STAMFORD UNIVERSITY BANGLADESH

DEPARTMENT OF CIVIL ENGINEERING

A STUDY ON SUB-SOIL EXPLORATION AND DETERMINATION OFGEOTECHNICAL PROPERTIES OF SOIL AT A SPECIFIED PROJECT OF SIX STORIED RESIDENTIAL BUILDING AT. MOUZA-KAZIRGAON, DAG NO S.A- 397, R.S-41,WEST MUSLIMBAG, KARDIGHIRPAR, KALINDI, KERANIGANJ, DHAKA, BANGLADESH.

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JULY 2023

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Supervised by:

Prof. Md. Anisur Rahman

DEPARTMENT OF CIVIL ENGINEERING

STAMFORD UNIVERSITY BANGLADESH

In partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Civil Engineering.

STAMFORD UNIVERSITY BANGLADESH
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The Project & Thesis Titled“A STUDY ON SUB-SOIL EXPLORATION AND DETERMINATION OFGEOTECHNICAL PROPERTIES OF SOIL AT A SPECIFIED PROJECT OF SIX STORIED RESIDENTIAL BUILDING AT. MOUZA-KAZIRGAON,DAG NO S.A- 397, R.S-41,WEST MUSLIMBAG, KARDIGHIRPAR, KALINDI, KERANIGANJ, DHAKA ,BANGLADESH.” Submitted By Md Atikur Rahman (ID No: CEN 067 10125), Omar Faruq (ID No: CEN 067 10099), Al Masud, (ID No: CEN 066 09980), Md. Arafat Hossain **(**ID No: CEN 068 10239**)**, students of the department of Civil Engineering has been accepted in partial fulfillment of the requirements for the degreeof Bachelor Of Science (B.Sc.) In Civil Engineering In December, 2022.

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DECLARATION

We are Md Atikur Rahman ,Omar Faruq, Al Masud, Md Arafat Hossain, the students of B.Sc.in Civil Engineering here by solemnly declare that the works presented in this project & thesis has been carried out by us and has not previously been submitted to any other University/College/Organization for any academic qualification/ certificate/ degree/diploma.

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DEDICATION

We would like to dedicate this thesis to our parents and teachers. We would also like to dedicate our work to our mentors Md. Anisur Rahman, Professor, Department of Civil Engineering, Stamford University Bangladesh.

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At first we would like to thank the Almighty Allah for giving us the strength to accomplish the research work within appropriate time without any significant problem. The years spent working towards the completion of this thesis was challenging, stimulating and exciting. Even though the reasons to embark in this academic experience were personal, many people were part of it and deserve recognition. It is our greatest pleasure to acknowledge our deepest gratitude to our supervisor Prof. Md. Anisur Rahman. For his constant guidance, suggestions and care to attain there search objectives and editing the thesis. We wish to express our sincere thanks to him for his suggestions and providing us the scope and necessary support to complete the project and thesis entitled "**A STUDY ON SUB-SOIL EXPLORATION AND DETERMINATION OFGEOTECHNICAL PROPERTIES OF SOIL AT A SPECIFIED PROJECT OF SIX STORIED RESIDENTIAL BUILDING AT. MOUZA-KAZIRGAON, DAG NO S.A-397, R.S-41,WEST MUSLIMBAG, KARDIGHIRPAR, KALINDI, KERANIGANJ, DHAKA ,BANGLADESH**" This work has been conducted in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Civil Engineering.

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ABSTRACT

Sub-soil exploration and determination of geotechnical properties of sub-soil performed to evaluate soil conditions, soil formations and different geotechnical parameters that affect the safety, cost effectiveness, design, and execution of proposed engineering project. Insufficient geotechnical investigations, faulty interpretation of result or failure to portray result in a clearly understandable manner may contribute to in appropriate designs. This thesis and project work consist so fan adequate program of field sampling, laboratory testing, and engineering analysis and evaluation. The analysis to be implemented for the various types of structures. This reports presents the results of the Geotechnical properties of 06 (six) Storied Residential Building **MOUZA-KAZIRGAON, DAG NO S.A- 397, R.S-41,WEST MUSLIMBAG, KARDIGHIRPAR, KALINDI, KERANIGANJ, DHAKA, BANGLADESH** During The Month Of December 2022.

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LIST OF ACRONYMS AND ABBREVIATIONS

A Cross-sectional area

Ac Air content

Av Area of voids

B Pore pressure parameter

C Cohesion intercept for Mohr's envelope of shear strength based on total stresses.

Ch Coefficient of consolidation in horizontal

C*v* Coefficient of consolidation in verticle

Cc Coefficient of curvature

Cu Uniformity of coefficient

Cv Coefficient of compressibility

D_f Foundation Depth

D_r Relative Density

D_{10} Particle size corresponding to 10% finer

D_{30} Particle size corresponding to 30% finer

D_{60} Particle size corresponding to 60% finer

E Modulus of Elasticity

e Void ratio

FS Factor of Safety

f Friction

G Specific Gravity

I Moment of Inertia

LL Liquid Limit

PL Plastic Limit

PI Plasticity Index

K Coefficient of absolute permeability

Ko Coefficient of earth pressure

Ka Coefficient of active pressure

Kp Coefficient of passive pressure

N **Number of blow (SPT)**

n **Porosity**

P **Force**

Q **Vertical load**

Qa **Allowable load**

Qu **Ultimate load**

q_u **Ultimate bearing capacity**

q_a **Allowable bearing capacity**

q_{nu} **Net-Ultimate bearing capacity**

q_{na} **Net- Allowable bearing capacity**

S **Degree of saturation**

s **Shear strength**

V_d **Volume of dry soil**

V_a **Volume of air**

V_w **Volume of water**

V_v **Volume of voids**

V_s **Volume of solids**

v **Velocity**

W **Total weight**

W_w **Weight of water**

W_v **Weight of voids**

η **Coefficient of viscosity**

µ **Poisson's ratio**

δ **Angle of friction**

y **Bulk unit weight**

y_d **Dry unit weight**

y_{sat} **Saturated unit weight**

$y_{y\,w}$ **Unit weight water**

ρ **Displacement**

σ **Total stress**

φ **Angle of internal friction.**

CHAPTER ONE

INTRODUCTION

Information on the soil exposed at the ground surface is very valuable geotechnical engineers also need to evaluate the sub-surface conditions by taking samples by boring or by digging exploratorypits. These activities are called subsurface exploration. Site investigations or sub-surface explorations are done for obtaining the information about subsurface conditions at the site of proposed construction. Site investigation in is generally required for every big engineering project. Information about the surface and sub-surface features is essential for the design of structures and for planning construction techniques.

The extent of exploration depends on the importance of the structure, the complexity of the soil conditions and the budget available for exploration. A detail soil exploration programmed involves deep boring, field tests and laboratory tests for determination of different properties of soils required for the design of any structure.

1.1 Background and Present State of the Work:

Geotechnical investigations are generally performed to evaluate the sub-surface conditions that affect the safety, cost effectiveness, design and execution of civil engineering projects such as dams, embankments, roads, highways, bridges, towers, water tanks, air ports, multi- storied building etc. Insufficient geotechnical investigations and wrong interpretation of test results may lead to in appropriate design, delay in construction schedules and increase cost of construction, even misinterpretation of test results may cause the failure of the structure and subsequent litigation. High rise buildings have been growing very rapidly in Dhaka metropolitan city.

Geotechnical properties of soils usually vary from place to place both in lateral and vertical direction even for a short distance. These are there a sons why geotechnical investigations are needed for the design and construction of every civil engineering project. Sub-Soil investigation is to provided equate in formation on sub-surface and surface condition for the foundation and other sub-structure for the proposed project, leading to their economical and safe design. After collection the sub-soil from the selected area, (Keraniganj, Dhaka**)** by dropping the sampler on wood or hard materials, the required samples were collected and placed in the weather proof polythene bags.

The sub-soil study performing different type of field and laboratory test, evaluation of bearing capacity and recommendation type of foundation to be suitable for the sub soilcondition. Term of tendered should furnished tentative programmed regarding the above along with his offer should take into account the site condition and time schedule for completing the work, comprising sub-surface features, borings, in-situ tests, sampling, visual observations and laboratory test of samples, reporting of the test results, including discussion, correlating the field test of samples, reporting of the test values and recommendations.

1.2 Purpose of thework :

- To select the type and depth of foundation for given structure.
- To determine the bearing capacity of the soil.
- To estimate the probable maximum and differential settlement.
- To establish the ground water level and to determine properties of water.
- To predict the lateral earth pressure against retaining walls and abutments.
- To select suitable construction techniques.
- To predict and solve potential foundation problems.
- To ascertain the suitability of the soil as a construction material.
- To investigate the safety of the existing structures and to suggest the remedial measures.

1.3 Objective:

The information from soil investigations will enable a Civil engineer to plan, decide, design, and execute a construction project. Soil investigations are done to obtain the information that is useful for one or more of the following purposes.

- Explore the suitable foundation of proposed project 06(Six) storied residential building at Keraniganj, Dhaka.
- To know the geological condition of rock and soil formation.
- To determine Index properties of sub-soil.
- To determine Geotechnical properties of sub-soil.

Table-1.1: The objectives of soil investigations from various requirementspoint of view is summarized

Design requirements	➢ Definestratigraphy/geology. ➢ Todeterminesoilpropertiesrequiredfor Design. ➢ Aid materialselection. ➢ Todeterminethetypeanddepthof Foundation.
Construction requirements	➢ To select suitableconstruction ➢ Techniques. ➢ Defineequipmentandtechniquesneeded. ➢ To locate suitable transportationroutes.
Auditing	➢ Checkingasitepriortosale/purchase. ➢ To establish procedures forsoil
Monitoring	➢ To observe the soil Performanceafter ➢ Construction. ➢ Determine reasons for poorbehavior. ➢ Documentperformanceforfuture Reference.

1.4 Scope of the Work

The main scopes of work for the investigation are as follows:

- Reconnaissance survey of the soil to fix up the actual points of boreholes.
- Drilling of 06 nos. borehole up to the maximum depth 30m, by means of wash boring.
- Recording the ground water table.
- Execution of Standard Penetration Test (SPT) and collection of disturbed and undisturbed soil sample.

- Execution of laboratory Penetration tests on selected soil samples such as Grain Size Analysis, Atterberg's Limits, Moisture Content, Specific Gravity Test, Density, Direct share Test, Unconfined Compressive Strength and Consolidation Test (One Dimensional) etc.

1.5 Sub-Surface Exploration Program:

A sub-surface exploration program depends upon the type of the structure to be built and upon the variability of the strata at the proposed site. The extent of sub-surface exploration is closely related to the relative cost of the investigations and that of the entire project for which it is undertaken. In general, the more detailed the investigations are done, the more is known about the sub-surface conditions. As a result, the greater economy can be achieved in the construction of the project because the element of uncertainty is considerably reduced. However, a limit is reached when the cost of investigations outweighs any saving in the cost of the project, and it increases the overall cost. It would not be economical to have investigations beyond that limit.

The extent of investigations would also depend upon the location of the project. A small house in an already built-up area would not require much exploration. On the other hand, if the house is to be built in a newly developed area, a detailed investigation would be required to ascertain the location of deferent soil strata and their physical characteristics. Planning of a sub-surface exploration program is a difficult task. Besides a thorough knowledge of soil engineering, it requires experience and engineering judgment. As the variability of the soil strata is found to increase, the extent of investigations is also increased. On the other hand, if the site is found to be underlain by uniform deposits, the extent of investigations is decreased.

1.6 Step in Sub-Surface Explorations:

Sub-surface explorations are generally carried out in three stages

- **Reconnaissance:** Site reconnaissance is the first step in sub-surface exploration program. Its providea general picture of the topography and geology of the site. It is necessary that take with on the site visit all the information gathered and compare with the current conditions of the site. Here visual inspection is done to gather information on topography, soil stratification, vegetation, water marks, ground water level, and type of construction nearby.
- **Preliminaryexplorations:** The aim of a preliminary exploration is to determine the depth, thickness, extent and composition of each soil stratum at the site. The depth of the rock and the ground water table is also determined.

- **Detailed explorations:** Detailed soils exploration. Here we make a detailed planning for soil exploration in the form trial pits or borings, their spacing and depth.

Accordingly, the soil exploration is carried out. The details of the soils encountered, the type of field tests adopted and the type of sampling done, presence of water table if met with are recorded in the form of bore log. The soil samples are properly labeled and sent to laboratory for evaluation of their physical and engineering properties. Write a report. The report must contain a clear description of the soils at Particular proposed site, methods of exploration, soil profile, test methods and results, and the location of the groundwater. This should include information and/or explanations of any unusual soil, water bearing stratum, and soil and groundwater condition that may be troublesome during construction.

1.7 Depth of Exploration:

The depth of exploration required at a particular site depends upon the degree of variation of the substructure data in the horizontal and vertical directions. it is not possible to fix the number, deposition and depth of boring without making a few preliminary borings or soundings at the site. The depth of exploration is governed by the depth of the influence zone. The depth of the influence zone depends upon the type of the structure, intensity of loading, shape and deposition of the loaded area, the soil profile and the physical characteristics of the soil.

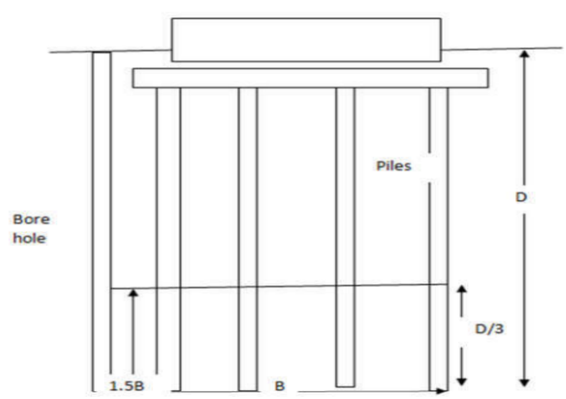


Figure-1.1: Depth Exploration

1.8 Lateral Extent Method of Exploration

The lateral extent of exploration and the spacing of bore holes depend mainly on the variation of the strata in the horizontal direction. The exploration should be extensive so as to reveal major changes in the properties of the sub-surface strata. For small or less important building, even one bore or a trial pit in the Centre may suffice. But for compact building, covering an area of about 0.4 hectares, there should be at least 5 bore holes, one at the Centre and four near the corners. The spacing the bore holes is generally kept between 10m to 30m. For highways, sub-surface exploration bore holes usually varies between 150m to 300m. In case of concrete dams, the spacing of bore holes generally varies between 40m to 80m.

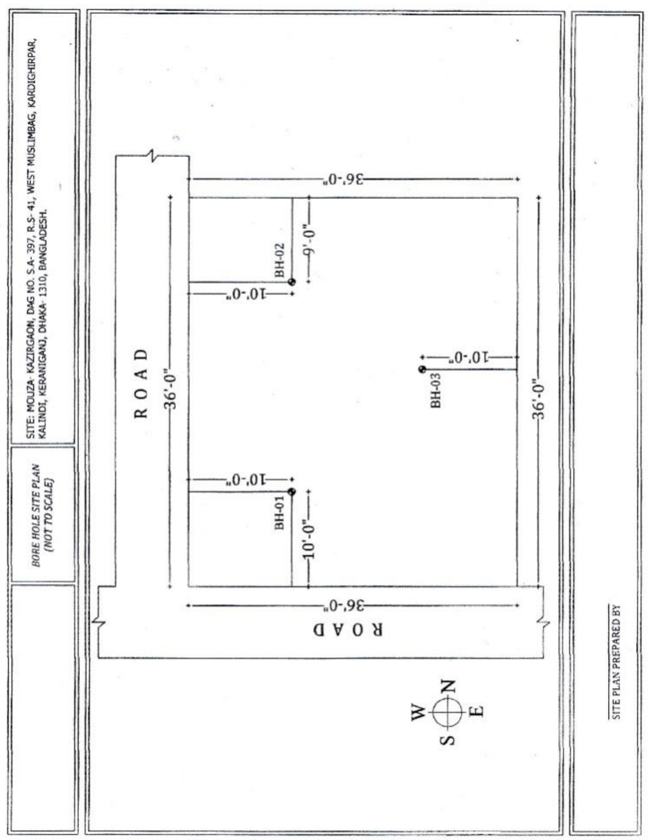


Fig-1.2: Borehole location

1.9 Open Excavation Methods of Exploration

In this method of exploration, an open excavation is made to inspect the sub-strata. The methods can be divided into two categories:

1. **Pits and trances**

Pits and trances are excavated at the site to inspect the sub-strata. The size of the pit should be sufficient to provide necessary working space. Is: 4453-1967 recommends a clear working space of 1.2m x 1.2m at the bottom of pit. The depth of the pit depends upon the requirement of the investigation.

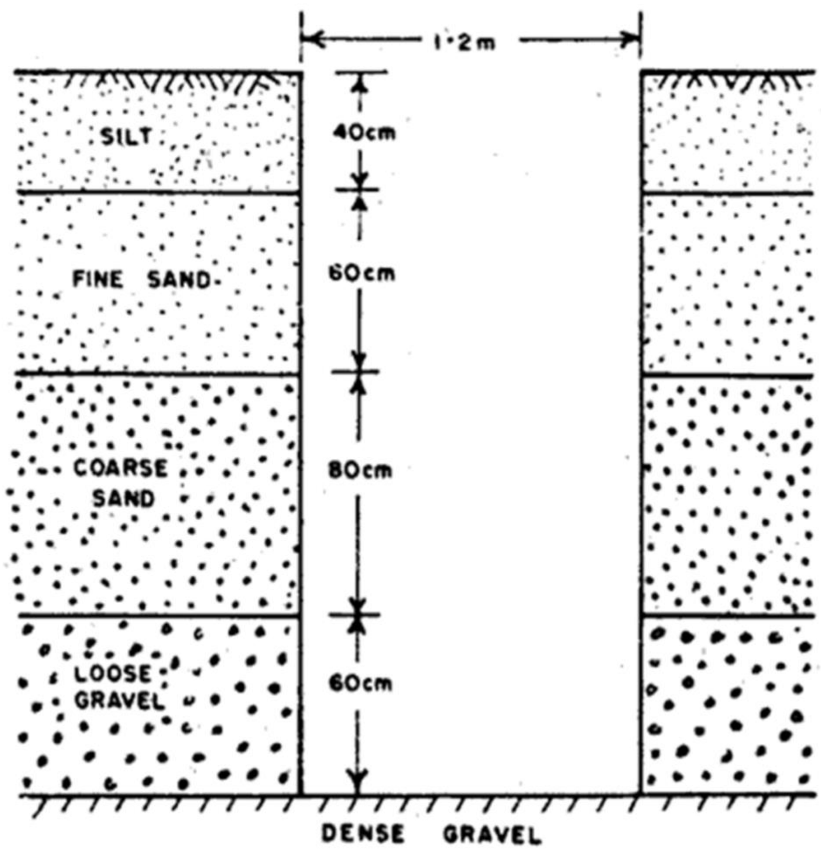


Figure-1.3: Trial Pit

1. Drift and shaft

Drift are horizontal tunnels made in the hill-side to determine the nature and structure of thegeological formation. IS : 4453-1980 recommends that a drift should have the minimum clear dimension of 1.5m width and 2m height in hard rock.

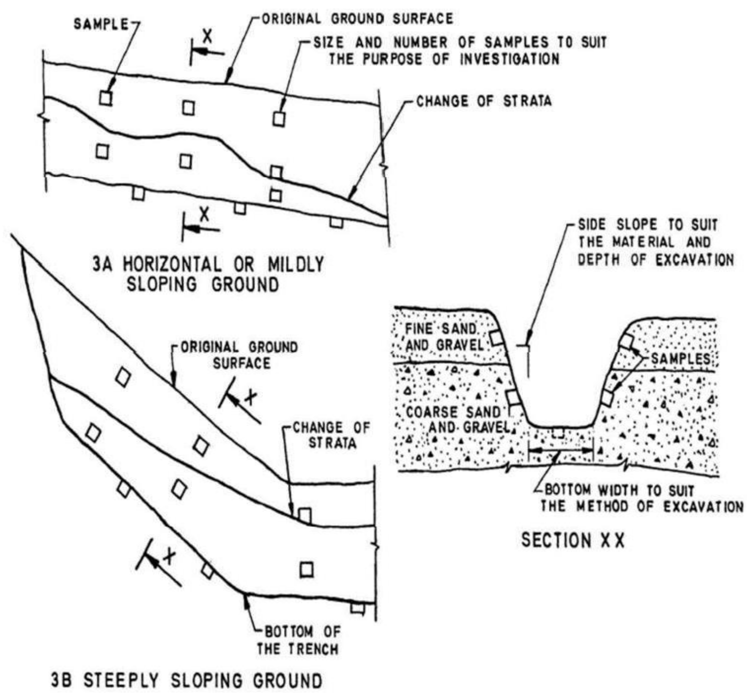


Figure- 1.4: Typical trenching layout

CHAPTER TWO

GEOLOGYOF THE AREA

2.1 Introduction of the site:

The term site characterization is used here to describe the process by which geological, geotechnical and other information relevant to the construction of a particular facility is determined. Together with knowledge about local geology to infer subsurface geologic structure. Proposed site is irregular Shaped. The object of the preliminary work to provide information about subsurface condition & geotechnical parameters of the proposed project area.

2.2 Surface Geology:

Geologically, the project area is located in the Terrace. The Terrace is a part of Modhupur Inliers, an elevated landmass surrounded by the flood plain of the rivers,Turag, Burigangs Padma and Meghna. The elevation of the terrace is about 8m from the MSL. The Terrace is bounded by number of faults. The terrace is formed of elevated dome shaper low hillocks and dish shaped depressions resulted due to erosion. The depression is interconnected by intricate streams of Deep valleys. The present site is located at a shallow depression of the terrace. Tectonically the site is located in the deeper part of Bengal basin. No surface folding or faulting could be identified in and around the area.

