



According to New Revised Credit System Syllabus

FOUNDATION ENGINEERING

Third Year Degree Course In
CIVIL ENGINEERING (Semester - II)

SPPU

Includes

Model Question Papers for
In-Semester (30 Marks) &
End-Sem Exams (70 Marks)

Dr. RAVIRAJ R. SORATE
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ADVANCEMENT OF KNOWLEDGE

A TEXT BOOK OF

FOUNDATION ENGINEERING

FOR
SEMESTER – II

THIRD YEAR DEGREE COURSE IN CIVIL ENGINEERING

Strictly According to New Revised Credit System Syllabus
of Savitribai Phule Pune University
(w.e.f. June 2017)

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PREFACE

It gives us great pleasure to present the book '**Foundation Engineering**' for the students of Third Year Degree Course in Civil Engineering of the Savitribai Phule Pune University. This book is strictly as per the **New Revised Credit System Syllabus 2015** Pattern with effect from the Academic Year 2017-18.

As per New Revised Examination Scheme which has been implemented from this academic year, In-semester assessment carries 30 marks over first three units and End Semester Examination carries 70 marks over entire syllabus out of which first three units will carry 20 marks and units 4, 5, 6 will carry 50 marks. The theory course will have 4 credits.

The book is written such that all the basic concepts are explained in simplified manner. It is presented in a more conceptual manner rather than mathematical, as required by the new examination system. It is our objective to keep the presentation systematic, consistent, intensive and clear through explanatory notes and figures.

Main feature of this book is, Complete Coverage of the New Credit System Syllabus with large number of Worked Solved Examples, Exercises, Model Question Papers of In Sem. and End Sem. Exams.

We are sure that this book will cater to all needs of students for this subject.

We also take this opportunity to express our sincere thanks to Shri. Dineshbhai Furia, Shri. Jignesh Furia, Mrs. Nirali Verma, Shri. M. P. Munde and entire team of Nirali Prakashan namely Mrs. Deepali Lachake (Co-ordinator), who really have taken keen interest and untiring efforts in publishing this text.

The advice and suggestions of our esteemed readers to improve the text are most welcomed, and will be highly appreciated.

SYLLABUS

Unit-I : Subsurface Investigations for Foundations

(06 hours)

Purpose and planning of subsurface exploration. Methods of Investigation: Trial pits, borings, depth & number of exploration holes, core recovery, RQD, Core Log. Geophysical methods– Seismic refraction and Electrical resistivity method. Disturbed and undisturbed sampling, types of samplers, degree of disturbance of a sampler. Field tests- SPT, N value correction and significance, DCPT, SCPT and introduction of advanced testing techniques like Pressure meter test. **Site visit is recommended to learn this topic.**

Unit-II : Bearing capacity and Shallow Foundation

(06 hours)

Basic definitions, Modes of shear failure, bearing capacity analysis- Terzaghi's, Hanson's, Meyerhof's, Skempton's, Vesic's equations and IS code method - Rectangular and Circular footings. Bearing Capacity evaluation: - Plate Load Test and SPT. Housel's perimeter shear concept. Bearing capacity of layered soil. Effect of water table on bearing capacity. Effect of eccentricity. Shallow foundation- Types and Applications. Floating foundation. Presumptive bearing capacity.

Unit-III

(06 hours)

(a) Settlement and Consolidation Settlement: - Introduction, Causes of settlement. Pressure bulb, Contact pressure, Significant Depth of foundation, Allowable settlement, Differential settlement - I.S. criteria, Types - Elastic settlement, Consolidation settlement. Use of Plate Load test and SPT in settlement analysis. Allowable soil pressure.

(b) Consolidation - Introduction, spring analogy, Terzaghi's consolidation theory, Laboratory consolidation test, Determination of coefficient of consolidation- Square root of time fitting method and logarithm of time fitting method. Time factor. Rate of settlement and its applications in shallow foundation. Introduction of Normal consolidation, over consolidation and Preconsolidation pressure.

Unit-IV : Deep Foundations

(06 hours)

Introduction, Pile classification, Pile installation-Cast in-situ, driven and bored pile, Load carrying capacity of pile by static method, Dynamic methods-Engineering news formula and Modified ENR formula. Pile load test and Cyclic Pile load test. Group action- Feld rule. Rigid Blocks method. Negative skin friction. Settlement of pile group in cohesive soil by approximate method. Piers and Caissons- Definition, Types and uses. Well foundation: components, sand Island method.

