COMPARATIVE ANALYSIS OF LIQUID LIMIT BETWEEN CONE PENETRATION AND CASAGRANDE METHOD

Submitted by

Mst. Mustafim Mujrina
Student ID: 201-47-360

A Thesis Submitted to the Department of Civil Engineering, Daffodil International University in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Civil Engineering

Ahad Ullah

Sr. Lecturer

Department of Civil Engineering

Daffodil International University

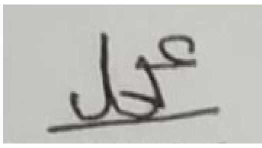
Department of Civil Engineering

Daffodil International University

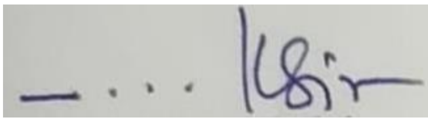
The thesis titled "**Comparative Analysis of Liquid Limit Between Cone Penetration and Casagrande Method**" was submitted by Mst. Mustafim Mujrina, Student ID: 201-47-360, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering on 9th June 2024.

BOARD OF EXAMINERS

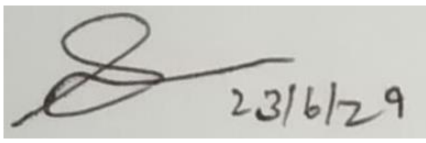
Ahad Ullah
Sr. Lecturer
(Supervisor)
Department of Civil Engineering
Daffodil International University



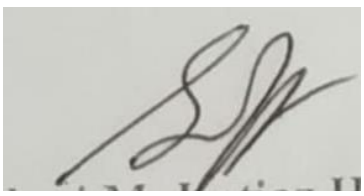
Dr. M.R. Kabir
Professor
Chairman
Department of Civil Engineering
Daffodil International University



Saurav Barua
Assistant Professor
Member (Internal)
Department of Civil Engineering
Daffodil International University

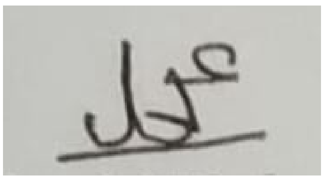


Madani M. Imtiaz Hossain
Technical Director
Member (External)
Department of Civil Engineering
Daffodil International University



Apporoval

This project report, written by Mst. Mustafim Mujrina (201-47-360) has been certified as partial satisfaction of the requirements for the Bachelor of Science in Civil Engineering degree. I oversaw the students in question while they finished their project. They proved to be reliable and diligent along the course of the research project.



Ahad Ullah
Sr. Lecturer
Department of Civil Engineering
Daffodil International University

Declaration

It is hereby declared that this Project is the work carried out by the author under the supervision of Ahad Ullah, Sr. Lecturer, Department of Civil Engineering, Daffodil International University (DIU). Neither thesis nor any part of this has been submitted or is being concurrently submitted elsewhere for any other purpose.

Mst. Mustafim Mujrina

Mst. Mustafim Mujrina
ID: 201-47-360
Department of Civil Engineering
Daffodil International University

Acknowledgment

At first, the author would like to convey his profound gratitude to almighty Allah for giving him the strength and patience to bring about the successful completion of this thesis work. Then, she would like to express her sincere gratitude and hearty admiration to her honorable supervisor Ahad Ullah, Sr. Lecturer, Department of Civil Engineering, Daffodil International University (DIU), Dhaka. For his valuable suggestion and inspiration, constant guidance and support, and cordial encouragement toward the successful completion of this research. Finally, the author thanks all of her classmates whose cooperation was very much valuable in the progress of this thesis.

Abstract

Comprehending the liquid limit of soils is crucial as it provides essential information on their plasticity and engineering behavior, influencing decisions in geotechnical engineering and construction projects. This thesis investigates the distinctions in liquid limits between the cone penetration method and the Casagrande approach. The study aims to compare the results obtained from these two methods in assessing the liquid limits of fine-grained soils, specifically clays and silty soils. Samples were collected from various locations in Bangladesh to conduct the tests. The findings reveal that the Casagrande method consistently yielded lower liquid limit values compared to the cone penetration method. Statistical analysis indicated minimal variation between the two methods in most cases, although notable discrepancies were observed. Overall, the cone penetration method tended to provide higher liquid limit values than the Casagrande method. These results underscore the importance of methodological choice in accurately assessing soil behavior, particularly in geotechnical engineering applications.

Table of Contents

List of Figures

List of Tables

List of Abbreviation and Notation

CPT	Cone Penetration Test
LL	Liquid Limit
PL	Plastic Limit
JU	Jahangirnagar University
SLT	Standard Laboratory Test
SL	Shrinkage Limit
CL	Low-Plastic Clay
ML	Low-Plastic Silt
OL	Low-Plastic Organic Soil
CH	High-Plastic Clay
MH	High-Plastic Silt
OH	High-Plastic Organic Soil
USCS	Uniform Soil Classification System
G_s	Specific Gravity
G_t	G_S at water temperature T°C
W_s	Weight of soil
R_a	Observed Hydrometer Reading
R_l	Hydrometer Correction Only for Meniscus
C_m	Meniscus Correction
C_t	Temperature Correction
F_s	Sleeve Friction
R_c	Corrected Hydrometer Reading
γ_W	Unit Weight of Water
G_s	Specific Gravity
L_b	Length of Bulb
V_b	Volume of Bulb
C_z	Zero Correction

Dedications

This thesis is dedicated to all of our parents and teachers who were the inspiration to make this effort possible

Chapter 1

INTRODUCTION

1.1 General

It is an essential step to Find soil's liquid limit in geotechnical engineering since it gives important information on the soil's engineering characteristics. There are several ways to calculate the liquid limit two well-known approaches are the con penetration method and Casagrande Method. By defining the moisture content at which a soil changes from a plastic to a semi-solid state, both methods seek to characterize the plasticity of the soil.