The project area is located in the seismic zone-II of seismic Zoning map of Bangladesh where the basic seismic co-efficient may be considered around 0.05.

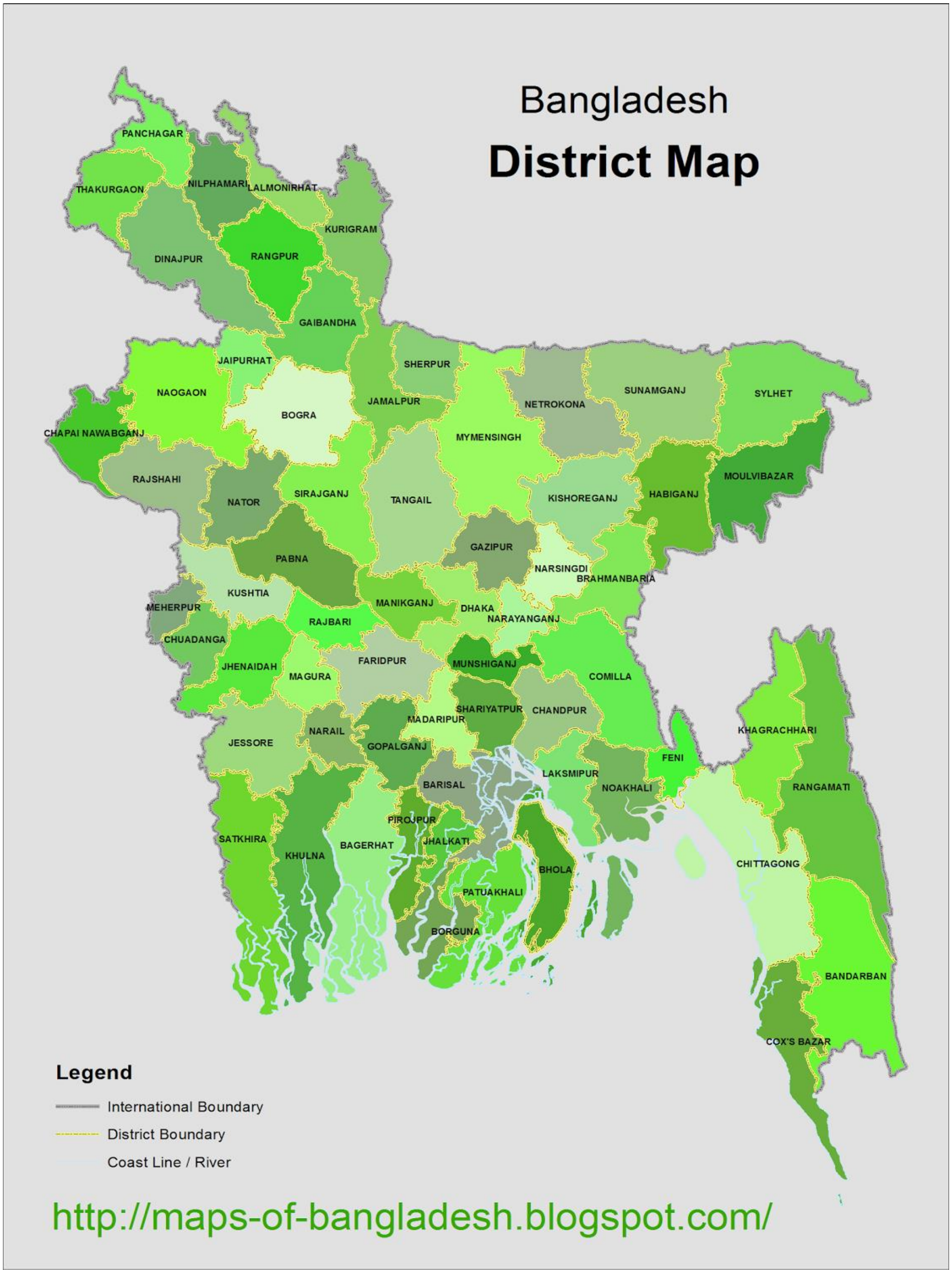
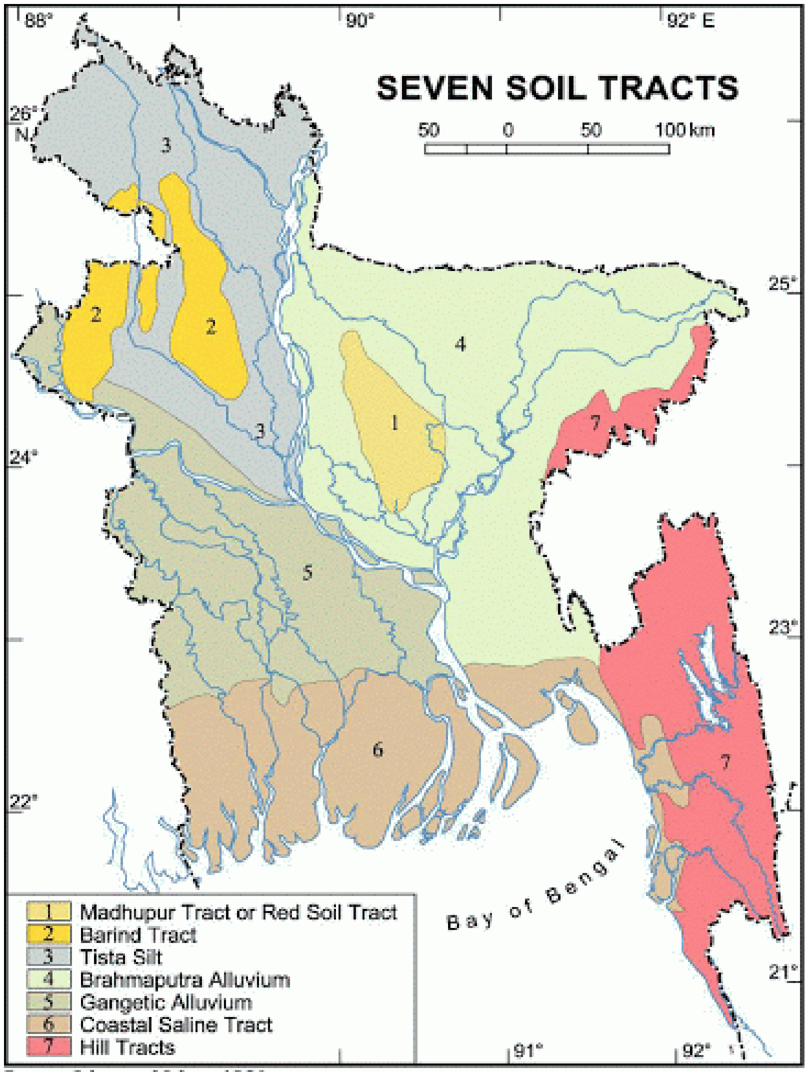


Figure-2.1: Bangladesh Map

2.3 Stratigraphic succession in and around Dhaka, Keraniganjarea in Table-

<u>Table 2.1:</u>

z	Formation	Litho logy	Thickness (Meters)
Holocene	Alluvium	Lowland: River bed deposit: Gray sand and silty sand, Medium to fine grained.	0-9
		Local unconformity	1.21-4.7 .
		Natural levee and inter stream deposit: Sandysilt,siltandloam,grayandfriable. BackSwampanddepressiondeposits:Clay andsiltyclay,gray,bluishgreyto-dark grey.	0.61-1.5
		Highland: silt and clay above the present flood level.	0-3.5
Pleistocene	Madhupur Clay	Red clay: Light brown to brick red and massive, pisolitic with fossil wood, ferruginous and Calcareous nodules and surificial deposits of slag. Mottled clay: Earthinggraywithpatchesoforange,brown color, massive and containingand ferruginous nodules.	31
		Unconformity	
Pliocene	DupiTila	Sandstone; Yellow to yellowish grey, massive, cross bedded, mostly fine to mediumgrainedContainingscatteredgravel lenses, moderatelyconsolidated.	> 90+



Source: Islam and Islam, 1956

Figure-2.2: Seven Soil tracts of Bangladesh

Figure-2.3: General Soil Map of Bangladesh

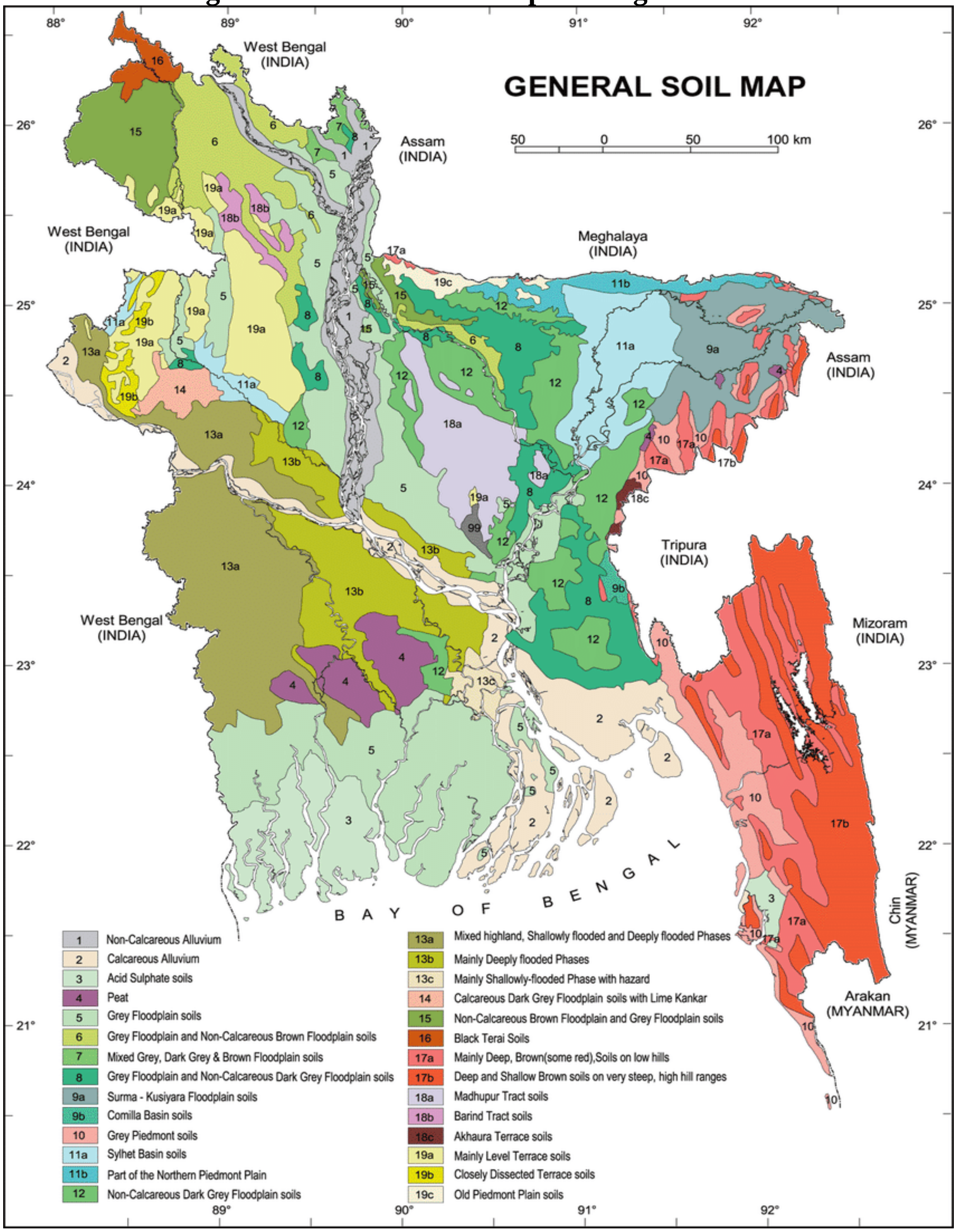


Figure-2.2: Ganeral Soil Map

2.4 Geomorphology of the Site:

The project area located in the South-part of the Bengal Fore deep, which is surrounded on its north by the Shilling Plateau in Assam in India and on its west side by the Rajmahal Hills in India. The eastern limits of the Bengal Fore deep are the Tripura Hills to the east and the Chittagong Hills to the south-east. The Bengal Fore deep is floored with Quaternary sediments deposited by the rivers of the Brahmaputra, the Meghna and their numerous associated streams and distributaries. The Bengal Basin is subsiding owing mainly to compaction of the recent sediments and is possibly due to structural down warping. Concerning tectonics and seism city, Bangladesh situates in one of the most active tectonic region of the world where three plates - The Indian plate, the Tibet and the Burmese Sub plates are colliding and thrusting against each other. Consequently, tremendous seismic activities have been resulted in the north and east of Bangladesh and caused some major earthquakes within and outside the country. As the earthquake epicenter in Assam in India is not far from Bangladesh, it is suggested to provide sufficient margin of safety, in designing the structure.

2.5 Earthquake and Seismicity:

The Spatial distribution of the entire recoded earthquake up to 1989 dated back to 1664in the around Bangladesh shown an increasing trend of earthquake since 1960. It is known from the past record that Dhaka was rocked in 1664. The 1737 earthquake claimed thousands of lives in the vicinity of Calcutta. Since then this region has experienced several earthquake from 1762 to 1950. In the opinion of Dr. AbtabAlam Khan, Associate Professor of Geology, Dhaka University as Stated in his article “Level of earthquake hazard in Bangladesh” Published in “The Daly Independent” of Saturday, 29th November, 1997, Bangladesh is extremely vulnerable to earthquake activities.

Bangladesh has been divided in to three seismic zones, i.e, Zone-I., Zone-II and Zone-III which have seismic zoning co-efficient Z of 0.075, 0.15 and 0.25 respectively. The present site within Aftabnagar,Badda premises of Dhaka city is located in Zone-II. i.e, In the Moderate shock zone of the seismic zoning map. A copy of seismic zoning map from BNBC-1993 is enclosed at Annex-1 for ready reference.

