perceptible settlement or shear failure.

Depth of boring Depends upon

- ➢ Type of structure
- ➢ Intensity of Loading
- ➢ Soil profile
- ➢ Physical characteristics of soil

Should extend up to the significant depth below the baseof the foundation

D_B D_f + 2B for square / circular footings

D_f + 6B for strip / continuous footings

In the case of pile foundations,

D_B length of pile + significant depth below the base of the pile group.

D_f – Depth of footing

B – Width of footing

DEPTH OF EXPLORATION

FOUNDTION TYPE	DEPTH
General	1.5 to 2 times of loaded area
Pile Foundation	10 to 30 metres or more
Retaining Wall	1.5 times of base width (or) 1.5 times of height of the wall
Dams	1.5 times of base width (or) up to bed rock
Roads(cuts & Fills)	1 metre for little cut or fill (or) 2 metres below the ground or equal to the ht. of the fill or cut

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

https://civilblog.org/2015/09/25/how-to-decide-depth-and-spacing-of-trial-pits-and-boring/

https://www.youtube.com/watch?v=gaRx1FCy8eI

https://www.youtube.com/watch?v=-ozWwrK_Z0A

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 859 to 862)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 73 to 74)

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LECTURE HANDOUTS

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Spacing Of Bore Hole

Introduction:

The position and depth of exploration and investigation has to be selected based on previously conducted exploration such as geological conditions, structure dimensions and the character of the engineering problem, foundation depth etc.,

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Site investigation
- ✓ Depth of boring
- ✓ Methods of boring

Detailed content of the Lecture:

Spacing of borings

FOUNDTION TYPE	DEPTH
General	1.5 to 2 times of loaded area
Pile Foundation	10 to 30 metres or more
Retaining Wall	1.5 times of base width (or) 1.5 times of height of the wall
Dams	1.5 times of base width (or) up to bed rock
Roads(cuts & Fills)	1 metre for little cut or fill (or) 2 metres below the ground or equal to the ht. of the fill or cut

For Smaller Buildings

1 bore hole or test pit in the centre of the site.

For Larger Buildings

1 bore hole at each corner and 1 in centre.

For Very Larger Buildings

Areas should be divided in a grid pattern and borings are carried out at every 100 metre depends upon the soil.

For Dam Sites

Borings are made at the intervals of 50 m spacing along the upstream.

For Roads

Generally at the intervals of every 100 m, for uniform soil it is increased to every 500 m and it is decreased to 30 m for non uniform soil.

- The depth and spacing of trial pits or exploratory borings should be such as to give a true picture of the underlying soil, with regard to any major changes in thickness, depth or properties of the strata over the base area of the structure and in its immediate vicinity.
- Only a preliminary estimate of spacing is made first. This may be decreased or increased depending upon the information revealed by borings.When the bed rock is met, the surface should be plotted by a number of borings or surroundings in order to locate any depressions.

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

https://civilblog.org/2015/09/25/how-to-decide-depth-and-spacing-of-trial-pits-and-boring/

https://www.youtube.com/watch?v=K3i3RlaDt8c

https://www.youtube.com/watch?v=7EQGeH9K-VI

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no –860 to 861)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 73 to 74)

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Sampling – Methods -Thick, Thin wall samplers, Stationery piston sampler

Introduction:

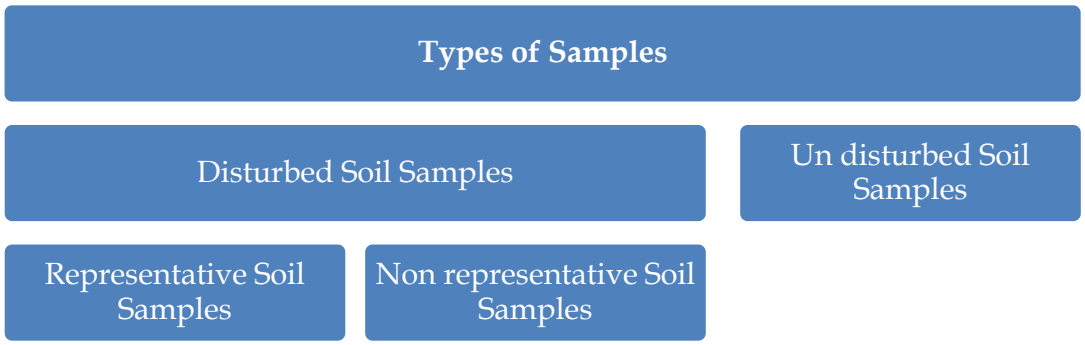
Soil samples are obtained by

- Driving or pushing a sampling tube into the ground.
- An open ended cylindrical tube is known as sampling tube.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Methods of boring
- ✓ Site investigation
- ✓ Depth of boring

Detailed content of the Lecture:



DISTURBED SAMPLES:- Soil samples in which the natural water content or structure gets modified or destroyed is known as disturbed samples.

NON-REPRESENTATIVE SAMPLES: Mixture of soils from different layers/levelscomplete disturbance to soil structure and properties can not be used for any test

REPRESENTATIVE SAMPLES: Disturbance to soil structure water content may or may not be changed no change in mineral constituents suitable for classification and identification tests

UNDISTURBED SAMPLES:- Little or no disturbance to the soil structure natural structure and properties will be preserved useful for important laboratory tests like shear test, consolidation test etc.,

Sampling Techniques

Depending upon the mode of operation, the samplers can be classified as

1. **Open Drive Sampler(Chunk Sample)**

- Obtained from open pit

Sampling steps:

- ✓ During excavation a block of soil is left undisturbed
- ✓ An open ended box is placed on the block of soil sample
- ✓ The sample is cut at the base and removed
- ✓ The open top is sealed using wax and transported to laboratory

This type of samples can be taken at shallow depths of 1 to 2m

2. **Shelby Tube Sampler (Thin Wall Sampler)**

- The sampler is a open end steel tube with a cutting edge

Sampling steps:

- ✓ The sampler is placed at the bottom of the bore hole
- ✓ The sampler is pushed into the ground
- ✓ The sampler pulled out and the sampler with the sample is transporter to the lab.
- ✓ This type of sampling is suitable in soils having some cohesion.
- ✓ Not suitable in hard soils and gravels

3. **Split Spoon Sampler (Thick Wall Sampler)**

- This is an open ended cylindrical tube

It consists of

- ✓ A cutting shoe at the bottom
- ✓ A barrel (pipe) split longitudinally into two halves
- ✓ A coupling at the top for connection to drill rods

Sampling steps:

- ✓ Same as for thin walled open drive sampling.
- ✓ After the sample is taken the two halves of the tube can be seperated to expose the sample.

4. **Stationary Piston Sampler**

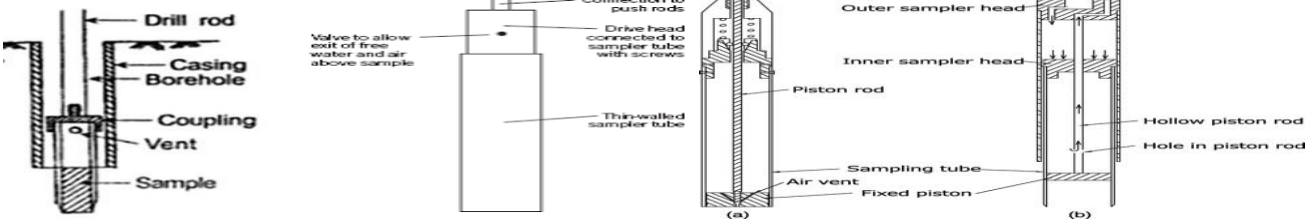
This consists of:

- ✓ Sampler tube

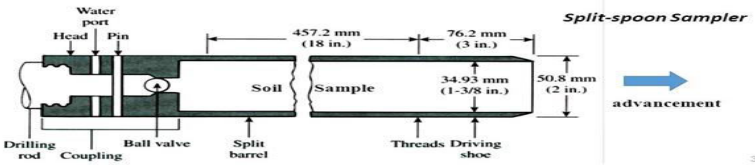
- ✓ Piston

Sampling steps:

- ✓ Sampler tube with the piston is placed at the bottom of bore hole
- ✓ The sampler is pushed into the soil keeping the piston at the bottom of the bore hole
- ✓ Sampler along with the piston is lifted up. Negative pressure is created if the soil tends to move downwards. This helps to retain the sample



Open Drive SamplerShelby Tube SamplerStationary Piston Sampler



Split Spoon Sampler

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

https://www.youtube.com/watch?v=4hCXQbkbEaI

https://www.youtube.com/watch?v=jo64QIE4hr4

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 864 to 867)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 81 to 94)

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L - 06

LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Penetration tests

Introduction:

The standard penetration test (SPT) is an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil. This test is the most frequently used subsurface exploration drilling test performed worldwide The test provides samples for identification purposes and provides a measure of penetration resistance which can be used for geotechnical design purposes.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Methods of exploration
- ✓ Methods of boring
- ✓ Site investigation

Detailed content of the Lecture:

Penetration tests (penetrometer tests).

1. Standard penetration test (SPT)
2. Static cone penetration (SCPT / CPT)

Standard penetration test

- ✓ This is a very widely used penetration test

Test setup and equipment:

It consists of:

i. Tripod

ii. Pulley

iii. Hammer
iv. Drill rod
v. Split spoon
vi. Winch
vii. Deive head

Test procedure

The test is carried out in a bore hole. The test is carried out at every 0.75m or 1.5m depth intervals as the bore hole is advanced.

Steps:

1) The bore hole is advanced to the reguired depth
2) The split spoon sampler is attached to drill rods and lowered to the bottom of the bore hole
3) The split spoon sampler is driven into the soil using a hammer.
   Weight of hammer= 65Kg.; the height of fall of hammer = 75cm
4) Number of blows required for penetration of every 15cm is noted.
   The sampler is penetrated upto 45cm
5) The number of blows for the last 30cm penetration (15cm to45cm) is recorded as 'N' value
6) The split spoon sampler is then withdrawn. The sample is collected for tests in the lab

Corrections to SPT 'N' values

The 'N' values obtained in SAND soils have to be corrected for:

No correction is applied to N value obtained in cohesive soils.

1. Overburden pressure correction

The overburden pressure increases with depth. For the same relative density of sand ,the 'N' values are under estimated at smaller depths and over estimated at larger depths. Therefore the observed values, N_{obs} are corrected to a standard effective overburden pressure

The corrected N value is given by:

$N' = C_N \ N_{obs}$

2. Correction for dilatancy

The corrected value,N_{cor} is given by,

$N_{cor} = 15+0.5(N'-15)$

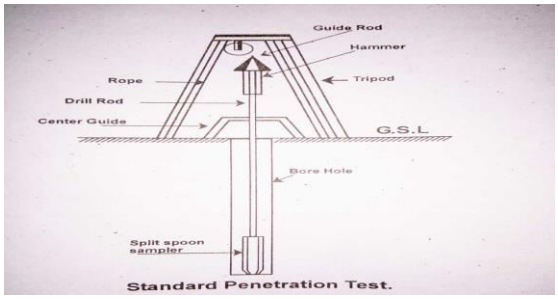
Static cone penetration test (SCPT)Or Cone penetration test (CPT)

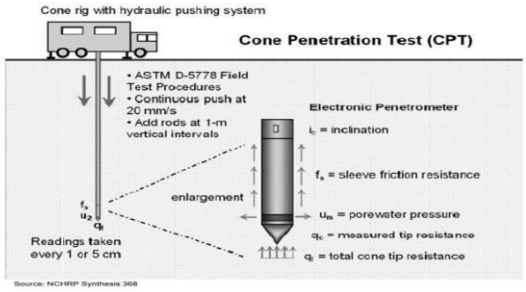
1) A cone with apex angle 60^o , base area $10cm^2$

2) A friction jacket
3) Sounding rod
4) Hand operated or motorized pushing equipment
5) Pressure gauges

Test procedure

- ✓ The soil resistance to penetration is measured
- ✓ The cone is pushed and the cone tipresistance, q_c is measured
- ✓ The cone and the friction jacket both are pushed and the total resistance q_t is measured
- ✓ q_t - q_c = Frictional resistance, f_s
- ✓ A plot of depth Vs penetration resistance is made





Standard penetration test **Static cone penetration test**

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

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

https://www.youtube.com/watch?v=yRoBXfrA9sw

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 680 to 683)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 98 to 116)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Bore Log Report

Introduction:

- Information on subsurface conditions obtained from the boring operation is typically presented in the form of a boring record, commonly known as "boring log"
- It is a record, made by the driller or geologist, of the rocks penetrated in the borehole. In the laboratory, a more detailed log is prepared giving particulars relating to lithology, palaeontology, water analysis, etc.,

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Methods of boring
- ✓ Depth of boring
- ✓ Sampling techniques

Detailed content of the Lecture:

DETAILS IN BORELOG PERIOD :

1. Description or classification of various soil and rock type
2. Ground water table details
3. Test data

CHECKLISTS IN BORELOG REPORT

1. Introduction
2. Description of the proposed structure
3. Location and geological condition of the site
4. Methods of exploration
5. Number of borings, their depth and location

6. General description of sub-soil condition as obtained from the SPT and cone test
7. Details and results of the laboratory test conducted
8. Depth of ground water table and its fluctuations
9. Discussions of the results
10. Recommendation about allowable bearing pressure, depth and type of foundation
11. Conclusions and limitations of the investigations

Information's to be Recorded

Trial pits, trenches and boreholes should be

- ✓ Given reference numbers
- ✓ located on plan
- ✓ Their ground level and the date of excavation recorded.

Additional information:

(1) Type of rig, diameter and depth of bore

(2) Diameter and depth of any casing used and why it was necessary.

(3) Depth of each change of strata and a full description of the strata

(4) Depths at which samples taken, type of sample and sample reference number.

(5) In situ test depth and reference number.

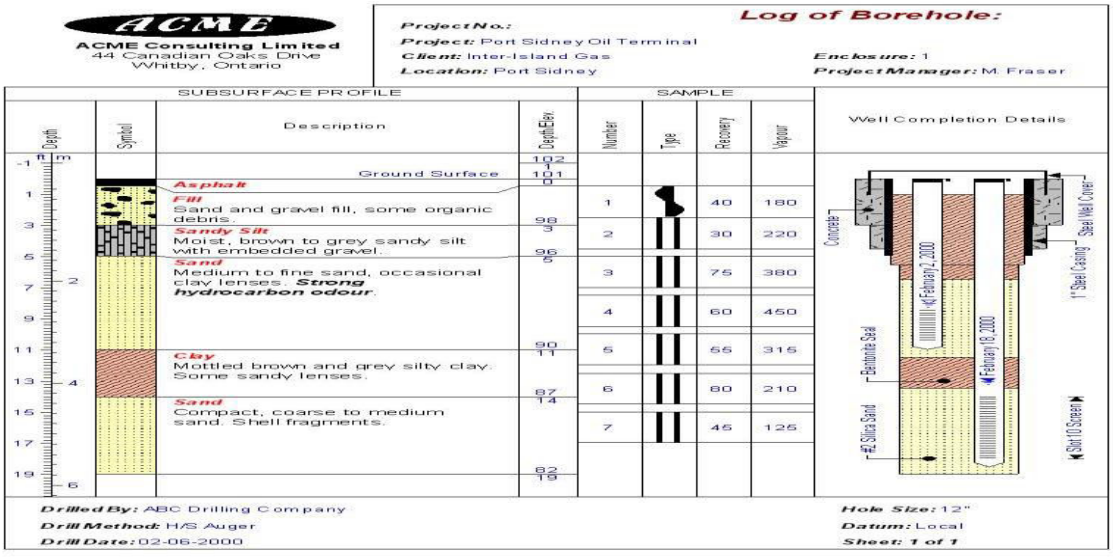
(6) The levels at which groundwater was first noted, the rate of rise of the water, its level at start and end of each day

(7) Depth and description of obstructionsencountered.

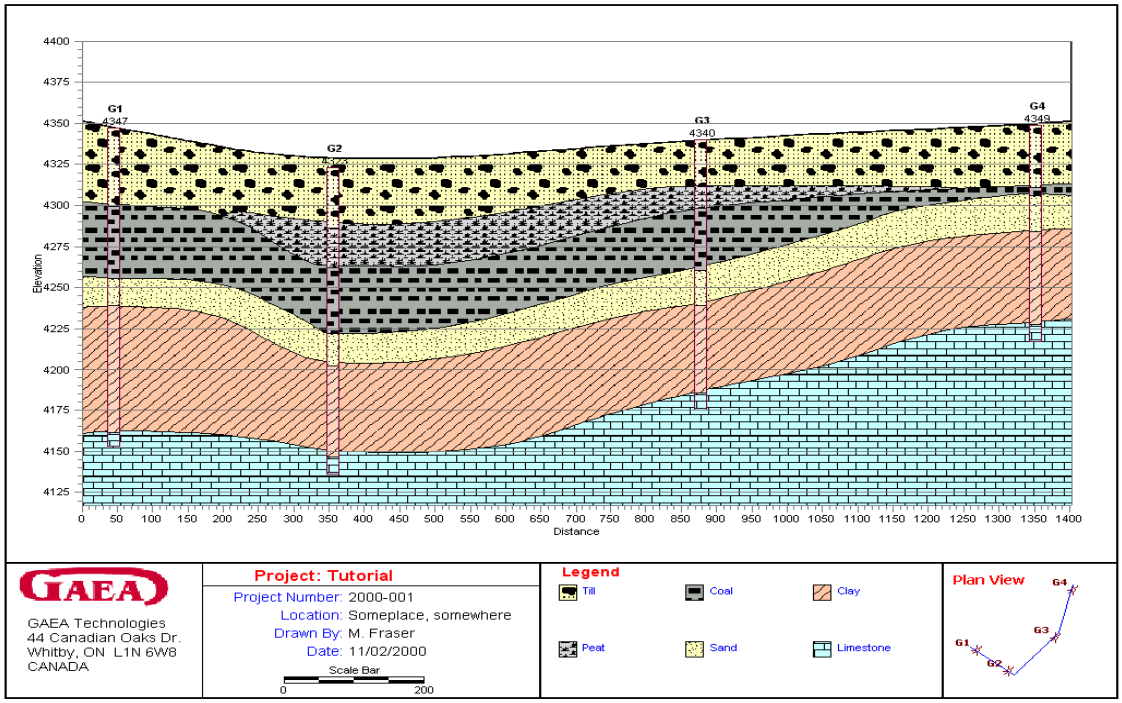
(8) Rate of boring

(9) Name of supervising engineer.

(10) Date and weather conditions during investigation.



Sample Bore Log Report



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

https://mea.gov.in/Images/attach/18_Bore_Log_Details_Part_I_Bridge_1_to_Bridge_19.pdf

https://www.youtube.com/watch?v=weVJ5yBOFvw

https://www.youtube.com/watch?v=37ftaJmr604

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 1.13 to 1.16)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –117 to 118)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Data Interpretation

Introduction:

Borehole is small diameter vertical hole drilled into ground to take samples for soil investigation and evaluation. Borehole data is used to specify suitable types of foundation for structure. While boreholes are interpreted, certain errors are highly likely to be made which could be fatal for the foundation and safety of the structure.

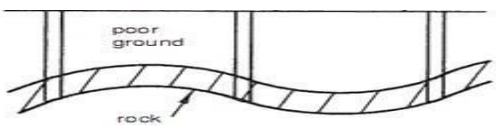
Prerequisite knowledge for Complete understanding and learning of Topic:

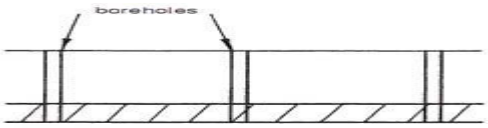
- ✓ Basics of soil mechanics
- ✓ Bore log report
- ✓ Methods of exploration

Detailed content of the Lecture:

1. **Interpreting Folded Strata as Straight Strata**

This type of error is made due to borehole distribution. In this situation, borehole data tells straight strata and other interpretation cannot be made based on that number and layout of the boreholes. This type of error could lead to increase in cost of foundation construction when piles with specified length do not reach soil layer with adequate bearing capacity and consequently the pile length should be increased.

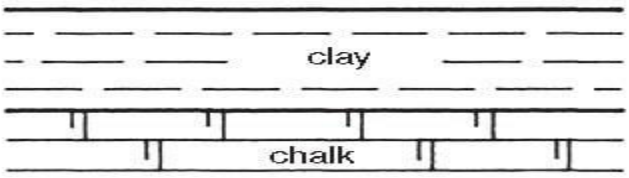




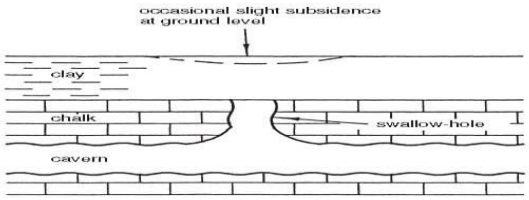
Actual strata shape **Unrealistic Assumption of Strata Formation**

2. **Drift Underlain by Unexplored Rock**

It is possible that strong layer of soil sits on a low bearing capacity soil layer. For example, layer of clay material overlay layer of chalk. In this case, borehole may not reach chalk layer and clay layer would shows satisfactory strength and consequently appropriate for foundation construction.But this assumption would be fatally wrong and would lead to not only extend construction period but also increase construction cost. This type of case has been encountered practically and these detrimental effects were encountered.