Unit V : Cofferdams and Foundation on Black Cotton Soils

(06 hours)

a) Cofferdams: Types and concepts of Steel Sheet Piles and Precast Concrete Piles, Interlocking Circular Piles, RC Diaphragm wall method.

b) Foundation on Black Cotton Soils: Characteristics of black cotton soil, swelling potential and its evaluation methods, Engineering problems, Swelling pressure measurement, Foundations on black cotton soil: design principles, Construction techniques in B.C soils, under reamed piles- Design principles and its construction Techniques. Stone Columns prefabricated vertical Drains, Preloading technique, and vibro flotation technique.

Unit VI : Soil Reinforcement and Earthquake Geo-techniques

(06 hours)

a) Soil Reinforcement: Basic components and Mechanism of reinforced soil. Geosynthetics: type's, functional properties and requirements. Geosynthetic Applications in Civil Engineering.

b) Earthquake Geo-techniques Introduction, Earthquake Terminology, Sources of earthquake, Seismic zones of India, Magnitude of an earthquake, Intensity of earthquakes, Effect of ground motion on structures, General principles of earthquake resistant design. Liquefaction Phenomenon

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SUBSURFACE INVESTIGATIONS FOR FOUNDATIONS

1.1 INTRODUCTION

(Feb. 16)

The basic aim of site investigations or sub-surface exploration is to obtain the information about the surface conditions at the site of proposed construction. For every big or major engineering project site investigations are required for one or the other reason. The information collected during the surface and sub-surface exploration is beneficial for the design of structures and for planning construction techniques.

Site investigation comprises of :

- Determination of profile of the natural soil deposits at the site.
- Determination of engineering properties of the soils by taking the samples.

1.2 PURPOSE OF INVESTIGATION

(Dec. 10, May 11, Feb. 16)

Site investigations are done for obtaining information, which is useful for one or more of the following purposes :

- Determination of the bearing capacity of the soil.
- Selection of type and depth of foundation for a given structure.
- Investigation of the safety of the existing structures and for necessary remedial measures.
- Selection of suitable construction technique.
- Calculation of the lateral earth pressure against retaining walls and abutments.
- Estimation of probable maximum and differential settlements.
- Prediction and solving of potential foundation problems.
- Establishing the ground water table level and determination of the properties of water.
- Determining the suitability of the soil as a construction material.

The necessary information is gathered :

- By drilling holes or bore holes.
- By taking the soil samples.
- By determining the index and engineering properties of soil.

- By conducting In-situ (on-site) tests to determine the properties of soils in natural conditions.

1.3 PLANNING OF SUB-SURFACE EXPLORATION

A programme for sub-surface exploration depends upon :

- The type of the structure to be built.
- The variability of the strata at the proposed site.

The extent of sub-surface exploration closely depends upon the relative cost of investigation and that of the entire project for which it is to be done. In short, if we go for detailed investigation, we will come to know more about the sub-surface conditions. Therefore, the greater economy can be achieved in the construction of the project because the element of uncertainty is considerably reduced. But, in some cases the cost of investigations outweighs any savings in the cost of project which ultimately increases overall cost, which is not desirable.

The location of the project also governs the extent of investigations. For example, a small house in a well developed area may not require much exploration because we can get information from public in that area regarding hard strata, ground water table etc. On the other side, a house to be built in a newly developing area requires detailed site investigation for knowing depth of hard strata and other physical properties of soil. Also in case of a multi-storeyed building, extensive investigation is necessary. Multi-storeyed buildings impose very heavy loads and their zone of influence is also very deep. Therefore, it is desirable to invest some amount on sub-surface exploration than to over-design the building and increase its construction cost.

Planning of a sub-surface exploration programme is a difficult task because, alongwith knowledge of soil mechanics (engineering), it also requires experience and engineering judgement. In some cases, the exploration programme has to be changed as the investigation progresses. If variability in soil strata is found to be increased then extent of investigations is also increased. On the other hand, site is having uniformly laid strata (layers of soils), the extent of investigations is decreased.

The cost of investigation varies between 0.05 to 0.2% of the total cost of the entire structure or project. In some unusual cases cost may be even upto 1%.