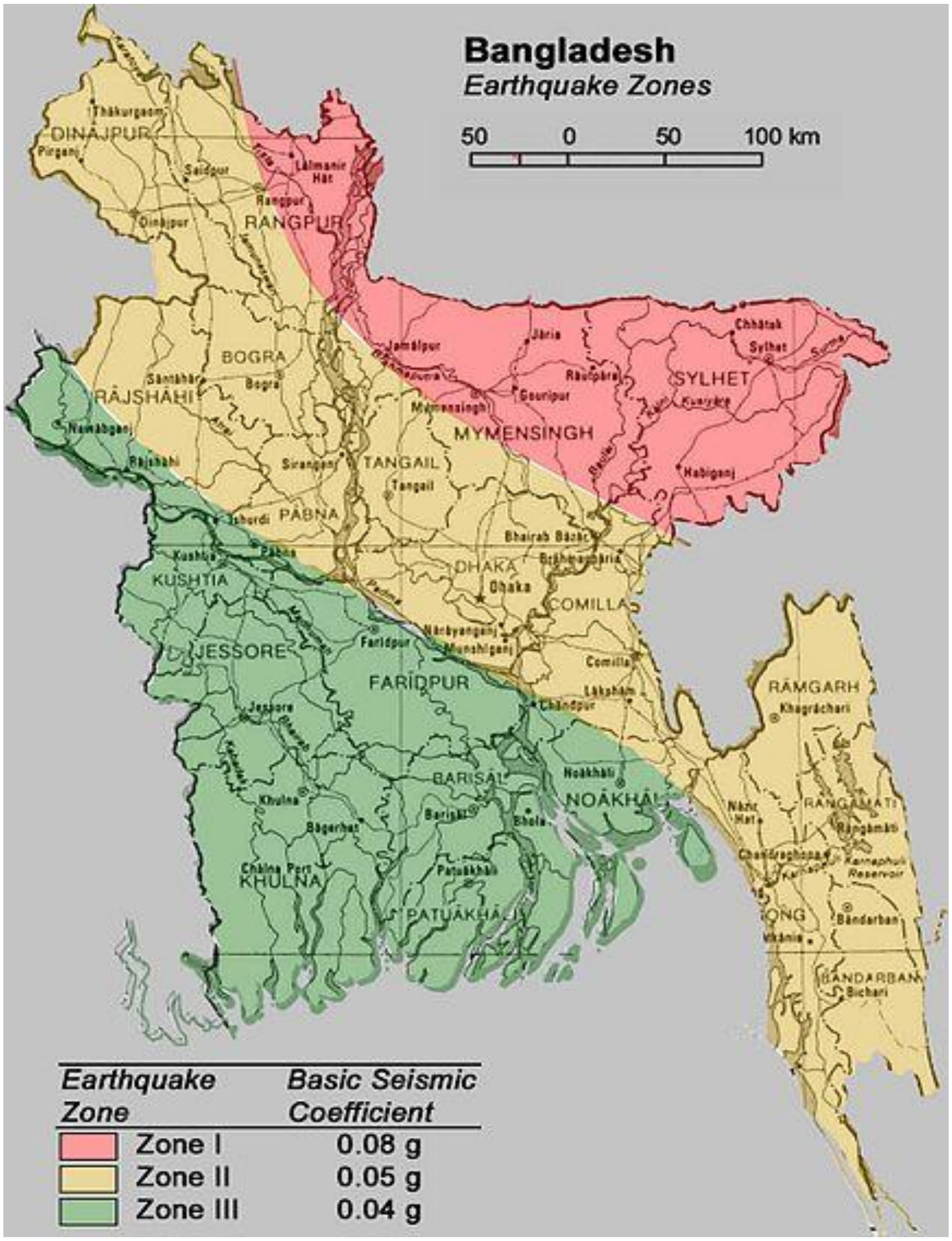


Figure-2.4: Earthquake zone

Figure-2.5: Proposed area location in Dhaka city

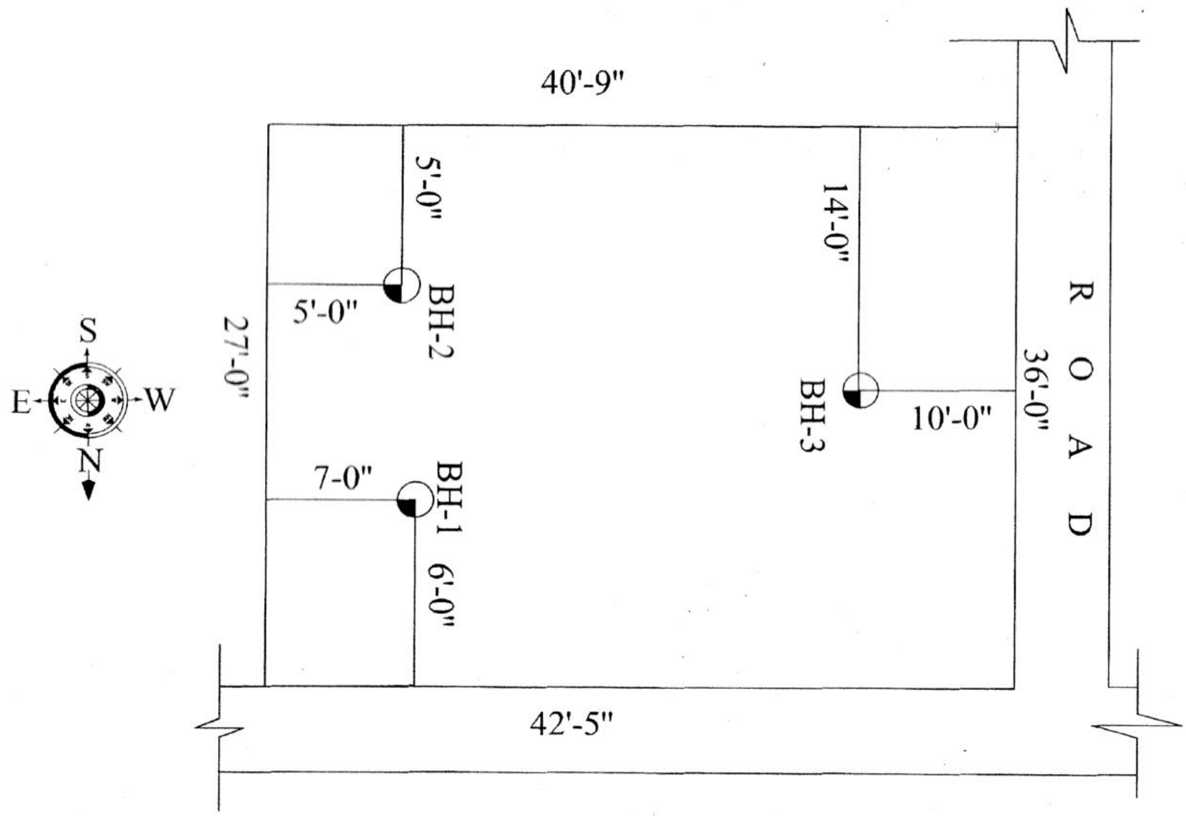


Figure-2.6 : Location Sketch of Bore hole Point

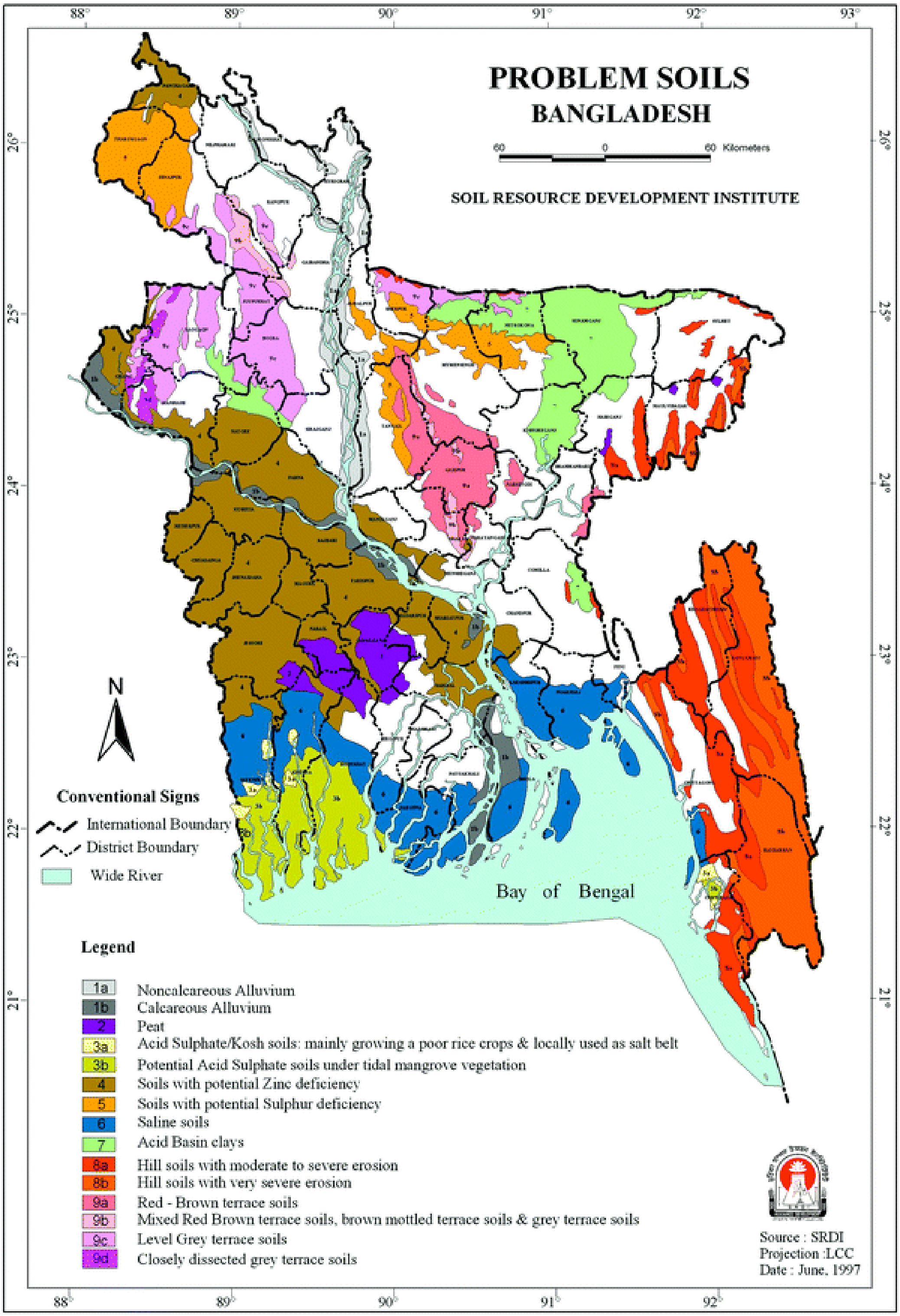


Figure-2.7: Soil problem of Bangladesh

2.6 Rating of ground conditions

Table-2.2: The ground conditions in the Dhaka, Keraniganj area may be rated as hazardous, poor or favorable according to the following factors.

Rating	Factors	Units	Areas
Hazardous	a. Liquefaction	3	Flood Plain of river Ganges and Buriganga in the west of the city.
	b. Slope failure	2&1	Along streams and depression edges.
	c. Flood	3&2	Areas below flood level (<6 meters above msl)
	d. water-logging	1&2	Areas where natural drainage is blocked
	e. Fill collapse	3	Filled up water wells and depressions
Poor	a. Ground collapse and subsidence	3	Lowareasofpartialitysubsidencesaturatedsand/silt (<2 meters abovemsl)
	b. Swelling clays	1	Found mainly the high areas
	c. Soft to firm clays: Organic soils: Municipal waste.	2&3	Easternsideofthestudyareaandalongthestream beds
Favorable	a. Elevated land	1&2	Central high area and sporadic areas in the high and low complex

CHPTER THREE

METHODOLOGY

CHAPTER THREE

METHODOLOGY

3.1 Introduction:

This Chapter addresses the geotechnical field investigation, including the development of the subsurface exploration program, the methods of generating subsurface information, and the criteria to be applied for test borings in the various conditions that will be encountered. It is organized by activities and policies involved prior to, during, and after exploration.

Earthwork forms the largest activity of a Civil Engineer. It is well understood that irrespective of the type of civil engineering structure on earth :

- It has to be rested either in soil
- Rested on soil
- The structure is itself constructed making use of soil

This implies that a better knowledge of the spatial variation of the soils encountered is essential. Before construction of any civil engineering work a thorough investigation of the site is essential. Site investigations constitute an essential and important engineering program which, while guiding in assessing the general suitability of the site for the proposed works, enables the engineer to prepare an adequate and economic design and to foresee and provide against difficulties that may arise during the construction phase. Site investigations are equally necessary in reporting upon the safety or causes of failures of existing works or in examining the suitability and availability of construction materials.

Site investigation refers to the methodology of determining surface and subsurface features of the proposed area. Information on surface conditions is necessary for planning the accessibility of site, for deciding the disposal of removed material (particularly in urban areas), for removal of surface water in water logged areas, for movement of construction equipment, and other factors that could affect construction procedures. Information on subsurface conditions is more critical requirement in planning and designing the foundations of structures, dewatering systems, shoringor bracing of excavations, the materials of construction and site improvement methods.

The subsurface investigation work includes execution of five borings extending to the depth of 78.72ft or 24m, performance of the various types of field and laboratory tests, evaluation of the bearing capacity and finally recommendation for the safe and the appropriate type of foundation suited to the subsoil conditions. The information, so far have been obtained from carrying out the above subsurface investigation program, are provided in detail, in the following articles.

3.1.1 Soil Sampling

- **Need for sampling**

Sampling is carried out in order that soil and rock description, and laboratory testing can be carried out.

Laboratory tests typically consist of:

- Index tests (for example: specific gravity, water content)
- Classification tests (for example: Atterberg's limit test on clays) and
- Tests to determine geotechnical properties.

- **Factors to be considered while sampling soil**
  - Samples should be representative of the ground from which they are taken.
  - They should be large enough to contain representative particle sizes, fabric, and fissuring and fracturing.
  - They should be taken in such a way that they have not lost fractions of the in situ soil (for example: coarse or fine particles) and where strength and compressibility tests are planned, they should be subject to as little disturbance as possible.

3.1.2 Type of soil samples

- **Non-Representative samples**

Non-Representative soil samples are those in which neither the in-situ soil structure and moisture content nor the soil particles are preserved.

- They are not representative.

- They cannot be used for any tests as the soil particles either gets mixed up or some particles may be lost.

❖ **Representative samples**

1. Disturbed soil samples

Soil sample in the disturbed state have been extracted from the each 0.9m & 1.52m depth of each boring using split spoon sampler. These soil samples after extraction, have duly been classified in situ,in order to reconstruct a depth wise stratification chart of the each bore hole.

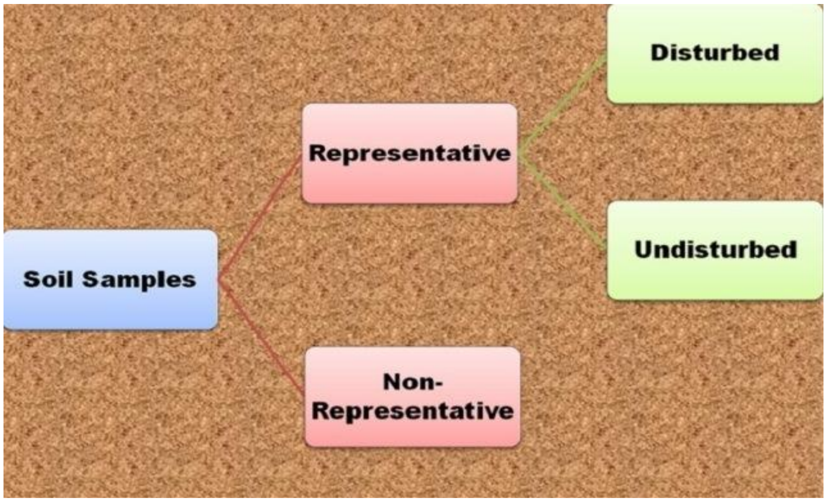


Figure-3.1: Types of soil samples

2. Undisturbed soil samples

As both of the physical and the engineering properties of the are greatly affected by the disturbance of the soil sample, soil sample in the undisturbed state are generally preferred in collection in order to perform certain laboratory tests which eventually help to evaluate the bearing capacities as well as Geotechnical observation. Undisturbed soils are collected from cohesive strata.

3.1.3 Causes of soil disturbances

- Friction between the soil and the sampling tube.
- The wall thickness of the sampling tube.
- The sharpness of the cutting edge.
- Care and handling during transportation of the sample tube to minimize friction.

- The sampling tube should be pushed instead of driven into the ground.
- Sampling tube that are in common use have been designed to minimize sampling disturbance.

3.1.4 Field Exploration

- **Field exploration includes:**

- Boring
- Sampling
- In-situ testing of soil and
- Stratification of the area

These are briefly described as below:

- **Exploratory borings**

Boring is carried out in the relatively soft and un-cemented ground (engineering soil) which is normally found close to ground surface. The techniques used vary widely across the world.

- **Location, spacing and depth of borings**

It depends on:

- Type of structure.
- Size of the structure.
- Weight coming from the structure.

- **General guidelines for location and depth of bore holes are generally located at**
- The building corners.
- The center of the site.
- Where heavily loaded columns or machinery pads are proposed.
- At least one boring should be taken to a deeper stratum, probably up to the bedrock if practicable.
- Other borings may be taken at least to significant stress level

❖ **Spacing of Bore Holes**

According to IS 1892 (1979) Code of practice for subsurface investigation:

- For a small building one bore hole or test pit at the center can give necessary data.
- For a small building one bore hole or test pit at the center can give necessary data corner and one at center is adequate.
- For a large project, the number will depend on its geological features and variation of strata. Generally a grid of 50m spacing should be used with a combination of bore holes and sounding tests.

Table-3.1: Gives the general guidelines for the spacing of boreholes.

Type of project	Spacing (m)	Spacing (ft)
Multi-storey building	10-30	30-100
Industrial plant	20-60	60-200
Highway	250-500	800-1600
Residential subdivision	250-500	800-1600
Dams and dikes	40-80	130-260

3.1.5 Depth of Investigation

The depth of investigation depends on:

- The size and type of proposed structure
- Sequence of proposed strata

The depths of boreholes should cover the zone of soil that will be affected by the structural loads. There is no fixed rule to follow. In most cases, the depths of boreholes are governed by experience based on the geological characteristics of the ground, the importance of the structure, the structural loads and the availability of equipment.

3.1.6 Guidelines for depth of investigation

1) At least one boring should be taken to deeper stratum.
2) Borings should penetrate at least 3 m into rock.
3) Other borings may be taken at least to significant stress level.
4) In compressible soils such as clays, the borings should penetrate at least between 1 and 3 times the width of the proposed foundation until the stress increment due to the heaviest foundation load is less than 10%, whichever is greater.
5) In very stiff clays, borings should penetrate 5-7 m to prove that the thickness of the stratum is adequate.
6) Borings must penetrate below any fills or very soft deposits below the proposed structure. The minimum depth of boreholes should be 6 m unless bedrock or very dense material is encountered.

3.1.7 Significant depth

The investigation shall be carried out to the point at which the vertical stress due to proposed structure is equal to or less than 10% of original effective stress at the point before the structure is constructed is called significant depth.

3.2 Boring For Exploration:

When the depth of exploration is large, boring are used for exploration. A vertical bore hole is drilled in the ground to get the information about the sub-soil strata. Samples are taken from the bore hole and tasted in a laboratory. Extensometers or pressure meter may also be installed in the bore hole for the measurement of deformation in the sub-strata. Depending upon the type of soil and the purpose of boring, the following methods are used for drilling the hole:

- **Auger boring:** preferred for shallow depths, low ground water table.
- **Wash boring:** high water table, deeper soil deposit.
- **Core boring.**
- **Rotary drilling:** high quality boring, also for rock drilling.
- **Percussion drilling:** fast drilling, not taking samples, gravel.

3.2.1 Auger Boring

An auger is a boring tool similar to one used by a carpenter for holes in wood. It consists of a shank with a cross-wise handle for turning and having center tapered feed screw. The augers can be operated manually or mechanically. Auger borings is generally used in soils which can stay open without casing or drilling mud. Clays, silts and partially saturated sands can stand unsupported. Auger boring is particularly useful for subsurface investigations of highways, rail ways and air fields, where the depth of exploration is small. The investigations are done quite rapidly and economically by auger boring. The main disadvantage of the auger boring is that the soil samples are highly disturbed.

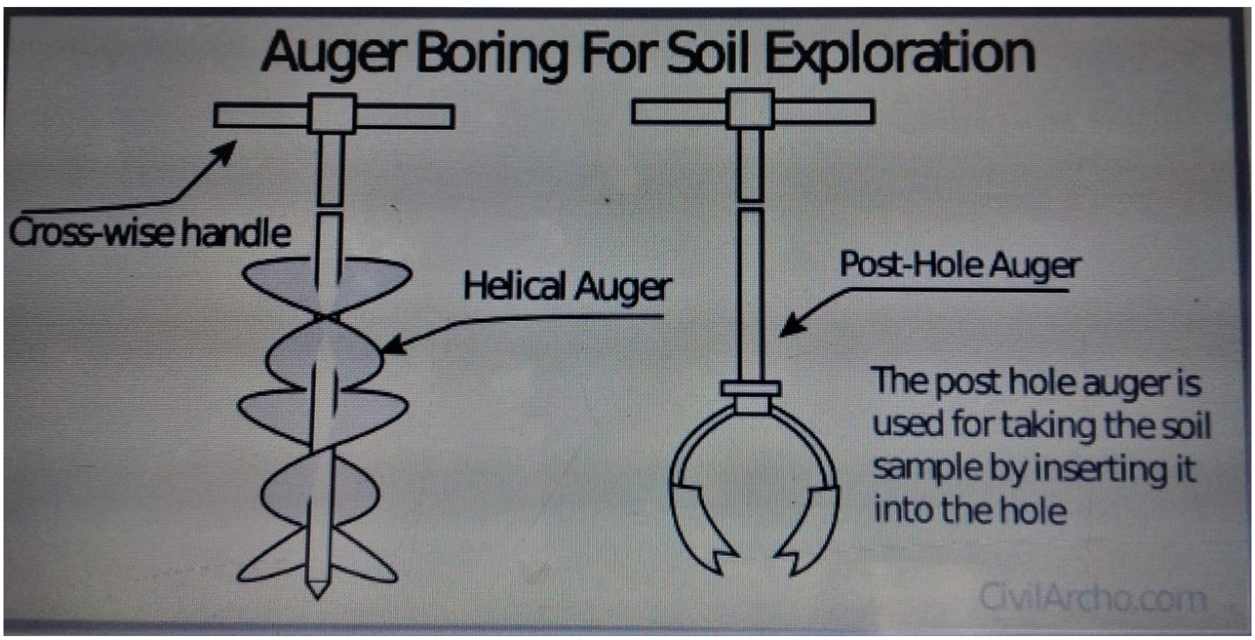


Figure-3.2: Auger system

3.2.2 Wash Boring

In wash boring, the bore hole drilled by first driving a casing, about 2 to 3m long and then inserting into it a hollow drill rod with a chisel-shaped chopping bit at its lower end. Water is pumped down the hollow drill rod which is known as wash pipe. The bore hole is advanced by a combination of chopping action and the jetting action as the drilling bit and the accompanying water jet disintegrate the soil. The hole is further advanced by alternatively rising and dropping the chopping bit by a winch. The wash samples collected in the tube do not represent the soil in true condition. There is complete breakdown of particles by chopping action. There is also mixing of the particles and the loss of fine particles in transportation. The wash boring is mainly used for advancing a hole in the ground. Once the hole has beendrilled, a sampler is inserted to obtain soil samples for testing in a laboratory. The equipment used in wash borings is relatively light and inexpensive. The main disadvantages of the methods are that it is slow in stiff soils and coarse grained soils.

Picture 1: Wash boring

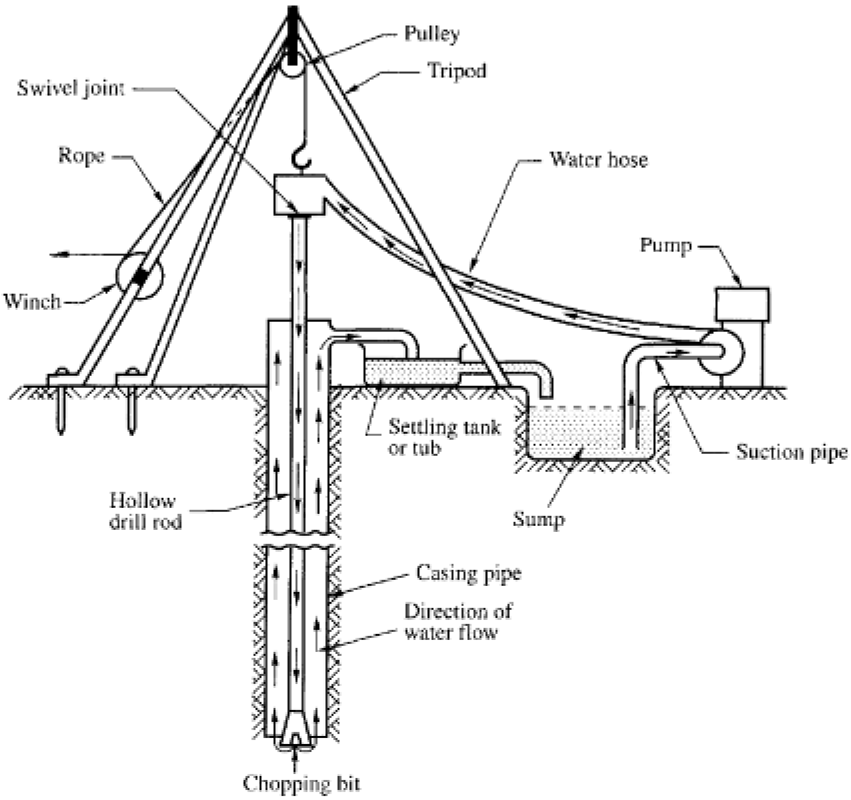


Figure-3.3: Wash boring installation

3.2.3 SPT Hammer System

Barkom is manufacturing Automatic SPT Hammer and Hydraulic SPT Hammer by using high quality raw material for Standard Penetration Test (SPT). Usage of Automatic SPT Hammer SPT Drive Rods and a Split Tube Sampler are connected to base of the anvil of Automatic SPT Hammer and driven into the ground by the falling weight of 63.5kg complete mechanism by automatically. The overall length of the hammer is 2.6m extended and 1.8m when no extended. In an energy calibration study by kovacs the mean energy ratio delivered by a safety hammer was found about 60% whereas the mean energy ratio for a donut hammers was about 45%. The common practice in performing the SPT is to raise the hammer 30% by means of a rope wrapped around a rotating pulley and then throw the rope smartly to dissociate it from the pulley in this way letting fall onto the anvil fastened to the top of the drill stem.

Motor Requirement for Hydraulic SPT Hammer:

Maximum Flow Rate: 60 l/min = 15.85 g/pm

Maximum Pressure: 140 bar = 2030.5 psi

Motor can work with open spool control valve also.

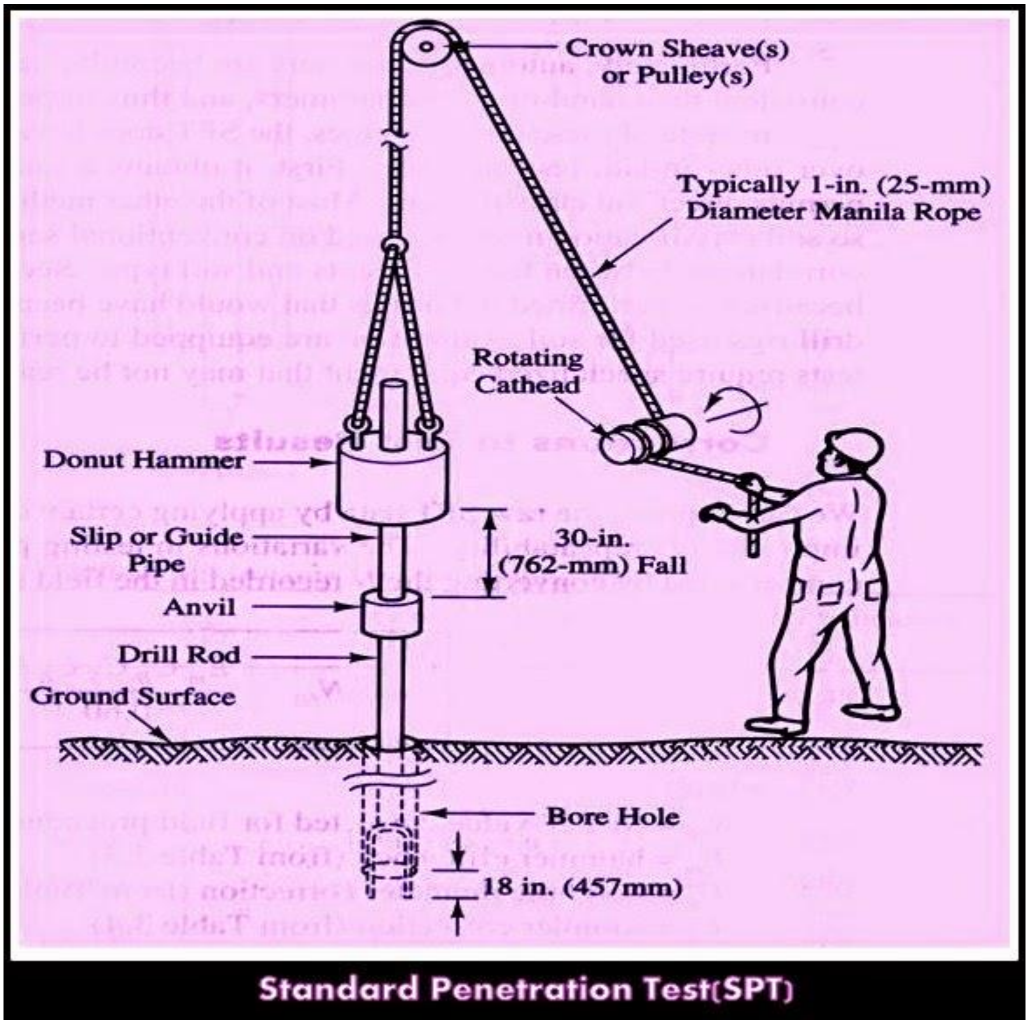


Figure-3.4: SPT

3.2.4 Rotary Drilling

In the rotary drilling methods, the bore hole is advanced by rotating a hollow drill rod which has a cutting bit at in its lower end. A drill head is provided at the top of the drill rod. It consists of a rotary mechanism and an arrangement for applying downward pressure. Rotary drilling can be used in clay, sand and rock. Bore holes of diameter 50 to 200 mm can be easily made by this method. The method is not well adapted for use in materials containing a large percentage of particles of gravel size and large. The particles of this size start rotating beneath the drill rod and it becomes difficult to advance the hole.