Clay Overlay Chalk



Water infiltrate into the ground

3. **Overloading Due to Lack of Dip Assessment**

Occasionally, foundations would be subjected to a load that is out of expectation due to unexamined dip in the construction area.So, it is recommended to check any dips if existing, to prevent foundation overloading and subsequent failure.

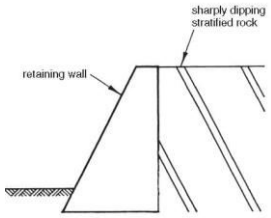
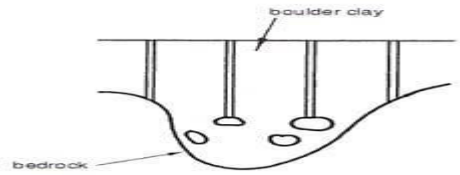


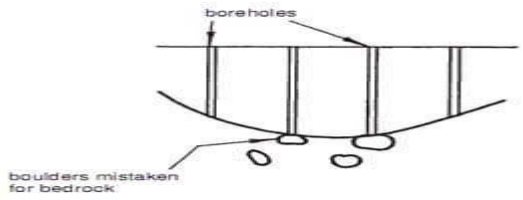
Fig.7: The existing dip has not been assessed, as a result, extra loads are imposed for which the retaining wall has not been designed

4. **Bedrock Misinterpretation**

Making errors in the interpretation of bedrock is possible. This might occur when borehole machine reach boulders in boulder clay and consequently bedrock would be assumed wrongly.This problem could be avoided by drilling higher number of boreholes.



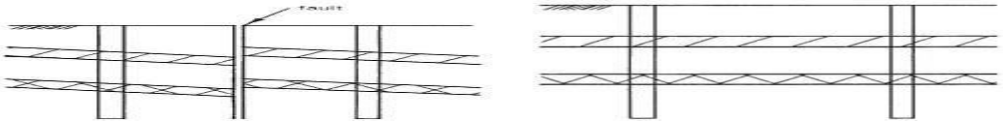
True Soil Profile, Boreholes Reach Boulders



Wrong Interpretation of Bedrock due to Boulders in Clay

5. **Improper Interpretation of Strata Formation**

This error might encounter when there is a fault in the area and is not examined. Consequently, strata formation generated would not represent the actual strata.



Realistic Formation of Strata **Interpreted strata formation**

6. **Misinterpretation of Soil Profile**

It is possible to interpret soil profile wrongly due to small number of boreholes or poor borehole layout.

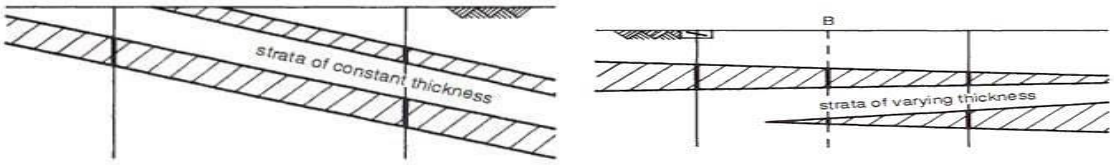


Fig.12: Misinterpreted Soil Profile **Fig.13: Actual soil profile**

The above possible errors should be considered while boreholes are used for soil investigations. As it has been pointed out, some of the errors could be prevented by increasing the frequency of boreholes.

Video Content / Details of website for further learning (if any):
https://www.smart-fertilizer.com/articles/soil-test/
https://www.youtube.com/watch?v=UsexgQw3Uhk
https://www.youtube.com/watch?v=co-5OvL_720

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

1. Murthy.V.N.S., Soil Mechanics and Foundation Engineering,Geotechnical Engineering Series, CBS Publishers & Distributors Pvt Ltd., 2013. (Page no – 532 to 537)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –177 to 180)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code :FOUNDATION ENGINEERING - 19CEE12

Course Teacher :Mrs.R.SELVAPRIYA

Unit : I – SITE INVESTIGATION AND SELECTION OF FOUNDATION

Date of Lecture:

Topic of Lecture: Selection Of Foundation

Introduction:

Selection criteria for foundation for buildings depend on two factors, i.e. factors related to ground (soil) conditions and factors related to loads from the structure. The performance of foundation is based on interface between the loadings from the structure and the supporting ground or strata.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Soil type
- ✓ Test on soils
- ✓ Site investigation

Detailed content of the Lecture:

Type of foundation depends on:

- ✓ Soil conditions at the site
- ✓ Type of the super structure like buildings, water tanks , chimneys, Bridges etc.,
- ✓ The magnitude of loads
- ✓ Type of load like vertical , lateral , static, dynamic , earthquake loads etc.,
- ✓ Ground water conditions

Environmental factors like structure in river beds , sea , hill slopes etc.,

S.No	Soil Condition	Preferable Foundation Type
1	Compact Sand Deposit To A Greater Depth	Spread Footings

2	Firm Clay Or Silty Clay To A Greater Depth	1. Spread Footings 2. Pile Foundation (If Uplift Forces Are Observed)
3	Soft Clay To A Greater Depth	1.Spread Footing For Low & Medium Loading 2. Deep Foundations For Heavy Loadings
4	Loose Sand	Raft Foundation
5	Soft Clay But Firmness Increases With Depth	1.Friction Piles Or Pier Foundations 2. Raft Or Mat Foundations Also Considered
6	Hard Clay	Piers Or Pile Foundations
7	Rock Surface	Foundations Directly Laid On Rock Surface

FACTORS AFFECTING THE SELECTION OF FOUNDATION

1. Loads from building
2. Type of soil
3. Type of structures in neighbourhood
4. Type of foundations

1. **LOADS FROM BUILDING:**

- ✓ In case of low rise building with large span, the extent of loading is relatively modest, so shallow foundation is preferred in this case.
- ✓ While high-rise building with short span has high loads. Therefore, deep foundation is required in such cases. Deep foundation is provided because ground at greater depth are highly compacted.
- ✓ In case of framed structure multi-storey building, where loads are concentrated at the point of application, the use of pads and piles are common. Where, loads of the buildings are uniformly distributed, like from masonry claddings, the piles are not needed.

2. **TYPE OF SOIL:**

- ✓ Where soil close to the surface is capable of supporting structure loads, shallow foundations can be provided.
- ✓ Where the ground close to surface is not capable of supporting structural loads, hard strata is searched for, and in some cases, it may be very deep, like in case of multi-storey buildings, where loads are very high. So, deep foundations are suitable for such cases.
- ✓ Field up ground have low bearing capacity, so deep foundation is required at that place, whereas uniform stable ground needs relatively shallow foundation.

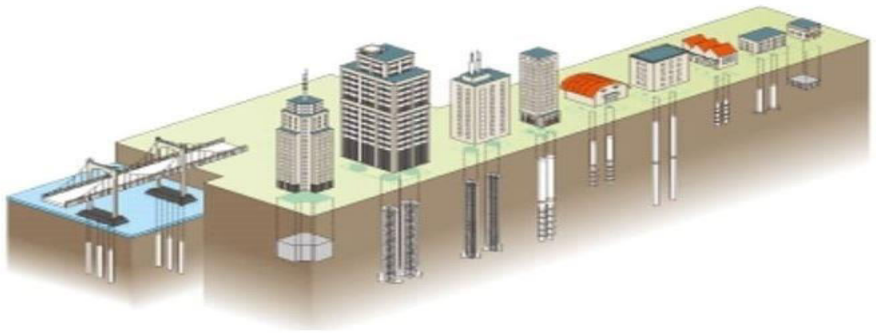
3. **TYPE OF STRUCTURES IN NEIGHBOURHOOD:**

- ✓ The selection of foundation for building construction can also be done based on the type of foundation selected for the buildings in the neighbouring buildings for the same types.

- ✓ Based on the success or failure of foundations for such buildings, decision can be taken for the selection of foundation.

4. TYPE OF FOUNDATIONS:

- ✓ Types of foundation such as isolated foundations, combined footings, pile foundations and raft or mat foundations etc.
- ✓ Based on the type of soils and loads from the buildings can be selected based on suitability and requirement.



Selection Of Foundation

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

https://civilblog.org/2016/02/22/how-to-select-a-suitable-type-of-foundation/

https://www.youtube.com/watch?v=_hqSWYxPQq0

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

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 680 to 683)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –133 to 135)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Introduction

Introduction:

A foundation transfers the loads from the superstructure to the soil safely. The foundations are designed such that:

- The soil does not fail in shear and
- Settlement is within the safe limits

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Site investigation
- ✓ Methods of exploration
- ✓ Type of soil

Detailed content of the Lecture:

Shallow foundation ($D_f \leq B$)

- ✓ The depth of foundation is small
- ✓ $(D_f / B) \leq 1$ (for shallow foundation)
- ✓ $1 < (D_f / B) \leq 15$ (for moderate shallow foundation)
- ✓ Construction in open excavations

Types of shallow foundation

- ✓ Isolated footing, square , rectangular or circular
- ✓ Continuous or strip or wall footing
- ✓ Combined footing - rectangular or trapezoidal
- ✓ Strap footing

- ✓ Raft / mat foundation

1. SPREAD FOOTING:

- A spread footing also called as isolated footing, pad footing and individual footing is provided to support an individual column.
- A spread footing is circular, square or rectangular slab of uniform thickness.
- Sometimes, it is stepped or haunched to spread the load over a large area.

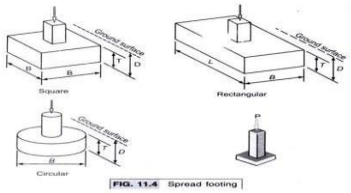

FIG. 11.4 Spread footing

2. CONTINUOUS FOOTING:

- A strip footing is provided for a load-bearing wall.
- A strip footing is also provided for a row of columns which are so closely spaced that their spread footings overlap or nearly touch each other.
- In such a case, it is more economical to provide a strip footing than to provide a number of spread footings in one line.
- A strip footing is also known as continuous footing.

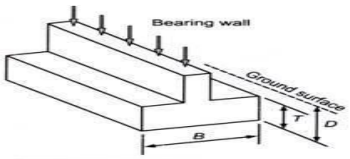

FIG. 11.7 Continuous footing

3. COMBINED FOOTING:

- A combined footing supports two columns.
- It is used when the two columns are so close to each other that their individual footings would overlap.
- A combined footing is also provided when the property line is so close to one column that a spread footing would be eccentrically loaded when kept entirely within the property line.
- By combining it with that of an interior column, the load is evenly distributed. A combined footing may be rectangular or trapezoidal in plan.

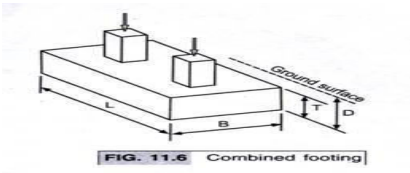

FIG. 11.6 Combined footing

4.STRAP FOOTING:

- A strap (or cantilever) footing consists of two isolated footings connected with a structural

strap.

- The strap connects the two footings such that they behave as one unit.
- The strap is designed as a rigid beam. The individual footings are so designed that their combined line of action passes through the resultant of the total load.
- A strap footing is more economical than a combined footing when the allowable soil pressure is relatively high and the distance between the columns is large.

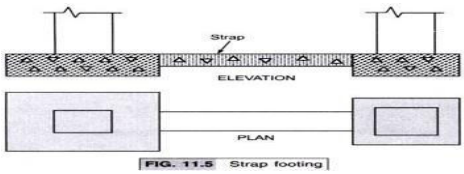

FIG. 11.5 Strap footing

5. RAFT FOOTING:

- A mat or raft foundation is a large slab supporting a number of columns and walls under the entire structure or a large part of the structure.
- A mat is required when the allowable soil pressure is low or where the columns and walls are so close that individual footings would overlap or nearly touch each other.
- Mat foundations are useful in reducing the differential settlements on non-homogeneous soils or where there is a large variation in the loads on individual columns.

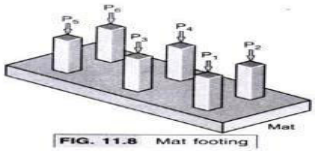

FIG. 11.8 Mat footing

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

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

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

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 707 to 716)
2. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 2.1 to 2.3)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Location and depth of foundation

Introduction:

Location of foundation:

a) Footings in sloping ground

b) Adjacent footings at different levels

c) Footings of new structures adjacent to old building

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Spacing of boring
- ✓ Depth of boring
- ✓ Soil condition

Detailed content of the Lecture:

Footings in sloping ground:

When foundation is to be located on a sloping ground, the depth of foundation should be such that a line drawn from the bottom edge of the foundation at angle of 30° and at a horizontal distance of 90 cm should not intersect, as shown in figure.

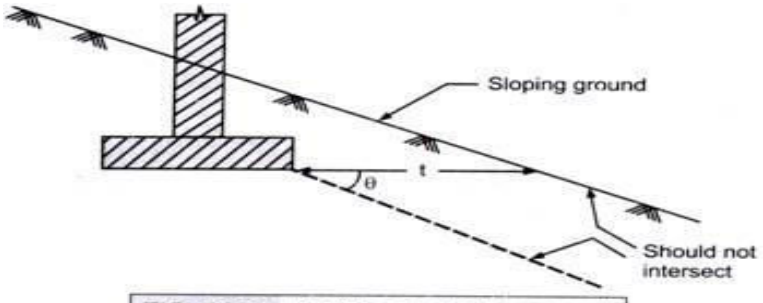

FIG. 11.11 Footing on sloping ground

Adjacent footings at different levels

- If a construction is to be made near an adjacent property line, the foundation should be so located that it should not extend into adjacent property line to avoid legal disputes.
- If a new foundation is to be laid near a existing structure, then the bottom edge of the near foundation must be at minimum distance 'S' away from the old foundations where S is the larger of the two foundations widths.
- The depth of new foundation should be such that the line drawn from the bottom edge of old foundation (at 30° for average soil and 45° for soft soil) should not intersect the bottom edge of the new foundation as shown in the figure.

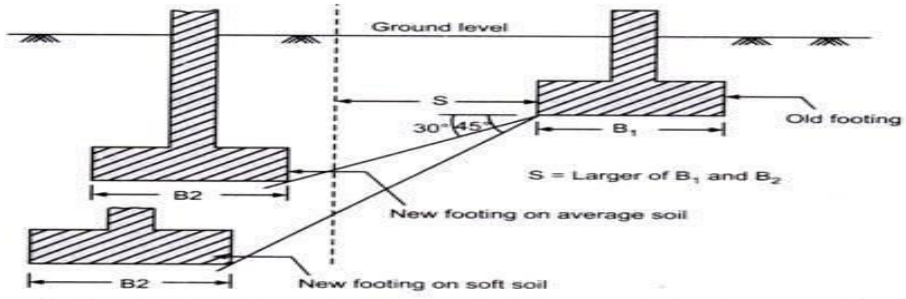

FIG. 11.10 Locating new footing adjacent to existing structure

Foundations at different level:

In situations where bottom of the foundations of a structure are at different level, BIS makes the following recommendations:

(a) For footing in granular soil, a line drawn between the lower adjacent edges of adjacent foundations should not have a slope steeper than 2 H: 1 V, as shown figure.

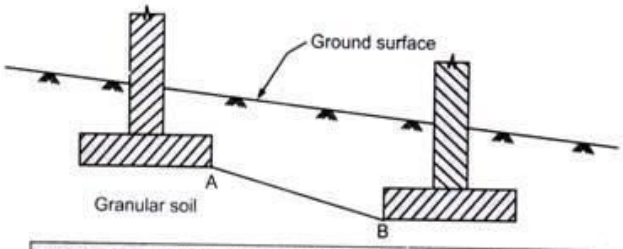

FIG. 11.12 Foundations at different level in granular soils

(b) For footing in clay soils, a line drawn between the lower adjacent edge of the upper footing and upper adjacent edge of lower footing should not have a slope steeper than 2H: 1 V as shown in figure.

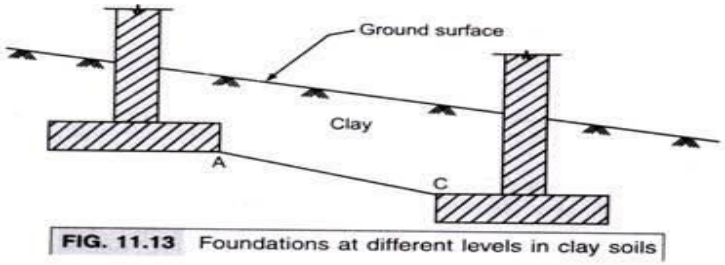

FIG. 11.13 Foundations at different levels in clay soils

Depth of foundation:

- ✓ At a depth where the soil is adequately strong
- ✓ Minimum depth = 50cm below ground level
- ✓ Below the depth of scour in foundations in river beds
- ✓ Below the zone of moisture change i.e ,below the zone of seasonal variation of water content
- ✓ Below the zone of frost heave in areas where temperature goes below zero.

General factors to be considered for determining depth of foundation are:

- ✓ Load applied from structure to the foundation
- ✓ Bearing capacity of soil
- ✓ Depth of water level below the ground surface
- ✓ Types of soil and depth of layers in case of layered soil
- ✓ Depth of adjacent foundation

Rankine's formula provides the guidance on minimum depth of foundation based on bearing capacity of soil.

$$d = (q/ Ø){(1 - \sin\varphi)/(1 + \sin\varphi)}^2$$

Where Ø is the angle of repose

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

https://www.youtube.com/watch?v=1Dt62PqHZfM&t=240s

https://www.youtube.com/watch?v=8sqSjToVes4

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 2.3 to 2.5)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 2.8 to 2.10)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Bearing capacity of shallow foundation on homogeneous deposits

Introduction:

Types of shear failure of foundation soils

- ✓ Depending upon the compressibility of soil and depth of footing with respect to its breadth (i.e D/B Ratio).
- ✓ When the ultimate bearing capacity of the soil is reached, it may fail in one of the following three failure mode depending upon the type of soil and depth to width ratio of the footing (i.e. D/B).

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Soil exploration
- ✓ Sampling techniques

Detailed content of the Lecture:

General Shear Failure

- ✓ This type of failure occurs in stiff clay or dense sand.
- ✓ In this type of failure, failure takes place at a very small strain.
- ✓ The load settlement curve shows a well-defined peak.
- ✓ At failure entire soil mass within the failure wedge participates and well defined rupture surfaces develop.
- ✓ The failure is accompanied by a considerable bulging of sheared mass of soil.
- ✓ There is only marginal difference between the load causing local shear failure and general Shear failure.

- ✓ General shear failure is accompanied by low strain (e<5%) in a soil with considerable (ø>36^{o}) and large N (N > 30) having high relative density (I_D> 70%).

The following are some characteristics of general shear failure

- ✓ Continuous, well defined and distinct failure surface develops between the edge of footing and ground surface.
- ✓ Dense or stiff soil that undergoes low compressibility experiences this failure.
- ✓ Continuous bulging of shear mass adjacent to footing is visible.
- ✓ Failure is accompanied by tilting of footing.
- ✓ Failure is sudden and catastrophic with pronounced peak in curve.
- ✓ The length of disturbance beyond the edge of footing is large.
- ✓ State of plastic equilibrium is reached initially at the footing edge and spreads gradually downwards and outwards.

Local Shear Failure

- ✓ This type of failure occurs in medium dense sand with relative density between 35 – 70 %.
- ✓ In this type of failure, failure takes place at a very large strain.
- ✓ The load settlement curve does not show a well-defined peak.
- ✓ At failure only a small portion of soil underneath the footing participates and well-defined rupture surfaces develop only at points directly below the footing.
- ✓ Bulging of soil at surface begins when strain exceeds about 8 %.
- ✓ The curve shows increase in resistance after failure.
- ✓ Local shear failure is accompanied by large strain (e> 10 to 20%) in a soil with considerably low (ø<28) and low N (N < 5) having low relative density (I_D> 20%).

The following are some characteristics of local shear failure

- ➢ A significant compression of soil below the footing and partial development of plastic equilibrium is observed.
- ➢ Failure is not sudden and there is no tilting of footing.
- ➢ Failure surface does not reach the ground surface and slight bulging of soil around the footing is observed.
- ➢ Failure surface is not well defined.
- ➢ Failure is characterized by considerable settlement.
- ➢ Well defined peak is absent in p - Δ curve.