1.4 STEPS IN SUB-SURFACE EXPLORATION

Sub-surface explorations are generally carried out in three steps or stages.

- 1. Reconnaissance :** It is the first step in a sub-surface exploration programme. It consists of a visit to the site and to study the maps and other necessary records. It helps in deciding future programme of site investigations, method of exploration to be adopted, scope of work, types of sample to be taken and the laboratory testing and in-situ testing.
- 2. Preliminary Explorations :** The basic aim of preliminary explorations is to determine the depth, thickness, extent and composition of each soil layer at the site. Alongwith above parameters, ground water table and depth of rock is also determined.

The **preliminary** explorations are done in the form of trial pits or borings.

Geophysical methods are also used for locating the boundaries of different strata as a part of preliminary investigation.

- 3. Detailed Explorations :** The objective of the detailed explorations is to determine the engineering properties of the soils in different stratum. It consists of sampling of testing of the samples in a laboratory and an extensive boring programme.

To determine the properties of the soils in natural state, field tests such as vane shear test, plate load test and permeability test are conducted. Also if needed the tests for the determination of dynamic properties are carried out.

At sites, where there is uniform strata, may not require detailed investigations but for projects involving heavy structures such as bridges, dams, multi-storey buildings, it is necessary to carry out detailed explorations.

1.4.1 Reconnaissance

The Civil Engineer or Geotechnical Engineer makes a visit to the proposed site for a careful visual inspection. Following information is collected during reconnaissance.

- The general topography of the site including the existence of drainage ditches and dumps of debris and sanitary landfills.
- The location of HFL (High Flood Level) on nearby buildings and bridges.
- The depth of ground water table which can be obtained from existing wells.
- The pattern of natural drainage existing at the site.
- Type of vegetation at the site which gives idea about nature of soil present at the site.
- The stratification of soils, which can be obtained from deep cuts near the site.

- Presence of settlement cracks in the structure, which are already existed near structure.
- The evidence of creep of soils, landslides, and the shrinkage cracks.
- Presence of natural springs, swamps near the site.
- Existence of underground water mains, power lines etc. at the site.

Apart from making site visits, the civil engineer has to study geological maps, arial photographs, soil maps, topo-sheet and the blue-prints of existing buildings.

1.5 METHODS OF INVESTIGATION

The various methods of soil explorations can be generalised as follows :

- Open excavation.
- Boring.
- Sub-surface soundings.
- Geophysical methods.

1.5.1 Open Excavation

Open excavation method for sub-surface exploration is adopted to inspect the sub-strata. Open excavation for soil exploration can be done by two ways :

1. Pits and Trenches.
2. Drifts and Shafts.

1. Pits and Trenches : Pits and trenches are excavated at site for inspection of strata. The pit and trench size should be such as to provide necessary working space. According to IS : 4453-1967, a clear working space of 1.2 m × 1.2 m should be provided at the bottom of the pit.

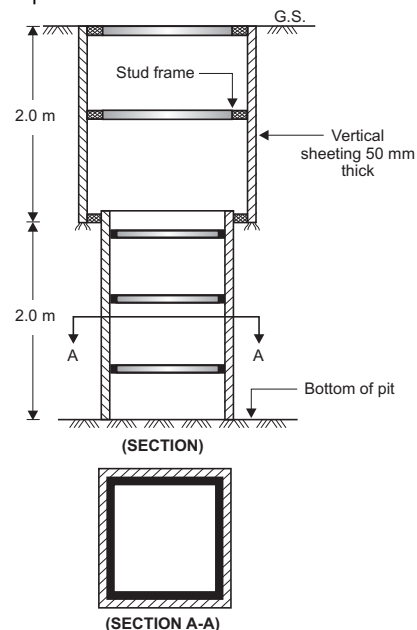


Fig. 1.1 : Pits and trenches

The shallow pits do not require lateral supports, if depth is up to 3 m. If pits are deeper and below ground water table, they require the lateral support in the form of sheeting and bracing system.

But, if depth of pits goes on increasing, cost also increases rapidly. Therefore, for depths greater than 6 m, bore holes are more economical than pits.

In case of deeper pits, proper ventilation is necessary to avoid unhygienic conditions. If water is encountered in a pit, it should be properly disposed.