1.2 Motive of the Present Research

It does seem that there hasn't been much research done in the published literature on the simultaneous evaluation of the plastic limit (PL) and liquid limit (LL) using a single laboratory test procedure and comparing the results with established test methods. There is a noteworthy research gap concerning the creation of thorough approaches for defining and measuring clay minerals in connection to the features of soil flexibility.

Using the cone penetration method and a modified cone penetration methodology, this study attempts to determine the liquid limit of clay soil within a specified range of low to high plasticity. Then, in order to address any disparities that might occur when using the conventional method described in BS 1377 for calculating the liquid limit, a comparative analysis will be carried out against the results obtained via the standard and recognized method for determining the liquid limit value of soil. Therefore, the goal is to create a technique for estimating the liquid limit that is less dependent on the operator. If the fall cone apparatus could be used to establish the plastic limit, it would be perfect (Rashid, 2016). The study also intends to look into the connections between them.

The study also intends to look at the connections that may exist between these boundaries and the soil's clay minerals.

1.3 Objective of Study

- To investigate the distinctions in liquid limits between the cone penetration method and the Casagrande approach.

1.4 Organization of the Thesis

The current study is divided into multiple chapters, each of which focuses on a different area of the investigation:

Chapter 1: It discusses the background and objectives of the study. This chapter presents an overview of the background, goals, and research methodology of the study.

Chapter 2: reviews the literature on determining liquid limits. This chapter reviews a number of literature sources related to figuring out the plastic limit. It covers both conventional techniques and non-conventional methods for figuring out the plastic limit. There is an exploration of past research endeavors, conventional methods, and novel approaches for ascertaining the plastic limit of soil laboratory investigations.

Chapter 3: The laboratory tests carried out as a component of the current investigation are covered in detail in this chapter. It describes the methods utilized in this study and talks about how the cone used in the soil experiments was made.

Chapter 4: Results and Analysis of Research: This chapter focuses on the research's findings, namely the cone penetrometer's measurement of the penetration depth. Context and insights are provided by comparisons with the findings of earlier studies, key findings and conclusions.

Chapter 5: The primary results and conclusions from the current study are presented in this chapter. To direct future investigation in this area, suggestions for study directions are also given.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Particle size distribution affects fine-grained soils engineering qualities, but so do other elements including moisture content, mineral and structural makeup, and so on. In order to classify and evaluate the mineral composition and engineering behavior of these soils, tests such as the liquid and plastic limits evaluations aid in understanding how water content impacts these soils. Cone-penetration techniques have become more popular as substitute methods for determining plastic limits in recent years. These techniques have the potential to be more accurate and efficient. Cone-penetration techniques and conventional processes are compared for effectiveness in this literature review, which also examines the advantages and disadvantages of each approach. This review attempts to offer insights into the applicability and dependability of these methods in geotechnical engineering applications through a thorough investigation of the current literature.

2.2 Atterberg Limits

The six consistency limits for fine-grained soils are known as the Atterberg Limits, and they were first proposed by Albert Atterberg. These limitations (ASTM Standard D4318-84, 1991) include the liquid limit, which is the highest limit of viscous flow, as well as the sticky, cohesion, plastic, and shrinkage limits. The Swedish scientist Atterberg created a technique to evaluate fine-grained soil consistency at different moisture levels in the beginning of the 20th century. Soil shows liquid-like flow at high moisture contents, while it acts more like a solid at low moisture contents. Because moisture content thus greatly affects soil behavior, soil can be divided into four basic groups according to moisture thresholds: solid, semisolid, plastic, and liquid (Rashid, 2016).

2.3 Liquid and Plastic Limits

Changing the water content of clay modifies its mechanical characteristics. When enough water is added, clay softens and transforms into a slurry that acts like a viscous liquid; this is referred to as the liquid state. The material ultimately starts to stick together and provide some resistance to deformation if the water content is steadily lowered by drying it slowly; this is known as the plastic state. As more water is lost, the clay shrinks and becomes more rigid, eventually turning brittle this is the semisolid state. The clay shrinks until it reaches a consistent minimum volume as drying proceeds. Past that point, more drying results in no more volume loss; this is the solid state. The transition between states happens gradually rather than suddenly. By establishing the shrinkage limit SL, plastic limit PL, and liquid limit LL, these smooth transitions are empirically characterized. The plasticity index (PI), which measures the plasticity of clay, is the moisture content between PL and LL.