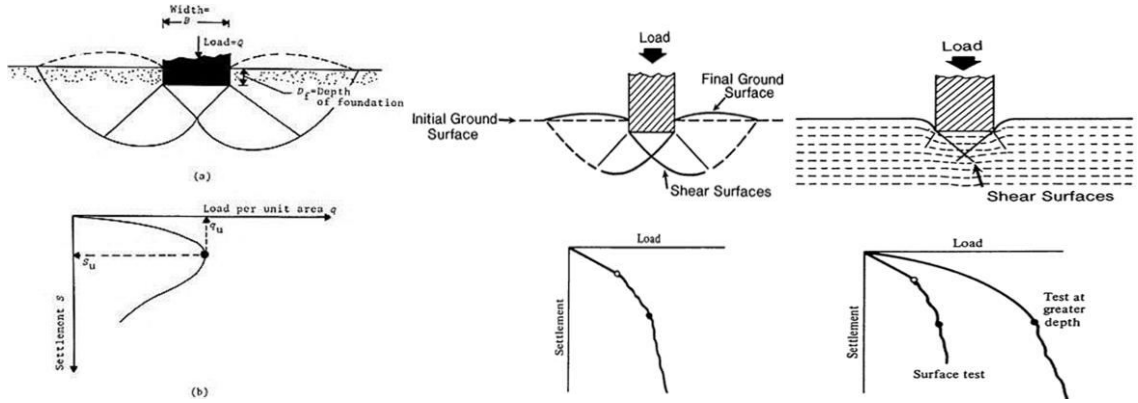
Punching Shear Failure

- ✓ This type of failure occurs in loose sand or soft clay with relative density less than 35 %.
- ✓ In this type of failure, footing penetrates into the soil without any bulging in the soil at the surface.

- ✓ Increase in vertical load increases the vertical movement and compression in the foundation soil.
- ✓ The failure is accompanied by vertical shear around the perimeter of the footing.
- ✓ At failure, soil outside the loaded area does not participate and there will be no movement of soil on the sides of the footing.

The following are some characteristics of punching shear failure

- ✓ This type of failure occurs in a soil of very high compressibility.
- ✓ Failure pattern is not observed.
- ✓ Bulging of soil around the footing is absent.
- ✓ Failure is characterized by very large settlement.
- ✓ Continuous settlement with no increase in P is observed in curve.



General shear failure | Local shear failure | Punching shear failure

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

https://www.youtube.com/watch?v=YEltCJUZ0hk

https://www.youtube.com/watch?v=2ugkE5EvLZg

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 641 to 643)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –133 to 136)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Terzaghi's formula and BIS formula

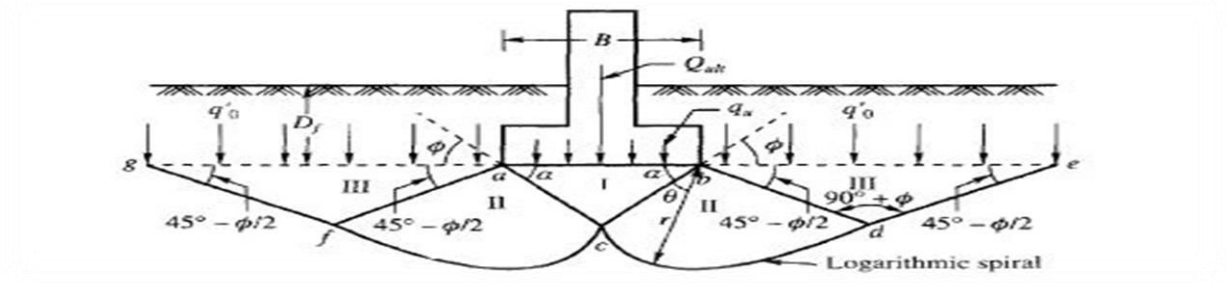
Introduction:

- ✓ In geotechnical engineering, bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil.
- ✓ Ultimate bearing capacity (q_f) is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity (q_a) is the ultimate bearing capacity divided by a factor of safety. Sometimes, on soft soil sites, large settlements may occur under loaded foundations without actual shear failure occurring; in such cases, the allowable bearing capacity is based on the maximum allowable settlement.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of shallow foundation
- ✓ Modes of failure
- ✓ Bearing capacity

Detailed content of the Lecture:



Shear stresses based on Terzaghi's soil bearing capacity theory

- ✓ Zone I: A relatively undeformed wedge of soil below the foundation forms an active Rankine zone with angles ($45^o + Ø/2$).
- ✓ Zone II: The transition zones take the form of log spiral fans.
- ✓ Zone III: The wedge pushes soil outwards, causing passive Rankine zones to form with angles ($45^o - Ø/2$).

Terzaghi's bearing capacity theory:

- ✓ Based on Terzaghi's bearing capacity theory, column load P is resisted by shear stresses at edges of three zones under the footing and the overburden pressure, ($q = \gamma D$) above the footing. The first term in the equation is related to cohesion of the soil.
- ✓ The second term is related to the depth of the footing and overburden pressure.
- ✓ The third term is related to the width of the footing and the length of shear stress area. The bearing capacity factors, Nc, Nq, Nγ, are function of internal friction angle, Ø.

Terzaghi's Bearing capacity equations:

Strip footings:

$Qu = c N_c + \gamma D N_q + 0.5 \gamma B N\gamma$

Square footings:

$Qu = 1.3 c N_c + \gamma D N_q + 0.4 \gamma B N\gamma$

Circular footings:

$Qu = 1.3 c N_c + \gamma D N_q + 0.3 \gamma B N\gamma$

Where,

- ✓ C: Cohesion of soil (apparent cohesion intercept); γ: unit weight of soil; D: depth of footing (depth of embedment); B: width/breadth of footing; Nc, Nq, Nγ: Terzaghi's bearing capacity factors depend on soil friction angle, Ø
- ✓ K_p=passive pressure coefficient.
- ✓ (Note: from Bowles' Foundation analysis and design book, "Terzaghi never explained..how he obtained K_p used to compute Nγ")

BIS (IS) formula for bearing capacity

IS : 6403 – 1981 has recommended the following formula which accounts for (i) shape of footing (ii) depth of footing (iii) inclination of load

$qunet = c Nc Sc dc ic + \gamma Df (Nq - 1) Sq dq iq + 0.5 \gamma B N\gamma S\gamma d\gamma i\gamma$

Sc , Sq , Sγ---------shape factors

dc , dq , dγ– Depth factors

ic , iq , iγ– Inclination factors consideration of W.T , local shear failure are done the sand way as in Terzaghi's eqn

Table 1. Terzaghi's Bearing Capacity Factors.

Ø	N_c	N_q	$N\gamma$
0	5.7	1	0
5	7.3	1.6	0.5
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5
25	25.1	12.7	9.7
30	37.2	22.5	19.7
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	297.5
48	258.3	287.9	780.1

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

https://www.youtube.com/watch?v=8BiAxmZ4CVc

https://www.youtube.com/watch?v=JRHhR3SaAWQ&t=661s

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 643 to 646)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –136 to 141)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Factors affecting bearing capacity – Problems

Introduction:

The bearing capacity of soil is influenced by various factors. The bearing capacity for cohesive and cohesionless soil is different. The physical features of foundation such as type of foundation, size of foundation, depth of foundation and shape of foundation significantly affect the bearing capacity.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Bearing capacity
- ✓ Types of foundation
- ✓ Strength of soil

Detailed content of the Lecture:

- ✓ The amount of total and differential settlement is one of the main controlling factors for the bearing capacity of the soil.
- ✓ The relative density in the case of granular soil and consistency in the case of cohesive soil play a decisive role in influencing the bearing capacity.
- ✓ The physical as well as engineering properties of soils such as density, cohesion and friction, position of water table and original stresses are the other factors governing the soil bearing capacity.

Factors affecting bearing capacity:

- ➢ Total and differential settlements
- ➢ Location of ground water
- ➢ Initial stresses

- Nature of soil
- Physical and engineering properties of soil
- Nature of proposed foundation
- Size and shape of the foundation
- Depth of foundation below the ground surface
- Rigidity of the foundation structure

Problem 1: Determine the net ultimate bearing capacity of (i) a strip footing of 1.5m wide (ii) a rectangular footing of 1.5m x 2m (iii) a circular footing of 1.5m diameter. The soil has c=20kN/m^2 and ø= 30^o , γ = 18kN/m^3. The footing is placed at a depth of 1.0m below G.L.

Solution

Assume general shear failure

For ø = 30^o,

N_c = 35 ,

N_q = 20 ,

N_γ = 20 from the chart

For strip footing

$q_{unet} = c\,N_c + \gamma D_f \quad (N_q - 1) + 0.5\,\gamma\,B\,N\gamma.$

q_{unet}= 20 * 35 + 18 * 1 (20-1) + 0.5*18*1.5*20

q_{unet}=1312 kN/m^2

For rectangular footing,

$q_{unet} = 1.2\,c\,N_c + \gamma\,D_f \quad (N_q - 1) + 0.4\gamma B\,N_{\gamma.}$

q_{unet}= 1.2 * 20 *35 + 18 *1 * 19 + 0.4 * 18 *1.5 *20

q_{unet}= 1398 kN/m^2

For circular footing,

$q_{unet} = 1.2\,c\,N_c + \gamma D_f \quad (N_q - 1) + 0.3\gamma B\,N_{\gamma.}$

q_{unet}= 1.2 * 20 *35 + 18 *1 * 19 + 0.3 * 18 *1.5 *20

q_{unet}=1344 kN/m^2

Problem 2: Obtain the gross and net ultimate bearing capacity of a square footing of side 2m resting on sand having ø = 35^o. The footing is placed at a depth of 1.5m below G.L. the soil above is C L and has a unit weight of 18 kN/m^2 and the sand below base has γ_t of 20 kN/m^3 .

For ø= 35^o,

N_q = 40 ,

N_γ = 45

$q_{ugross} = \gamma\,D_f\,N_q + 0.4\,\gamma\,B\,N_{\gamma.}$

q_{ugross}=18 * 1.5* 40 +0.4 * 20 * 2 *45

q_{ugross}=1080 + 720

q_{ugross}=1800 kN/m^2

$q_{unet} = \gamma D_f \quad (N_q - 1) + 0.4\gamma B N\gamma.$

q_{unet} = 18 * 1.5 * 39 + 0.4 * 20 * 2* 45 = 1773 kN/m^2

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

https://www.youtube.com/watch?v=86jDOqHw7So

https://www.youtube.com/watch?v=y6BH4a3NFhU

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 2.15 to 2.17)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 2.4 to 2.5)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Bearing capacity from in-situ tests (SPT, SCPT and plate load)

Introduction:

- ✓ Plate load test is performed to determine the ultimate load bearing capacity of soil over the in-situ conditions.The plate load test is mandatory in case of designing foundation over the sandy and clayey soil.
- ✓ This test gives the highest rate of accuracy determining the safe bearing capacity of of soil in case of shallow foundations.This test determines the Ultimate Bearing capacity of Soil, Settlement of foundation & Allowable bearing pressure of soil.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Bearing capacity of soil
- ✓ Ultimate load on soil
- ✓ Type of soil

Detailed content of the Lecture:

- ✓ This test gives the highest rate of accuracy determining the safe bearing capacity of of soil in case of shallow foundations.This test determines the Ultimate Bearing capacity of Soil, Settlement of foundation & Allowable bearing pressure of soil.
- ✓ Plate load test is suitable for Cohesionless soil as in case of Cohesion soil the settlement takes place in longer duration which this test is not suitable.
- ✓ Then the settlement per each load increment is recorded to calculate the bearing capacity of the soil.

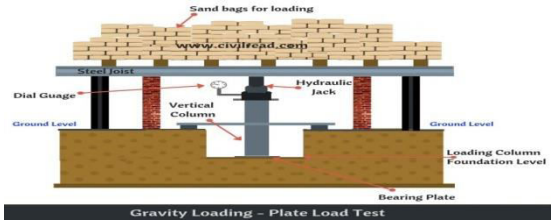
Varieties in Plate load test and their durations:-

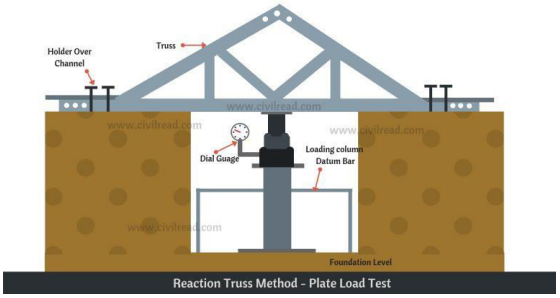
1.Gravity load test

- ✓ In this type of method, a rigid platform is utilized to transfer loads through loading of sandbags or concrete blocks. These blocks and sandbags act as a dead weight, and whole arrangement rests upon vertical columns.
- ✓ The hydraulic jack is provided in between the rigid plate and top of the column to transfer the load properly.

2.Reaction truss method

- ✓ In this method, the reaction generated through jack is borne by reaction truss installed over it.
- ✓ The undesirable movement of truss is controlled by soil anchors or nails fixed into the soil with the help of hammers.The most commonly observed truss is made of mild steel sections.In order to curb later movement, truss is locked with guy ropes.





Gravity load testReaction truss method

Plate load test apparatus / equipment

- ✓ Excavating tools
- ✓ Hydraulic jack (ball socket type with 50 T capacity)
- ✓ Mild steel plate (25 mm thickness & (30*30) cm)
- ✓ Dial gauges (minimum 3)
- ✓ Reaction beam and reaction truss with soil nails
- ✓ Plum Bob (To determine center)

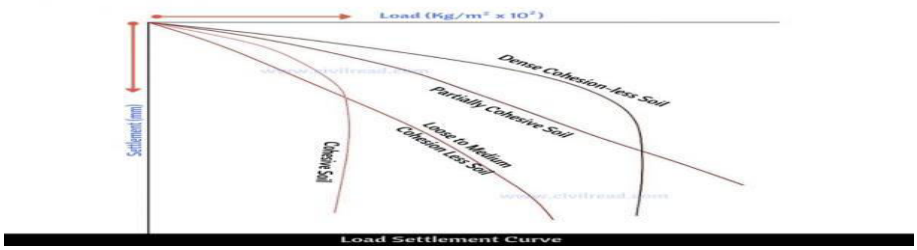
Plate load test procedure

- ✓ The pit is excavated over the site of test with the size of 1.5×1.5m and to the depth of proposed foundations.
- ✓ One needs to find the centre of excavated pit and portion to the size of the plate is eroded to the depth 1-2 cm.
- ✓ Ensure that the foundation area must be 5 times the area of plate and the seating load of 0.07Kg/cm² is applied to prevent undulations below the plate.

- ✓ The eroded portion is filled with rock dust in order to counter undulations and that of plate installed is completely horizontal which on later is checked by tube level.
- ✓ Spacers are installed over the hydraulic plate on which hydraulic jack is installed.
- ✓ The hydraulic jack in order to counter the load applies pressure which in result leads to transmission of pressure over the plate.
- ✓ Setting load of 7kN/m² is applied for some time and released. This is followed by the application of safe load with an increment of 30%.
- ✓ In case of loading through truss, both free sides are anchored with soil nails with uniformly loading at the ends.

Results recording:

- ✓ Dial gauges arranged at the bottom of the pit record are used to record settlement at every 5 minutes for first 30 minutes and every 10 minutes for rest 30 minutes.
- ✓ The observation are made until 25 mm settlement is observed which can take few hours for clayey and soft soil or even up-to couple of days for hard strata.



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

https://www.youtube.com/watch?v=BsX69r9oKIo&t=43s

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

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 673 to 679)
2. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 2.22 to 2.24)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Allowable bearing pressure – Seismic considerations in bearing capacity evaluation

Introduction:

There are two design procedures used in practice in North America.

- ✓ One is allowable stress design (ASD);
- ✓ The other is load and resistance factor design (LRFD).

In ASD, the ultimate load (stress) resistance is determined, and then this is divided by a factor of safety (FS) to obtain the allowable load (stress).

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Settlement
- ✓ Types of settlement
- ✓ Bearing capacity of soil

Detailed content of the Lecture:

ALLOWABLE BEARING PRESSURE (OR) STRESS AND LOADANDRESISTANCE FACTORDESIGN:

Allowable load (stress or strength) = Ultimate load 1stress or strength2 /FS

- ✓ The factor of safety has no fundamental basis. It is based on experience and judgment of the performance of existing foundations. ASD is the long-standing (conventional) design method.
- ✓ LRFD is based on reliability methods considering the uncertainties in loads, soil resistance, method of analysis, and construction. The loads are multiplied by load factors, usually greaterthan one in different combinations, and the ultimate soil resistance is multiplied by

a factor, called the performance factor, usually less than one. The governing equation for design based on LRFD is

$$\sum_i \rho_i P_i < \varphi_i R_i$$

Where r is load factor;

P is load;

R is resistance;

w is the performance factor;

h is a ductility, redundancy,and operational performance factor;

and *i* is the load type, such as dead load or live load, and the resistance type.

- ✓ Codes (e.g., International Building Code, UBC), engineering organizations (e.g., American Society for Civil Engineers, ASCE), and agencies (e.g., American Association of State Highway and Transportation Officials, AASHTO) have their own recommendations on load and resistance factors and load combinations.
- ✓ We will consider only two types of loads, dead load (DL) and live load (LL), one load combination, and a limited set of performance factors. They are intended only to show how to apply these methods.
- ✓ The load factors apply only to strength. For settlement calculation, the factored load or allowable stress isused.

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

https://www.youtube.com/watch?v=U61UmSMSV4g

https://www.youtube.com/watch?v=9GsPNc-ZA-s

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 708 to 709)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –263 to 266)

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Determination of Settlement of foundations on granular and clay deposits - Total and differential settlement - Allowable settlements – Codal provision

Introduction:

The total vertical displacement that occur at **foundation** level is termed as **settlement**. The cause of **foundation settlement** is the reduction of volume air void ratio in the **soil**.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Settlement
- ✓ Types of settlement
- ✓ Bearing capacity of soil

Detailed content of the Lecture:

The following formula as suggested by **Terzaghi and Peck** is used to calculate the settlement of footing ,

For granular soil.

$$S_f = S_p[B_f (B_p + 0.3)/B_p(B_f + 0.3)]^2$$

For clayey soil the following equation can be used.

Sf = Sp*(B/Bp)

Where,

Sp = Settlement of plate, mm

Sf = Settlemnt of footing, mm

Bp = Width or dia of plate, m

B = Width of footing, m

Settlement

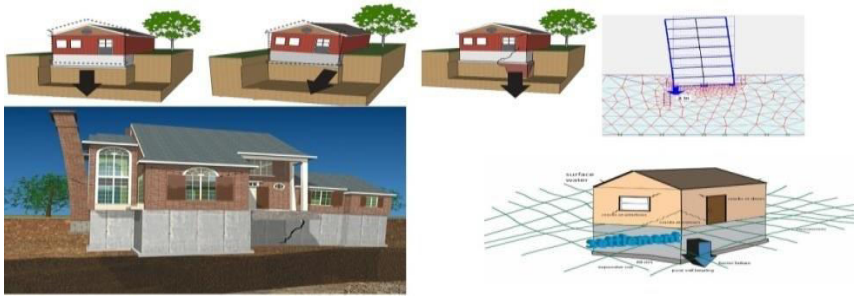
Moisture Content Changes: Moisture content in foundation soil can change and damage settlement. If too much moisture soaks through foundation soil and causes the softening or weakening of clay silt, reducing the soils ability to support the load and typically results in foundation settlement.

Total settlement

It is the magnitude of downward movement. Differential settlement is non-uniform settlement. It is "the difference of settlement between various locations of the structure.

Differential settlement

During and after the building construction, settlement of the foundation structure is considered normal and acceptable to a certain extent. However, a potential problem occurs with differential settlements. Differential settlements are uneven foundation settlements that can be the result of numerous causes.



Settlement

Allowble settlement:

- ✓ The allowable settlement is defined as the acceptable amount of settlement of the structure and it usually includes a factor of safety.
- ✓ It is the maximum settlement beyond which the foundation fails due to excessive settlement.
- ✓ It's permits a maximum allowable settlement of 40mm for isolated foundations on sand and 65mm for those on clay.
- ✓ For raft foundations on sand 40mm to 65mm and that on clay 65mm to 100mm.
- ✓ Average settlement ranging from 20 mm to 300 mm have been permitted in engineering practice, depending on the type of soil, structure, construction type.

According to IS 1904 permits tolerable settlement S as under,

	Sand	**clay**
(a) Isolated foundations	60 mm	75 mm
(b) Raft foundations	65 mm	100mm

According to British code permits tolerable settlement S as under,

	Sand	**clay**
(a) Isolated foundations	50 mm	75 mm
(b) Raft foundations	75 mm	125

Problem:The settlement of plate of size 300mm on sand for a particular loading intensity is 12.8mm. Find the settlement of foundation of size 1.5m on the same sand for the same loading intensity.