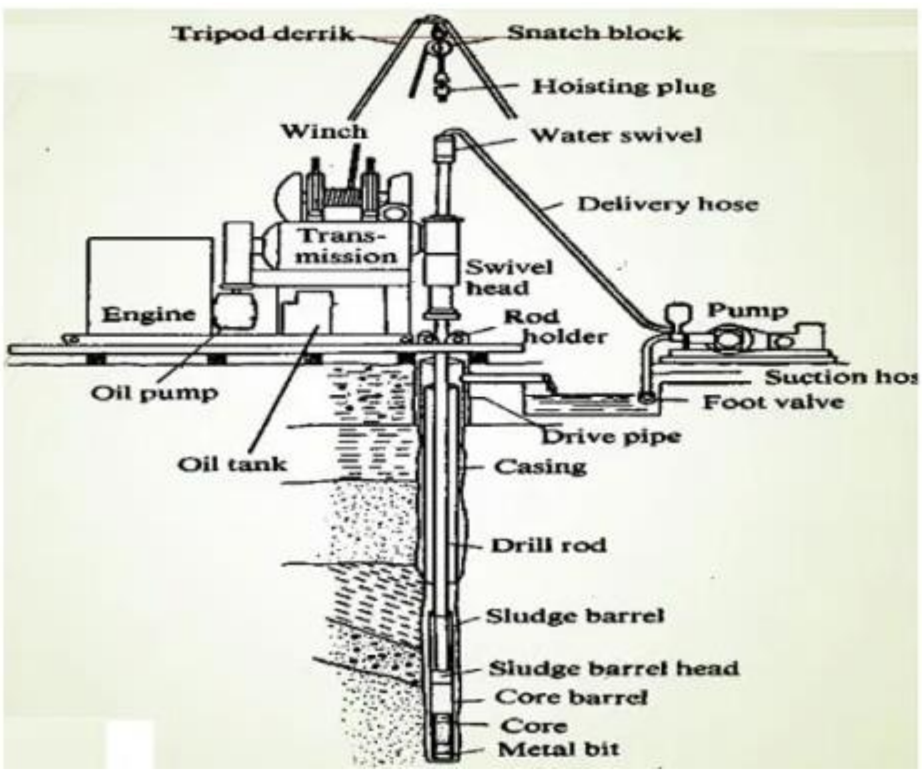


Figure 3.6: Rotary Drilling

3.2.5 Percussion Drilling

The percussion drilling method is used for making holes in rocks, boulders and hard strata. In this method, a heavy chisel is alternatively lifted and dropped in a vertical hole. The material gets pulverized. If the point where the chisel strikes is above the water table, water is added to the hole. Percussion drilling may require a casing. Percussion drilling is also used for drilling of tube wells. The main advantages of this method are that it can be used for all types of materials. It is particularly useful for drilling holes in glacial tills containing boulders. One of the major disadvantages is that the material at the bottom of the hole is disturbed by heavy blows of the chisel.

3.2.6 Core Drilling

The core drilling method is used for drilling holes and for obtaining rock cores. In this method, a core barrel fitted with a drilling bit is fixed to a hollow drilling rod. As the drilling rod is rotated, the bit advances and cuts an annular hole around an intact core. The core is then removed from its bottom and retained by a core lifter and brought to the ground surface. Water is continuously into the drilling rod to keep the drilling bit cool and to carry the disintegrated materials to the ground surface.

3.2.7 Design Features affecting the sample disturbance

- Area ratio
- Inside clearance
- Outside clearance
- Recovery ratio
- Inside wall friction
- Design of non return valve
- Method of applying force

1. Area ratio

$$\text{Area ratio} = \frac{\text{Max Cross-sectional area of the cutting edge}}{\text{Area of soilsample}} x100$$

$$A_r = \frac{D_2{}^2 - D_1{}^2}{D1} x100$$

Where, D1 = inner diameter of the cutting edge

D2 = outer diameter of the cutting edge

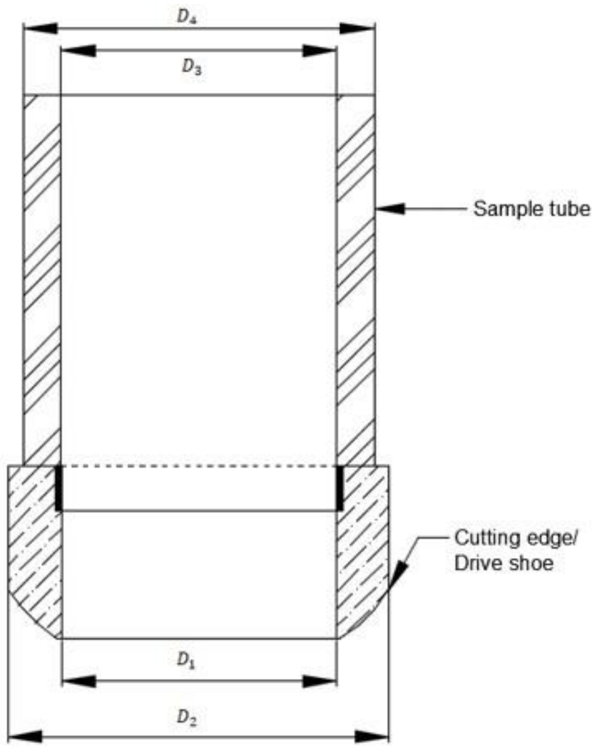


Figure-3.6: Typical Sampling Tube

- ❖ For obtaining good quality undisturbed samples, the area ratio should be less than or equal to 10%.

- It may be high as 110% for thick wall sampler like split spoon sampler and may be as low as 6 to 9% for thin wall samples like Shelby tube.

2. Inside Clearance

$$C_i = \frac{D_3 - D_1}{D_1} x100$$

Where, D3 = inner diameter of the sample tube

- The inside clearance allows elastic expansion of the sample when it enters the sampling tube.
- It helps in reducing the frictional drag on the sample and also helps to retain the core.
- For an undisturbed sample, the inside clearance should be between 0.5 and 3%.

3. Outside Clearance

$$Co = x100 \frac{D_2 - D_4}{D_4}$$

Where, D4 = outer diameter of the sample tube.

- Outside clearance facilitates the withdrawal of the sample from the ground.
- For reducing the driving force, the outside clearance should be as small as possible.
- Normally, it lies between 0 and 2%.
- Co Should not be more than Ci.

4. Recovery Ratio

Rr = L/H

Where,

L = length of the sample within the tube .

H = Depth of penetration of the sampling tube.

Rr = 96~98 % for getting a satisfactory undisturbed sample.

5. Inside wall friction

- The friction on the inside wall of the sampling tube causes disturbances of the sample.
- Therefore the inside surface of the sampler should be as smooth as possible.
- It is usually smeared with soil before use to reduce friction.

6. Design of non-return value

- The non-return value provided on the sampler should be of proper design.
- It should have an orifice of large area to allow air, water or slurry to escape quickly when the sampler is driven.
- It should close when the sample is withdrawn.

7. Method of applying force

- The degree of disturbance depends upon the method of applying force during sampling and depends upon the rate of penetration of the sample.
- For obtaining undisturbed samples, the sampler should be pushed and not driven.

8. Sample recovery

Poor sample recovery may be the most serious results of sample disturbance and may be dependent on a number of factors which include:

- Suction below the sample tube results as the tube is pulled from the soil deposit.
- The tensile strength of the soil sample must be overcome to separate the soil sample from the soil deposited.

3.2.8 Types of Soil Samplers

1. Split-Spoon Sampler

The most commonly used sampler for obtaining a disturbed sample of the soil is the standard split-spoon sampler. It consists mainly of three parts:

i) Driving shoe: Made of tool-steel, about 75mm long.

ii) Steel tube: About 450mm long, split longitudinally in two halves.

iii) Coupling : At the top of the tube about 150mm long.

Has an inside diameter of 38mm and an outside diameter of 50mm. Has a split barrel which is held together and a cap at the upper end. The thicker wall of the standard sampler permits higher driving stresses than the Shelby tube but does so at the expense of higher levels of soil disturbances. Split spoon samples are highly disturbed. They are used for visual examination and for classification tests.

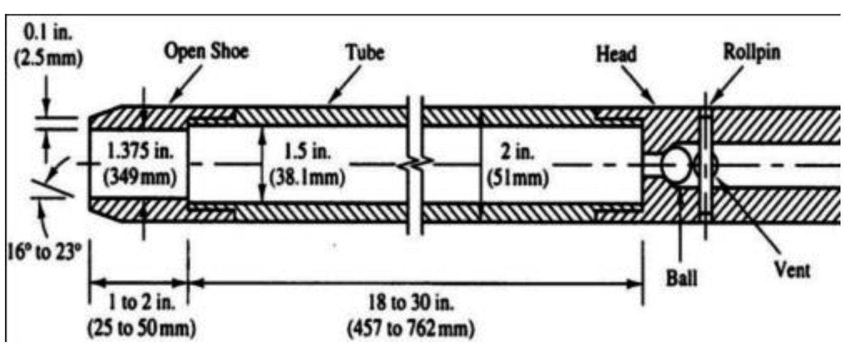


Figure-3.7: Standard Split Spoon Sampler

2. Scraper Bucket Sampler

If a sandy deposit contains, it is not possible to obtain samples by standard split-spoon sampler or split-spoon sampler fitted with a spring core catcher. The pebbles come in between the springs and prevent their closure scraper bucket sampler can also be used for obtaining the samples of cohesion less soils bellow the water table.

3. Shelby Tubes Sampler

Shelby tubes are thin wall tube samples made of seamless steel. The outside diameter of the tube may be between 40 to 125mm. The commonly used samplers have the outside diameter of either 50.8mm or 76.2mm. The bottom of the tube is sharpened and beveled which acts as a cutting edge. Shelby tubes are used for obtaining undisturbed samples of clay. The tubes can be attached to drilling rods. The drilling rod with the sampler attached is lowered to the bottom of the borehole and the sampler is pushed into the soil. The soil sample inside the tube is then pulled out. The two ends of the sampler are sealed and sent to the lab. The samples can be used for consolidation or shear test.

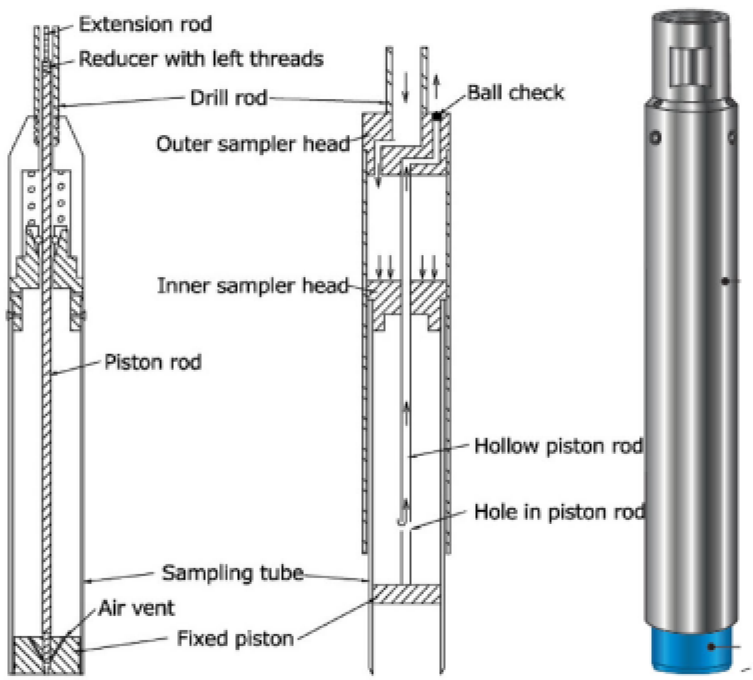


Figure-3.8: Thin Walled & Shelby Tube

4. Piston Sampler

A piston sampler consists of a thin-walled tube with a piston inside. The piston keeps the lower end of the sampling tube closed when the sampler is lowered to the hole. After the sampler has been lowered to the desired depth the piston is prevented from moving downward by a suitable arrangement which differs in different types of piston samplers. The piston samplers are used for getting undisturbed soil samples from soft and sensitive clays.

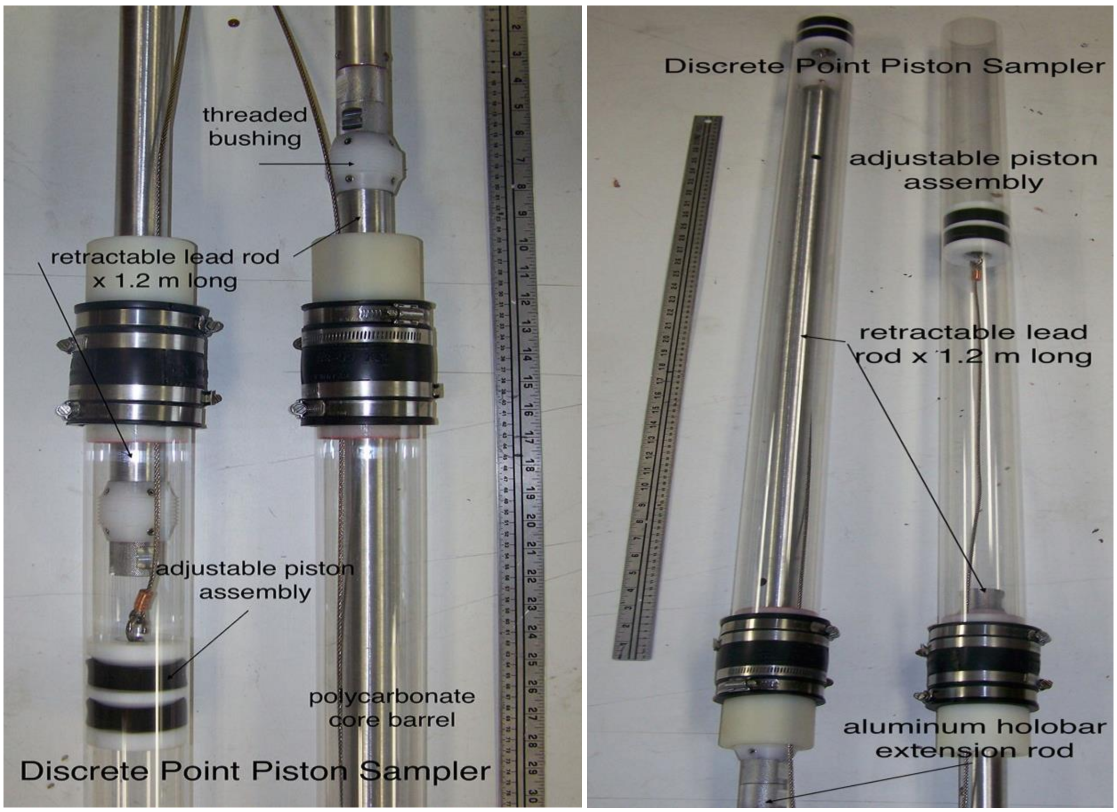


Figure-3.9: Piston sampler

4. Denison Sample

The Denison sampler is a double-walled sampler. The outer barrel rotates and cuts into the soil. The samples are obtained in the inner barrel. The inner barrel is provided with a baskettype core retainer. The sampler is lowered to the bottom of the drilled hole. A downward force is applied on the top of the sampler. A fluid under pressure is introduced through the inner barrel to cool the coring bit when the outer barrel rotates. The fluid returns through the annular space the two barrels. The rotation of the outer barrels is continued till the required length of the sample is obtained. The Denison sampler is mainly used for obtaining samples of stiff to hard cohesive soils and slightly cohesive sands. However, it can’t be used for gravelly soils, loose cohesion less sands and silts below ground water table and very soft cohesive soils.

Figure-3.10: Denison sampler

3.2.9 In-Situ Testing of Soil:

There is a wide variety of different tests that can be used for evaluating the properties of the ground. It is often preferable to do an in situ test in an attempt to measure a particular parameter rather than obtain a sample and do a laboratory test. Sampling results in disturbance (reduces strength and stiffness) or sometimes only best (strongest) material is recovered and is not representative of overall in situ material.

- **Parameters obtained from in-situ testing**

Typical parameters that may be obtained either directly or indirectly from in situ tests:

1. Strength
2. Stiffness
3. Permeability
4. Relative density

3.2.10 Standard Penetration Test:

Standard penetration tests were executed at each 1.5 interval in all the bore holes with the simultaneous collection of the disturbed soil samples. The tests were executed by using a split spoon sampler of 50mm outer dia. and 37.5mm inner dia. Attached to lower end of the drilling rod. 63.5 kg automatic hammer was allowed to fall freely from a height of 760mm. The blows of the automatic hammer drove the spoon into the soil up to 450mm. The nos. of blows required for each 150mm. of penetration of the spoon was recorded. The number of blows required for last 300mm. of penetration of the spoon was entered into the bore chart as being the standard penetration test result.

3.2.11 SPT Value Correction:

- **Dilatancy Correction:**

Silty fine sands and fine sands bellow the water table develop pore pressure which is not easily dissipated.

Terzaghi and peak (1967) recommended the flowing correction in the case of silty fine sands when the observed value of N exceeds 15.

corrected penetration number, $N_c = 15 + 1/2(N_r - 15)$

Where, N_r is the recorded value and

N_c is the corrected value.

If, $N_r \le 15$, then = $N_c = N_r$

❖ Overburden Pressure Correction:

In granular soils. The overburden pressure affects the penetration resistance. If the two soils having same relative density but different confining pressure are tested, the one with higher confining pressure gives a higher penetration number. As the confining pressure in cohesion less soils increase with the depth, the penetration number for soils at shallow depths is underestimated and that greater depth is overestimated.

Gibbs and Holtz recommended the use of the following equation: $Nc = Nf * 350/\sigma o + 70$

Where,

Nf= recorded N value

N c = corrected N value

σo = effective ov̄erburden pressure (kn/m²)

Peack, Hansen And Thornburg give the chart for correction of N values to an effective overburden pressure of 96 KN/M², N = 0.07 $\times$ Nr $\times$ log $(1905/\bar{\sigma})$

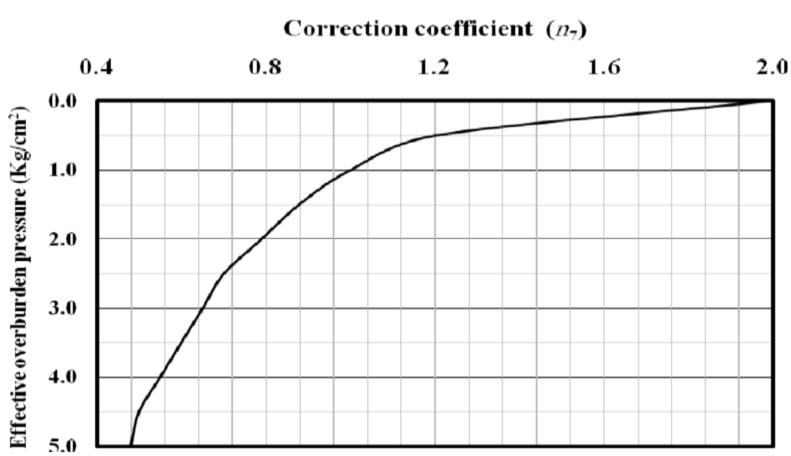


Figure-3.11: Over burden pressure correction

❖ Correlation of "N" with Engineering Properties

The value of the standard penetration number N depends upon the relative density of the cohesion less soil and the unconfined compressive strength of the cohesive soil. If the soil is compact or stiff, the penetration number is high. The angle of shearing resistance (Φ) of the cohesion less soil depends upon the number of N in general, the greater the N value, the greater is the angle of shearing resistance.