Trenches can be defined as 'Long Shallow Pits'. A trench is continuous over a considerable length and it provides exposure along a line. On sloping ground trenches are more suitable than pits.

The pits and trenches excavation can be done manually or mechanically.

2. Drifts and Shafts : Drifts can be defined as 'horizontal tunnels made in the hill side to determine the nature and structure of the geological strata'. According to IS 4453-1980 a drift should have the minimum clear dimension 1.5 m wide and 2.0 m in height in hard rock. In case of soft rock arched roof can be provided instead of flat roof.

Large size vertical holes made in the geological formation are called **Shafts**. For a circular shaft, minimum diameter is 2.4 m and for rectangular shaft minimum width is 2.4 m. In case of deep shaft proper ventilation is necessary. Generally, shafts are used to reach a strata at a depth of 4 m or more.

1.5.2 Boring and Boring Methods

(Feb. 16, 17, May 17)

Borings are used for explorations only when depth of exploration is large. The information about sub-soil strata is obtained by drilling a vertical bore hole in the ground. Samples are extracted from bore holes and tested in a laboratory. In-situ tests can be conducted and water table can be located by using bore holes. For measurement of deformation in the sub-strata, extensor meters and pressure meter may also be used.

The following methods can be used for drilling bore holes depending upon the type of soil and the purpose of boring.

1. Auger boring.
2. Wash boring.
3. Percussion drilling.
4. Core boring.

These methods are explained below :

1. Auger Boring (Feb. 17): In cohesive and other soft soils above water table, augers are used.

An auger is a boring tool, similar to one used by a carpenter for boring holes in a wood. It consists of a cross-wise handle for turning and having central tapered feed screw. Augers can be

operated mechanically or manually. Hand augers used for depths upto about 6 m and mechanically operated augers are used for greater depth and they can be used in gravelly soils.

The hand augers are used in boring are about 15 to 20 cm in diameter. The lower end of hand auger is attached to a pipe of 18 mm diameter.

For taking samples from readily driven hole, a auger known as 'Post-Hole Auger' is used.

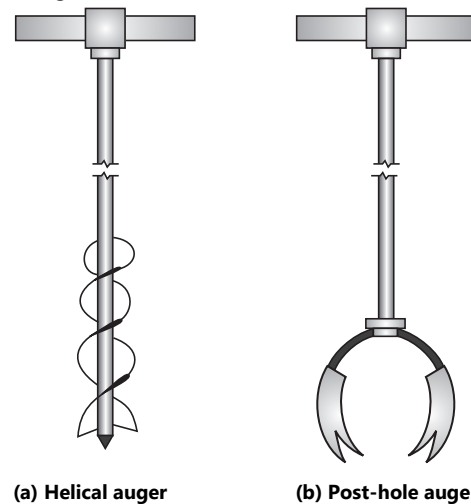


Fig. 1.2 : Types of augers

Mechanical augers are driven by power. If depth of bore hole increases above 12 m, then mechanical augers become inconvenient and other boring methods are used.

Auger boring becomes trouble-some. When there are large boulders, cobbles and other obstructions which prevent drilling of hole.

The site investigations are done quite rapidly and economically by using auger boring. For sub-surface investigations of highways, railways and air fields, auger boring is used because depth of exploration is small.

It becomes difficult to locate the exact change in soil strata in auger boring because soil samples obtained are highly disturbed.

2. Wash Boring (May 15) : Wash boring is a fast and simple method for drilling holes in all types of soils. In wash boring a hole is drilled by driving a casing about 2 to 3 m deep and then inserting into it a hollow drill rod having a chisel-shaped chopping bit at its lower end. Water is pumped down the hollow drill rod, which is called as 'Wash Pipe'. As a result, water comes as a strong jet through a small opening of the chopping bit. By a combination of chopping action and the jetting action the hole is drilled. The drilling bit and water jet together disintegrate the soil. The chopped particles are thrown upward through the space between the drill rod and the casing. The return water is loaded with soil cuttings and is known as 'Wash Water'. A T-shaped pipe is fixed at the top of the casing to collect wash water in a tub.