Given Data

Size of plate = 300mm

Load intensity settlement = 12.8mm

Foundation width = 1.5m

Solution

$$\text{Settlement } (S_f) = S_p \left[\frac{B_f(B_p + 0.3)}{B_f(B_p + 0.3)}\right]^2$$

$$(S_f) = 12.8 \left[\frac{1.5(0.3 + 0.3)}{0.3(1.5 + 0.3)}\right]^2$$

$$(S_f) = 35.6\text{mm}$$

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

https://www.youtube.com/watch?v=58Tz6L9-bo8

https://www.youtube.com/watch?v=w_4f3iLiulo

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 678 to 679)
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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : II – SHALLOW FOUNDATION

Date of Lecture:

Topic of Lecture: Methods of minimizing total and differential settlements

Introduction:

- Differential settlement is the term used in structural engineering for a condition in which a building's support foundation settles in an uneven fashion, often leading to structural damage.
- All buildings settle somewhat in the years following construction, and this natural phenomenon generally causes no problems if the settling is uniform across the building's foundation or all of its pier supports.
- But when one section of the foundation settles at a faster rate than the others, it can lead to major structural damage to the building itself.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Settlement
- ✓ Types of settlement
- ✓ Bearing capacity of soil

Detailed content of the Lecture:

Methods of minimising settlementand differential settlement:

- ✓ Preloading or pre-compaction to decrease compressibility.
- ✓ Decreasing the effective load by floating foundation effect.
- ✓ Increasing the depth of foundation (in sandy soils) to take advantage of increasing modulus of soil.
- ✓ Use of piles or piers.

- ✓ In-situ reinforcement of bearing layer.
- ✓ Differential settlement is not usually a sign of carpentry construction flaws, although some people view it that way. Instead, the phenomenon results when the soil beneath the structure expands, contracts, or shifts in an uneven fashion, causing the foundation to settle at an uneven rate. Thus, the villain is not the carpentry construction practice, but rather the prior evaluation and preparation of the building site itself and the construction of the foundation.

Causes

- ✓ Uneven settlement of a foundation is always caused by some form of shifting of the soil beneath the foundation, but this shifting can take place for several reasons.

Soils with weak bearing capacity

- ✓ Some soils are weak and highly compressible by nature, and buildings erected on such soils require special footings to spread the load over a wider area.
- ✓ This tends to be an issue about which local building architects are well familiar, and it is generally addressed during the excavation and construction of the foundation.

Poorly compacted soil

- ✓ Building sites for commercial or residential structures often consist of land that has been artificially leveled and filled for ease of construction.
- ✓ When properly compacted, this fill soil can provide a perfectly solid base for supporting foundations, but when not compacted, the soil may settle and compress unevenly under the foundation, leading to structural damage.

Changes in soil moisture

- ✓ Soil that is either too dry or too wet can cause foundation settlement. When moisture builds up, soils saturate and lose their load-bearing capacity.
- ✓ Dry soils shrink in volume. Either situation can cause uneven settling of the foundation. Soil moisture changes can come about due to prolonged drought or by mature trees and other plantings that draw moisture from the soil.
- ✓ In rare instances, leaking in subfloor heating, ventilation, and air-conditioning ductwork can affect the soil moisture beneath the foundation.

Trees and vegetation

- ✓ Large trees, shrubs, and other vegetation planted along a building's foundation or close to it can gradually draw the moisture out of the soil and cause it to shrink.
- ✓ This situation is more common with shallow foundations than with basement-level foundations that extend down many feet.
- ✓ When foundation settlement begins to occur several decades after construction, the soil

has likely shrunk because large trees are drying out the soil.

Soil consolidation

- ✓ The weight of a building on the underlying soil, especially fill soils that were added just prior to construction, will naturally compress the soil.
- ✓ Clay soils, in particular, become very dense as moisture is squeezed out. As the soil consolidates and shrinks, the foundation settles downward, a movement that can cause cracks and other structural damage.

Vibration

- ✓ Vibration of the soil from seismic activity or even from nearby road traffic can cause soils to settle or shift unevenly, leading to structural damage to the building.

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

https://www.youtube.com/watch?v=8rRX4VeKN-o

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

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 344 to 347)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 263 to 267)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Types of footings

Introduction:

- ✓ Footing is one of the most important parts of a structure which transfers loads of a structure to the underlying soil. The selection of suitable type of footing generally depends on the following factors:

1. The depth of the soil at which safe bearing strata exists.
2. The type and condition of soil.
3. The type of the superstructure.

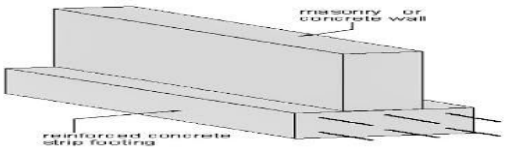
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Soil condition
- ✓ Methods of exploration

Detailed content of the Lecture:

1. **Strip footing:**

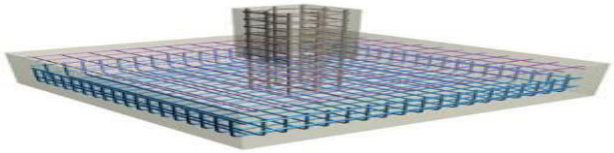
- ✓ It is a component of shallow foundation which distributes the weight of a load bearing wall across the area of the ground. It is also known as wall footing.



2. **Spread Footing:**

- ✓ As the name suggests, a spread is given under the base of the foundation so that the load

of the structure is distributed on wide area of the soil in such a way that the safe bearing capacity of the soil is not exceeded.



3. Isolated Footings:

✓ It is square, circular or individually rectangular slab of uniform thickness, provided under each column.

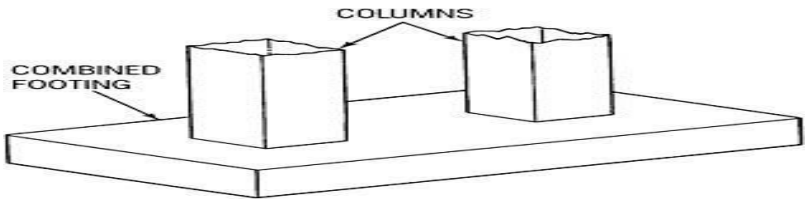
4. Stepped Footings:

✓ The main purpose of using stepped footing is to keep the metal columns away from direct contact with soil to save them from corrosive effect. They are used to carry the load of metal columns and transmit this load to the below ground.

5. Combined Footings:

✓ When two or more columns are supported by a footing it is called combined footing. This footing may be of rectangular or trapezoidal in plan. Combined footing is provided under following situations.

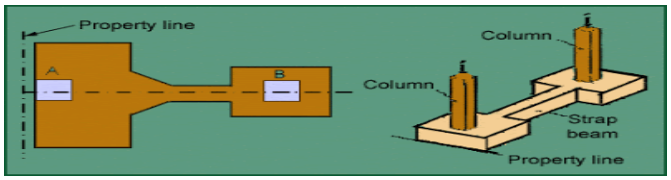
- ✓ When columns are close to each other and their individual footings overlap.
- ✓ Soil having low bearing capacity and requires more area under individual footing.
- ✓ The column end is situated near the property line and the footing can not be extended.



6. Strap Footing:

✓ In such footing, the outer and inner column is connected by a strap beam, does not transfer any load to the soil. The individual footing areas of the columns are so arranged that the C.G of the combined loads of the two columns pass through the C.G of the two

footing areas. Once this criterion is achieved, the pressure distribution below each individual footing will be uniform.



7. **Mat Foundation:**

✓ This foundation covers the entire area under the structure. This foundation has only RCC slab covering the whole area or slab and beam together. Mat foundation is adopted when heavy structures are to be constructed on soft made-up ground or marshy sites with uncertain behavior. Mat foundation is also known as raft foundation.

8. **Sloped Footing:**

✓ The footings having sloping top or side faces are known as sloped footings. This type of footing is useful in the construction of formwork.

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

https://www.youtube.com/watch?v=vN8smpxhL9c

https://www.youtube.com/watch?v=3ths577Wxpw

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.1 to 3.5)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 3.1 to 3.7)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Contact pressure distribution

Introduction:

- ✓ Contact pressure is the actual pressure transmitted from the foundation to the soil. On the assumption that the vertical settlement of the foundation is uniform, it is found from the elastic theory that the stress intensity at the edges of a foundation on cohesive soils is infinite.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of footing
- ✓ Types of soil
- ✓ Presuure on the soil

Detailed content of the Lecture:

- ✓ On the underside of the footing, the soil reaction produce a upward pressure which is assumed uniform in deriving different relationship for soil-structure interaction problem. This pressure is called contact pressure. But actually a footing are not flexible as well as contact pressure is not uniform, necessitating more investigation for actual contact pressure distribution.
- ✓ The contact pressure is the ratio of the normal load to the true contact area, which is the sum of the front and rear areas. It may be called the scratch hardness only in the case of plastic contact.
- ✓ The actual distribution of contact pressure depends upon a number of factors such as

1) Elastic properties of footing

2) Elastic properties of soil
3) Thickness of footing

Contact Pressure On Saturated Clay

- ✓ Flexible Footing When a footing is flexible, it deforms into shape of bowel, with the maximum deflection at the center.
- ✓ The contact pressure distribution is uniform.Rigid FootingWhen a footing is rigid, the settlement is uniform.
- ✓ The contact pressure distribution is minimum at the center and the maximum at the edges.
- ✓ The stresses at the edges in real soils can not be infinite as theoretically determined for an elastic mass. In real soils, beyond a certain limiting value of stress, the plastic flow occursand the pressure becomes finite.

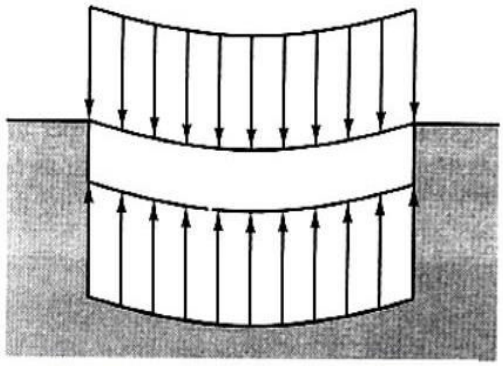
Contact pressure on sand

- ✓ Flexible footingIn this case, the edges of flexible footing undergo a large settlement than at the centre.
- ✓ The soil at the centre is confined and, therefore, has a high modulus of elasticity and deflects less for the same contact pressure.
- ✓ The contact pressure is uniform. Rigid footingIf the footing is rigid, the settlement is uniform.
- ✓ The contact pressure increases from zero at the edges to a maximum at the centre. The soil, being unconfined at edges, has low modulus of elasticity.
- ✓ However, if the footing is embedded, there would be finite contact pressure at edges.
- ✓ Thus it is observed that the contact pressure distribution for flexible footing is uniform for both clay and sand.
- ✓ The contact pressure for rigid footing is maximum at the edges for footing on clay, but for rigid footings on sand, it is minimum at the edges

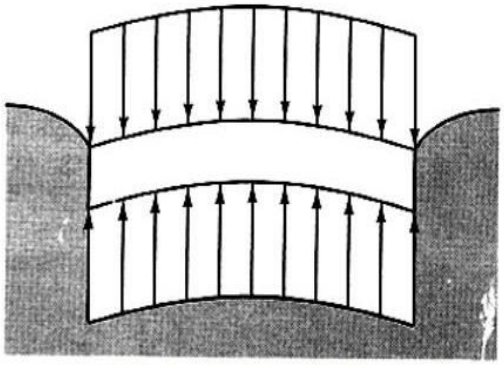
Consequence of assuming uniformity in pressure

- ✓ For convenience, the contact pressure is assumed to be uniform for all types of footings and all types of soils if load is symmetric.
- ✓ The above assumption of uniform pressure distribution will result in a slightly unsafe design for rigid footing on clays, as the maximum bending moment at centre is underestimated.
- ✓ It will give a conservative design for rigid footings on sandy (cohessionless) soils, as the maximum bending moment is overestimated. However, at the ultimate stage just before failure, the soil behaves as an elasto-plastic material (and not an elastic material) and the contact pressure is uniform and the assumption is justified at the ultimate stage.

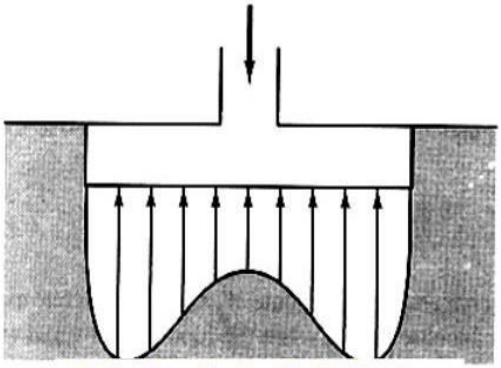
Contact Pressure and Settlement distribution



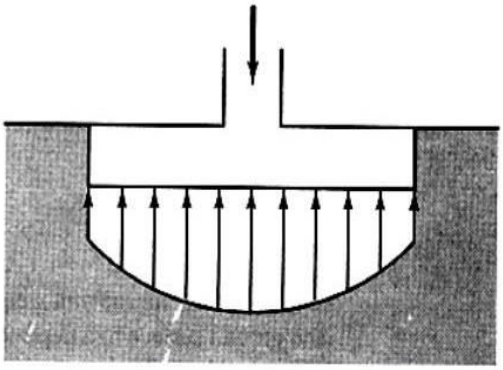
Cohesive Soil - Flexible Footing



Granular Soil Flexible Footing



Cohesive Soil - Rigid Footing



Granular Soil - Rigid Footing

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

https://www.youtube.com/watch?v=34HONH40vY0

https://www.youtube.com/watch?v=0Z5yC67h5Ys

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3. 6 to 3.8)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 3.11 to 3.12)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Isolated footing

Introduction:

Spread footings are the most widely used type among all foundations be because they are usually more economical than others. Least amount of equipment and skill are required forthe construction of spread footings. Further, the conditions of the footings and the supportingsoil can be readily examined.

Other types of foundations are more favourable when the soil has a very low bearingcapacity or when excessive settlementsare expected to result due to the presence of compressible strata within the active zone.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of footing
- ✓ Loads on structure
- ✓ Soil type

Detailed content of the Lecture:

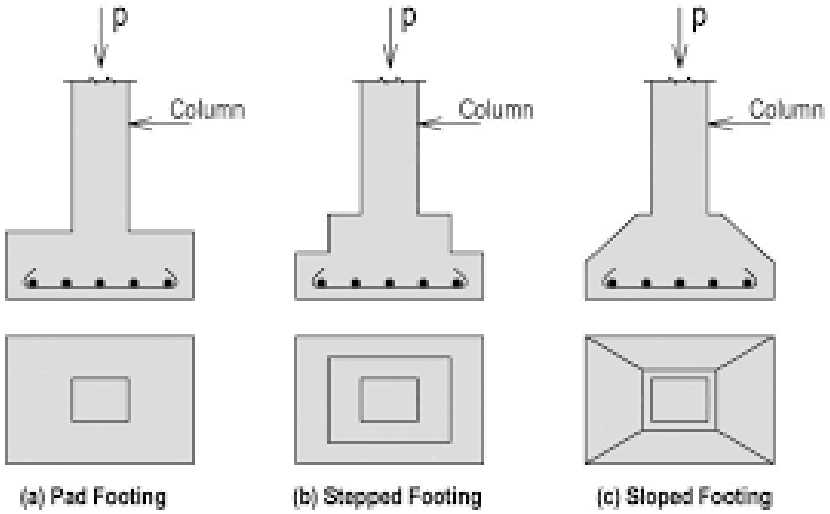
- ➢ A spread footing is a type of shallow foundation used to support a wall or a column. In the former case, it is called a continuous or wall footing and in the latter, it is called an isolated or individual footing.
- ➢ The base area of the footing is governed by the bearing capacity of the soil. The plainfooting is usually of reinforced concrete and is used to support a reinforced concrete column.
- ➢ The mass concrete footing is used to support a steel column. Usually the sloped footing

will beof the same material as that for the column; alternatively, it can be of reinforced concrete.

- Thestepped footing is used either for a column or for a wall. All the steps may be of concrete or thebottom most step alone may be of concrete, the others being of the same material as for the column.

PROPORTIONATING FOOTINGSIZE

Footing sizes are basically designed for safe bearing and then checked for permissible total and differential settlements. The size is modified if the permissible settlements are notsatis- fied. While proportionating, the following procedure may be followed (Teng,1962):



1. Calculate the load on thestructure:

   L_l + d = live load + dead load

   for the column which has the largest live load to dead load ratio.

2. Calculate the service load for the same column:

   L_S = dead load + C (live load)

   where C is ½ for ordinary buildings and ¾ for warehouses and storage floors.

3. Decide the storage floor's safe bearingpressure:

   Q_a = safe bearing pressure from theories or field tests

4. Compute the designpressure:

   Q_d = design pressure

   for all footings except the one with the lowest live load to dead load ratio.

   $q_d = L_c \,/\, A$

   where L_S is the service load. That is,

proportioned area of footing = service load / qd

5. Computetheareaoffootingsupportingthecolumnwiththelowestliveloadtodeadload ratio: $A = (L_l + d) / q_s$
6. Decide the length and width of footing and check for permissible settlement and alter width if needed.

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

https://www.youtube.com/watch?v=E5b6UlV7g44

https://www.youtube.com/watch?v=h2LSftATAZw&t=293s

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.11 to 3.12)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 3.23 to 3.28)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.Selvapriya

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Proportioning of footing (Rectangular combined footing)

Introduction:

- ✓ A combined footing is generally rectangular in plan if sufficient space is available beyond each column, If one of the columns is near the property line, the rectangular footing can still be provided if the interior column is relatively heavier.
- ✓ However, if the interior column is lighter, a trapezoidal footing is required to keep the resultant of the column loads through the centroid of the footing.
- ✓ Thus the resultant of the soil reaction is made to coincide with the resultant of the columnloads.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of footing
- ✓ Types of combined footing
- ✓ Loads on structure

Detailed content of the Lecture:

Rectangular Combined Footing:

The design of a combined footing consists of selecting length and width of the footing such that the centroid of the footing and the resultant of the column loads coincide.

With the dimensions of the footing established, the shear force and bending moment diagram are drawn. The thickness of the footing is selected from the bending moment and shear force considerations.

The footing is designed as a continuous beam supported by two columns in the

longitudinal direction. The reinforcement is provided as in a continuous beam.

The procedure consists of following steps:

1. Determine the total column loads. $Q = Q_1 + Q_2$

   Where Q_1 – exterior column load

   Q_2 – interior column load
2. Find the base area of the footings.

   $A = Q / q_{na}$

   Where q_{na} – allowable soil pressure.Locate the line of action of the resultant of the column loads measured from one of the column, say exteriorcolumn.

   $\bar{x} = Q_2 X x_2/Q$

   Where x_2 - distance between columns.
3. Determine the total length offooting. $L = 2(\bar{x}+b_1/2)$

   Where b_1 – width of exterior column.
4. Find the width of the footing. $B = A/L$
5. As the actual width and length that are provided may be slightly more due to rounding off, the actual pressure is givenby

   $q_0 = Q / A_0$

   Where A_0 – actual area
6. Draw the shear force and bending moment diagrams along the length of the footing, considering the pressure q_0. For convenience the column loads are taken as concentric column loads acting at thecentres.
7. Determine the bending moment at the face of the columns and the maximum bending moment at the point of zeroshear.
8. Find the thickness of the footing for the maximum bendingmoment.
9. Check the diagonal shear and punching shear as in the case of isolated footings. Check for bond at the point of contraflexure.
10. Determine the longitudinal reinforcement for the maximum bendingmoment.For transverse reinforcement, assume a width of (b + d) to take all the bending moment in the short direction, where b is the column side and d is the effective depth.

    Problem: Find the dimensions of a rectangular footing to carry a design load of 1000kN with a factor of safety of 3. The foundation is at a depth of 1.2m below ground level in a clayey soil of unconfined compressive strength of 120 kPa. The width / length ratio of the footing can be taken as 0.8. Adopt BIS 6403recommendation.

Solution

Area required = Design load / Safe bearing capacity

Soil is clay ; C = Unconfined comp. st / 2 = 120 / 2= 60kN/m^2

ø=0 B/L=0.8

$q_{u\ net}$ = C N_c S_c d_c i_c

for ø = 0; N_c = 5.7

Load is vertical; i_c =1;

S_c = 1 + 0.2 B / L ; 1+ 0.2*0.8 =1.16

d_c = 1+ 0.2 D_f / B tan (45+ø/2)

= (1+0.2 (1.2/B)) = 1+0.24/B

$q_{u\ net}$ = 60*5.7*1.16*(1+0.24/B)

q_{safe} = $q_{u\ net}$ / 3 = (132) * (1+0.24B)

Area required = 1000 / 132 * (1+0.24B)

Choose B/L = 0.8; L = B/0.8 =1.25B

ie., 1000/(132*(1+0.24B)) = B* 1.25B

ie., 165 B^2 +39.6B -1000 =0

Solving, B=2.35m

B/L=0.8: L=2.94m

Choose a rectangular footing of size **2.35m * 2.95m**

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

https://www.youtube.com/watch?v=GBa-vtXp7lg

https://www.youtube.com/watch?v=QYz6ZMHwVOs

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.9 to 3.15)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 3.29 to 3.42)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Proportioning of footing (Trapezoidal combined footing)

Introduction:

The geometric proportions and shape are so fixed that the centeroid of the footing area coincides with the resultant of the column loads. This results in uniform pressure below the entire area of footing. Trapezoidal footing is provided when one column load is much more than the other.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of footing
- ✓ Types of combined footing
- ✓ Loads on structure

Detailed content of the Lecture:

Trapezoidal combined footings:

Trapezoidal combined footings are provided to avoid eccentricity of loading with respect to the base. Trapezoidal footings are required when the space outside the exterior column is limited and the exterior column carries the heavier load.