$$(PI = LL - PL)$$

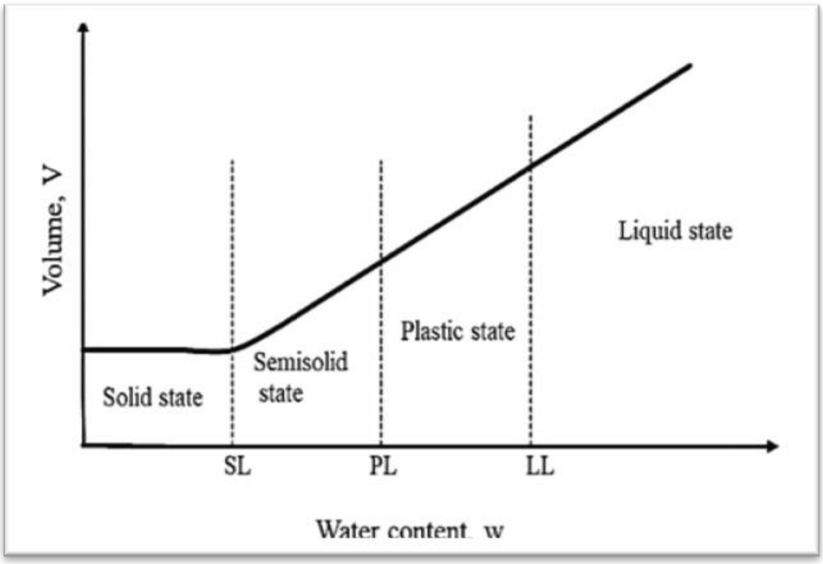


Figure 2-1: Variation of consistency of fine-grained soil with water content

2.4 Plasticity Chart

The hydrometer test can be used to estimate the percentage of clay in the soil, but it cannot identify the type of clay since clay particles are so small that visual inspection with electron microscopes is necessary. For engineering uses, x-ray diffraction is an expensive and time-consuming method of identifying clay minerals. Alternatively, a workable answer is provided by the liquid and plastic limit tests. These fundamental engineering studies categorize clay soils and determine the sorts of clay minerals present. The liquid and plastic limits, which are determined using rather straightforward laboratory techniques, provide important information about the properties of cohesive soil. These tests are commonly used by engineers to identify soil and connect different physical properties.

Above the A-line, there is also a prominent U-line that indicates the upper limit of the link between the plasticity index and the liquid limit that has been seen in soils thus far. For the U-line, the equation is about PI = 0.9(LL-8). There is an additional function for both the A-line and the U-line. Casagrande suggested that if the plasticity index and liquid limit of a soil are known, then the shrinkage limit of that soil might be roughly approximated.

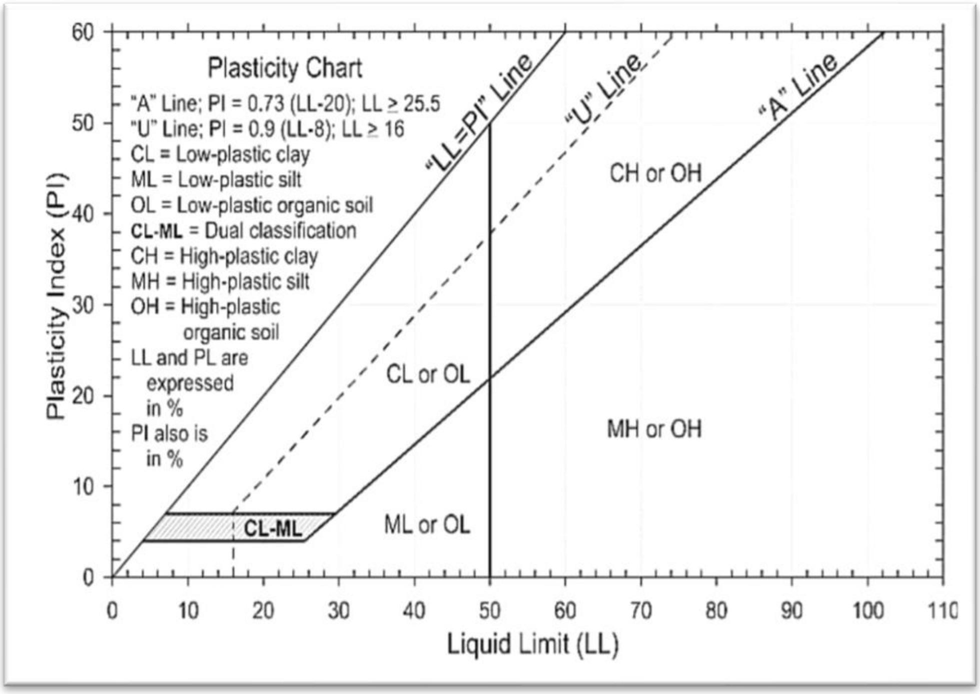


Figure 2-2: Plasticity chart

The relationship between the plasticity index and the liquid limit is used in the Uniform Soil Classification System (USCS) to create sub-groups within fine soils. An artificial border between silts and clays is shown by the A-line in the chart. Five degrees of flexibility are further defined by vertical divisions based on the percentage of liquid limit.

Table 2-1: Plasticity based on liquid limit

Plasticity	Liquid Limit Range
Low plastic	Less than 35%
Intermediate plastics	Between 35%-50%
High plastic	Between 50%-70%
Very high plastic	Between 70%-90%
Extremely plastic	More than 90%

2.5 Cone Penetration Method

A mainstay of contemporary geotechnical engineering, the Cone Penetration Test provides a fast, accurate way to evaluate the intricate behavior of soils below the surface of the Earth. The Cone Penetration Test was first created in the 1930s and has since been improved upon throughout the years, becoming a vital resource for engineers all over the world that offers vital insights into stratigraphy, soil mechanics, and geotechnical conditions.

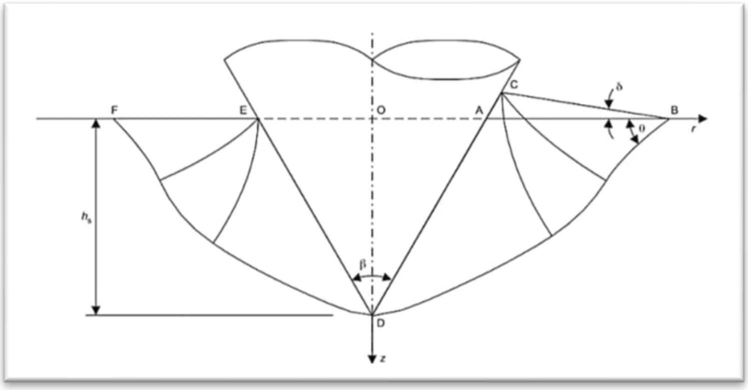


Figure 2-3: Schematic diagram of fall cone test (Koumoto and Houlsby, 2001)

Fundamentally, a cone-tipped penetrometer is inserted into the ground at a controlled rate of penetration, usually between one and two centimeters per second. As the penetrometer moves forward, it measures a number of variables that are essential to comprehending the behavior of soil, such as pore water pressure (u), sleeve friction (fs), and cone resistance (qc). These measures, which are continuously recorded during the test, give engineers a thorough insight of the qualities and attributes of the soil. A penetrometer assembly is connected to a number of rods that are driven or pushed into the ground by means of hydraulic or mechanical systems as part of the apparatus used in a Cone Penetration Test. The penetrometer is equipped with advanced sensors that enable it to record exact information about how the soil reacts to penetration. In geotechnical design and construction, this data is used to evaluate soil behavior and make educated decisions. It can be recorded for later analysis or sent in real-time to on-site engineers.