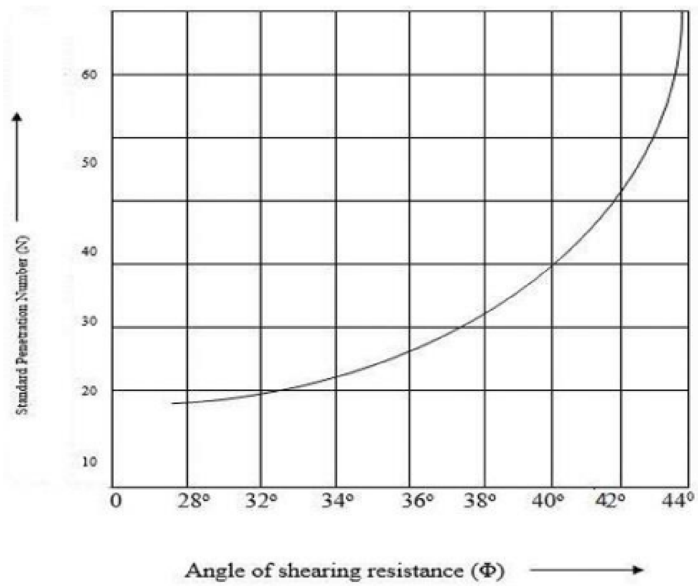


Figure-3.12: Correlation of SPT value

Table-3.2: Correlation between N and Φ

SPT (N)	Denseness	(Φ)
0-4	Very loose	25°-32°
4-10	Loose	27°-35°
10-30	Medium	30°-40°
30-50	Dense	35°-45°
>50	Very dense	>45°

Table-3.3: Correlation between N and qu

SPT (N)	Consistency	qu (KN/M²)
0-2	Very soft	< 25
2-4	Soft	25-50
4-8	Medium	50-100
8-15	Stiff	100-200
15-30	Very stiff	200-400
>30	Hard	>400

3.3 Field Exploration Work :

Field exploration program was conducted during the period of Aug. of 2020. The program was carried out by team from "Strain Field Geotechnics Ltd." who were responsible for measuring standard Penetration Test (SPT) value and obtaining disturbed and undisturbed samples of the subsurface soils. A total of Six (6) exploratory boreholes (wash boring) with maximum depth up to 79'-9" (24.00m) below the existing ground surface were made. Standard Penetration Tests, collection of disturbed and undisturbed samples and recording of ground water table (GWT) were done.

- **Purpose of the work**

The purpose of this investigation the result of the sub-surface exploration for the proposed construction of the six storied residential building was to characterize the pertinent geotechnical aspects of soil for the site. This investigation would provide geotechnical information on different soil properties for the proposed project. The project and thesis work would consist of an adequate program of sub-surface exploration, in-situ testing, soil sampling, laboratory testing, engineering analysis and evaluation.

❖ **Objectives**

- Explore the suitable foundation of proposed project.
- To select suitable construction techniques whenever necessary.
- To ascertain the type of substrata and their characteristics.
- To evaluate the bearing capacity for foundations of the structures.

For fulfilling the objectives the relevant information was obtained by determining the index and engineering properties of soil.

❖ **Scope of the work**

To explore the sub-surface conditions of the proposed construction of the g+08 (g+ eight) storied residential building at at. Mouza-Kazirgaon, dag no S.A- 397, R.S-41, West Muslimbag, Kardighirpar, Kalindi, Keraniganj, Dhaka, Bangladesh.

1. To carry out field Standard Penetration Test (SPT) 63.5kg weighted hammer having a free fall of 750mm to determine the natural bearing capacity resistance of the subsoil for the purpose of design.

2. The number of the blows necessary to produce the penetration was recorded in three different stages, each at 15cm of interval. The number of the blows required in the 2nd and 3rd 15cm of the penetration of the sample is called the SPT value and is represented by 'N" values are shown in the bore-log chart against the respective interval of the depth.

3. To obtain disturbed & undisturbed soil samples for carrying out the laboratory tests to determine the natural and relevant physical properties of the subsoil pertaining to the project for the purpose of design.

The Ground Water Table at Bore Holes were measured after 24 hours from completion of Boring Works. The Depth of Water has been found at Project Area was (-) 2.5m each bore hole from the EGL.

3.4 Method of Site Investigation:

The borehole in the size of 89mm in diameter was advanced by boring machine for clayey / sandy layer. A wash boring is advanced by jetting water which is pumped through the hollow drilling rods. Cuttings were removed from the hole by the circulating water. The drilling rods are moved up and down by pulling and slackening the rope and are at the same time rotated back and forth by means of a driller. The water is pumped from a small swamp and the soilladen water from the borehole is discharged in to the same reservoir, where the course materials settled out and from which the so-called ‘wet samples’ can be secured. Casing in the size of NX 89mm is required in the soft or cohesion less soils but is often omitted in stiff, cohesive soils which only small representative samples as desired. Changes in the character of the soils are determined partly by the feel of the spoils in the water as it emerges from thecasting. But definite identification of the soil can only be made when representative samples are taken from the bottom of the boreholes.

3.5 Field Standard Penetration Test (SPT):

Standard penetration test (SPT) utilizes a 50mm (2”) outer diameter and 38mm (1-3/8”) inner diameter and 600mm (2’) long, 7.5mm thick-walled spit spoon sampler tube driven into undisturbed soil under the impact of a sliding hammer weighting 63.5kg (140lb) having a free fall of 760mm (2.5’) has been executed at regular intervals of 5ft through required depth of borings. The penetration resistance of ‘N’ value is recorded as the number of hammer blows required to achieve a penetration of 300mm (12”) after the initial penetration of 150mm (6”) (To allow for any disturbed materials at the bottom of the borehole). After the completion of the test, the sampler tube is removed and disassembled to provide a ‘disturbed’ but representative’s sample.

Picture 2: Standard Penetration Test (Wash Boring Method)

- **Disturbed Soil Samples**

The disturbed soil samples are generally collected during of Standard Penetration Test. The samples were collected and duly preserved in polythene bags. However, these samples represent the composition and the mineral content of the soil. Properly labeled and shifted to the laboratory for testing. These samples truly represent the composition and the mineral content of the soil. Disturbed samples can be used to determine the index properties of the soil such as grain size, plasticity characteristics, specific gravity etc. The disturbed samples were collected with the help of split spoon sampler used during Standard Penetration Test at every 5 feet (1.5m). Each sample was removed from the sampler in field and examined carefully. All the samples were dully preserved in polythene bags, properly marked and then shifted to the laboratory for testing.

Disturbed samples can be used to determine the index properties of the soil such as grain size, plasticity characteristic and specific gravity.

Picture 3: Soil sample collection from split spoon sampler

- **Undisturbed Soil Sample**

numbers of undisturbed soil samples were collected by means of thin wall sharp ended 3" (75mm) diameters. Shelby tubes from the cohesive soil formation. The collected tubes were than labeled with detailed job designation, date and shifted to the laboratory for testing. Without disturbing the natural conditions of a soil sample such as its structure, texture, density, natural water contents or the stress condition the sample obtained is called undisturbed soil sample. Undisturbed soil samples in which the natural structure of the soil and the water content are retained. Some disturbance is investable during sampling, even when the utmost care is taken. Even the removal of the sample from the ground produces a change in the stresses and causes disturbance. Undisturbed samples are used for determining shear strength, Unit weight, Void ratio, Compression index (Cc), Unconfined Compressive Strength, Angle of internal friction (Φ) etc. However, it may be mentioned that it is impossible to get truly undisturbed samples. The undisturbed samples of cohesive in to the undisturbed soil formation by applying rapid but continuous force. The samplers recovered in the Shelby tubes were properly marked and wax sealed at both ends and then transmitted to the laboratory.

3.6 Ground Water Table Measurement :

The water in each borehole was taken while drilling was in progress at the following times:

- Before work commence in the morning,
- Before the mid day break,
- After the mid day break,
- After work has finished in the evening but before water is added to the borehole to stabilize it. The levels at the bottom of the boreholes and at the bottom of the casing (if any) were measured and recorded at the same time as each water table reading. Final water levels are included in the bore loges.

3.7 Laboratory Testing of Soil:

3.7.1 Introduction

Soil inspection or say geotechnical inspection is very important in understanding the physical properties of soil and the rocks beneath. This is required to ascertain the type of foundation required for the proposed construction. Various tests are done to explore the sub surface and surface characteristics of soil.

3.7.2 Grain Size Analysis : (Sieve Analysis and Hydrometer Test)

Sieve Analysis :

Purpose:

Sieve Analysis is generally performed on silts, sands, and gravels (>200 mesh grain size analysis testing). This test is performed to determine the percentage of different grain sizes contained within a soil. The grain size analysis is an attempt to determine the relative proportions of the different grain sizes that make up a given soil mass (Obviously statistically representative of the soil mass). The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

4. **Standard Reference:**

ASTM D 422 -63 Standard Test Method for Particle-Size Analysis of Soils.

5. **Significance:**

The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution and it is required in classifying the soil.

6. **Apparatus:**

1. ASTMsieves #4, #8, #30, #50, #100, #200
2. Balance
3. Pan
4. Cleaning brush
5. Sieve shaker
6. Mixer (blender)
7. 152H Hydrometer
8. Sedimentation cylinder
9. Control cylinder
10. Thermometer

- **Test Procedure : (**Sieve Analysis**)**

Picture 4: Grain Size Analysis by Sieve Analysis

i) Write down the weight of each sieve as well as the bottom pan to b used in the analysis.

ii) Record the weight of the given dry soil sample.

iii) Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (#4 sieve at top and #200 sieve at bottom). Place the pan below #200 sieve. Carefully pour the soil sample into the top sieve and place the cap over it.

iv) Place the sieve stack in the mechanical shaker and shake for 10 minutes.

v) Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

Data Analysis (Sieve Analysis):

i) Obtain the mass of soil retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of the soil sample. A loss of more than two percent is unsatisfactory.

ii) Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

iii) Calculate the percent passing (or percent finer) by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure.

iv) Make a semi logarithmic plot of grain size vs percent finer.

v) Compute Uniformity coefficient, C_u and Coefficient of gradation, $C_z$for the soil.

$$C_u = \frac{D60}{D10} \text{and } Cz = D^2_{30} / D_{60} * D_{10}$$

➢ **Test Procedure : (**Hydrometer Analysis**)**

i) Take the fine soil from the bottom pan of the sieve set, place it into a beaker, and add 125 mL of the dispersing agent (sodium hexa meta phosphate (40g/L)) solution. Stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.

ii) While the soil is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading. between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.

iii) Transfer the soil slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.

iv) Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark.

v) Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute.

vi) Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading. (Note: It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing).

vii) The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the control cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.

viii) Take hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24 hours.

Picture 5: Hydrometer Analysis

Data Analysis (Hydrometer Analysis):

i. Apply meniscus correction to the actual hydrometer reading.

ii. Obtain the effective hydrometer depth L in cm.

iii. For known G s of the soil (if not known, assume 2.65 for this lab purpose), obtain the value of K.

iv. Calculate the equivalent particle diameter by using the following formula: D = K$\sqrt{L}/t$

Where, t is in minutes and D is given in mm.

v. Determine the temperature correction.

vi. Determine correction factor "a" and using G s.

vii. Calculate percent finer as follows: $P = \frac{Rc*a}{ws} * 100$

viii. Adjusted percent fines as follows: $Pa = \frac{P*F200}{100}$

Where, F200 = % finer of #200 sieve as a percent

ix. Plot the grain size curve D versus the adjusted percent finer on the semi logarithmic Graph.

Table-3.4: Value Of K For use in equation computing diameter of particle in hydrometer analysis.

Temperature °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.0394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01269	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

From Grain Size Distribution Curve:

% Gravel= 9.5 D10 = 0.002 mm

% Sand= 46.4D 30 = 0.017 mm

% Fines= 44.1 D 60 = 0.25 mm

Cu = (D 60 / D 10) = 0.25/0.002 =125

Cc = (D 30)^2/ (D 60 * D10) = (0.017)^2/ (0.25*0.002) = 0.58

3.7.3 Specific Gravity Determination:

- **Scope of the test:**

This test is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of unit weight of soil at a stated temperature to the unit weight of same volume of gas-free distilled water at a stated temperature.

- **Standard reference:**

ASTM D 854-00 Standard Test for Specific Gravity of Soil Solids by Water Pycnometer.

- **Equipment**

  i. Pycnometer (volumetric bottle)
  ii. Balance (0.01g sensitivity) , Distilled water, Drying oven, Desiccator,
  iii. Vacuum source (optional)
  iv. Funnel, Thermometer, Pipette or medicine dropper, Spoon etc.

- **Significance**

  i. Specific gravity of a soil is used in the phase relationship.
  ii. Soil density calculation.

- **Test Procedure:**

i. Clean and dry the density bottle
   a. wash the bottle with water and allow it to drain.
   b. Wash it with alcohol and drain it to remove water.
   c. Wash it with ether, to remove alcohol and drain ether.
ii. Weigh the empty bottle with stopper (W1)
iii. Take about 10 to 20 gm of oven soil sample which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the bottle and soil (W2).
iv. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
v. Again fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature water baths (Tx 0).

vi. Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W3).

vii. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W4 at temperature (Tx 0 C).

viii. Repeat the same process for 2 to 3 times, to take the average reading of it.

➢ **Data Analysis:**

The specific gravity of the soil solids was calculated by using the following formula:

$$\textbf{Specific Gravity of soil} = \frac{\boldsymbol{Density\ of\ water\ at\ 27\ c}}{\boldsymbol{Weight\ of\ water\ of\ equal\ volume}}$$

$$= \frac{(\boldsymbol{W2-W1})}{(\boldsymbol{W4-W1})-(\boldsymbol{W3-W2})}$$

$$= \frac{(\boldsymbol{W2-W1})}{(\boldsymbol{W2-W1})-(\boldsymbol{W3-W4})}$$

Picture 6:Specific gravity test

3.7.4 Atterberg's Limit Test:

- **Purpose:**

The Atterberg's limits are a basic measure of the nature of a fine-grained soil. Depending on the content of the soil, it may appear in four states such as solid, semi-solid, plastic and liquid. In each state the consistency and behavior of a soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg's limits can be used to distinguish between different types of silts and clays. These limits were created by Albert Atterberg's, a Swedish chemist. They were later refined by Arthur Casagrade. This lab is performed to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) is laboratory defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13mm (1/2 in.) when subjected to 25 shocks from the cup being dropped 10mm in a standard liquid limit apparatus operated at a rate of two shocks per second.

- **Significance:**

The Atterberg's limits are based on the moisture content of the soil. The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state. Liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced. A wide variety of soil engineering properties have been correlated to the liquid and plastic limits, and these Atterberg's limits are also used to classify a fine-grained soil according to the Unified soil classification system or AASHTO system.

- **Equipment:**

  - Liquid limit device
  - Porcelain (evaporating) dish
  - Flat grooving tool with gage
  - Eight moisture cans
  - Balance

- Glass plate
- Spatula
- Wash bottle filled with distilled water
- Drying oven set at 105°C

➢ **Reference:**

ASTM D 4318 Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. ASTM D 427-04 Standard Test Method for Shrinkage Factors of Soils by the Mercury Method.

➢ **Test Procedure**:(**Liquid Limit**)

1. The soil was mixed thoroughly with a small amount of distilled water unit it appeared as a smooth uniform paste. The dish was covered with cellophane to prevent the moisture.
2. Four of the empty moisture can was weighted with their lids and recorded the respective weights and can numbers on the data sheet.
3. The liquid limit apparatus was adjusted by checking the height of drop of the cup. The point on the cup that was come in contact with the base raised to a height of 10mm. The block on the end of the grooving tool was 10mm height and used as a gauge. The cup was used for practice and the correct rate to rotate the crank was determined, so that the cup approximately dropped two times per second.
4. A portion of the previously mixed soil was placed into the cup of the liquid limit apparatus at the point where the cup rest on the base. The soil was squeezed down to eliminate air pockets and spread it into the cup to a depth of about 10mm at its deepest point. The soil past was formed an approximately horizontal surface.
5. The grooving tool was used carefully to cut a clean straight groove down to the center of the cup. The tool was remained perpendicular to the surface of the cup as groove was being made. Extreme care used to prevent sliding the soil relative to the surface of the cup.
6. The entire soil specimen was remixed in the porcelain dish. A small amount of distilled water was added to increase the water content so that the number of drops decreased to close the groove.
7. The base of the apparatus below the cup and the underside of the cup was cleaned. The crank was turned off the apparatus at the rate of two drops per second and the number of

drops were counted (N), it was taken to made the two halves of the soil pat came into contact at the bottom of the groove along a distance of 13mm (1/2 in.). If the number of drops exceeds 50 then back to step eight and not recorded the number of drops, otherwise, the number of drops recorded on data sheet.

Picture 7: Liquid Limit Test

8. A sample was taken, used the spatula, from edge to edge of the soil pat. The sample included the soil on both sides of where the groove came into contact. The soil was placed into a moisture can and covers it. Immediately, the moisture can contain the soil was weighted, recorded its mass, removed the lid, and the can was placed into the oven. The moisture can was left in the oven for at least 16 hours. The remaining soil was placed in porcelain dish from the cup.
9. Steps six, seven and eight were repeated at least two additional trials for producing successively lower numbers of drops to closed the groove. One of the trials was a closure between 25 to 25 drops, one was a closure between 20 and 30drops and one of the trial was a closure between 15 to 25 drops. The water content was determined from each trial by using the same method used in the first laboratory. The same balance was used for all weighing.

Picture 8: Apparatus of liquid limit determination

- **Test Procedure(Plastic Limit):**

1. Remained 1/4 of the original soil sample was taken and added distilled water until the soil was at a consistency where it was rolled without sticking to the hands.
2. Soil was formed into an ellipsoidal mass. The mass was rolled between the palm or the fingers and the glass plate. Sufficient pressure was used to rolled the mass into a thread of uniform diameter by using about 90 stocks per minute. (A stroke was one complete motion of the hand forward and back to the starting position.) The thread was deformed, so that its diameter reached 3.2mm (1/8in.), not more than two minutes was taken.
3. When the diameter of the thread reached the correct diameter, the thread was broken into several pieces. Knead and reformed the pieces into ellipsoidal masses and re-rolled them. This alternate rolling, gathering together, kneading and rerolling was continued until the thread crumbled under the pressure required for rolling and could not be longer for rolled into a 3.2mm diameter thread.
4. The portion of the crumble thread was gathered and the soil placed into moisture can, then covered it. If the can did not contain at least 6 grams of soil, then soil was added to the can for the next trial.

Picture 9: Plastic limit determination

5. The moisture can containing the soil was immediately weighted, recorded its mass, removed the lid and the can was placed into the oven. The moisture can was left in the oven for at least 16 hours.
6. Steps three, four and five were repeated at least two more times. The water content each trial by using the same method used in the first laboratory was determined. The same balance was used for all weighting.

Analysis:

❖ **Liquid Limit:**

1. Calculate the water content of each of the liquid limit moisture cans after they have been in the oven for at least 16 hours.
2. Plot the number of drops (N) on the log scale versus the water content (w). Draw the best-fit straight line through the plotted points and determine the liquid limit (LL) as the water content at 25 drops.

❖ **Plastic Limit:**

1. Calculate the water content of each of the plastic limit moisture cans after they have been in the oven for at least 16 hours.
2. Compute the average of the water contents to determine the plastic limit, PL. Check to see if the difference between the water contents is greater than the acceptable range of two results.
3. Calculate the plasticity index, PI=LL-PL. Report the liquid limit, plastic limit and plasticity index to the nearest whole number, omitting the percent designation.

3.7.5 Unconfined Compressive Strength Test

➢ **Purpose:**

Unconfined Compressive Strength Purpose of this test is to determine the Unconfined Compressive Strength, which is then used to calculate the unconfined untrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the Unconfined Compressive Strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the Unconfined Compressive Strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial attain, whichever occurs first during the performance of a test.

➢ **Significance:**

For soils, the un-drained shear strength (s u) is necessary for the determination of the bearing capacity of foundations, dams, etc. The un-drained shear strength (s u) of clays is commonly determined from an unconfined compression test. The un-drained shear strength (s u) of a cohesive soil is equal to one-half the unconfined compressive strength (q u) when the soil is under the f = 0 condition (f = the angle of internal friction). The most critical condition for the soil usually occurs immediately after construction, which represents un-drained conditions, when the un-drained shear strength is basically equal to the cohesion (c).

This is expressed as: $Su = C = \frac{qu}{2}$

Then, as time passes, the pore water in the soil slowly dissipates, and the inter granular stress increases so that the drained shear strength (s) is given by, $s = c + \sigma \tan \emptyset$

- **Equipment:**
  - Compression device
  - Load and deformation dial gauges
  - Sample trimming equipment
  - Balance
  - Moisture can

- **Standard Reference:**

ASTM D 2166 - Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.

Picture 10: Unconfined Compressive Strength Test

➢ **Test Procedure:**

1. Extrude the soil sample from Shelby tube sampler. Cut a soil specimen so that the ratio (L/d) is approximately between 2 and 2.5. Where L and d are the length and diameter of soil specimen respectively.
2. Measure the exact diameter of the top of the specimen at three location 120° apart and then make the same measurements on the bottom of the specimen. Average the measurements and record the average as the diameter on the data sheet.
3. Measure the exact length of the specimen at three locations 120° apart and then average the measurements and record the average as the length on the data sheet.