1. Determine the total column loads. $Q = Q_1 + Q_2$

   Where Q_1 – exterior column load Q_2 – interior column load
2. Find the base area of the footings. $A = Q / q_{na}$

   Where q_{na} – allowable soil pressure.
3. Locate the line of action of the resultant of the column loads measured from one of the column, say exteriorcolumn.

$\bar{x} = Q_2 * x_2 / Q$

Where x_2 - distance between columns.

4. Determinethedistance"x"oftheresultantfromtheouterfaceoftheexteriorcolumn. $x'' = \bar{x} + b_1/2$ where b_1 – width of exterior column.

   A trapezoidal footing is required if $L/3 < x'' < L/2$

   Where L – length of the trapezoidal footing determined from $L = 2(\bar{x} + b_1/2)$

   If $x'' = L/2$, a rectangular footing is provided. However if $x'' < L/3$, a combined footing cannot be provided. In such a case, a strap footing is suitable.

5. Determine the width B1 and B2 from the followingrelations.

   Once the dimension B1 and B2 has been found, the rest of the design can be done as in the case of rectangular combinedfooting.

   As the actual width and length that are provided may be slightly more due to rounding off, the actual pressure is givenby

   $q_0 = Q / A_0$

   Where A_0 – actual area

6. Draw the shear force and bending moment diagrams along the length of the footing, considering the pressure q_0. For convenience the column loads are taken as concentric column loads acting at thecenters.
7. Determine the bending moment at the face of the columns and the maximum bending moment at the point of zeroshear.
8. Find the thickness of the footing for the maximum bendingmoment.
9. Check the diagonal shear and punching shear as in the case of isolated footings. Check for bond at the point of contraflexure.
10. Determine the longitudinal reinforcement for the maximum bendingmoment.

Problem:A trapezoidal footing is to be proportion to support two square columns of 30cm and 50cm sides respectively. Columns are 6m apart and the safe bearing capacity of the soil is 400kN/m². The bigger column carries a load of 500kN and the smaller carries a load of 3000kN. Design a suitable size of the footing that does not extend beyond the face of the column.

CG loads:

Taking moment about the left end

5000 * 0.25 + 3000 * 6.25 = (5000+ 3000) * x

x = (5000 * 0.25 + 3000 * 6.25) / 8000 =2.50 m from the left end

To ensure CG coincides with the centroid of the trapezium

(a + 2b)/(a+b) * 6.4/ 3 = 2.5----------(1)

The area required = 8000/400 = 20m^2

i.e.,(a+b/2) * 6.4 = 20----------(2)

Solving (1) and (2)

a= 5.15m and b = 1.07m

Say, **a= 5.2m**; **b = 1.10m**

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

https://www.youtube.com/watch?v=cHZ8HmPLR7A

https://www.youtube.com/watch?v=NkpQPRNFW3I

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.9 to 3.15)
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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Types of mat foundation

Introduction:

- ✓ A raft or mat is a combined footing that covers the entire area beneath the structure and supports all the walls and columns.
- ✓ when the allowable soil pressure is low, or the building loads are heavy, the use of spread footings would cover more than one-half of the area and it may prove more economical to use mat or raft foundation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Soil condition
- ✓ Types of foundation
- ✓ Load on the structure

Detailed content of the Lecture:

- ✓ They are also used where the soil mass contains compressible less or the soil is sufficiently erratic so that the differential settlement would be difficult to control.
- ✓ The mat or raft trends to bridge over the erratic deposits and eliminates the differentialsettlement.Raft foundation is also used to reduce settlement above highly compressive soils, by making the weight of structure and raft approximately equal to the weight of the soil excavated.

TYPES OF RAFT FOUNDATION:

(a) FLAT TAPETYPE:

In this type of mat foundation a mat of uniform thickness is provided. This type is most

suitable when the column loads are relatively light and the spacing of columns is relatively small and uniform.

(b) FLAT PLATE THICKENED UNDERCOLUMN:

When the column loads are heavy this column is thickened to provide enough thickness for negative bending moment and diagonalshear.Sometimes instead of thickening a slab, a pedestal is provided under each column above the slab to increase the thickness.

(c) BEAM AND SLABCONSTRUCTION:

In this type of construction, the beams run in two perpendicular directions and a slab is provided between the beams. The columns are located at the intersection of beams. This type is suitable when the bending stresses are high because of large column spacing and unequal column loads.

(d) BOXSTRUCTURES:

In this type of mat foundation, a box structure is provided in which the basement walls acts as a stiffeners for the mat. Boxes may be made of cellular construction or rigid frame consisting of slabs and basement walls. This type of mat foundation can resist very high bendingstresses.

(e) MATS PLACED ONPILES:

The mat is supported on the piles in this type of construction. This type of mat is used where the soil is highly compressible and the water table is high. This method of construction reduces the settlement and also controls buoyancy.

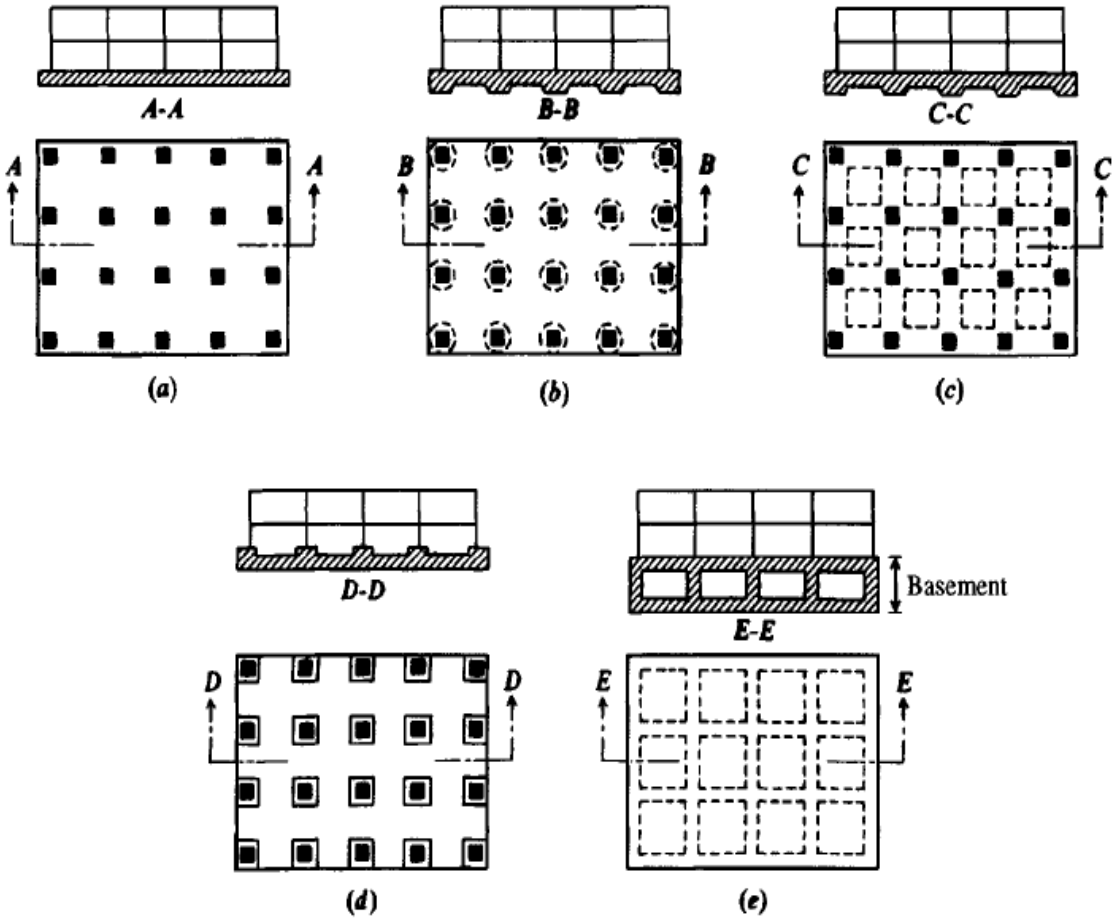
ADVANTAGES:

1. The foundation and ground floor slab is poured at the same time so which reduces our construction time and material.
2. It requires less excavation.
3. It is provided where the shallow foundation is possible but the condition of the soil is poor.
4. Reduces the cost of constructing a floor slab (But not fully economical).
5. It helps in the transferring of loads over a wide area.
6. It shows good resistance and cannot slide during the flood.
7. We can handle more heavy loads as compared to other types of foundations.

DISADVANTAGES:

1. Raft foundation requires a large quantity of steel and concrete.
2. This foundation is costly (Volume of footing was increasing).
3. It is not suitable and used for domestic home construction.

4. Special measurement is needed in case of concentrated loads.
5. In the mat foundation, skilled laborers are required.



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

https://www.youtube.com/watch?v=GoqySK7Gavw

https://www.youtube.com/watch?v=xT50WymJSh8

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.15 to 3.17)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 3.63 to 3.65)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Proportioning of footing(Mat foundation)

Introduction:

- When the loads are heavy and the soil is weak .
- In loose sand or soft clay deposits when the sum of the area required for individual footings become more than 50% of the plinth area of the building. i.e., Σ area of individual footing > 50% of plinth area of the building.Where pockets of loose / soft soil exist at the site.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Soil condition
- ✓ Methods of boring

Detailed content of the Lecture:

The raft is used under the following situations:

1. When the structural loads are heavy and the supporting soil is very weak or highly compressible.
2. If the soil has very low bearingcapacity.To minimise differentialsettlement.
3. In the bridging over weak spots or loose pockets in the underlyingsoil.
4. If the individual footings cover more than half of the area then use of raft is more exponential.
5. In high compressible soil, if the settlement under individual footings are quitehigh. For resisting large, hydraulic upliftpressure.

Assumption:

1. Raft isrigid
2. Contact pressure is uniform or linear or planar as per super structureloading.
3. So the centroid of the soil pressure coincides with the line of action of the resultant force of all the loads action on the matfoundation.

Design procedure

1. Compute the column loads (dead load, live load, wind load, earthquake load, snow load etc. From super structure)
2. Determine the line of action of all theloads
3. Calculate the contact pressure as per the assumption and the conventional – empirical analysis designformula

   $q = (Q_t / A) \pm (Q_t e_x / I_y) \pm (Q_t e_y / I_x) y$

   Where Q_t = total load on mat; A = total area of the mat

   X, Y = coordinates of any given points on the with respect to the x and y axes passing through the centroid of the area of the mat.e_x, e_y = eccentricities of the resultant forces.

   I_x , I_y = moment of inertia of the mat with respect to the x and y axes respectively.
4. The mat is treated as strip in X and Y direction for the analysis for shear force and bending moment.
5. The design dimensions and reinforcement are arrived in both thedirection.

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

https://www.youtube.com/watch?v=bZ-_xomld2s

https://www.youtube.com/watch?v=-L7BgNtfi94

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.9 to 3.15)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no – 3.29 to 3.42)

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LECTURE HANDOUTS

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Proportioning of mat foundation(Problems)

Introduction:

- When the loads are heavy and the soil is weak
- In loose sand or soft clay deposits when the sum of the area required for individual footings become more than 50% of the plinth area of the building.
- i.e., Σ area of individual footing > 50% of plinth area of the building.
- Where pockets of loose / soft soil exist at the site.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Mat foundation
- ✓ Types of mat foundation
- ✓ Proportioning of mat foundation

Detailed content of the Lecture:

Problem 1:

A building has to be supported on R.C.C. raft foundation of dimensions 15m * 23 m. The soil is clay, which has an average unconfined weight of the strength of 15kN/m^2. The pressure on the soil due to the weight of the building and the loads that it will carry will be 150kN/m^2 at the base of the raft. The building has provision for basement floors. At what depth should the bottom of the raft be placed to provide a factor of safety of 3 against shear failure?

γ_{clay} = 20kN/m^2 ;

C=15/2 = 7.5kN/m^2;

For clay, ø = 0; N_c = 5.7

q_{safe} = 1.2 C N_c/F + γ D_f = Loading pressure

q_{safe}= (1.2 * 7.5 * 5.7) / 3 + 20 * D_f = 150 kN/m^2

i.e., 20 D_f = 150-17.1

D_f =6.65m

Problem 2:

The soil profile at a site consists of clay of unconfined compressive strength of 110kPa and unit weight 19 kN/m^3 extending to a great depth. A raft foundation of plan dimensions of 40m* 16m is to be installed at a depth of 3m below ground level and it carries a load of 100kN/m^2 including its self weight. There is a provision for basement floor. Determine the factor of safety as per BIS 6403

C=110/2=55kN/m^2; ø=0; N_c =5.7

q_{safe} = C N_c S_c d_c i_c / F + γ D_f

S_c = (1+0.2 B/L) = (1+0.2*16/40) =1.08

d_c = (1+0.2 D_f/B)= (1+0.2 * 3/16) = 1.0375

i_c = 1 (Load is vertical)

Loading pressure, q=q_{safe}

i.e., 100kN/m^2 =(55 * 5.7 * 1.08 * 1.0375)/F + 19 *3

Solving, **F=8.2**

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

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

https://www.youtube.com/watch?v=9-tNDTT26II

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LECTURE HANDOUTS

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : III – FOOTINGS AND RAFTS

Date of Lecture:

Topic of Lecture: Floating Foundation

Introduction:

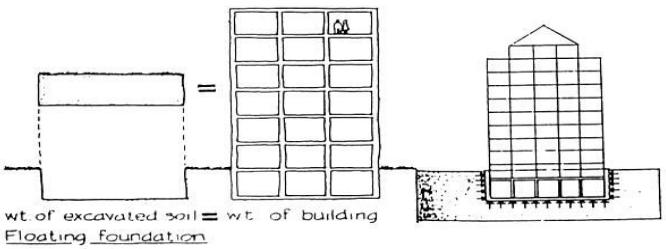
A floating raft foundation, or floating foundation, the foundation has a volume such that were that volume filled with soil, it would be equal in weight to the total weight of the structure. When the soil is so soft that even friction piles will not support the building load, the final option is the use of a floating foundation, making the building like a boat that obeys Archimedes' principle—it is buoyed up by the weight of the earth displaced in creating the foundation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Soil type
- ✓ Boring technology

Detailed content of the Lecture:

1. Mat (consisting of slabs, usually of reinforced concrete, which underlie the entire area of a building), or floating types. A floating foundation consists of boxlike rigid structures set at such a depth below ground that the weight of the soil removed to place it equals the weight of the building.

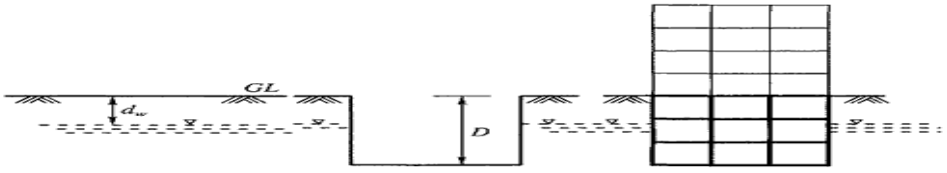


2. Floating raft is type of land-based foundation that protects against settlement and the liquefaction of soft soil due to seismic activity. It was a necessary innovation in the development of tall buildings in the wet soil of Chicago in the 19th century, where it was developed by John Wellborn Root who came up with the idea of interlacing the concrete slab with steel beams.
3. A floating foundation is the foundation of a building that does not use footings. It is a poured cement slab that has two deep edges that go just below the frost line in northern climates. The foundation actually does float on the earth and moves as temperatures compact and expand the soil.
4. In a typical floating foundation, the plumbing and electrical lines are fastened to the slab by simply running them through the floor as it is poured. This means that the plumbing, drainage, and electrical lines must all be completed prior to pouring the foundation. In many cases, it is a much more affordable method of building than using a footing equipped foundation, but it can lead to very expensive repair bills if the plumbing requires work in the future. In warmer climates, the floating slab is much more friendly to homeowners as it does not flex too much because there are fewer extreme changes in temperature. It also helps to cool the structure, as the foundation's contact with the ground draws cool temperatures through the concrete and disperses them throughout the building.
5. When constructing out-buildings such as sheds, the term can take on another meaning. Some flooring systems for outside sheds are known as floating foundation floors and do not require any concrete to be poured. In these applications, the foundation is merely lumber framing placed upon blocks. This allows the floor of the shed to sit elevated off of the ground, which prevents water from seeping into the shed and protects the shed's contents.
6. When pouring a floating slab foundation, it is imperative to install reinforced steel rods or heavy wire mesh in the floor before pouring the concrete. The wire and steel prevent the floor from cracking and breaking as the slab flexes with the earth. Without this reinforcement, the slab will likely crack and possibly cause damage to the walls and ceiling, as the floor will be allowed to flex unevenly. Often, the flexing of an un-reinforced slab will cause doors to not close or open correctly and windows to stick or even crack. Walls are also subject to cracking, and drywall is prone to break at the seams.

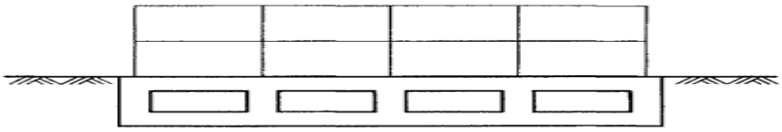
Principle:

1. The principle of floating foundation is an exact balance of weight removed against weight imposed.

2. The result is zero settlement of the building.
3. The principle of floating foundation can be used partially leaving some excess load on the soil.
4. The floating foundation is used to reduce settlement to an acceptable value.
5. The shear strength of the foundation soil is so low, that rupture of the soil would occur in the building where to be ground level.
6. If excavation extend below the water table, the problem of water lowing will be considered.



Balance of stresses in foundation excavation


(d) Rigid raft foundation

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

https://www.youtube.com/watch?v=2fiR_Za4Ax4

https://www.youtube.com/watch?v=N3msAkpUumI

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

1. Dr.S.Arunachalam., Foundation Engineering, Laxmi Publications Pvt Ltd, Eigth Edition, 2017. (Page no – 3.16 to 3.17)
2. Dr.R.Sudharsanan., Foundation Engineering, Second Edition, Sri Krishna Hitech Company Pvt Ltd, 2017. (Page no –3.7 to 3.8)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Types of piles and their function

Introduction:

Types ofpiles

- ✓ The use of piles as a foundation can be traced since olden times.
- ✓ The art of driving piles was well-established in Roman times and the details of such foundations were recorded by Vitruvious in 59 AD.
- ✓ Today, pile foundation is much more common than any other types of deepfoundation.
- ✓ Modern pile driving started with the first steam pile drivers, invented by Nasmythin 1845.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Soil strength test
- ✓ Layes of soil

Detailed content of the Lecture:

Classification based on the function

Based on the function or the use, piles may be classified as:

- ✓ End bearingpile
- ✓ Frictionpile
- ✓ Compactionpile
- ✓ Tension pile or upliftpile
- ✓ Anchorpile
- ✓ Fender pile and dolphins

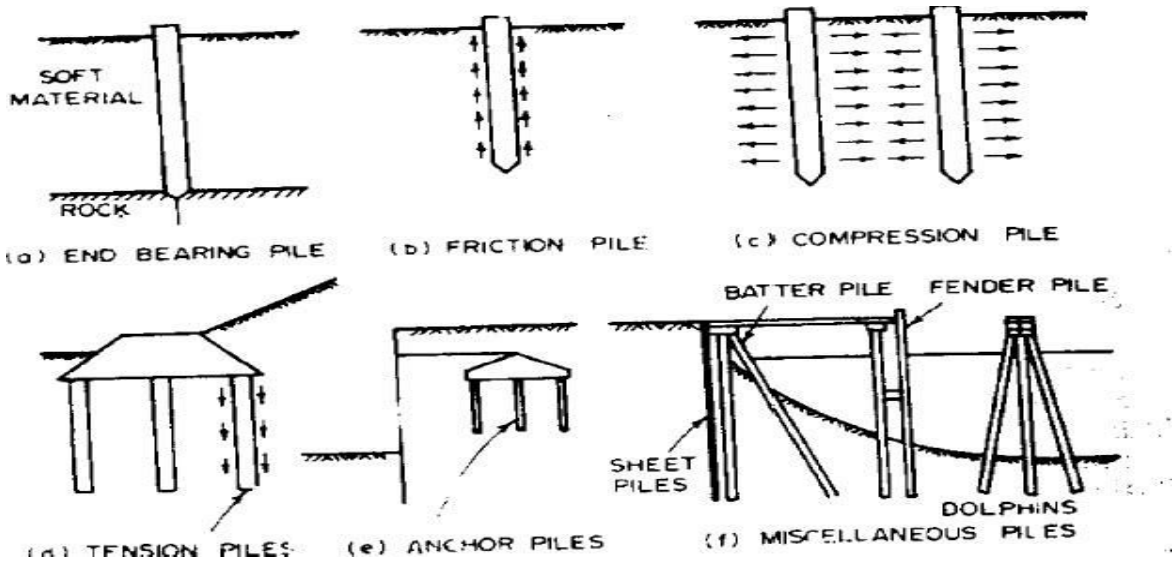
- ✓ Batterpile
- ✓ Sheet pile.
- ✓ End bearing piles are used to transfer load through water or soft soil to asuitablebearing stratum.
- ✓ Friction piles are used to transfer loads to a depth of a friction load carryingmaterial by means of skin friction along the length of thepiles.
- ✓ Compaction piles are used to compact loose granular soil, thus increasing theirbearing capacity.
- ✓ The compaction piles themselves do not carry any load. Hence they may beofweaker material— sometimes of sand only.
- ✓ The pile tube, driven to compact the soil, is gradually taken out and sand is filledinits place thus forming a 'sandpile'.
- ✓ Tension or uplift piles anchor down the structures subjected to uplift duetohydrostatic pressure or due to overturningmoment.
- ✓ Anchor piles provide anchorage against horizontal pull from sheet piling orotherpulling forces.
- ✓ Fender piles and dolphins are used to protect water front structures againsttheimpact from ships or other floatingobjects.
- ✓ Sheet piles are commonly used as bulkheads, or as impervious cutoff toreduceseepage and uplift under hydraulicstructures.
- ✓ The batter piles are used to resist large horizontal or inclinedforces.