A sophisticated grasp of soil mechanics and geotechnical principles is necessary to interpret the data obtained from a Cone Penetration Test. Cone resistance, sleeve friction, and pore water pressure data are examined by engineers in order to determine important soil features, including stratigraphy, compaction characteristics, shear (Methods of test for soils for civil engineering purposes - Classification tests, 1990) (Harison, 1988) (Houlsby, 1982) (Das, 2002) (Methods of test for soils for civil engineering purposes - Classification tests, 1990)strength, and soil classification. Through the correlation of these results with project specifications and environmental factors, engineers are able to create strong designs and construction techniques that are specifically adapted to the unique challenges presented by the subsurface circumstances The capacity of the Cone Penetration Test to offer real-time, in-situ data greatly reduces the need for time-consuming and frequently expensive laboratory testing, which is one of its main advantages. Engineers can quickly assess subsurface conditions, spot possible risks or abnormalities, and modify project plans as a result of this immediacy. Furthermore, because the Cone Penetration Test is non-destructive, it causes the least amount of disruption to the site, which makes it especially appropriate for projects that prioritize maintaining existing infrastructure or environmentally sensitive locations. The Cone Penetration Test's broad acceptance in contemporary geotechnical practice attests to its effectiveness and dependability. The Cone

Penetration Test is essential to guaranteeing the sustainability, safety, and effectiveness of infrastructure projects all over the world. It does this by analyzing slope stability, designing foundations, and conducting offshore engineering and environmental site assessments. The Cone Penetration Test is still a vital tool for engineers negotiating the complexity of the subsurface world as long as urbanization, infrastructure development, and environmental stewardship continue to shape our world.

2.6 Fall Cone Penetrometer Method

To evaluate the strength and uniformity of fine-grained soils, geotechnical engineers frequently employ the Fall Cone Penetrometer method. The Fall Cone Penetrometer method was created to assess low shear strength soils, like silts and clays. It offers insightful information about soil behavior that helps with slope stability analysis, foundation design, and construction scheduling.

The Fall Cone Penetrometer method basically includes allowing a normal cone-shaped penetrometer to fall into the soil freely while being pulled down by gravity. The depth of penetration attained in a certain amount of time is then calculated and utilized to deduce different soil characteristics.

The penetrometer device, which consists of a cone attached to a calibrated rod or shaft, is the standard piece of equipment used in the FCP method. For constant testing conditions, the cone's apex angle is designed to be a standard 60 degrees. Accurate penetration depth measurement is made possible by depth indicators on the rod, and testing intervals can be controlled with the use of a timing device.

In conclusion, the Fall Cone Penetrometer approach gives engineers a useful and trustworthy way to assess fine-grained soil characteristics. Its adaptability and effectiveness make it a vital tool for geotechnical studies, enabling well-informed choices and guaranteeing the accomplishment of building projects in a range of soil types.

Figure 2-4: Laboratory cone penetrometer

2.7 Combined Liquid and Plastic Limit Test Methods

Various techniques were used in place of independent, unconnected tests like the Casagrande cup and rolling beads as required by ASTM standard to achieve liquid and plastic limit values through a combined test method. The plastic limit and the liquid limit might be mechanically simpler, more practical, and more significant if fall cone tests were offered for both. According to George and Wood's report on cone test results, the data of the plasticity index is found to be 52%, as opposed to a value of 54% obtained when the plastic limit was evaluated using the conventional approach. (Georgen and Wood, 1976).

2.8 Summary

The chapter thoroughly discusses all facets of earlier research that are pertinent to this investigation, including methodological techniques, theoretical frameworks, and substantive findings. In conclusion, it is observed that figuring out the Atterberg limit using conventional methods requires a lot of time and depends on the sensitivity of the user. Researchers from all around the world have looked into the cone penetration technique as a potential solution to this problem. The 20 mm cone penetration method for determining the liquid limit is standardized by BS 1377. A survey of the literature suggests that, despite a great deal of research, a consistent method for figuring out the plastic limit has not yet been developed. As a result, the goal of the current study is to investigate if using a cone penetrometer to measure the plastic limit is feasible.

Chapter 3

METHODOLOGY

3.1 Introduction

It is clear from reading the literature that many investigations have been done on developing rolling as well as changing cone penetrometers. On the other hand, compared to studies on modified cone penetrometers, research on unmodified cones is quite rare. The goal of the current study is to provide a simple technique for figuring out a clay's plastic limit. Important geotechnical parameters, including the Atterberg limit, plasticity index, fluidity index, soil activity, and soil sensitivity, can be estimated and predicted with the use of the designed cone penetrometer. This chapter goes into further information about the laboratory research program and the specific test processes.