Picture 11: Unconfined Compressive Strength Test

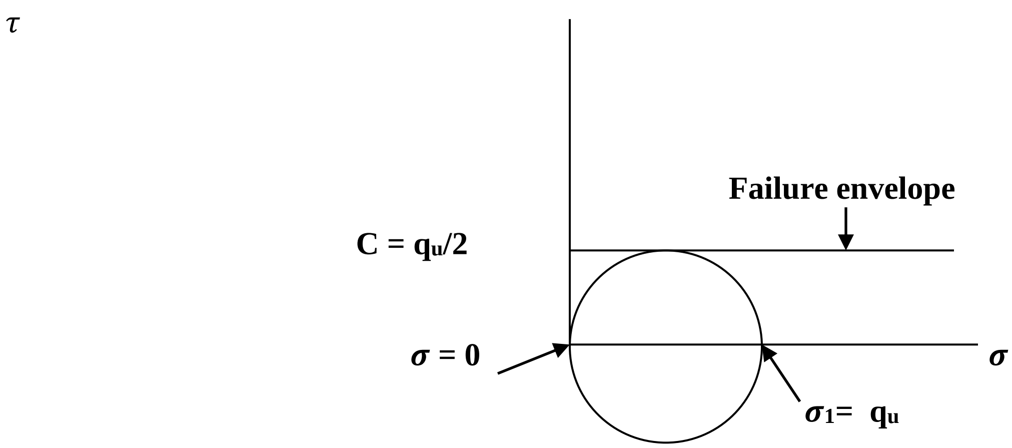
4. Weigh the sample and record the mass on the data sheet.
5. Calculate the deformation (ΔL) corresponding to 15% strain. Strain, (e) =ΔL/L 0

where, L 0 = Original specimen length.

6. Carefully place the specimen in the compression device and center it on the bottom plate. Adjust the device so that the upper plate just makes contact with the specimen and set the load and deformation dials to zero.
7. Apply the load so that the device produces an axial strain at a rate of 0.5 to 2.0% per minute and then record the load and deformation dial readings on the data sheet at every 20 to 50 divisions on deformation the dial.
8. Keep applying the load until (1) the load decreases on the specimen significantly (2) the load holds constant for at least for deformation dial readings or (3) the deformation is significantly past the 15% strain that was determined in step 5.
9. Draw a sketch to depict the sample failure.

- **Analysis:**

1. Convert the dial readings to the appropriate load and length units and enter these values on the data sheet in the deformation and total load columns.
2. Compute the sample cross-sectional area, $A_0 = \frac{\pi}{4} \times (d)^2$
3. Compute the strain, e = $\Delta L/L_0$
4. Computed the corrected area, $A' = A_0/1 - e$
5. Compute the specimen stress, $Sc = P/A'$
6. Compute the water content, W (%).
7. Plot the stress versus strain. Show q *u* as the peak stress (or at 15% strain)of the test. Be sure that the strain is plotted on the abscissa.
8. Draw Mohr's circle using q *u* from the last step and show the un-drained shear strength, s = c (or cohesion) = q *u* /2.



Mohr's circle

3.7.6 Moisture Content Determination

- **Scope Of The Test**

This test is performed to determine the water (moisture) content of soils. The water content is the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of soil to the mass of the dry soil solids.

- **Standard Reference**

ASTM D 2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

- **Equipment**

  - Drying oven
  - Balance
  - Moisture can
  - Gloves
  - Spatula

  - **Significance**

For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

- **Test Procedure**

1. Record the moisture can and lid number. Determine and record the mass of empty, clean, and dry moisture can with its lid (M1).
2. Place the moist soil in the moisture can and secure the lid. Determine and record the mass of the moisture can (now containing the moist soil) with the lid (M2).
3. Remove the lid and place the moisture can (containing the moist soil) in the drying oven that is set at 105 °C. Leave it in the oven overnight.
4. Remove the moisture can. Carefully but securely, replace the lid on the moisture can using gloves, and allow it to cool to room temperature. Determine and record the mass of the moisture can and lid (containing the dry soil) (M3).
5. Empty the moisture can and clean the can and lid.

Picture 12: Dry oven and other apparatus

- **Data Analysis**

1. Determine the mass of soil solids.

MS = M3-M1

2. Determine the mass of pore water.

MW=M3-M2

3. Determine the water content.

W = $\boldsymbol{MW/MSx100\%}$

Where,

M1 = Mass of empty, clean can + lid (gm)

M2 = Mass of can, lid and moist soil (gm)

M3 = Mass of can, lid and dry soil (gm)

MS = Mass of soil solids (gm)

MW =Mass of pore water (gm)

W = Water content %

3.7.7 Direct Shear Test:

- **Purpose:**

This test is performed to determine the consolidated-drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil because it is required whenever a structure is dependent on the soil shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts, finding the bearing capacity for foundations and calculating the pressure exerted by a soil on a retaining wall.

- **Significance:**

The direct shear test is one of the oldest strength tests for soils. In this laboratory, a direct shear device will be used to determine the shear strength of a cohesion less soil (i.e. angle of internal friction (f)). From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress. After the experiment is run several times for various vertical-confining stresses, a plot of the maximum shear stresses versus the vertical (normal) confining stresses for each of the tests is produced. From the plot, a straight-line approximation of the Mohr-Coulomb failure envelope curve can be drawn, f may be determined and for cohesion less soils (c = 0).

- **Equipment:**

i. Direct shear device
ii. Load and deformation dial gauges
iii. Balance.

Picture13: Direct Shear

- **Standard Reference:**

ASTM D 3080 - Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions.

- **Test Procedure:**

i. The initial mass of soil in the pan is weighted.

ii. The diameter and height of the shear box is measure 15% of the diameter in millimeters. Carefully assemble the shear box and place it in the direct shear device. Then place a porous stone and a filter paper in the shear box.

iii. Place the sand into the shear box and level off the top. Place a filter paper, a porous stone and a top plate (with ball) on top of the sand.

iv. Remove the large alignment screws from the shear box Open the gap between the shear box halves to approximately 0.025in using the gap screws and then back out the gap screws.

Picture 13: Direct Shear Test

v. Weigh the pan of soil again and compute the mass of soil used.

vi. Complete the assembly of the direct shear device and initialize the three gauges to zero.

vii. Set the vertical load (or pressure) to a predetermined value and then close bleeder valve and apply the load to the soil specimen by raising the toggle switch.

viii. Start the motor with selected speed so that the rate of shearing is at a selected constant rate and take the horizontal displacement gauge, vertical displacement gage and shear load gage readings. Record the readings on the data sheet.

- **Analysis :**

i. Calculate the density of the soil sample from the mass of soil and volume of the shear box.

ii. Convert the dial readings to the appropriate length and load units and enter the values on the data sheet in the correct locations. Compute the sample area and the vertical

stress, $S_v = N_v / A$

Where,

Nv = normal vertical force

Sv = normal vertical stress

iii. Calculate shear stress (λ) using, $t = F_h / A$

Where, F h = shear stress (measured with shear load gage).

iv. Plot the horizontal shear stress (λ) versus horizontal (lateral) displacement H.

v. Calculate the maximum shear stress for each test.

vi. Plot the value of the maximum shear stress versus the corresponding vertical stress for each test and determine the angle of internal friction (f) from the slope of the approximate Mohr-Coulomb failure envelope.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 SPT Result:

BORE HOLE-1

Depth(ft)	Field SPT
5.0	2
10.0	4
15.0	2
20.0	2
25.0	2
30.0	3
35.0	3
40.0	5
45.0	5
50.0	6
55.0	6
60.0	7
65.0	8
70.0	41
75.0	19
80.0	16
85.0	24
90.0	30
95.0	38
100.0	41
105.0	18
110.0	21
115.0	
120.0	

BORE HOLE-2

Depth(ft)	Field SPT
5.0	2
10.0	2
15.0	2
20.0	2
25.0	3
30.0	3
35.0	3
40.0	4
45.0	5
50.0	6
55.0	7
60.0	7
65.0	8
70.0	18
75.0	14
80.0	17
85.0	26
90.0	30
95.0	28
100.0	34
105.0	30
110.0	27
115.0	28
120.0	34

SPT Result:

BORE HOLE-3

Depth(ft)	Field SPT
5.0	2
10.0	2
15.0	2
20.0	2
25.0	2
30.0	2
35.0	4
40.0	5
45.0	5
50.0	6
55.0	8
60.0	7
65.0	12
70.0	16
75.0	19
80.0	23
85.0	24
90.0	27
95.0	31
100.0	29
105.0	27
110.0	26
115.0	
120.0	

BORE HOLE-4

Depth(ft)	Field SPT
5.0	2
10.0	2
15.0	2
20.0	2
25.0	3
30.0	4
35.0	4
40.0	4
45.0	5
50.0	6
55.0	8
60.0	9
65.0	17
70.0	18
75.0	25
80.0	30
85.0	31
90.0	29
95.0	25
100.0	27
105.0	27
110.0	26
115.0	
120.0	

Table No – 4.1: Relation of N-Value with the consistency and the unconfined compressive strength of cohesive Soils.

N-values	Consistency	Unconfined Compression Strength(qu) Tsf
Bellow 2	Very Soft	Bellow 0.25
2-4	Soft	0.50-1.00
4-8	Medium	0.50-1.00
8-15	Stiff	1.00-2.00
15-30	Very Stiff	2.00-4.00
Over 30	Hard	Over 4.00

Table No- 4.2: N and Ø Relation Density for Non – Cohesive soil.

N-values	Compactness	Relative Density, Dr%	Ø(Degree)
0-4	Very Loose	0.0-0.20	25-30 (Degree)
4-10	Loose	0.20-0.40	30-35(Degree)
10-30	Medium	0.40-0.60	35-40 (Degree)
30-50	Dense	0.60-085	40-50 (Degree)
Over 50	Very Dense	1.00	45 (Degree)

4.2 Grain size analysis:

- **Discussion:**

Grain size analysis is to determine the size of the soil grains and the percentage by weight of soil particles of different particle size and comprising a soil sample. The process consists of either sieve analysis or hydrometer analysis.

Grain Size Results:

Table 4.3: Grain Size Results

Bore hole No.	Depth in(ft.)	Sand %	Silt or Clay %
BH-1	5.0	56	44
	40.0	7	93
	110.0	22	78
BH-2	25.0	4	96
	65.0	11	89
	120.0	28	72
BH-3	35.0	6	94
	85.0	78	22
	105.0	26	74

- **4.3 Specific Gravity Test:**

This lab is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

- **Result:**

Specific gravity varies from 2.64 to 2.68.

4.4 Atterberg's Limit Test:

- **Liquid and Plastic Limit:**
  - **Discussion:**

The liquid limit of a soil is the moisture content, expressed as a percentage of the weight of the oven dried soil, at the boundary between the liquid and plastic states of consistency. The moisture content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together, for a distance of ½ in. (12.7mm) along the bottom of a groove of standard dimensions separating the two halves, when the cup of a standard liquid limit apparatus is dropped 25times from a height of 0.3937 in. (10mm) at the rate of two drops/second.

- **Result:**

The liquid limit of the cohesive soil varies from 42.00 to 44.00 % and
The plastic limit of the cohesive soil varies from 21.00 to 23.00 %.

4.5 Direct Shear Test:

- **Discussion :**

This test is performed to determine the consolidated drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil because it is required whenever a structure is dependent on the soil shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts finding the bearing capacity for foundations. The direct shear test is one of the oldest strength tests for soils. In this laboratory, a direct shear device will be used to determine the shear strength of a cohesion less soil. From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress. After the experiment is run several times for various vertical confining stresses, a plot of the maximum shear stresses versus the vertical (normal) confining stresses for each of the tests is produced.

- **Result:**

Angle of internal friction varies from 29^o to 31^o and Cohesion is zero.

- **4.6 Unconfined Compressive Strength Test:**
  - **Discussion:**

From the laboratory testing investigation on unconfined compressive strength of soil, the following concluding remarks are drawn. The unconfined compression test is a type of unconsolidated undrained test that is commonly used for clay specimens. In this test, the confining pressure is 0. An axial load is rapidly applied to the specimen to cause failure. At failure, the total load minor principal stress is zero. Test specimens with soil did not show significant improvement in unconfined compressive strength after 7 curing days in water. This was largely due to the peat's high natural moisture content and highly acidic nature of organic matter in the soil.

- **Result:**

- **4.6 Moisture Content Determination**

  - **Discussion**

Oven drying method is widely used in determination of moisture. Water is removed due to heating at 105 °C. Loss of weight due to vaporization of water is taken as weight of moisture. But spices like cinnamon contain volatile oil in addition to moisture and these volatile oils also get loss during oven drying. Due to this the weight loss due to the loss of volatile oils also gets counted for moisture determination. This is the main disadvantage of oven drying method. This method is not suitable to determine the moisture content of thermally unstable compounds and this method removes only free water. Since oven drying method is simple, low cost and easy, it is widely used for routine analysis.

- **Result:**

Natural moisture content of the investigation soil usually varies from 42.39 to 43.65%

CHAPTER FIVE

CONCLUSION & RECOMMENDATION

5.1CONCLUSION:

The following conclusions may be drawn regarding the sub-soil condition of the project.

1. The overall soil formation of investigated site is more or less regular in between the bore hole location.
2. The entire subsoil formation of the project site, up to the depth of the investigation, consist the soil layer of both plastic and non-plastic in nature.
3. The 1st layer of the soil strata which varies from 0 to 27 feet consist of grey, very loose, silty fine sand SM with mica for bore hole no. 1 to 4.
4. The 2nd layer of the soil strata which varies from 27 to 37 feet consist of black, soft, silty clay, CL, with sand for bore hole no. 1 to 4.
5. The next layer of black, medium stiff, silty clay, CL, with sand for bore hole 1 to 4. Depth of this strata varies from 27 feet to 57 feet.
6. Next soil comprises of brown, hard, clayey, silt, with sand from 57 ft to 62 ft. from bore hole no. 1 to 4.
7. The 5th layer of the soil strata which varies from 62 ft to 72 ft consists of brown, very stiff, clayey silt, with sand for bore hole no. 1 to 4.
8. Next soil comprises of brown, very stiff to hard, clayey silt, with sand from 72 ft to 92 ft.
9. Lastly we found the Lt brown, very stiff, silty clay, CL, with sand from92 ft to 110 ft for bore hole no. 1 to 4.
10. The specific gravity of the soil varies from 2.64 to 2.68.
11. The liquid limit of the cohesive soil varies from 42.00 to 44.00 % and
    the plastic limit of the cohesive soil varies from 21.00 to 23.00 %.
12. Angle of internal friction varies from 29^{o} to 31^{o} and Cohesion is 0.
13. Specific gravity varies from 2.64to 2.68.
14. Natural moisture content of the investigation soil usually varies from 42.39 to 43.65%

5.2 RECOMMENDATION:

Recommendation for a foundation typed does not depend only on soil parameters rather some other factors like architectural layout, loading condition, importance factor, financial constraints, availability of building material in particular region and construction technique etc. also play important role. Since it is beyond the scope of our assigned job, we refrain job, we refrain from recommending specific foundation.

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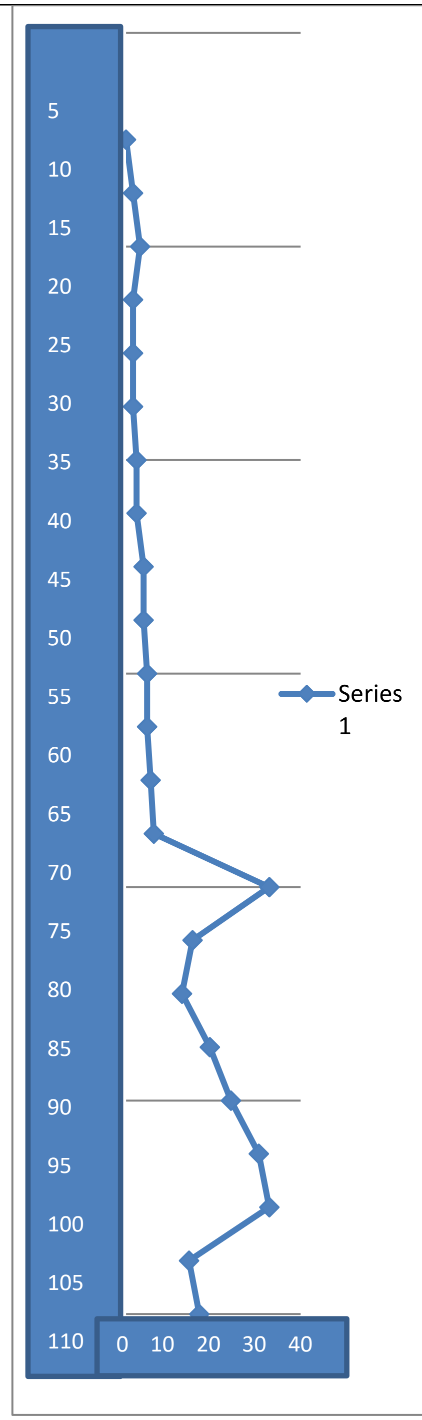
- Atterberg Limits (Principles of Geotechnical Engineering, B. M. Das)
- Lecture notes of SUB, BUET and AUST.
- Working and observation DDC Soil Laboratory

Bore Hole No. # 1.0 **R.L.=1’-5” Down** **G.W.T.=4’-0”**

Date	Sample no	Sample	Depth in ft	Thickness	Description of Materials	BH log	Boring dia	SPT 15c	SPT 15cm	SPT 15cm	SPT 10cm
	D-1		5	27 ft	Grey, very lose, silty fine sand, SM, with mica. (Filling Sand)		10cm Precussion Method	1	1	1	**2**
	D-2		10					1	2	2	**4**
	D-3		15					1	1	1	**2**
	D-4		20					1	1	1	**2**
	D-5		25					1	1	1	**2**
	D-6		30	10 ft	Block, soft, silty Clay, CL, with sand.			1	1	2	**3**
	D-7		35					2	2	3	**5**
	D-8		40	30 ft	Black, medium stiff, silty clay, CL, with sand.			2	2	3	**5**
	D-9		45					2	2	4	**6**
	D-10		50					2	3	3	**6**
	D-11		55					2	3	4	**7**
	D-12		60					2	3	5	**8**
	D-13		65					10	18	23	**41**
	D-14		70	5 ft	Brown, hard, clayey silt, with sand			6	8	11	**19**
	D-15		75	10 ft	Brown, very stiff, clayey silt, with sand.			6	6	10	**16**
	D-16		80					6	10	14	**24**
	D-17		85	20 ft	Brown, very stiff to hard, clayey silt, with sand.			6	14	16	**30**
	D-18		90					10	17	21	**38**
	D-19		95					10	18	23	**41**
	D-20		100								
	D-21		105	8 ft	Lt Brown, very stiff, silty clay, CL, with sand.			7	8	10	**18**
	D-22		110					6	9	12	**21**
	D-23		115								
	D-24		120								

Chart for Standard Penetration Test or SPT value



Disturb Index

Clay

silt

sand

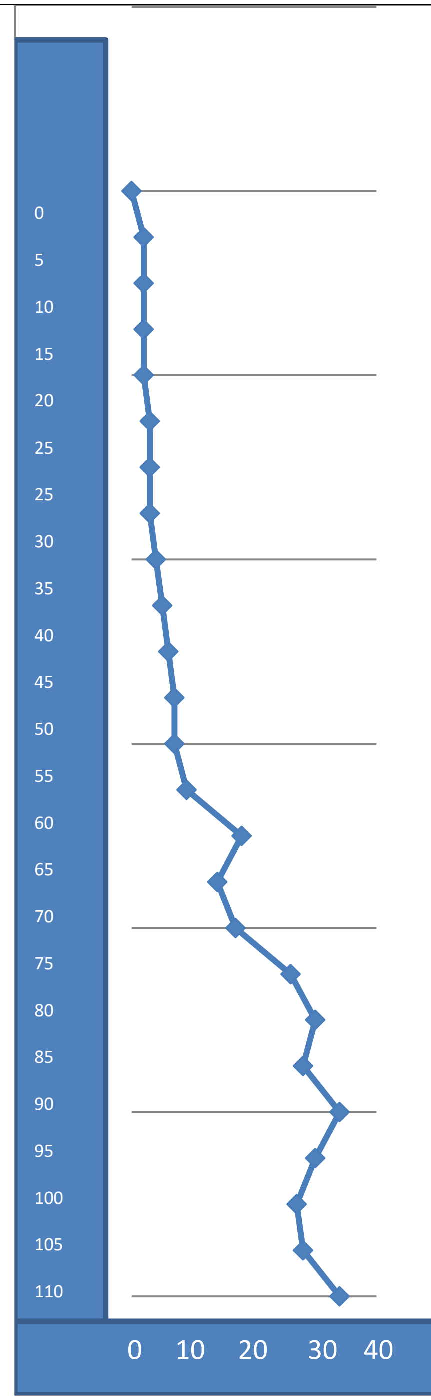
Rubbish

Distributed Undistributed

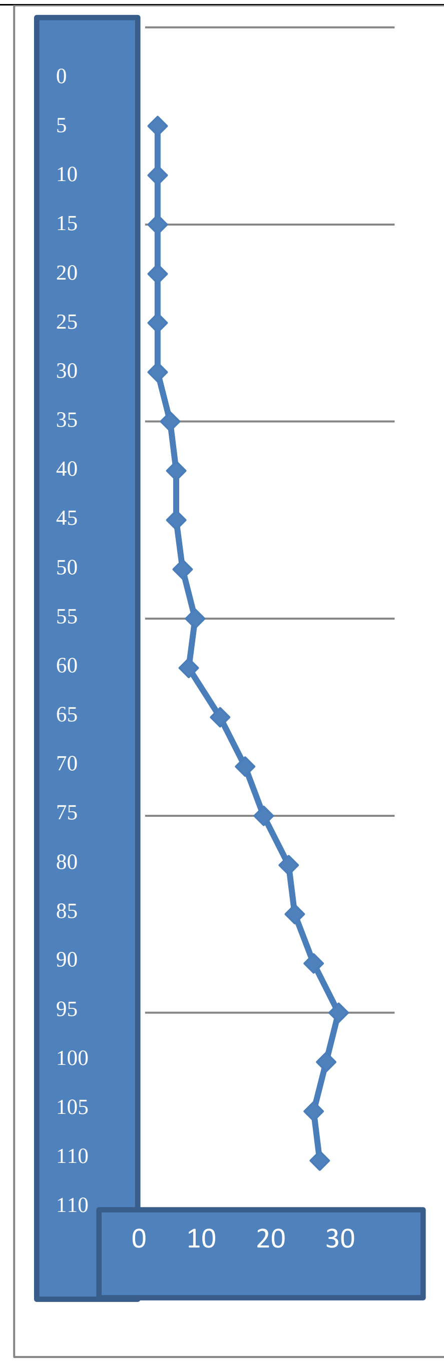
Bore Hole No. # 2.0 **R.L.=1'-5" Down** **G.W.T.=4'-0"**