CLASSIFICATION BASED ON MATERIALS AND COMPOSITION

- ✓ Concretepiles
- ✓ Precast
  - ➢ Cast-in-situ
  - ➢ Driven piles Cased oruncased
- ✓ Bored piles : Pressure piles andunder
  - ➢ Timberpiles
  - ➢ Steelpiles
  - ➢ H-piles
  - ➢ Pipe pile
  - ➢ Sheetpile
- ✓ Compositepiles
  - ➢ Concrete andtimber
  - ➢ Concrete andsteel.

The common types are as follows

- ✓ Raymond standardpile,
- ✓ Raymond step-taperpile,
- ✓ Union metal pile of monotube,
- ✓ MacArthur compressed uncased pile,
- ✓ MacArthur cased pile,
- ✓ Franki standardpile,
- ✓ Western button bottom pileetc.,



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

https://www.youtube.com/watch?v=fUZHMegAL74https://www.youtube.com/watch?v=SxN9HnrVHa4

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 727 to 729)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 535 to 545)

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Factors influencing the selection of pile

Introduction:

Factors Affecting Selection of Piles

- ✓ They are used for large structures, and in situations where the soil under is not suitable to prevent excessive settlement.
- ✓ Piles are required for setting out of towers for high power transmission lines and in some cases are also used for supporting the multistory buildings.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Soil strength test
- ✓ Types of pile foundation

Detailed content of the Lecture:

Among the factors that will influence the selection of type of piles for a given project are the following:

- ✓ Type, size, and weight of the structure to be supported.
- ✓ Physical properties of the soil at the site.
- ✓ Depth to a stratum capable of supporting the piles.
- ✓ Possibility of variations in the depth to a supporting stratum.
- ✓ Availability of materials for piles.
- ✓ Number of piles required.
- ✓ Facilities for driving piles.

- ✓ Comparative costs in place.
- ✓ Durability required.
- ✓ Types of structures adjacent to the project.
- ✓ Depth and kind of water, if any, above the ground into which the piles will be driven.

Situations Which Demand Pile Foundations

- ✓ Sub-soil water table is so high that it can easily affect the other foundations.
- ✓ Load coming from the structure is heavy and non uniform.
- ✓ Where grillage or raft foundations are either very costly or their adoption impossible due to local difficulties.
- ✓ When it is not possible to maintain foundation trenches in dry condition by pumping, due to very heavy inflow of seepage or capillary water.
- ✓ When it is not possible to timber the excavation trenches in the case of deep strip foundation. (strip foundation-spread footing under wall).
- ✓ When overlay soil is compressible, and water-logged and firm hard bearing strata is located at quite a large depth.
- ✓ When structures are located on river-bed or sea-shore and foundations are likely to be scoured due to action of water.
- ✓ Large fluctuations in sub-soil water level.
- ✓ Canal or deep drainage lines exist near the foundations.

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

https://www.youtube.com/watch?v=hzcyUbwgqqQhttps://www.youtube.com/watch?v=ZwQI0t8ITzk

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 729 to 732)
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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Carrying capacity of single pile in granular and cohesive soil – static formula – dynamic formulae (Engineering news and Hileys) – Capacity from insitu tests (SPT and SCPT)

Introduction:

- The ultimate load carrying capacity, or ultimate bearing capacity, or the ultimate bearing resistance Qt of a pile is defined as the maximum load which can be carried by a pile, and at which the pile continues to sink without further increase ofload.
- The allowable load Qa is the safe load which the pile can carry safely and is determined on the basis of :
- Ultimate bearing resistance divided by suitablefactor ofsafety,
- The permissiblesettlement,Overall stability of thepile-foundation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Factors influencing the selection of pile
- ✓ Types of pile foundation

Detailed content of the Lecture:

The load carrying capacity of a pile can be determined by the following methods

- ✓ Dynamicformulae
- ✓ Staticformulae
- ✓ Pile loadtests
- ✓ Penetrationtests

STATICFORMULAE

The static formulae arc based on assumption that the ultimate bearing capacity Qf of a pile isthe sum of the total ultimate skin friction R, and total ultimate point or end hearing resistance Rp:

$$Q = Rf + RPOrQf = As.\ rf + Ap.rr$$

Where

As= surface area of pile which the s-kin friction acts

Ap = area of cross-section of pile on which hearing resistance acts. For tapered piles, A may be taken as the cross-sectional area at the lower one third of the embedded length.

rf =average skin friction

RP = unit point or toe resistance

A factor of safety of 3 may he adopted for finding the allowableload.

(i) For cohesive soil:

For the pile in cohesive soil, point bearing is generally neglected for individual pile action, since it is negligible as compared to frictional resistance. The unit skin friction may be taken equal to the shear strength of (he soil :

$$rf = c = qu / 2$$

$$rp = c\ .\ Nc = 9c\ Qp = c\ Af + 9c\ .Ap$$

(ii) For noncohesive soil:

$$rf = K\ tan\text{ø}\ (\acute{Y}z + q)$$

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

https://www.youtube.com/watch?v=hBNk9y_Yf8Ehttps://www.youtube.com/watch?v=ZwQI0t8ITzk&list=TLPQMjUwOTIwMjAo-49qpso-5Q&index=4

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Carrying capacity of single pile in granular and cohesive soil – static formula – dynamic formulae (Engineering news and Hileys) – Capacity from insitu tests (SPT and SCPT)

Introduction:

DYNAMIC FORMULA

- ✓ When a pile hammer hits the pile, the total driving energy is equal to the weightof hammer times the height of drop or stroke.
- ✓ In addition to this, in the case of double acting hammers, some energy is alsoimpacted by the steam pressure during the return stroke.
- ✓ The total downward energy is consumed by the work done in penetrating the pileand by certain losses.
- ✓ The various dynamic formulae are essentially based on this assumption. It is alsoassumed that soil resistance of dynamic penetration of pile is the same as to thepenetration of pile under static or sustained loading.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Types of foundation
- ✓ Factors influencing the selection of pile
- ✓ Types of pile foundation

Detailed content of the Lecture:

Following are some of the commonly used dynamic formulae

(1) Engineering News formula. The Engineering News formula was proposed by A.M. Wellington (1818) in the following general form:

$$Q_a = \frac{WH}{F(S + C)}$$

Where,

Qa= allowable load

W = weight of Hammer

H = height of fall

F = factor of safety =6

S = final set (penetration) per blow, usually taken as average penetration, cm per blow for the last 5 blows of a drop hammer, or 20 blows of a steam hammer.

C = empirical constant

Denoting W in kg, H in cm, S in cm, and

C = 2.5 cm for drop hammer and

C = 0.25 cm for single and double acting hammers,

The above formula reduces to the following forms: Drop hammers:

Qa= WH / [6 (S + 2.5)]

Single acting steam hammers: Qa= WH / [6 (S +0.25)]

Double acting steam hammers:

Qa = [(W + ap) H] / [6 (S +0.25)]

Where, a = effective area of piston P = mean effective steam pressure

R = Whn / (s + c / 2)

Where

R = Ultimate driving resistance in ton W = Mass of Ram in ton

h = Height of free fall in cm considered at 80% for winch operated drop

n = Efficiency of the blow representing ratio of energy after impact to striking energy of ram

s = Average final set per blow in cm

c = Average sum of temporary elastic compression

- ✓ Applying the factor of safety, the safe load for the pile is then calculated. Comments about the use of dynamic formulae
- ✓ Dynamic formulae are best suited to coarse grained soils for which the shearstrength is independent of rate of loading, because they allow no developmentof excess pore pressure around the pile during driving if saturated ordry.
- ✓ The great objection to any of the pile driving formulae is the uncertainty aboutthe relationship between the dynamic and static resistance ofsoil.
- ✓ In case of submerged loose uniform fine sands, impact of driving maycause

- ✓ Liquefaction of soil, thus showing much less resistance than that which willoccur under a static load.
- ✓ Similarly, very dense saturated fine sand may show an increased drivingresistance which decreases withtime.
- ✓ For clays, the dynamic formulae are valueless because the skin frictiondeveloped in clay during driving is very much less (due to change in soilstructure from flocculent to disperse or due to thyrotrophic effect) than whichoccurs after a period oftime.
- ✓ Also, the point resistance is much more at the time 0 driving because of porepressure developed in clay, which reduces later on when the porepressure dissipate.
- ✓ Dynamic formulae give no indication about probable future settlement ortemporary changes in soilstructure.
- ✓ The formulae do not take into account the reduced bearing capacity of pilewhen in a group.
- ✓ Law of impact used for determining energy loss is not strictly valid for pilessubjected to restraining influence of the surroundingsoil.
- ✓ In Engineering News formula, the weight of the pile and hence its inertiaeffect is neglected.Energy losses due to vibrations, heat and damage so dolly or packing are notaccounted for.
- ✓ In Hiley's formula, a number of constants are involved, which are difficultto determine.

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

https://www.youtube.com/watch?v=WuqQISU7vsQ

https://www.youtube.com/watch?v=c7NxX0h7SKs

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 732 to 733)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 551 to 567)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Negative skin friction

Introduction:

Negative skin friction is usually a downward shear drag acting on a pile or pile group due to downward sinking of surrounding soil relative to the piles. This shear drag movements are expected to occur when a segment of the pile penetrates a compressible soil stratum that can consolidate. Downward drag may be caused by

- ✓ Placement of fill on compressible soils, lowering of the groundwater table.
- ✓ Placement of fill on Under-consolidated natural or compacted soils.

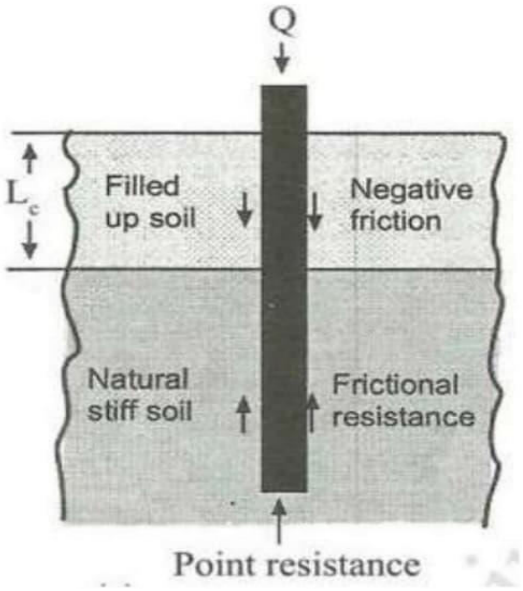
Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Dynamic formulae
- ✓ Capacity from insitu tests
- ✓ Types of pile foundation

Detailed content of the Lecture:

- ✓ These situations in the site can cause the compressible soils surrounding the piles to consolidate. When the tip of pile is bearing in a relatively stiff stratum, the upper compressible soil will move down relative to the pile this will induce a drag load on the pile/pile group. This induced drag load can be quite large and it should be added to the design load for assessing the stresses in the pile.
- ✓ Vesic found that a relative downward drop of as slight as 15mm of the soil with respect to the pile may be ample to mobilize full negative skin friction. Though the geotechnical capacity of the pile is unaffected by down-drag, it does serve to increase the stresses

&increase settlement in the pile/pile cap. It changes the axial force distribution pattern along the pile shaft. From geotechnical point of view, it is a Service State problem.



Calculating Negative Skin Friction

For pile groups, it can be presumed that there is no relative displacement between the piles and the soil in-between the piles. Thus, the total force acting down is equal to the weight of the block of soil held between the piles, plus the shear adjacent to the pile group perimeter due to negative skin friction. The avg. downward load transferred to a pile in a pile group can be estimated by

$$Q = 1/N [A \times g \times L + s \times L \times P]$$

Where,

Q = Average downward load transferred to a pile in a pile group

A = horizontal area bounded by the pile group or cross-sectional area of piles and enclosed soil

N = no. of piles in pile group

g = unit weight of fill or compressible soil layers

L = length of embedment above the bottom of the compressible soil layers

s = shear resistance of the soil

P = perimeter of the area A

For a single pile, the downward load transferred to the pile is equal to the shearing resistance along the pile as

$Q = s \times L \times P'$

Where,P' = perimeter of pile.

The total applied load (QT) on a pile group or single pile is the live load, dead load, and the drag load due to negative skin friction.

QT = Q + A x g x L + s x L x P for pile group

QT = Q + s x L x P' – for single pile

Where,Q = LL+DL

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

https://www.youtube.com/watch?v=_8O1RrAzfoY

https://www.youtube.com/watch?v=OYFpS4Q2tFg

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 740 to 744)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 568 to 575)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Group capacity and efficiency (Feld's rule, Converse – Labarra rule and block failure)

Introduction:

- ✓ Capacity of pile group is the sum of the individual capacities of piles, but it is influenced by the spacing between the piles. Piles are driven generally in groups in regular pattern to support the structural loads. The structural load is applied to the pile cap that distributes the load to individual piles.
- ✓ If piles are spaced sufficient distance apart, then the capacity of pile group is the sum of the individual capacities of piles. However, if the spacing between piles is too close, the zones of stress around the pile will overlap and the ultimate load of the group is less than the sum of the individual pile capacities especially in the case of friction piles, where the efficiency of pile group is much less.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Dynamic formulae
- ✓ Capacity from insitu tests
- ✓ Types of pile foundation
- ✓ Negative skin friction

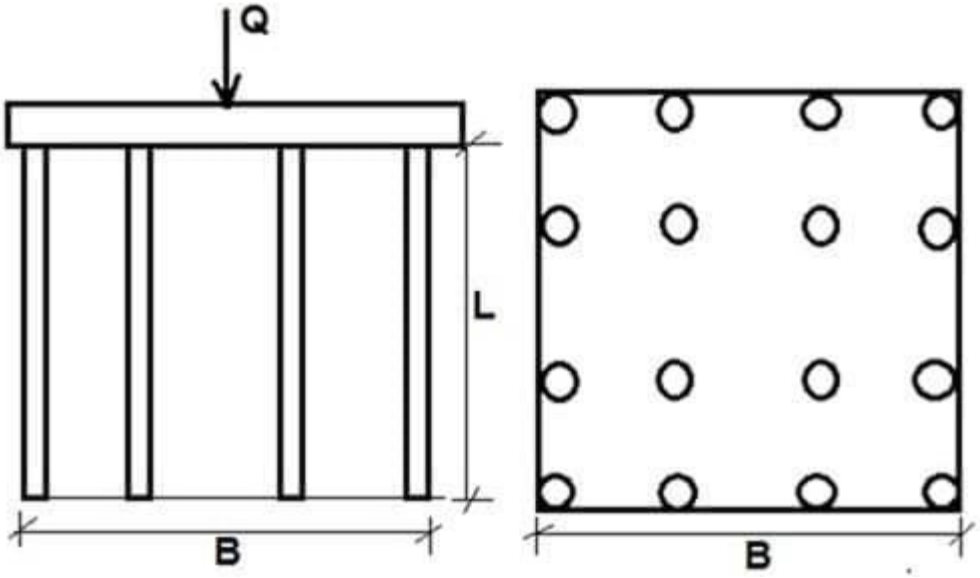
Detailed content of the Lecture:

Capacity of Pile Group

- ✓ Group action of piles is evaluated by considering the piles to fail as a unit around the perimeter of the group. Both end bearing and friction piles are considered in evaluating

the group capacity.

- ✓ End bearing pile is evaluated by considering the area enclosed by the perimeter of piles as the area of footing located at a depth corresponding to the elevation of pile tips.
- ✓ The friction component of pile support is evaluated by considering the friction that can be mobilized around the perimeter of the pile group over the length of the piles as shown in figure below:



Pile group capacity, $Q = q_0 X B2 + 4 x B x L x f$ (Square)

Where, Q = ultimate capacity of pile group

q_0 = ultimate bearing pressure of footing of area B2 (B = size of pile group)

L = Length of pile

f = shear resistance

Efficiency of Pile Group

The efficiency of pile group depends on the following factors:

1. Spacing of piles
2. Total number of piles in a row and number of rows in a group, and
3. Characteristics of pile (material, diameter and length)

- ✓ The reduction in total bearing value of group of piles is more in case of friction piles, particularly in clayey soils. No reduction in grouping occurs in end bearing piles.
- ✓ The pile groups which are resisting the load by combined action of friction and end bearing, only the load carrying capacity of friction is reduced. The efficiency of the pile group can be calculated by using the following formula:

$$\eta_g = \frac{Q_{g(u)}}{NQ_u} \times 100$$

- ✓ Thus, the pile group efficiency is equal to the ratio of the average load per pile in the

group at which the failure occurs to the ultimate load of a comparable single pile.

- ✓ Efficiency of a pile group can also be obtained by using Converse – Labarre formula:

$$\eta_g = 1 - \frac{\theta}{90}\left(\frac{(n-1)m + (m-1)n}{m \times n}\right)$$

Where m = number of rows

n = number of piles in a row

$\theta = \tan^{-1}\frac{d}{s}$ in degrees

d = diameter of pile end

s = spacing of piles.

Generally center to center spacing between piles in a group is kept between 2.5 d and 3.5d where d is the diameter of the pile.

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

https://www.youtube.com/watch?v=9gm4RgCzM-0

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

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 737 to 740)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –617 to 626)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Settlement of pile groups

Introduction:

- ✓ It may often be required to use more than one pile below a column, depending on the column load and the load capacity of a single pile. Usually, driven piles should be provided in groups and a single pile should not be used.
- ✓ This is because the pile may move laterally during the driving operation, resulting in the eccentricity of the load, causing additional bending stresses in the pile, decreasing both the structural capacity and the soil resistance capacity.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Dynamic formulae
- ✓ Capacity from insitu tests
- ✓ Types of pile foundation
- ✓ Negative skin friction

Detailed content of the Lecture:

The load capacity of a pile group may not be equal to the sum of the load capacity of the individual piles in the group due to the following reasons:

1. When piles are used in a group at close spacing, the pressure bulbs of individual piles may overlap, causing more stress in the overlapping soil zones. This causes a reduction in the load capacity.
2. When piles are driven in loose- to medium-dense cohesionless soils, it may cause densification of the soil, increasing the load capacity more than the estimated load capacity.

The efficiency of the pile group is defined as –

$$\eta_g = \frac{Q_{ug}}{NQ_u} \times 100$$

where Q_{ug} is the ultimate load capacity of the pile group, Q_u is the ultimate load capacity of the individual pile, and N is the number of piles in the pile group.

Spacing of Piles:

- ✓ For end-bearing piles founded on a very hard stratum, deriving their load capacity mainly from end-bearing resistance, the spacing of piles is governed by the competency of the end-bearing stratum. The minimum spacing of end-bearing piles is 2.5 d, where d is the diameter of the pile shaft. For piles resting on rock, the minimum spacing of piles is 2 d, where d is the diameter of the pile shaft.
- ✓ For friction piles, the pile spacing should ensure that the pressure bulbs of individual piles do not overlap, which otherwise causes a reduction in the pile capacity. The minimum spacing of friction piles is 3 d, where d is the diameter of the pile shaft. In the case, of non-circular piles, such as square or rectangular piles, the diameter of the circle circumscribing the pile is used to determine the minimum pile spacing.
- ✓ The spacing of piles should not be so close as to cause direct contact between two adjacent piles in a group at any level, arising due to the tolerance allowed in alignment for installation of piles.