3.2 Methodology

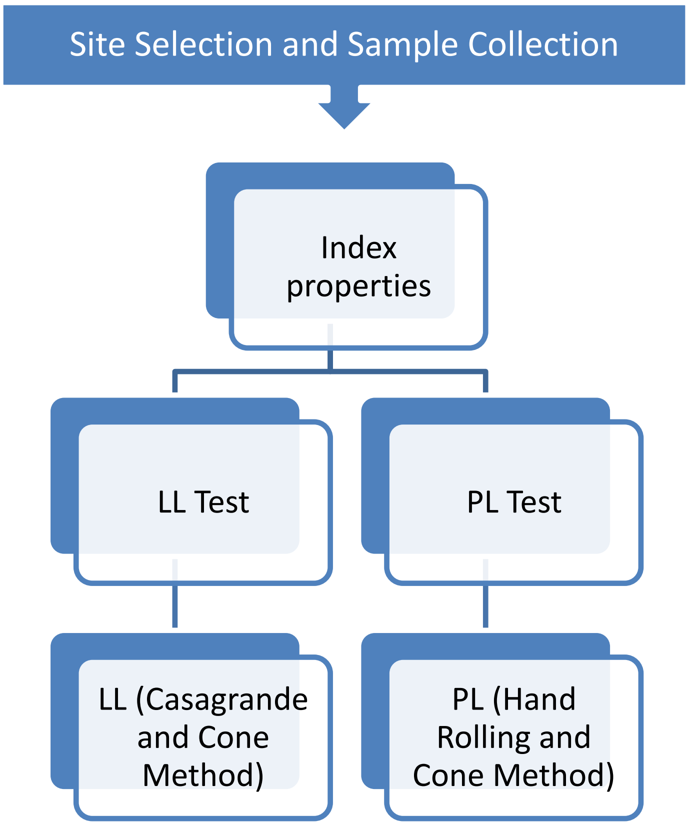


Figure 3-1: Site selection and sample collection

3.3 Soil Sample Collection and Preparation

Different types of soil samples were taken from different locations for LL and PL tests. For example, two soil samples were taken from Jahangirnagar University Shapla Chattor and Biology Faculty premises. Two samples were taken from Uptown and Barobazar two soil samples were taken from Chapai Nawabganj and BUET campus.

Table 3-1: Geographical location of the collected soil sample

Sl. No	Location	GPS
1	JU (Shapla Chattor)	23.885021, 90.267748
2	JU (Geology Department)	23.87781, 90.26666
3	Chapai Nawabganj	24.58699, 88.26995
4	BUET Campus	23.725209, 90.394600
5	Uptown, Ashulia	23.86861, 90.32620
6	Barobazar,Ashulia	23.87646, 90.33483

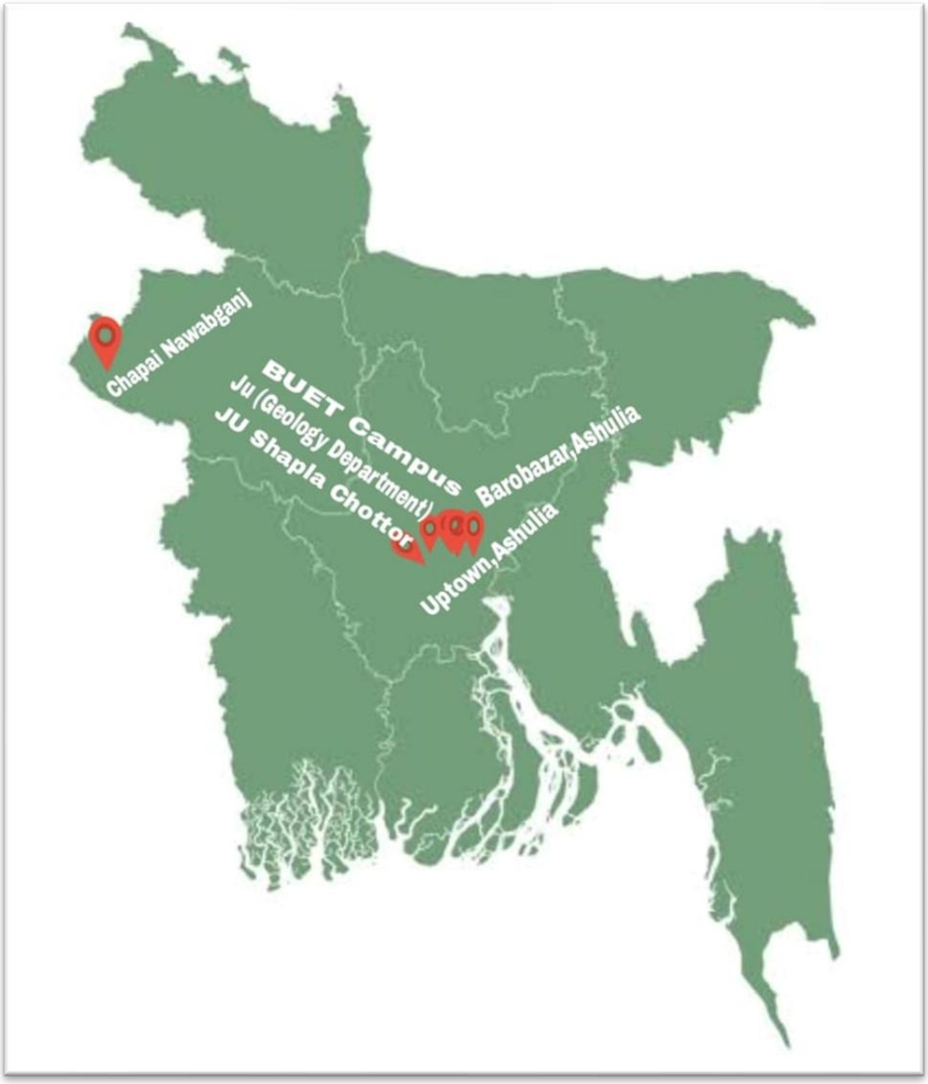


Figure 3-2: Map of Earth for soil sample collection location.

3.4 Test Methodology

Following standards are maintained for laboratory test of soil sample. These standards are followed to maintain the test accuracy and persistence.