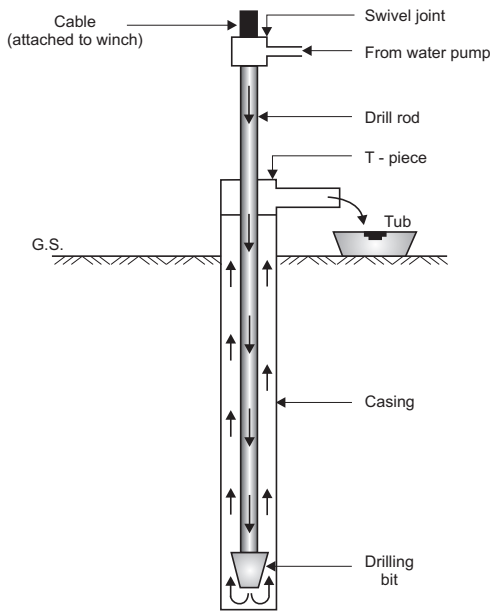


Fig. 1.3 : Wash boring

As there is complete breakdown of soil particles by chopping action, the wash samples collected in the tub do not represent the soil in its true form. The samples collected do not have much practical use. But, some idea about change in strata can be obtained by the reaction of chopping bit as the hole is drilled. Change in colour of wash water also suggests change in strata.

Mainly wash boring is used for drilling holes in the ground. Once hole is drilled, a sampler is inserted to obtain soil samples for laboratory testing.

Advantages of Wash Boring :

- Instrument used is relatively light in weight.
- Inexpensive method of boring.
- Fast and simple method.

Disadvantages of Wash Boring :

- It is slow in stiff and coarse grained soils.
- Cannot be used in rocky strata.
- Good quality undisturbed samples can not be obtained.
- Not suitable in areas where ground water table is very near to ground.

3. Rotary Drilling (Core Boring or Core Drilling) : Rotary boring or rotary drilling is a very fast method of advancing hole in the rocks and soils. In this method, hole is drilled by rotating a hollow drill rod which has a cutting bit at its lower end. At the top of drill rod, drill head is provided. It comprises of a rotary mechanism and an arrangement for applying pressure.

When the drilling rod is rotated, the cutting bit shears off chips of the material penetrated. A drilling fluid is introduced under pressure through the drilling rod to the bottom of the hole. The cuttings of the material penetrated are carried to the ground by

the fluid through the annular space between the drilling rod and the walls of the hole. Another function of fluid is to cool the drilling bit. The drilling fluid also supports the walls of the hole, in case of un-cased hole.

The drilling bit is replaced by a sampler, when soil sample is required to be taken.

Advantages of Core Boring :

- Rotary drilling can be used in clay, sand and rocks.
- Bore holes of diameter 50 mm to 200 mm can be easily drilled by this method.

Disadvantage of Core Boring :

If soil is containing a large percentage of particles of gravel size and larger, this method is not well adapted. Because, the particles of this size start rotating below the drill rod and it becomes difficult to drill the hole.

4. Percussion Drilling (May 17) : This method is specially used for making holes in rocks, boulders and other hard strata. Percussion drilling consists of lifting and dropping of a heavy chisel in a vertical hole. The material gets pulverised. Water is added to the hole, if the chisel strikes above water table. The water forms a slurry of disintegrated material, which is removed by sand pump or a boiler at intervals. Casing may be required for this method. For drilling tube wells also, percussion drilling is used.

Advantages of Percussion Drilling :

- Percussion drilling can be used for all types of materials.
- It is very much useful for boring holes in glacial hills containing boulders.

Disadvantages of Percussion Drilling :

- Because of heavy blows of the chisel, the material at the bottom is in disturbed state.
- More expensive as compared to other methods.
- Difficult to detect minor changes in the properties of the strata penetrated.

5. Core Drilling : This method is used for advancing holes and for obtaining rock cores. It consists of a core barrel fitted with a drilling bit and is fixed to a hollow drilling rod. The bit advances and cuts an annular hole around an intact core, as the drilling bit is rotated. Then the core is removed from its bottom and is retained by a core lifter and brought to ground surface. To keep the drilling bit cool and to carry the disintegrated material to the ground surface, water is pumped continuously into the drilling rod.

Drilling may be done by a diamond studded bit or a cutting edge having chilled shot. The diamond drilling is costlier, but is superior to the other type of drilling. If double tube core barrel is used, it gives good quality of the rock sample.

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