Load Capacity of Pile Group in Sand and Gravel:

- ✓ When piles are driven in loose- to medium-dense cohesionless soils, the soil around the pile is compacted, increasing the group efficiency. For better results, it is desirable to start the driving of piles at the center of the site and work outward. For dense sands, the driving of piles may reduce group efficiency due to dilatancy. In the case of bored piles, there is limited densification of soil around the pile. Group efficiency, therefore, depends on pile spacing, and may be less than 100% if piles are spaced closer than 3 d, where d is the diameter of the pile.The efficiency of the pile group may be obtained from the converse Lebarre equation for friction piles –

$$\eta_g = 1 - \left[\frac{(m-1)n + (n-1)m}{mn} \times \frac{\theta}{100} \right]$$

$$\theta = \tan^{-1}\left(\frac{B}{S}\right)$$

where m is the number of rows of piles, n is the number of piles in each row, B is the

diameter of the pile, and S is the spacing of piles.

The load capacity of a pile group is obtained from $-Q_{ug} = \eta_g N Q_u$

In the case of end-bearing piles, driven in dense sand at a spacing more than 3 d, where d is the diameter of the pile shaft, group efficiency is generally much more than 100%. The load capacity of the pile group is taken as $-Q_{ug} = NQ_u$

For bored piles in sand and gravel, group efficiency is about 2/3 to 3/4.

In the case of piles deriving their support mainly from friction and connected by a pile cap, the group may be visualized to transmit load to the soil as if from a column of soil enclosed by the piles. The ultimate capacity of the group may be computed following this concept, taking into account the frictional capacity along the perimeter of the column of soil as above and the end-bearing of the said column.

Settlement of a Pile Group:

The settlement of a pile or pile group in clay can be computed from the principles of consolidation. Settlement of a pile group is more than the settlement of a single pile, even when the load is the same. This is because the pressure bulb of the pile group is deeper than that of individual piles, causing the compression of a larger volume of soil by the pile group.

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

https://www.youtube.com/watch?v=20vdT3AEulYhttps://www.youtube.com/watch?v=oA3xzB8Ldh0

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 737 to 740)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –624 to 626)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Interpretation of pile load test (routine test only)

Introduction:

- ✓ It may often be required to use more than one pile below a column, depending on the column load and the load capacity of a single pile. Usually, driven piles should be provided in groups and a single pile should not be used.
- ✓ This is because the pile may move laterally during the driving operation, resulting in the eccentricity of the load, causing additional bending stresses in the pile, decreasing both the structural capacity and the soil resistance capacity.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Dynamic formulae
- ✓ Capacity from insitu tests
- ✓ Types of pile foundation
- ✓ Negative skin friction

Detailed content of the Lecture:

- ✓ Load tests on piles are conducted on completion of 28 days after casting of piles. Two types of tests namely initial and routine tests, for each type of loading viz.
- ✓ vertical, horizontal (lateral) pull out, are performed on piles.
- ✓ Load tests on piles are conducted on completion of 28 days after casting of piles. Two types of tests namely initial and routine tests, for each type of loading viz. vertical, horizontal (lateral) pull out, are performed on piles.
- ✓ Load tests on piles are conducted on completion of 28 days after casting of piles. Two types

of tests namely initial and routine tests, for each type of loading viz.

- ✓ vertical, horizontal (lateral) pull out, are performed on piles.

Initial Load Tests on Piles

- ✓ This test is performed to confirm the design load calculations and to provide guidelines for setting up the limits of acceptance for routine tests. It also gives an idea of the suitability of the piling system. Initial Test on piles are to be carried out at one or more locations depending on the number of piles required.
- ✓ Load applied for the initial (cyclic) load test is 2.5 times the safe carrying capacity of the pile. Loading for Initial Tests is conducted as per Appendix 'A' Clause 6.3 of **IS-2911 Part IV**.

Routine Load Tests on Piles

- ✓ Selection of piles for the Routine Test is done based on number of piles required subject to maximum of ½% of total number of piles required. The number of tests may be increased to 2% depending on the nature / type of structure. The test load applied is 1½ times the safe carrying capacity of the pile.
- ✓ The Maintained load method as described in Clause 6.2 of IS-2911 (Part IV) – 1985 shall be followed for loading for the Routine Tests.

This test will be performed for the following purposes:

a) To ensure the safe load capacity of piles

b) Detection of any unusual performance contrary to the findings of the Initial Test.

Vertical Load Tests on Piles

This test will be carried out as stipulated in IS-2911 (Part IV) 1995.

Fig: Vertical load test on piles

Lateral Load Tests on Piles

The jack should be placed horizontally, between two piles. The load on the jack shall be the same on both the piles. The load will be applied in increments of 20% of the estimated safe load and at the cut off level. The load will be increased after the rate of displacement is nearer to 0.1 mm per 30 minutes.

If the cut-off level is approachable, one dial gauge exactly at the cut-off level shall measure the displacement. In case the cut-off level is not approachable, 2 dial gauges 30 cm apart

vertically, shall be set up and the lateral displacement of the cut-off level calculated by similar triangles.

Fig: Horizontal load test on piles

Pull out Tests on Piles

A suitable set up shall be designed to provide an uplift force to the piles. The load increments and the consequent displacements shall be as per the case of a vertical load test.

Fig: Pull-out test on piles

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

https://www.youtube.com/watch?v=du0cf0dxUPQhttps://www.youtube.com/watch?v=2E7ESmRmAog

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 744 to 750)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 583 to 588)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : IV – PILE FOUNDATION

Date of Lecture:

Topic of Lecture: Under reamed piles - Capacity under compression and uplift

Introduction:

- ✓ A cast-in-situ concrete pile with an enlarged bulb at bottom made by either cutting or scooping out soil or by any other suitable process is called Under-Reamed Pile. Under-Reamed Piles are also called bored cast-in-situ concrete piles.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Pile load test
- ✓ Capacity from insitu tests
- ✓ Types of pile foundation
- ✓ Negative skin friction

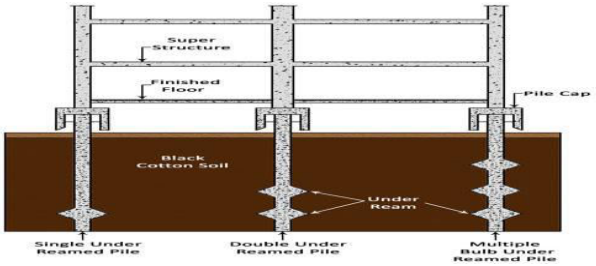
Detailed content of the Lecture:

- ✓ According to 'DR.B.C. Punmia, Ashok Kumar Jain, Arun Kumar Jain' (Author of Soil Mechanics and Foundations), An Under-Reamed Pile is a cast-in-situ concrete pile, having one or more bulb in its lower portion. This bulb is called an under ream.
- ✓ When only one bulb is provided at the bottom of the pile, it is known as single Under-Reamed Pile foundation. When two or more bulbs are provided at the bottom of the pile, it is known as multiple bulbs Under-Reamed Pile foundation.

Uses of Under-Reamed Piles

- ✓ Under-Reamed Piles are widely used for different types of soils such as sandy soils, clayey soils and also expansive soils. Under-Reamed Piles are required to be taken down to a certain depth because of the following considerations:

- ✓ To avoid the undesirable effect of seasonal moisture changes in expansive soils such as black cotton soils.
- ✓ To reach hard strata.
- ✓ To obtain adequate capacity for downward, upward, lateral loads and moments.
- ✓ To take the foundations below the scour level.
- ✓ They have also been found useful for factory buildings and machine foundations.
- ✓ Under-Reamed Piles are also used under situations, where the vibration and noise caused during construction of piles, are to be avoided.



Advantages of Under-Reamed Piles

- ✓ It decreases the vertical settlement and also differential settlement.
- ✓ It is used when soil tends to swell and shrink due to moisture variation or expansive nature of the soil.
- ✓ Provision of under-reams or bulbs has the advantage of increasing the bearing and uplift capacities.
- ✓ When the number of bulbs are increased from one to two, the load carrying capacity of the Under-Reamed Pile is increased.
- ✓ The provision of bulbs is of special advantage in Under-Reamed Piles to resist uplift and they can be used as anchors.
- ✓ The cost advantages of Under-Reamed Piles are due to the reduced pile shaft diameter, resulting in less concrete needed to replace the excavated material.

Disadvantages of Under-Reamed Piles

- ✓ At a depth, where nature of soil varies with a climatic condition, Under-Reamed Piles are not suitable for waterlogged soil, as they take load by friction.
- ✓ These piles need strict quality control and regular supervision during the construction.
- ✓ Most of the times, Under Reamed Piles are driven manually with hand operated machine. Hence maintaining plumb of pile is very essential, because if they are not in plumb whole load transfer mechanism would change.
- ✓ Two types of situation may be visualized. In the first, the soil strength is constant or increases with depth as in residual soil. Second, soft deposits occur below the strong top layers.

Capacity under compression and uplift:

- ✓ The major components resisting uplift forces on pile foundation are skin friction and self-weight of the pile.
- ✓ So the governing equation for uplift capacity isQuplift= fs.As + Weight of the pile
- ✓ The capacity of the pile (Axial/Lateral/Uplift) either arrived by field approach or theoretical approach is called Ultimate capacity which is divided with a factor to arrive at safe carrying capacity of the pile.
- ✓ The ultimate capacity is usually dictated by the limitations on settlements as per local engineering codes
- ✓ The main purpose of under reporting the pile capacity by dividing it with a factor of safety is to accommodate various un certainties in soil strata, Loading andPossible reduction in strength of sub soil strata due to installation technique, etc.

Problem: A 30cm dia 10 m long concrete pile is embedded in a clay deposit having unconfined comp.st. of 50kN/m^2. Estimate the safe uplift capacity of the pile. Assume FOS = 2; Adhesion factor $\dot{\alpha}$ = 0.4; γ_{conc} =25kN/m^3

$Q_{uplift} = \dot{\alpha}\ c\ (\pi d * L)\ /F + \pi d^2/4 * L * 25$

$Q_{uplift} = ((0.4 * 25 * \pi * 0.3 * 10)\ /2\ ) + ((\ \pi * 0.3^2\ )/\ 4\ ) * 10 * 25$

Q_{uplift} =47.1 + 17.7 = 64.8kN

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

https://www.youtube.com/watch?v=Wyn332e70Cs

https://www.youtube.com/watch?v=Jg6YzOejeko

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 750 to 757)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –606 to 611)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Plastic equilibrium in soils

Introduction:

- ✓ A body of soil is said to be in plastic equilibrium if every lift of it is on the verge of failure.
- ✓ Rankine investigated the stress conditions corresponding to those states of plastic equilibrium which can be developed simultaneously throughout a semi infinite mass of soil acted on by no force other thangravity.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Pile foundation
- ✓ Bearing capacity of soil
- ✓ Types of foundation

Detailed content of the Lecture:

- ✓ The stress condition during plastic equilibrium can be represented by the following Mohr Coulombequation:

$$\frac{\sigma_1 - \sigma_3}{2} - \frac{\sigma_1 + \sigma_3}{2} \sin\phi = c\cos\phi$$

$$\sigma_1 = 2c \tan(45° + \phi/2) + \sigma_3 \tan^2(45° + \phi/2)$$

Or

$$\sigma_1 = 2c\sqrt{N_\phi} + \sigma_3 N_\phi$$

Where

$N\phi$= tan' (45° + (ϕ/2)= flow value

ø1 and ø3 = major and minor principal stresses at any pointin the soil mass, atfailure.

In terms of stress components in *x*-*z* plane,

$$\sqrt{\left(\frac{\sigma_z - \sigma_x}{2}\right)^2 + \tau_{xz}^2} - \frac{\sigma_z + \sigma_x}{2}\sin\phi = c\cos\phi$$

The theory on which the computation of the stress in a state of plastic equilibrium is based is called the theory of plasticity. The theory of plasticity pertaining to soils is based on Mohr'stheory of rupture.

When the material is just on the point of flowing plastically, it is still in static equilibrium, satisfying the following equilibrium equation in x-z plane:

- ✓ Combining above equations lead to an equation, called Kotter'sequation, the solution of which for a given boundary condition gives theorientation of slip lines together with the stress at each point of the failurezone (Sokolovsky,1965).
- ✓ The equations of equilibrium in two dimensions are automatically satisfiedby the Mohr-circle. Also, the state of plastic equilibrium can be represented by two straight lines at an angle to thea-axis.
- ✓ Thus the Mohr diagram is a convenient tool for studying the stressconditions at equilibrium both before and at yield in thesoil.

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xz}}{\partial z} = 0$$
$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \sigma_z}{\partial z} + \gamma = 0$$

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

https://www.youtube.com/watch?v=Do0MMdU5cU8https://www.youtube.com/watch?v=OGvnQYSFD88

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 499 to 500)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –355 to 357)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Active and passive states

Introduction:

- ✓ Rankine's Theory assumes that failure will occur when the maximum principal stress at any point reaches a value equal to the tensile stress in a simple tension specimen at failure. This theory does not take into account the effect of the other two principal stresses. Rankine's theory is satisfactory for brittle materials, and not applicable to ductile materials. This theory is also called the **Maximum Stress Theory**.
- ✓ The Rankine theory assumes a frictionless soil-wall interface and a vertical wall (no wall slope).

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Soil strength
- ✓ Bearing capacity of soil
- ✓ Types of foundation

Detailed content of the Lecture:

Earth pressure

- ✓ A soil mass retained by a wall exerts a pressure on the wall. This pressure P is called 'earth pressure'. The magnitude of this earth pressure depends on the movement of the wall.

Earth pressure at rest-

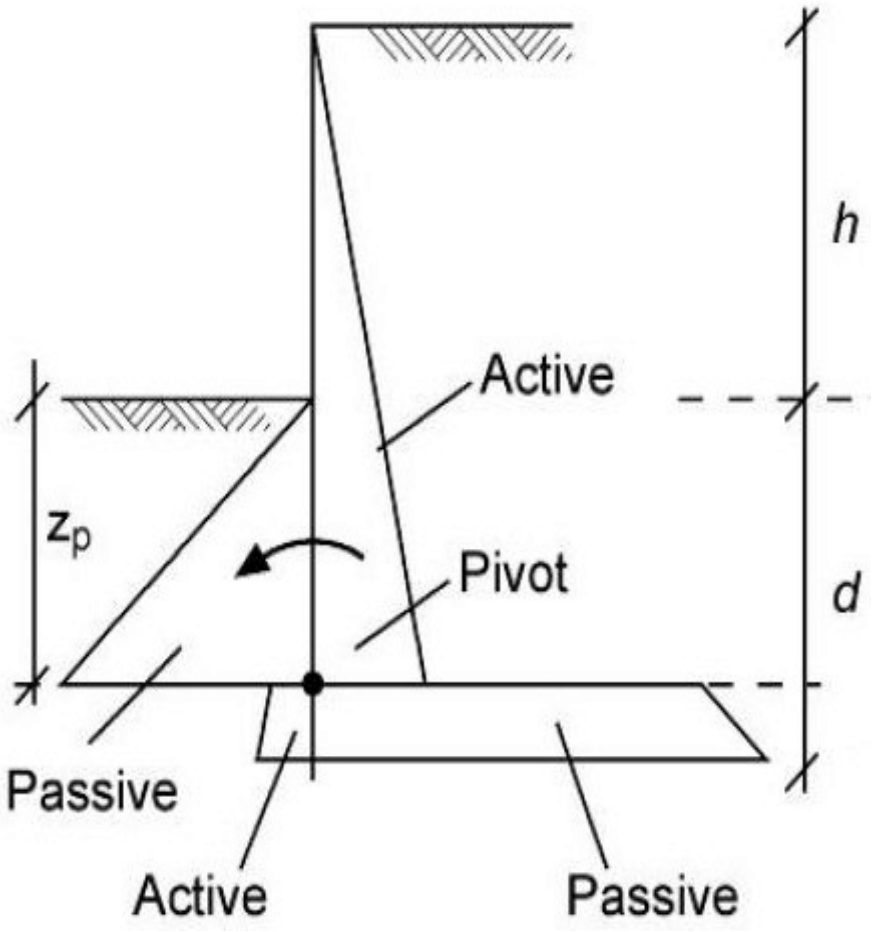
- ✓ When there is no movement of wall, the soil is in a state of rest, ie., there is no strain in the soil. The pressure corresponding to zero lateral strain is called 'earth pressure at rest' and is given by $p_0 = k_0 p_v$

Where, p_o – earth pressure at rest at depth 'z' below G L

k_o - coefficient of earth pressure at rest

p_v -effective vertical pressure at depth 'z'

Example situation : A basement wall ; Lateral movement of the wall is prevented.



Active earth pressure

- ✓ When a wall moves away from the back fill, the earth pressure reduces. Beyond certain movement, the earth pressure reaches a minimum value. This minimum pressure is known as 'active earth pressure', and is given by$p_a = k_a p_v$

  Where, p_a – active earth pressure

  k_a – coefficient of active earth pressure

  Ex : Retaining wall on a hill slope; Bridge abutments

Passive earth pressure

- ✓ When a wall moves towards the back fill, the earth pressure increases. Beyond certain movement, it reaches a maximum and is known as 'passive earth pressure'.

  Ex: Anchored sheet pile walls ; Anchors are subjected to passive pressure.

  Passive earth pressure is given by, $p_p = k_p * p_v$

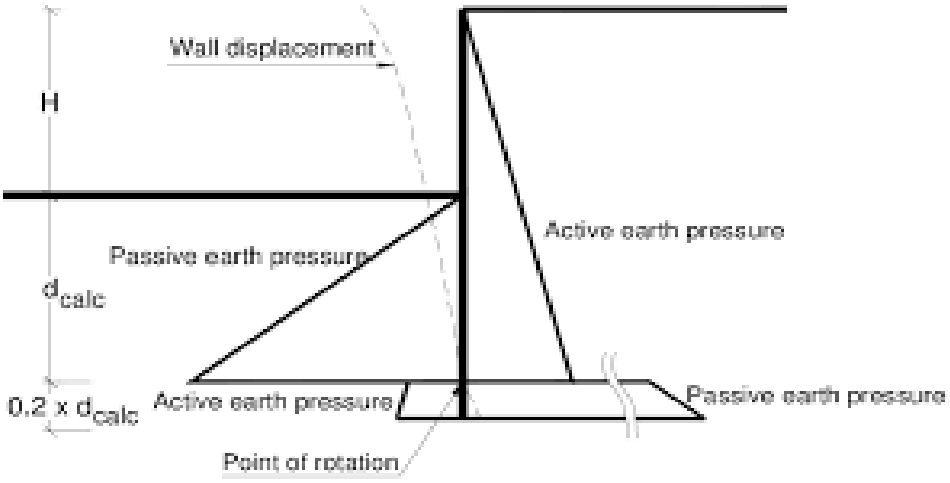
  Where, p_p – passive earth pressure

  k_p – coefficient of passive earth pressure

The coefficients, k_0, k_a , * k_p are obtained as:

$k_0 = 1- \sin ø$ or $k_a = (1-\sin ø) / (1+ \sin ø)$; $k_p = (1+ \sin ø)/(1- \sin ø)$

Where ø – angle of shearing resistance



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

https://www.youtube.com/watch?v=RC6-LJphzW4https://www.youtube.com/watch?v=gxsKH5zRWVI

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 499 to 503)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –375 to 377)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Active and passive states (Problems)

Introduction:

There are three types of earth pressures on the basis of the movement of the wall.