Table 3-2: Standard laboratory test

Name of Test	Standard
Liquid Limit and Plastic Limit	ASTM D4318-00 (BS 1377, 1975)
Specific Gravity	ASTM D854
Sieve Analysis	ASTM D6913
Hydrometer Analysis	ASTM D7928

3.5 Specific Gravity, G_s

Specific gravity (G_s) provides information about the density and makeup of materials and is a basic topic in many scientific fields. Specific gravity is a common measurement for comparing the densities of various materials. It is defined as the ratio of a material's density to that of a reference substance, usually water at a given temperature. Specific gravity is a key factor in describing soils and aggregates in geotechnical engineering and soil mechanics. Engineers can evaluate the compactness, porosity, and general composition of soil particles all important variables affecting the behavior and performance of soil in building projects by measuring the specific gravity of the soil particles. Furthermore, specific gravity helps to categorize different types of soil and forecast their engineering characteristics, which helps to make well-informed decisions during the geotechnical design and construction phases.

The specific gravity (G_s) is calculated using a formula considering the ratio of the weight of soil (W_s) to the weight of water displaced (($W_s - W_1 + W_2$), factoring in their volumes and densities.

$$G_s = G_T W_s / (W_s - W_1 + W_2)$$

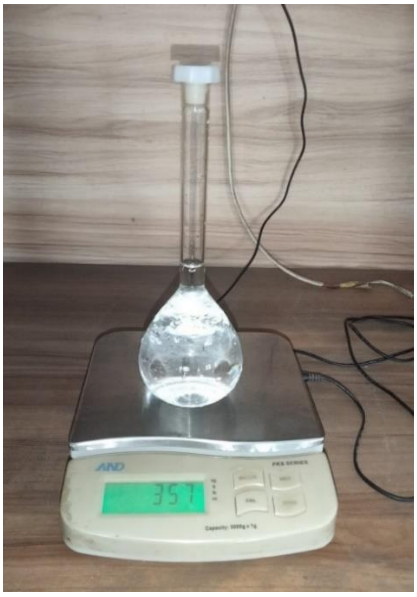


Figure 3-3: Weight of pycnometer with water

Figure 3-4:Weight of pycnometer with water and soil

Where, W_1 = weight of pycnometer + water + soil, W_2 = weight of pycnometer + water, and $G_T = G_S$ at water temperature T^oC

3.6 Particle Size Distribution

Particle size distribution is an essential component of material characterization that is widely used in many different fields of science and industry. Particle size distribution analysis measures the relative amounts of variously sized particles in a sample and offers important information on the physical characteristics and behavior of materials. Understanding particle size distribution is crucial for classifying soils, forecasting their engineering behavior, and choosing the right building methods and materials in geotechnical engineering and soil science. Similar to this, particle size distribution analysis directs efforts in environmental monitoring, process optimization, and product creation in sectors like mining, medicines, agriculture, and environmental science.

Particle size analysis are three methods:

- Sieve analysis
- Wash sieve analysis
- Hydrometer analysis

3.6.1 Sieve Analysis

Sieve analysis is a method for determining the particle size distribution of a granular material. It is a widespread technique in several industries, including mining, construction, and medicines. Here's a step-by-step instructions for conducting a sieve analysis:

Figure 3.6: Sieve shaking.

Sample Preparation:

- Get a representative sample of the material
- If required, dry the sample to ensure accurate readings
- Weigh the sample precisely and record the weight

Setup:

- Stack the sieves in order, beginning with the coarsest and progressing to the finest (with the pan)
- Place the entire stack on the sieve shaker

Figure 3.6: Sample with sieve

Sieving:

- Pour the sample through the top sieve
- Secure the stack to the sieve shaker and turn it on
- The shaking time varies, but it is usually between 10-15 minutes
- Make careful to follow any industry-specific rules or norms

Weighing:

- After shaking, carefully remove each sieve one at a time
- Weigh the particles left on each sieve and record the weight
- To avoid cross-contamination, make sure to wipe the sieves thoroughly before weighing

Calculation:

- Calculate the percentage of total sample weight retained by each sieve
- Use this formula:

$$Parcentage\ retained = \left(\frac{weight\ retained\ on\ sieve}{total\ sample\ weight}\right) \times 100$$

- Calculate the cumulative percentage passing through each sieve

Analyzing Data:

- Plot the cumulative % passing versus the sieve size to get the particle size distribution curve
- Examine the distribution to ascertain the material's gradation and other pertinent properties

3.6.2 Wash Sieve Analysis

- Sample Preparation: In accordance with standard procedure, a representative sample of the material is obtained and appropriately prepared. Depending on the needs, the sample may need to be dried by air or in an oven to get rid of moisture.

Figure 3-5: Wash sieve analysis

- Sieve Setup: Typically, a coarse sieve is placed at the top of the stack and a fine sieve is placed at the bottom, with a sequence of sieves with progressively finer mesh sizes organized in a stack. A catch pan or receiver is positioned at the bottom to collect the material that passes through the finest sieve, and the sieves are firmly piled on top of one another.

- Method of Sieving: To aid in the separation of particles according to size, the prepared sample is stacked on the top sieve and agitated manually or in a mechanical sieve shaker. Until no more material passes through the sieves, the sieving operation is continued for the predetermined amount of time.
- Wash Procedure: The material retained on each sieve is carefully removed once the sieving operation is finished, and water is used to wash away any fines that may have adhered to the bigger particles. Usually, this is accomplished by slowly stirring the material in a container or sieve nest while misting it with water. If there are any suspended particulates, the wash water can be filtered through a fine mesh sieve.
- Drying and Weighing: After being cleaned, the material is dried typically in an oven set at a particular temperature to eliminate any remaining moisture from each sieve. To ascertain the mass of particles inside each size fraction, the material remaining on each sieve is meticulously weighed upon drying.
- Data analysis: The cumulative particle size distribution, or sieve analysis curve, is computed using the mass of material retained on each sieve, the original sample mass, and the sieve sizes. For a variety of engineering and construction applications, this information aids in characterizing the material's gradation and particle size distribution.