Date	Sample no	Sample Type	Depth in ft	Thickness	Description of Materials	BH log	Boring dia	SPT 15cm	SPT 15cm	SPT 15cm	SPT 10cm	Disturb Index
	D-1		5	22ft	Grey, very lose, silty fine sand, SM, with mica. (Filling Sand)		10cm Percussion Method	1	1	1	2	
	D-2		10					1	1	1	2	clay
	D-3		15					1	1	1	2	
	D-4		20					1	1	1	2	
	D-5		25					1	1	2	3	silt
	D-6		30	20ft	Block, soft, silty Clay, CL, with sand.			1	1	2	3	
	D-7		35					1	1	2	3	
	D-8		40					2	2	2	4	
	D-9		45					2	2	3	5	
	D-10		50	25ft	Black, medium stiff, silty clay, CL, with sand.			2	3	3	6	sand
	D-11		55					2	3	4	7	
	D-12		60					2	3	4	7	
	D-13		65					4	4	5	9	
	D-14		70					6	8	10	18	Rubbish
	D-15		75	15ft	Brown, very stiff, clayey silt, with sand.			5	6	8	14	
	D-16		80					6	8	9	17	
	D-17		85	20 ft	Brown, very stiff to hard, clayey silt, with sand.			7	11	15	26	
	D-18		90					6	13	17	30	
	D-19		95					7	12	16	28	
	D-20		100					8	14	20	34	
	D-21		105					7	14	16	30	
	D-22		110	18ft	Lt Brown, very stiff to hard, silty clay, CL, with sand.			7	14	13	27	
	D-23		115					7	12	16	28	
	D24		120					8	16	18	34	

Chart for Standard Penetration Test or SPT value



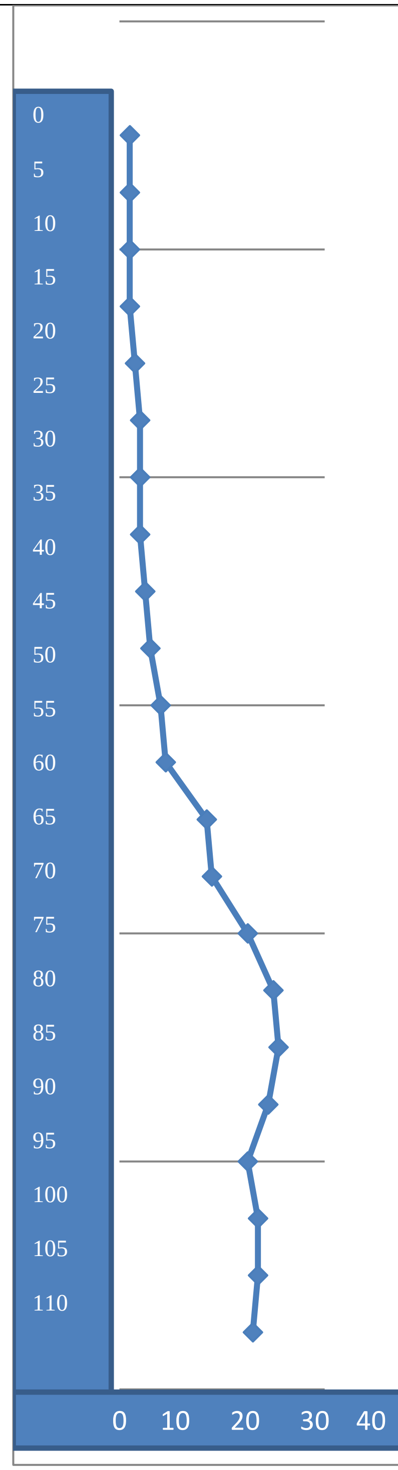
Bore Hole No. # 3.0 **R.L.=1'-5" Down** **G.W.T.=4'-0"**

Date	Sample no	Sample Type	Depth in ft	Thickness	Description of Materials	BH log	Boring data	SPT 15cm	SPT 15cm	SPT 15cm	SPT 10cm	Chart for Standard Penetration Test or SPT value	Disturb Index
	D-1		5	27 ft	Grey, very lose, silty fine sand, SM, with mica. (Filling Sand)		10cm Percussion Method	1	1	1	2		
	D-2		10					1	1	1	2		
	D-3		15					1	1	1	2		clay
	D-4		20					1	1	1	2		
	D-5		25					1	1	1	2		
	D-6		30	5 ft	Black, very soft, silty clay,CL, with sand			1	1	2	2		silt
	D-7		35					1	2	2	4		
	D-8		40	30 ft	Black, soft to medium stiff, silty clay, CL, with sand.			2	2	3	5		
	D-9		45					2	2	3	5		
	D-10		50					2	3	3	6		
	D-11		55					3	4	4	8		sand
	D-12		60					3	3	4	7		
	D-13		65					4	6	6	12		
	D-14		70	20 ft	Brown, stiff to very stiff, clayey silt, with sand.			6	6	10	16		Rubbish
	D-15		75					6	9	10	19		
	D-16		80					6	10	13	23		
	D-17		85					7	10	14	24		
	D-18		90	20 ft	Brown, medium dense to dense, silty fine sand, SM, with mica.			10	12	15	27		
	D-19		95					8	14	17	31		
	D-20		100					7	14	15	29		
	D-21		105	8 ft	Lt Brown, very stiff, silty clay, CL, with sand.			8	12	15	27		
	D-22		110					7	11	15	26		
	D23		115										
	D24		120										

Bore Hole No. # 4.0 **R.L.=1'-5" Down** **G.W.T.=4'-0"**

Date	Sample no	Sample Type	Depth in ft	Thickness	Description of Materials	BH log	Boring data	SPT 15cm	SPT 15cm	SPT 15cm	SPT 10cm
	D-1		5	23 ft	Grey, very lose, silty fine sand, SM, with mica, (Filling sand)		10cm Percussion Method	1	1	1	**2**
	D-2		10					1	1	1	**2**
	D-3		15					1	1	1	**2**
	D-4		20					1	1	1	**2**
	D-5		25					1	1	2	**3**
	D-6		30	20 ft	Black, soft, silty clay, CL, with sand.			1	2	2	**4**
	D-7		35					2	2	2	**4**
	D-8		40					2	2	2	**4**
	D-9		45					2	2	3	**5**
	D-10		50	20 ft	Black, medium stiff to stiff, silty clay, CL, with sand.			2	3	4	**6**
	D-11		55					3	4	4	**8**
	D-12		60					3	4	5	**9**
	D-13		65					5	7	10	**17**
	D-14		70	30 ft	Brown, medium dense to dense, sitly fine sand, with mica.			6	8	10	**18**
	D-15		75					7	11	14	**25**
	D-16		80					8	14	16	**30**
	D-17		85					6	14	17	**31**
	D-18		90					7	14	15	**29**
	D-19		95	17 ft	Brown, very stiff , clayey silt, with sand.			6	12	13	**25**
	D-20		100					7	10	17	**27**
	D-21		105					8	12	14	**27**
	D-22		110					8	12	14	**26**
	D-23		115								
	D-24		120								

Chart for Standard Penetration Test or SPT value



Disturb Index

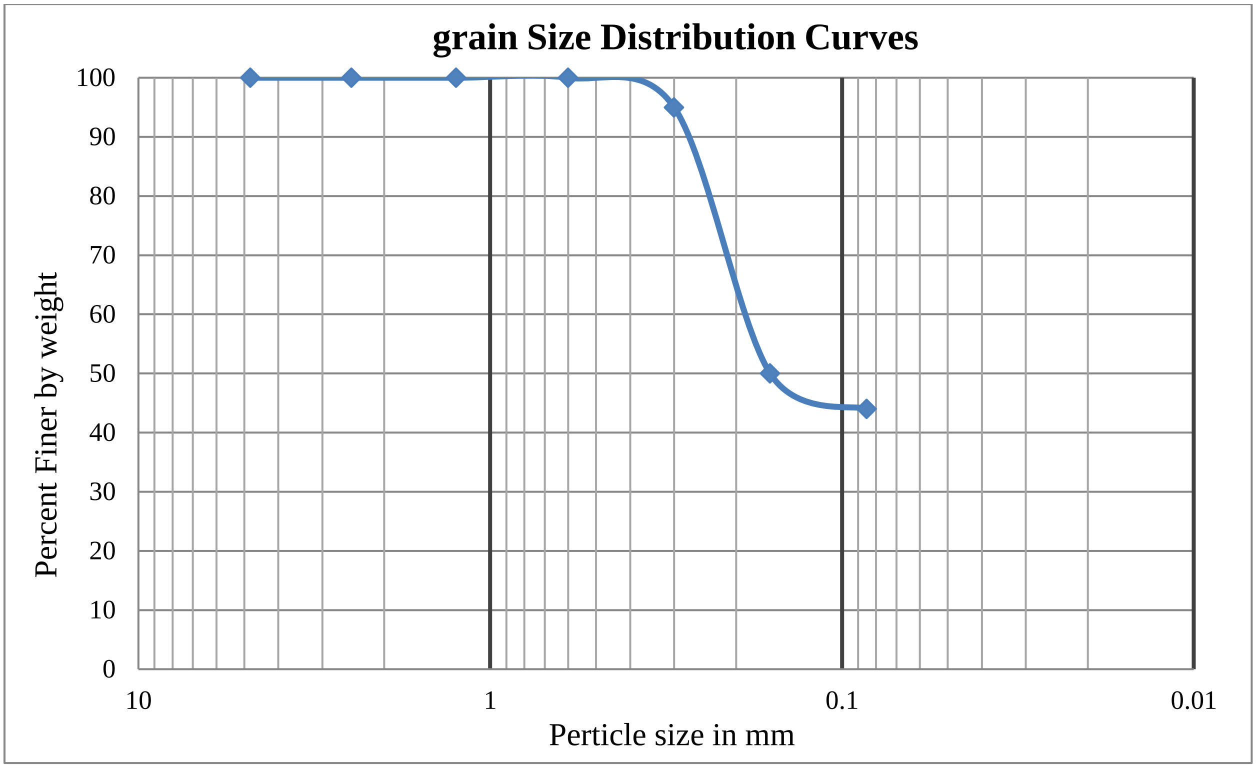
clay

silt

sand

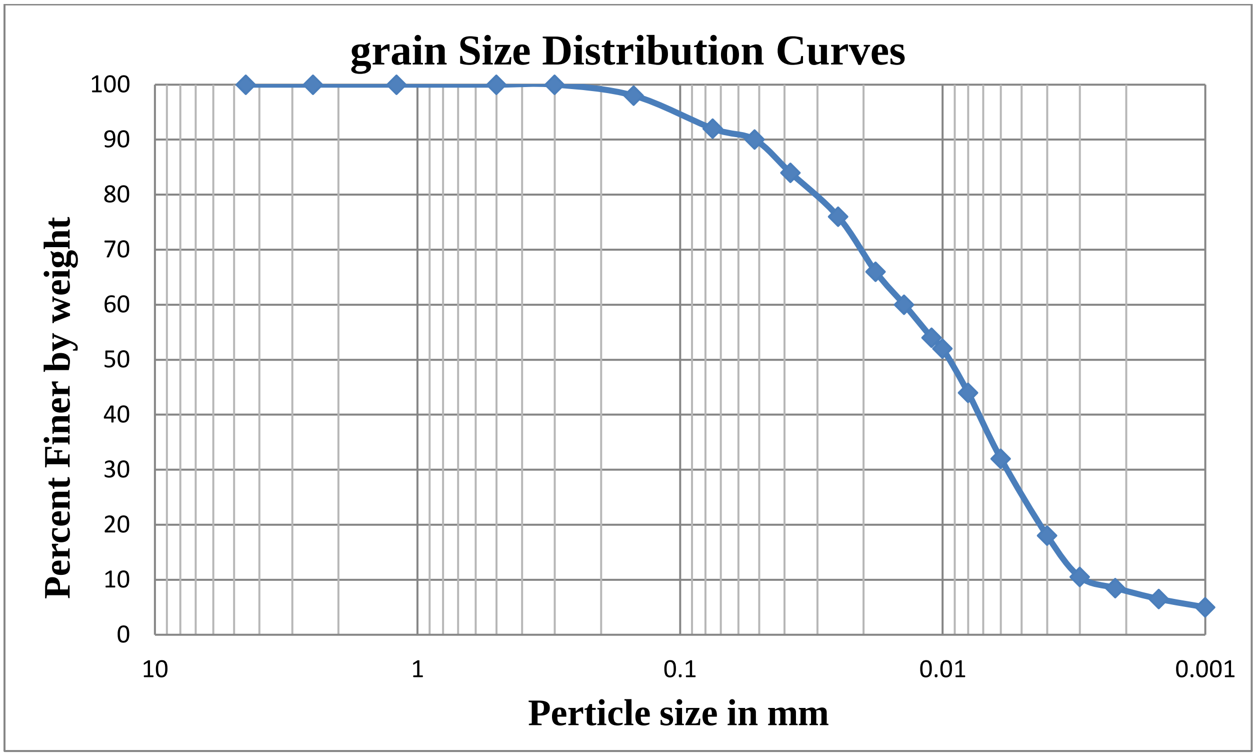
Rubbish

← Mechanical Sieve Analysis → ← Hydrometer Analysis →



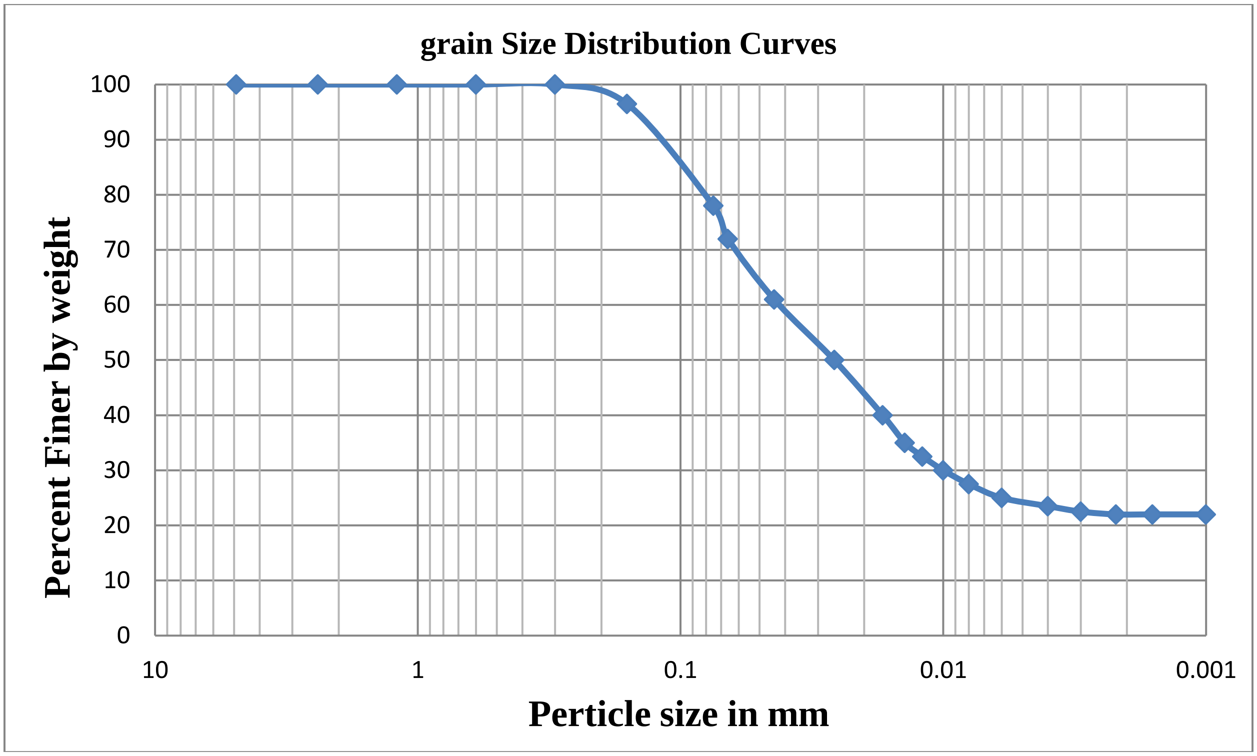
Borehole	Series	Sample	Depth in ft	Sand	Silt or clay	Specific Gravity	L.L	P.L
1	1	D-1	5.0	56	44	2.65		
						See the summary sheet.		

Mechanical Sieve Analysis Hydrometer Analysis

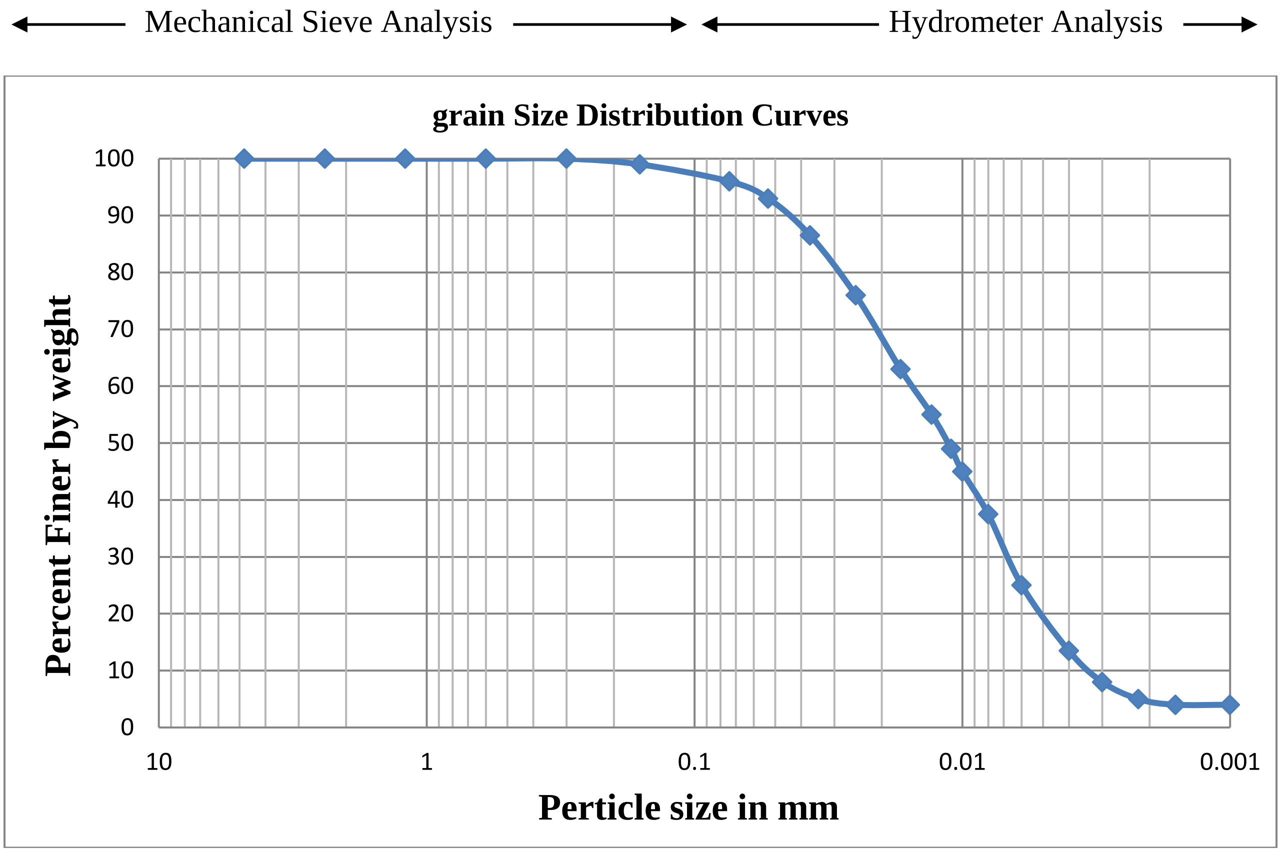


Borehole	Series	Sample	Depth in ft	Sand	Silt or clay	Specific Gravity	L.L	P.L
1	1	D-8	40.0	7	93	2.64		
						See the summary sheet.		