- Earth Pressure at rest
- Active Earth Pressure
- Passive Earth Pressure

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Bearing capacity of soil
- ✓ Types of foundation

Detailed content of the Lecture:

Problem 1: A retaining wall with a smooth vertical back retains a purely cohesive fill. Height of wall is 12m. Unit weight of fill is 20kN/m^3. Cohesion = 1 N/cm^2.(i) What is the total Rankine's thrust on the wall, (ii) At what depth does the resultant thrust act.

c = 1 N/cm^2 = 10kN/m^2

In a purely cohesive soil, ø = 0, k_a = 1

$p_a = \gamma z - 2c$

At z = 0, p_a = -2 c = -20kN/m^2

At z = 12, p_a = 20 * 12 – 2 * 10

= 220kN/m^2

At p_a = 0, $\gamma z = 2c$; z = 2* 10 / 20 =1 m

Total thrust = ½ * 220 * 11 – ½ * 20 * 1

= 1210 -10 = 1200 kN/m

Taking moment about the base,

((1210 * 11/3) –(10 * (11 + 2/3))) / 1200 = 4437 – 116.7 /1200

= 3.61 m from base

Problem 2: A smooth vertical wall is 4m height and retains a soil with a bulk unit weight of 18 kN/m^3 and ø = 30°. The top of the soil level with the top of the wall and is horizontal. The soil surface carries a uniformly distributed load of 30 kN/m^2. Determine the total active thrust per meter length of the wall and its point of application.

k_a = (1- sin ø) /(1 + sin ø) = (1- sin 30°)/(1 + sin 30°)= 0.5 /1.5 = 1/3

At z = 0, p_v = q = 30 kN/m^2 ; p_a = 1 / 3 * 30 = 10 kN/m^2

At z = 4 m, p_v =30 + 18 * 4 = 102 kN/m^2 ; p_a = 1/3 * 102 = 34 kN/m^2

Total earth thrust = 4 * 10 + ½ * 24 * 4 =88 kN

Resultant –

Taking moment about the base

40 * 2 + 48 * 4/3 = 88 * x

x = (80 + 64) / 88 = 1.64m

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

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

https://www.youtube.com/watch?v=zwrNbVmvNM&list=TLPQMzAwOTIwMjALfgNo9Q8SCA&index=2

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 503 to 504)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –377 to 380)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Rankine's theory – cohesionless and cohesive soil

Introduction:

Rankine (1857) consider the equilibrium of a soil element within a soil mass bounded by a plane surface.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Plastic equilibrium in soils
- ✓ Active and passive states

Detailed content of the Lecture:

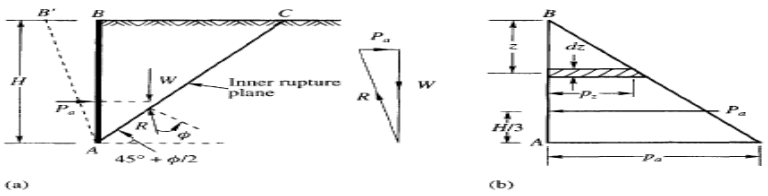
ASSUMPTION :

The soil mass is homogeneous and semi infinite

The soil is dry and cohesionless.

The back of the retaining wall is smooth and vertical .

The ground surface is plane ,which may be horizontal or inclined.

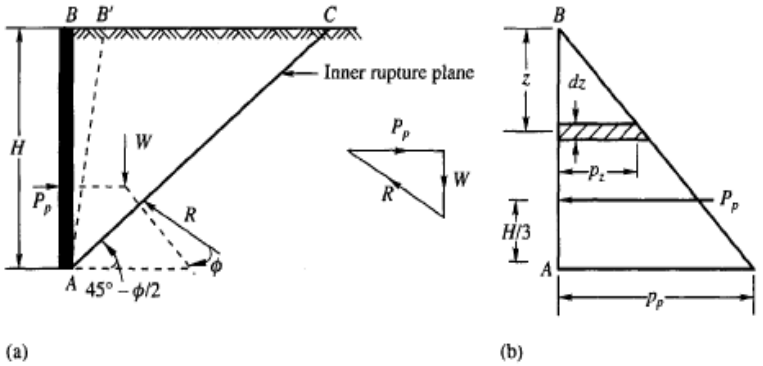


RANKINE'S –COHESIONLESS: Backfill Horizontal-Active Earth Pressure

1. A semi-infinite mass is replaced by a smooth wall AB in Fig.
2. The lateral pressure acting against smooth wall AB is due to the mass of soil ABC above

failure line AC which makes an angle of 45° + ϕ/2 with the horizontal.

3. The lateral pressure distribution on wall AB of height H increases in simple proportion to depth.
4. The pressure acts normal to the wall AB
5. Backfill Horizontal-Passive Earth Pressure
6. If wall AB is pushed into the mass to such an extent as to impart uniform compression throughout the mass, soil wedge ABC in Fig(a). will be in Rankine's passive state of plastic equilibrium.
7. The inner rupture plane AC makes an angle 45° + ϕ/2 with the vertical AB. The pressure distribution on wall AB is linear as shown in Fig(b).



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

https://www.youtube.com/watch?v=JGzoZ2dbmCU&t=82shttps://www.youtube.com/watch?v=vffZvVCmsjU&list=TLPQMzAwOTIwMjALfgNo9Q8SCA&index=1

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 504 to 510)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –328 to 331)

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LECTURE HANDOUTS

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Coulomb's wedge theory

Introduction:

- COULOMB'S(1776) developed a method for the determination of the earth pressure in which he considered the equilibrium of the sliding wedge which is formed when the movements of the retaining wall takes place.
- The **Coulomb theory** provides a method of analysis that gives the resultant horizontal force on a retaining system for any slope of wall, wall friction, and slope of backfill provided.
- This **theory** is based on the assumption that soil shear resistance develops along the wall and failure plane.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Plastic equilibrium in soils
- ✓ Active and passive states
- ✓ Rankine's theory

Detailed content of the Lecture:

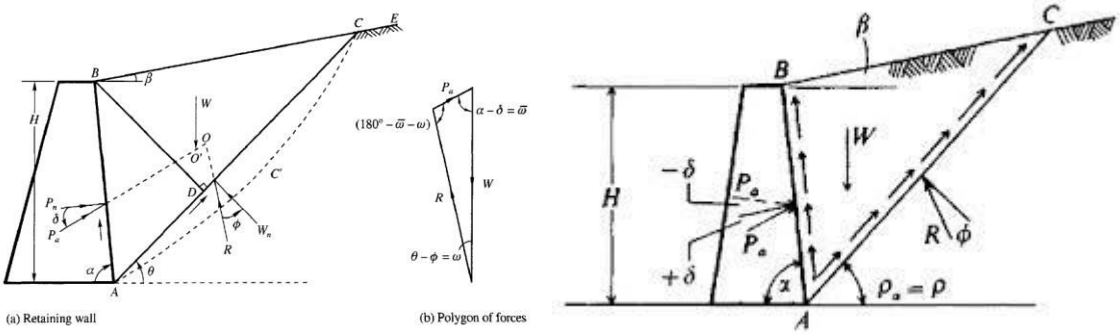
COULOMB'S THEORY

- ✓ The active case the sliding wedge moves downward and outward relative to the backfill.
- ✓ In passive case the sliding moves upwards.
- ✓ The lateral pressure on the wall is equal and opposite to the relative forces extended by the wall in order to keep the sliding wedge in equilibrium.

COULOMB'S THEORY –SAND – ACTIVE STATE

ASSUMPTIONS :

1. The soil is isotropic and homogeneous
2. The rupture surface is a plane surface
3. The failure wedge is a rigid body
4. The pressure surface is a plane surface
5. There is wall friction on the pressure surface
6. Failure is two-dimensional and
7. The soil is cohesionless



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

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

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

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 522 to 532)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –365 to 366)

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III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Coulomb's wedge theory (Derivation)

Introduction:

- Coulomb's made the following assumptions in the development of his theory and hence it is called Coulomb's Wedge Theory.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Plastic equilibrium in soils
- ✓ Active and passive states
- ✓ Rankine's theory

Detailed content of the Lecture:

COULOMB'S - ACTIVE STATE

In Fig AB is the pressure face, The backfill surface BE is a plane inclined at an angle ß with the horizontal

- ✓ α is the angle made by the pressure face AB with the horizontal
- ✓ H is the height of the wall
- ✓ AC is the assumed rupture plane surface, and
- ✓ θ is the angle made by the surface AC with the horizontal
- ✓ The weight of the wedge W length of the wall may be written as
- ✓ W = γA, where A = area of wedge ABC
- ✓ Area of wedge ABC = A = 1/2 AC x BD, where BD is drawn perpendicular to AC.

$$AC = AB\frac{\sin(\alpha+\beta)}{\sin(\theta-\beta)}, \quad BD = AB\sin(\alpha+\theta), \quad AB = \frac{H}{\sin\alpha}$$

- ✓ From the law of sines, we have
- ✓ Making the substitution and simplifying we have,
- ✓ The various forces that are acting on the wedge are shown in Fig.a

$$W = \gamma A = \frac{\gamma H^2}{2\sin^2 \alpha} \sin(\alpha + \theta) \frac{\sin(\alpha + \beta)}{\sin(\theta - \beta)}$$

- ✓ As the pressure face AB moves away from the backfill, there will be sliding of the soil mass along the wall from B towards A.
- ✓ The sliding of the soil mass is resisted by the friction of the surface.
- ✓ The direction of the shear stress is in the direction from A towards B.
- ✓ lf Pn is the total normal reaction of the soil pressure acting on face AB,
- ✓ The resultant of Pn and the shearing stress is the active pressure Pa making an angle δ with the normal.
- ✓ Since the shearing stress acts upwards, the resulting Pa dips below the normal.
- ✓ The angle δ for this condition is considered positive.
- ✓ As the wedge ABC ruptures along plane AC, it slides along this plane.
- ✓ This is resisted by the frictional force acting between the soil at rest below AC, and the sliding wedge. The resisting shearing stress is acting in the direction from A towards C.
- ✓ If Wn is the normal component of the weight of wedge W on plane AC, the resultant of the normal Wn and the shearing stress is the reaction R.
- ✓ This makes an angle ϕ with the normal since the rupture takes place within the soil itself.
- ✓ Statical equilibrium requires that the three forces Pa, W, and R meet at a point.
- ✓ Since AC is not the actual rupture plane, the three forces do not meet at a point.
- ✓ But if the actual surface of failure AC'C is considered, all three forces meet at a point.
- ✓ However, the error due to the non concurrence of the forces is very insignificant and as such may be neglected.The polygon of forces is shown in Fig.

$$\frac{P_a}{\sin(\theta - \phi)} = \frac{W}{\sin(180^\circ - \alpha - \theta + \phi + \delta)}$$

$$\text{or} \quad P_a = \frac{W \sin(\theta - \phi)}{\sin(180^\circ - \alpha - \theta + \phi + \delta)} \qquad P_a = \frac{1}{2}\gamma H^2 K_A \qquad \frac{dP_a}{d\theta} = 0$$

- ✓ In Eq. , the only variable is θ and all the other terms for a given case are constants. Substituting for W, we have

$$P_a = \frac{\gamma H^2}{2\sin^2 \alpha} \frac{\sin(\theta - \phi)}{\sin(180^\circ - \alpha - \theta + \phi + \delta)} \left(\sin(\alpha + \phi) \frac{\sin(\alpha + \beta)}{\sin(\theta - \beta)} \right)$$

- ✓ The maximum value for Pa is obtained by differentiating Eq. with respect to θ and

equating the derivative to zero, i.e.

- ✓ The maximum value of Pa so obtained may be written as
- ✓ where KA is the active earth pressure coefficient.
- ✓ The total normal component Pn of the earth pressure on the back of the wall is

$$P_n = P_a \cos\delta = \frac{1}{2}\gamma H^2 K_A \cos\delta \qquad K_A = \frac{\sin^2(\alpha+\phi)}{\sin^2\alpha \sin(\alpha-\delta)\left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta)}{\sin(\alpha-\delta)\sin(\alpha+\beta)}}\right]^2}$$

- ✓ If the wall is vertical and smooth, and if the backfill is horizontal, we have
- ✓ ß=δ= 0 and α= 90 deg, Substituting these values in Eq.

$$K_A = \frac{1-\sin\phi}{1+\sin\phi} = \tan^2\left(45^\circ - \frac{\phi}{2}\right) = \frac{1}{N_\phi} \qquad \text{where} \quad N_\phi = \tan^2\left(45^\circ + \frac{\phi}{2}\right)$$

COULOMB'S EARTH PRESSURE THEORY FOR SAND FOR PASSIVE STATE

- ✓ where Kpis the passive earth pressure coefficient.

$$K_P = \frac{\sin^2(\alpha-\phi)}{\sin^2\alpha \sin(\alpha+\delta)\left[1-\sqrt{\frac{\sin(\phi+\delta)\sin(\phi+\beta)}{\sin(\alpha+\delta)\sin(\alpha+\beta)}}\right]^2}$$

- ✓ The total normal component of the passive earth pressure Pn on the back of the wall is
- ✓ For a smooth vertical wall with a horizontal backfill, we have

$$P_{pn} = \frac{1}{2}\gamma H^2 K_p \cos\delta \qquad K_P = \frac{1+\sin\phi}{1-\sin\phi} = \tan^2\left(45^\circ + \frac{\phi}{2}\right) = N_\phi$$

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

https://www.youtube.com/watch?v=id_S7g23Zog

https://www.youtube.com/watch?v=4OZ7eUBRkng

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 522 to 532)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no – 546 to 567)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Earth pressure on retaining walls of simple configurations

Introduction:

- A soil mass retained by a wall exerts a pressure on the wall. This pressure P is called 'earth pressure'. The magnitude of this earth pressure depends on the movement of the wall.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Plastic equilibrium in soils
- ✓ Active and passive states
- ✓ Rankine's theory

Detailed content of the Lecture:

Earth pressure at rest-

When there is no movement of wall, the soil is in a state of rest, ie., there is no strain in the soil. The pressure corresponding to zero lateral strain is called 'earth pressure at rest' and is given by,

$$p_0 = k_0 p_v$$

Where, p_o – earth pressure at rest at depth 'z' below G L

k_o - coefficient of earth pressure at rest

p_v -effective vertical pressure at depth 'z'

Example situation : A basement wall ; Lateral movement of the wall is prevented.

Active earth pressure

When a wall moves away from the back fill, the earth pressure reduces. Beyond certain

movement, the earth pressure reaches a minimum value. This minimum pressure is known as 'active earth pressure', and is given by

$$p_a = k_a\, p_v$$

Where, p_a – active earth pressure

k_a – coefficient of active earth pressure

Ex : Retaining wall on a hill slope; Bridge abutments

Passive earth pressure

When a wall moves towards the back fill, the earth pressure increases. Beyond certain movement, it reaches a maximum and is known as 'passive earth pressure'.

Ex: Anchored sheet pile walls ; Anchors are subjected to passive pressure.

Passive earth pressure is given by,

$$p_p = k_p * p_v$$

Where, p_p – passive earth pressure

k_p – coefficient of passive earth pressure

The coefficients, k_0, k_a , * k_p are obtained as:

$k_0 = 1 - \sin ø$ or

$k_a = (1-\sin ø) / (1+ \sin ø)$; $k_p = (1+ \sin ø)/(1- \sin ø)$

Where ø – angle of shearing resistance

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

https://www.youtube.com/watch?v=aKseZc-d-zQhttps://www.youtube.com/watch?v=p4eTr5ZFRZQ

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 522 to 523)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –377 to 402)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Culmann Graphical method

Introduction:

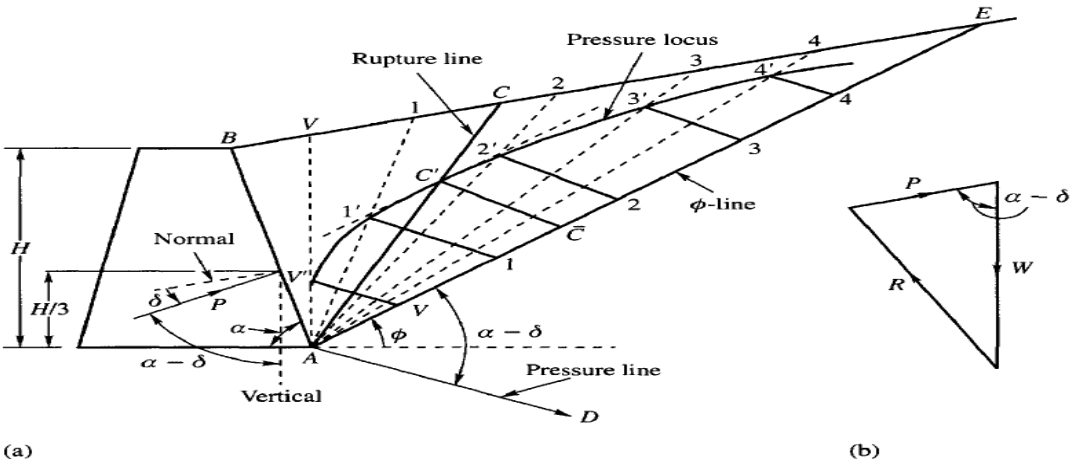
- CULMANN'S (1866)developed a method which is more general than rehbanns method
- It can be used to determine coulombs earth pressure for ground surface for any configuration for various types of surcharge loads and the layered backfills.
- The method of construction of the force triangle in a rotated orientation.

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Coulomb's wedge theory
- ✓ Active and passive states
- ✓ Rankine's theory

Detailed content of the Lecture:

CULMANN'S METHOD- GRAPHICAL REPRESENTATION



ACTIVE PRESSURE BY CULMANN'S METHOD FOR COHESIONLESS SOILS

Culmann's (1866) method is the same as the trial wedge method. In Culmann's method, the force polygons are constructed directly on the ϕ-line AE taking AE as the load line.

The procedure is as follows:

1. Draw ϕ -line AE at an angle ϕ to the horizontal.
2. Lay off on AE distances, AV, A1, A2, A3, etc.to a suitable scale to represent the weight of wedges ABV, A51, AS2, AS3, etc. respectively.
3. Draw lines parallel to *AD* from points V, 1, 2, 3 to intersect assumed rupture lines AV, Al,A2, A3 at points V", I',2', 3', etc. respectively.
4. Join points V, 1', 2' 3' etc. by a smooth curve which is the pressure locus.
5. Select point C′ on the pressure locus such that the tangent to the curve at this point is parallel to the ϕ-line AE.
6. Draw C'C parallel to the pressure line AD. The magnitude of C'C in its natural units gives the active pressure Pa.
7. Join AC" and produce to meet the surface of the backfill at C. AC is the rupture line. For the plane backfill surface, the point of application of Pa is at a height of H/3 from the base of the wall.

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

https://www.youtube.com/watch?v=whf_bhRvZk8https://www.youtube.com/watch?v=vhEZ8Kac5fA

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 532 to 535)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –405 to 428)

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LECTURE HANDOUTS

CIVIL

III / V

Course Name with Code : FOUNDATION ENGINEERING - 19CEE12

Course Teacher : Mrs.R.SELVAPRIYA

Unit : V – RETAINING WALLS

Date of Lecture:

Topic of Lecture: Stability analysis of retaining walls

Introduction:

STABILITY OF RETAINING WALLS

1. Check for sliding
2. Check for overturning
3. Check for bearing capacity failure
4. Check for base shear failure

The minimum factors of safety for the stability of the wall are:

1. Factor of safety against sliding =1.5
2. Factor of safety against overturning = 2.0
3. Factor of safety against bearing capacity failure = 3.0

Prerequisite knowledge for Complete understanding and learning of Topic:

- ✓ Retaining wall
- ✓ Coulomb's wedge theory
- ✓ Active and passive states
- ✓ Rankine's theory

Detailed content of the Lecture:

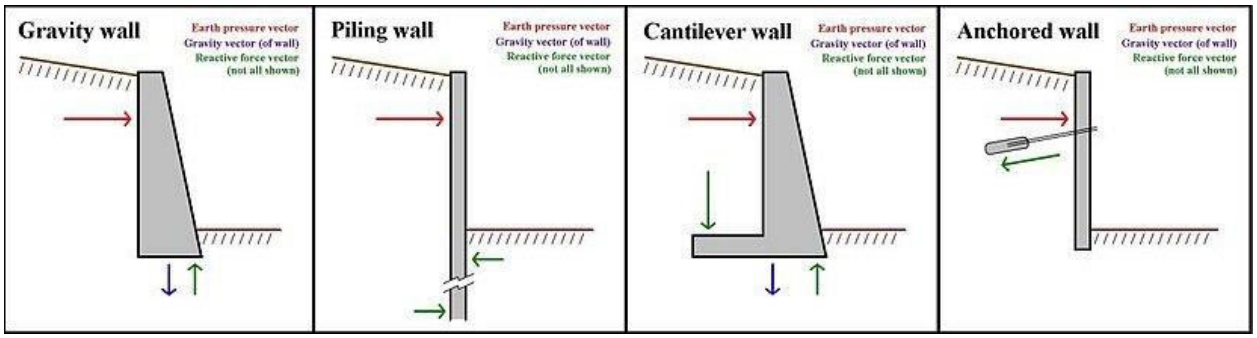
Conditions of Stability of Retaining Walls

To ensure the stability of a retaining wall, the following conditions or requirements must be met:

- ✓ The wall should be structurally capable of resisting the pressure applied to it.
- ✓ The wall should be so properly proportioned that it will not get overturned by the lateral

pressure.

- ✓ The wall should be safe from consideration of sliding, i.e., the wall should not be pushed out by the lateral pressure.
- ✓ The weight of wall together with the force resulting from the earth pressure acting on it, should not stress its foundation to a value greater than safe bearing capacity of the soil.
- ✓ It is important to prevent accumulation of water behind a retaining wall. The backing material should be suitably drained by providing weep holes.
- ✓ Long masonry retaining walls should be provided with expansion joints located at 6 to 9m apart.
- ✓ Weep holes may be provided to relieve water pressure



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

https://www.youtube.com/watch?v=LIAAhaeeA8Qhttps://www.youtube.com/watch?v=xplAmWV39A8

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

1. Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain., Laxmi Publications Pvt Ltd, Sixteenth Edition, 2005. (Page no – 538 to 543)
2. BrajaM. Das., Priciples of Foundation Engineering, Seventh Edition, Cengage Learning, 2015. (Page no –380 to 382)

Course Teacher

Verified by HOD