3.6.3 Hydrometer Analysis

- Sample Preparation: In accordance with conventional protocols, a representative soil sample is gathered and appropriately prepared. This could involve removing any organic material or waste, grinding, and air-drying.

Figure 3-6: Hydrometer analysis

- Suspension Preparation: To create a suspension with a particular solids-to-water ratio, a known mass of the prepared soil sample is combined with water. After that, the suspension is well mixed to guarantee that the soil particles are distributed evenly throughout the water.
- Hydrometer Setup: A hydrometer is a specialist tool used to gauge the density of liquids. It is gently dropped into the suspension. The specific gravity or density of the suspension at different depths can be measured using a calibrated hydrometer.
- Settling Process: The suspension is left to settle for a fixed amount of time, usually between forty and forty-eight hours. In this period, the size and density of the soil particles settle out of suspension; larger and denser particles settle more quickly than smaller and lighter ones.
- Density Measurements: Using a hydrometer, density readings are recorded at various suspension depths at regular intervals during the settling phase. The sedimentation curve can be calculated using the hydrometer measurements, which also reveal information about the rate at which particles settle.
- Data analysis: A sedimentation curve, also known as a particle size distribution curve, is created using the hydrometer values, settling time, and suspension characteristics. As a function of settling time or suspension depth, this curve displays the proportion of soil particles smaller than a certain size.

3.7 Liquid Limit by Casagrande

The liquid limit test is a basic geotechnical engineering process that was created by Arthur Casagrande in the 1930s to determine the moisture content at which a fine-grained soil changes from a plastic to a liquid condition. The inability of the soil to flow and keep a groove under conventional mechanical manipulation is what distinguishes this transition. The following actions are part of the Casagrande method:

Sample preparation: involves gathering and air-drying a representative soil sample. After that, the sample is ground up to get rid of any aggregates, and it is sieved to guarantee consistency and get rid of large particles. Mixing: To make a paste with different moisture contents, water is progressively added to the ground soil. This paste is completely blended to provide a uniform, homogenous texture. Test Setup: Get the conventional liquid limit apparatus ready, usually consisting of a Casagrande cup and grooving tools. After adding the soil paste to the cup, a grooving tool is used to create a groove across the diameter of the cup. Mechanical Manipulation: To force the soil paste to flow and seal the groove, the cup is repeatedly raised and lowered onto a hard surface.

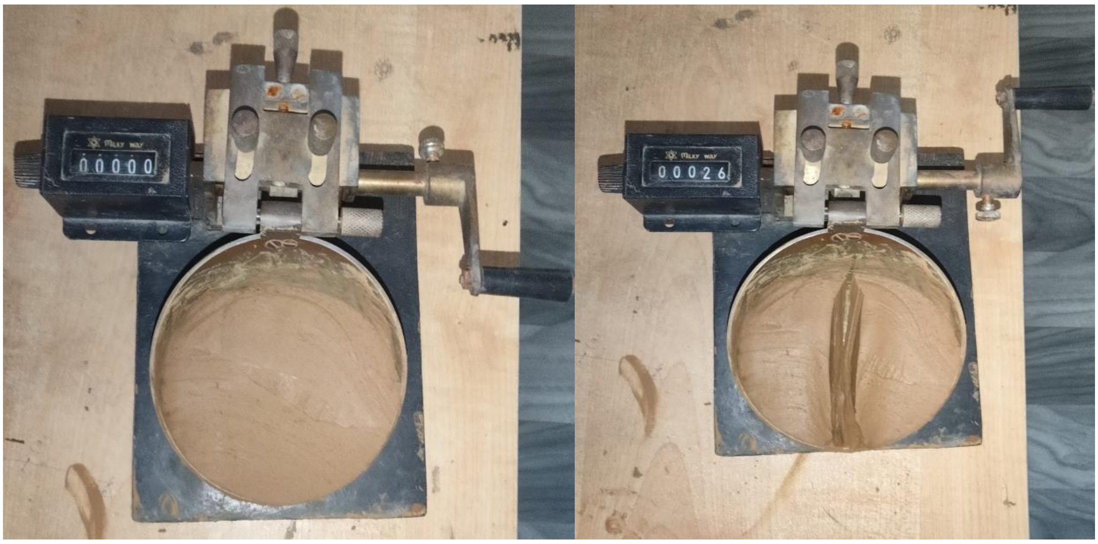


Figure 3-7: Liquid limit by Casagrande method

It is noted how many strikes are needed to close the groove over a given distance, usually 12.7 mm. Liquid Limit Determination: A standardized calibration curve or table is used to find the moisture content that corresponds to the number of blows. The soil's liquid limit is represented by this moisture content.

3.8 Plastic Limit by Hand Rolling Method

In geotechnical engineering, the plastic limit is a crucial metric that is used to assess the degree of plasticity in fine-grained soils, especially clays. The moisture level at which a soil changes from a plastic to a semi-solid condition is known as the plastic limit. The hand rolling method is a widely used technique for figuring out the plastic limit. It is a straightforward process that may be carried out in a lab or on the job. An outline of the process is provided below:

Sample Preparation: Take a representative soil sample from the location to start. The sample needs to be cleared of any large aggregates or debris and allowed to air dry. Subsequently, reduce the size of the soil sample and strain it through a 425-micron screen to eliminate large particles.

Mixing: Using your hands, thoroughly knead the soil sample until it achieves a consistency that allows it to be molded without disintegrating or clinging to your hands too much. Then, gradually add water to the soil sample. In order to guarantee even moisture distribution throughout the soil sample, this step is essential.

Rolling: On a non-absorbent surface (such a glass plate or smooth countertop), take a part of the moist soil sample and roll it between your palms to form a thread-like shape that is about 3 mm (or 1/8 inch) in diameter and 3 inches (or 75 mm) in length.