← Mechanical Sieve Analysis → ← Hydrometer Analysis →

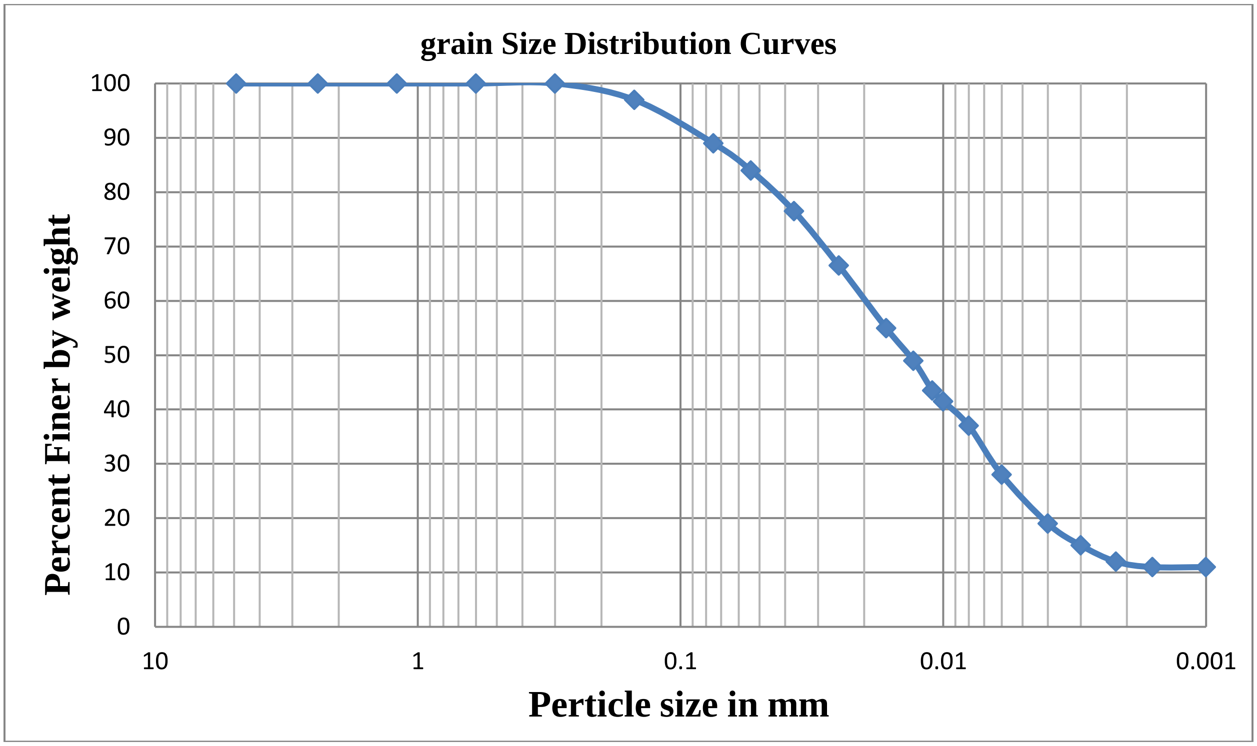


Borehole	Series	Sample	Depth in ft	Sand	Silt or Clay	Specific Gravity	Friction Angle°	Cohesion.
1						2.67		
						See the summary sheet.		
	3	D-22	110.0	22	78			



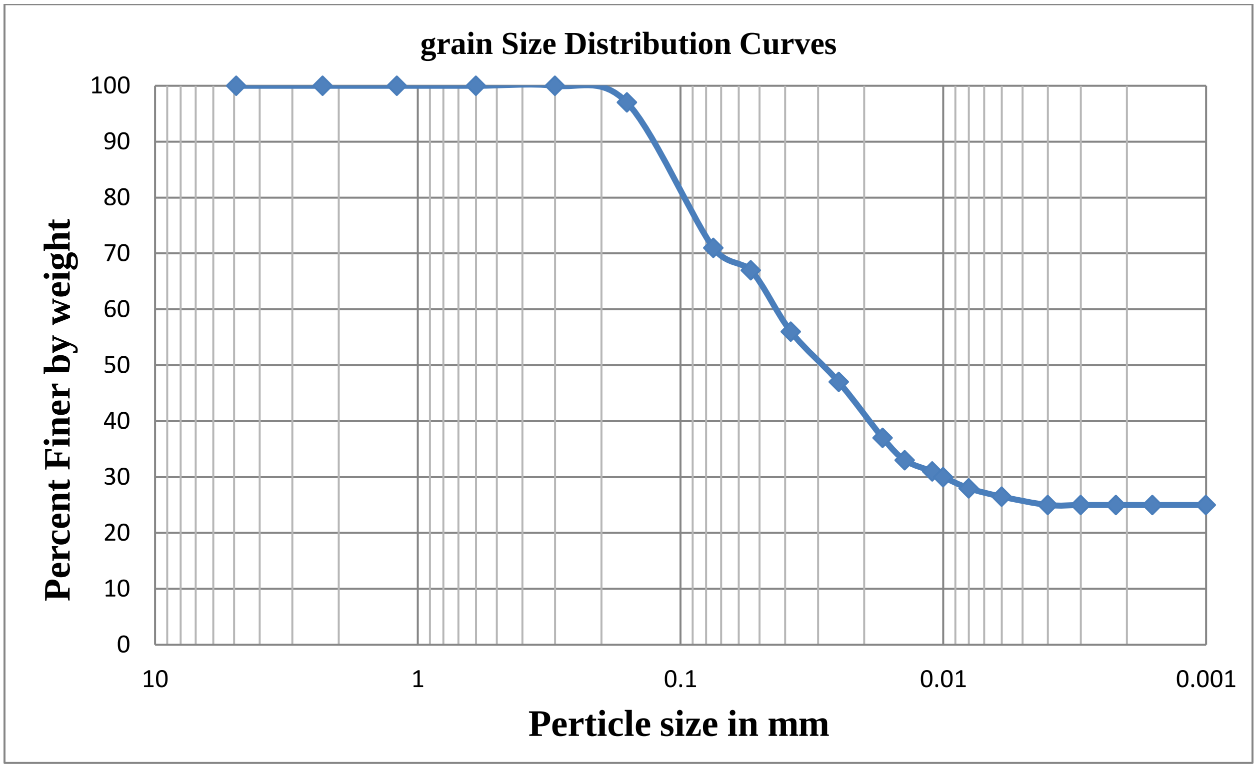
Borehole	Series	Sample	Depth in ft	Sand	Silt or clay	Specific Gravity	L.L	P.L
2	1	D-5	25.0	4	96	2.64	44	23
						See the summary sheet.		

← Mechanical Sieve Analysis → ← Hydrometer Analysis →



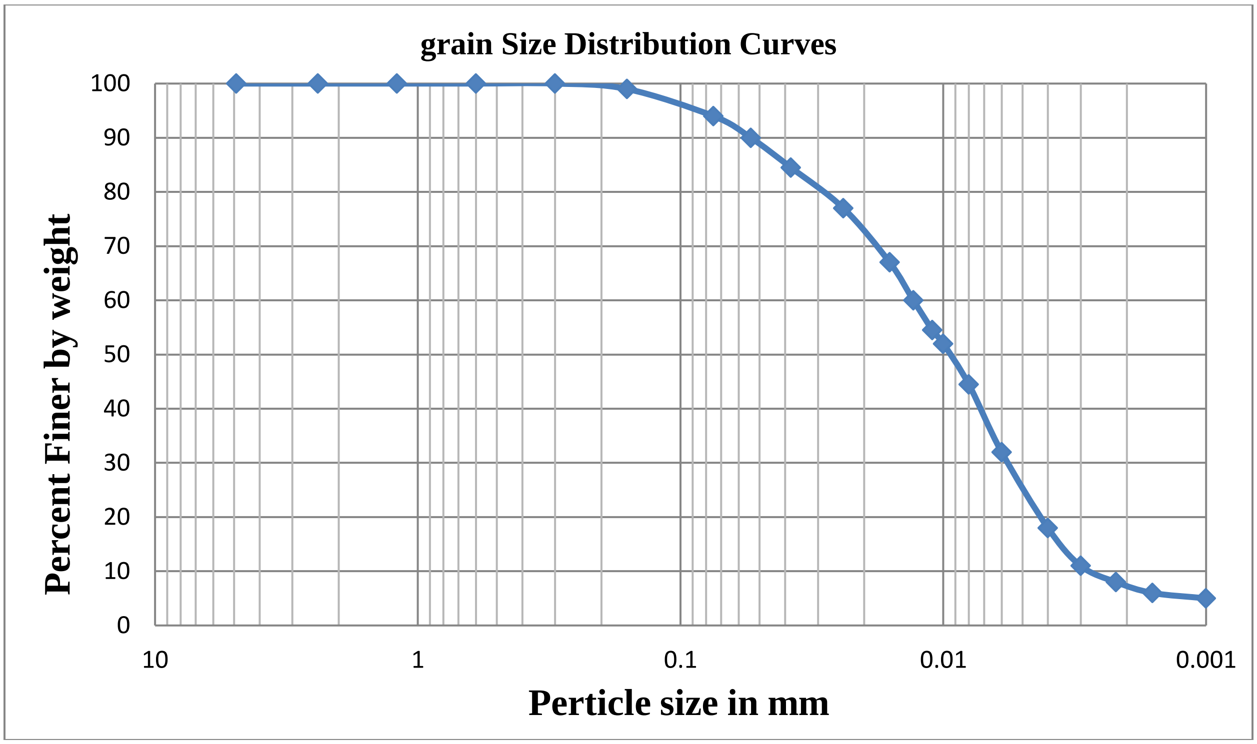
Borehole	Series	Sample	Depth in ft	Sand	Silt or clay	Specific Gravity	Friction Angle°	Cohesion.
2	1	D-13	65.0	11	89	2.64		
						See the summary sheet.		

← Mechanical Sieve Analysis → ← Hydrometer Analysis →



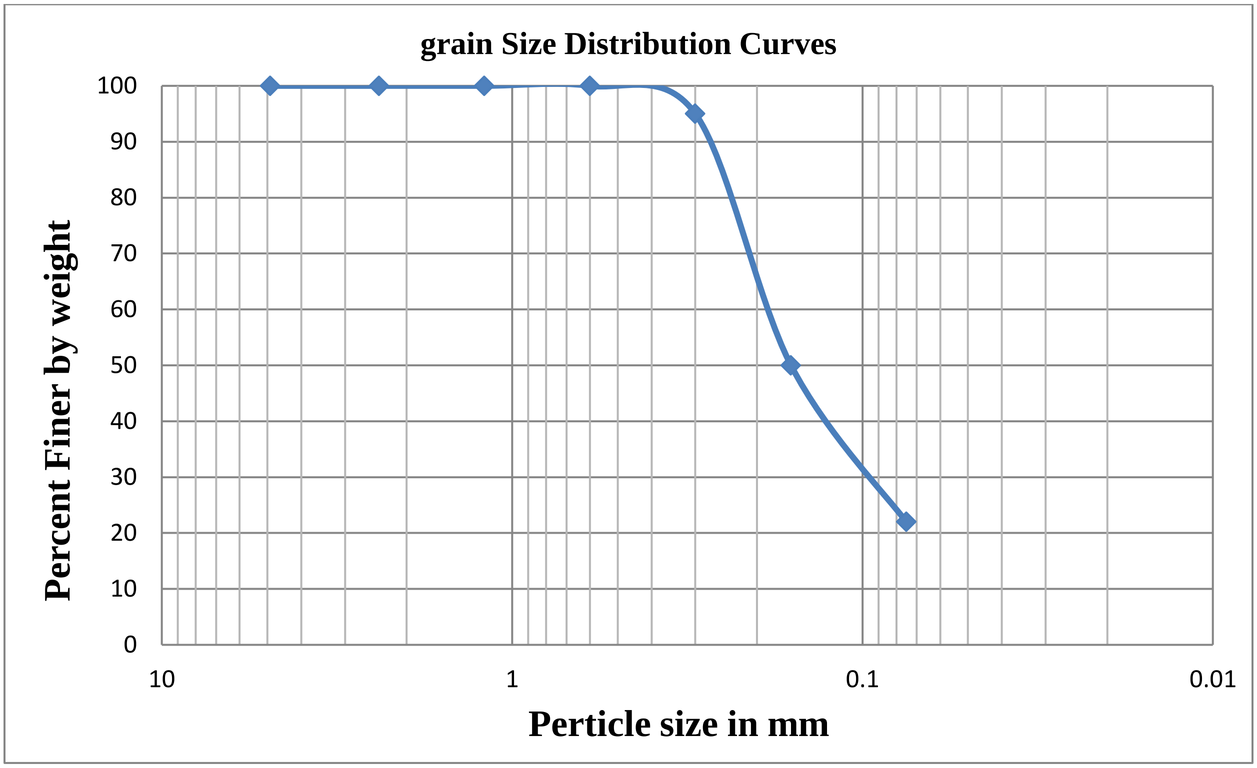
Borehole	Series	Sample	Depth in ft	Sand	Silt or Clay	Specific Gravity	Friction Angle°	Cohesion.
2						2.67		
						See the summary sheet.		
	3	D-24	120.0	28	72			

← Mechanical Sieve Analysis → ← Hydrometer Analysis →



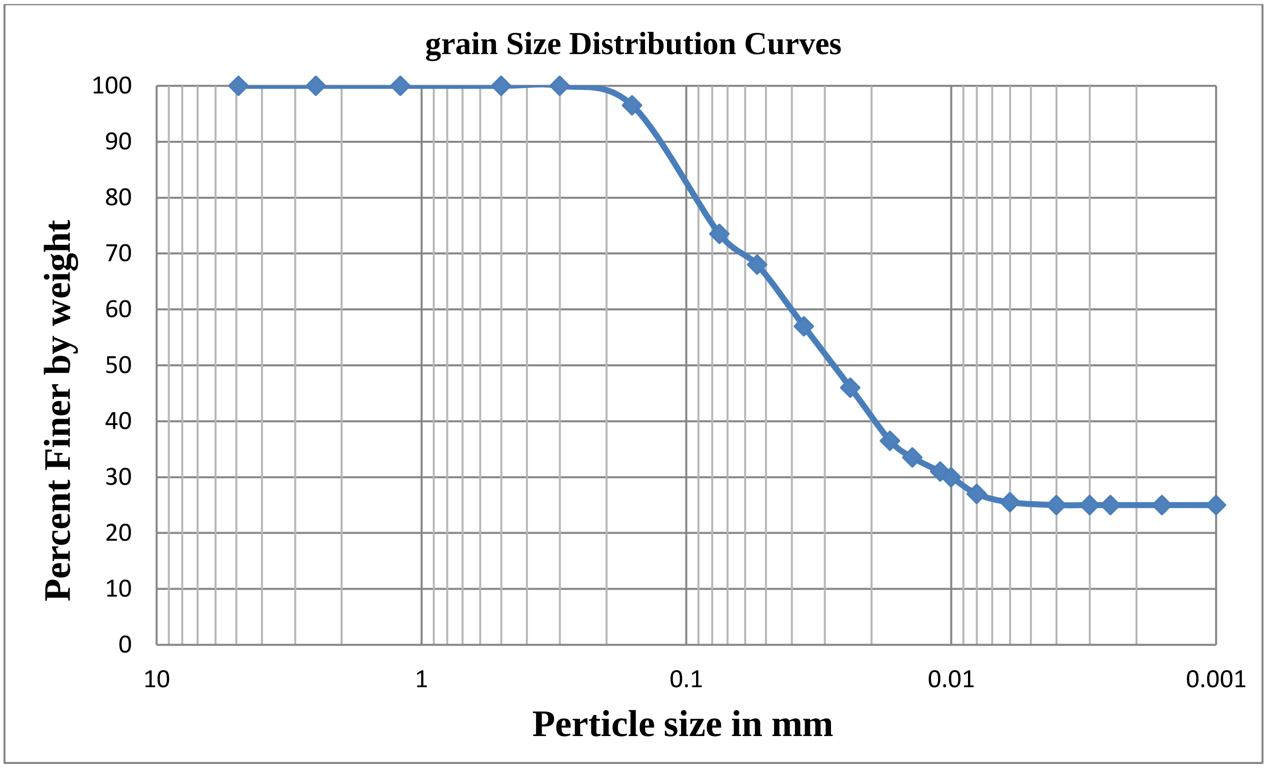
Borehole	Series	Sample	Depth in ft	Sand	Silt or clay	Specific Gravity	L.L	P.L
3	1	D-7	35.0	6	94	2.64	42	13
						See the summary sheet.		

← Mechanical Sieve Analysis → ← Hydrometer Analysis →

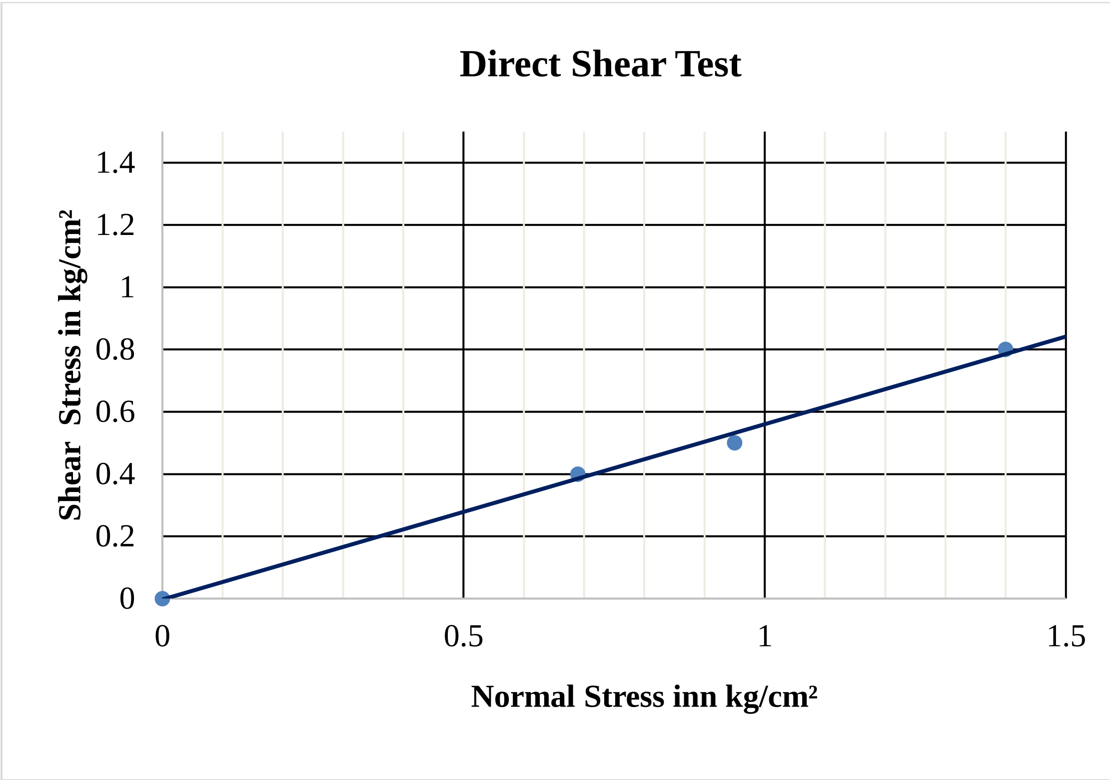


Borehole	Series	Sample	Depth in ft	Sand	Silt or clay	Specific Gravity	Friction Angle°	Cohesion.
3	1	D-17	85.0	78	22	2.67	29	0
						See the summary sheet.		

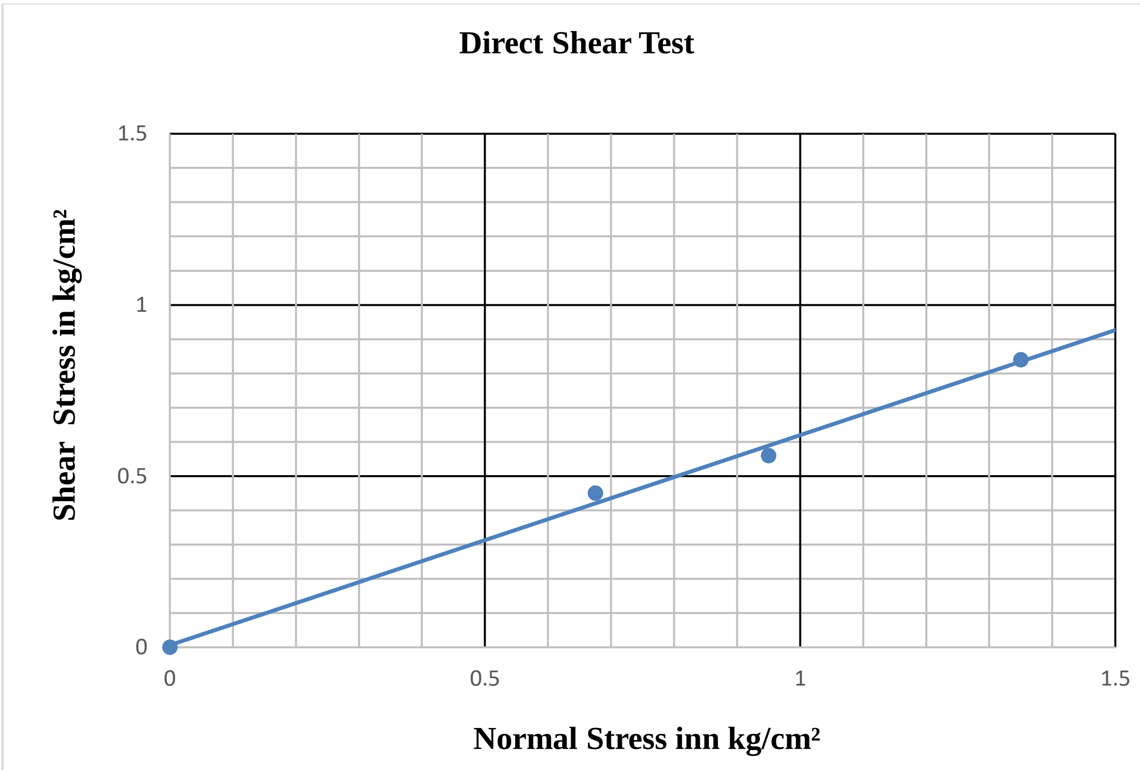
← Mechanical Sieve Analysis → ← Hydrometer Analysis →



Borehole	Series	Sample	Depth in ft	Sand	Silt or Clay	Specific Gravity	Friction Angle°	Cohesion.
3						2.68		
						See the summary sheet.		
	3	D-21	105.0	26	74			



Borehole:	**3**
Sample:	**17**
Depth:	**85.0 ft**
Shear Angle:	**29°**
Cohesion:	**0**



Borehole:	**4**
Sample:	**16**
Depth:	**80.0 ft**
Shear Angle:	**31°**
sCohesion:	**0**