Figure 3-8 Hand Rolling for plastic limit

Testing: Keep rolling more soil sample until it gets harder and harder to make threads without breaking them. The soil sample's moisture content should now be noted because it indicates the plastic limit.

Repeat: To guarantee precision and dependability of the outcomes, repeat the rolling procedure with extra soil samples. After taking several measurements, figure out the soil's average plastic limit.

Reporting: When the hand-rolled threads start to show indications of breaking and crumbling, report the plastic limit as the moisture content that corresponds to that stage. Usually, a percentage is used to represent this amount.

3.9 Cone Penetration Method: Followed Similar Process both LL and PL

In geotechnical engineering, the Cone Penetration Test and the assessment of the liquid limit (LL) and plastic limit (PL) are separate processes that are employed for different objectives. They are essentially different tests with distinct procedures and goals, even though they could have some equipment and testing concepts in common.

Below is a quick synopsis of each technique:

3.9.1 Cone Penetration Test:

Figure 3-9: Sample of soil void and level check

Figure 3-10: Sample of soil leveled with can height

Figure 3-11: Testing with cone penetrometer

The Cone Penetration Test is a popular in-situ testing technique used to assess the strength, stiffness, and stratigraphy of soil. It entails measuring the resistance encountered while continuously inserting a cone-shaped penetrometer into the earth.

Procedure: Using hydraulic or mechanical equipment, a penetrometer with a cone-shaped tip is pushed into the ground at a steady rate during the test. Cone resistance (qc) and sleeve friction (fs) data are continually recorded as the cone progresses. Geotechnical characteristics like shear strength and relative density, as well as soil attributes like consistency and type, are interpreted using these measurements.

Tests for Plastic Limit (PL) and Liquid Limit (LL):

The purpose of the plastic limit and liquid limit tests is to ascertain the water content at which a soil changes from a plastic to a semi-solid state (plastic limit) and from a plastic to a liquid state (liquid limit), respectively. These are laboratory tests. The consistency and plasticity of fine-grained soils must be evaluated using these tests. Procedure: The plastic limit test entails rolling a soil sample into threads of a certain size until it crumbles, whereas the liquid limit test usually entails repeatedly striking a soil sample with a standardized cup on a standardized groove until the soil changes from a plastic to a liquid state. The liquid limit and plastic limit, respectively, refer to the moisture content at which these transformations take place and are determined and reported.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 General

This important section presents the results of our exhaustive experimentation and analysis, which is the pinnacle of our research. Following a path of empirical investigation and theoretical analysis, conclusions have emerged that hold the potential to provide important new light on the topic at hand.

4.2 Specific Gravity

The Specific gravity has been calculated for the collected sample. Calculations are shown down below.

4.2.1 Specific Gravity for JU (Geology Department) Soil Sample

The calculation shows the specific gravity for the sample from JU (geology department).

Weight of Pycnometer = 112 g

Weight of Pycnometer + soil =162 g

Pycnometer + soil + water = 385g (W_1)

Pycnometer + water = 356 g(W_2)

Weight of soil = 50 g (W_s)

G_s (at 29°C) = $\frac{\boldsymbol{W_s}}{\boldsymbol{W_s - W_1 + W_2}} = \frac{\mathbf{50}}{\mathbf{50-385+356}} = 2.5$

G_s (at 20°c) = G_s (at T°c) X $\frac{\boldsymbol{G_w}\ \textbf{(at Tc)}}{\boldsymbol{G_w}\ \textbf{(at 20°C)}}$

$= G_s \text{ (at 29°c) } \frac{Gw\ (at\ 29°c)}{\text{Gw (at 20°c)}}$

$= 2.5\text{X}\ \frac{0.9960}{0.9982}$

=2.5

4.2.2 Specific Gravity for JU (Shapla Chattor) Soil Sample

This sample is from the JU (Shapla Chattor) the specific gravity has been determined of it.

Weight of Pycnometer. = 112 g

Weight of Pycnometer + soil = 162 g

Weight of Pycnometer + soil + water = 385g (W_1)

Weight of Pycnometer + water = 355 g(w_2)

wt. of soil 50 g (w_s)

Gs (at 29℃)= $\frac{W_s}{W_s-W_1+W_2}$= $\frac{50}{50-385+355}$ = 2.5

Gs (at 20°c) = Gs (at T°c) X $\frac{G_w\ (\text{at Tc})}{G_w\ (\text{at 20°C})}$

= Gs (at 29°c) $\times \frac{G_w\ (at\ 30°c)}{G_w\ (\text{at } 20°c)}$

= 2.5X $\frac{0.9960}{0.9982}$

=2.5

4.2.3 Specific Gravity for Uptown (Ashulia) Soil Sample

This specific gravity calculation shows the specific gravity value for Uptown (Ashulia).

Weight of Pycnometer = 111 g

Weight of Pycnometer + soil =161 g

Weight of Pycnometer + soil + water = 387g (W_1)

Weight of Pycnometer + water = 355 g(w_2)

wt. of soil 50 g (w_s)

Gs (at 30℃) = $\frac{W_s}{W_s-W_1+W_2}$= $\frac{50}{50-387+355}$ = 2.77

Gs (at 20°c) = Gs (at T°c) X $\frac{G_w\ (\text{at Tc})}{G_w\ (\text{at 20°C})}$

= Gs (at 30°c) $\times \frac{G_w\ (at\ 30°c)}{G_w\ (\text{at } 20°c)}$

$$= 2.77 \times \frac{0.9957}{0.9982}$$

$$=2.76$$

4.2.4 Specific Gravity for Barobazar (Ashulia) Soil Sample

Specific gravity has been determined for the sample from Barobazar (Ashulia)

Weight of Pycnometer = 112 g

Weight of Pycnometer + soil = 162 g

Weight of Pycnometer + soil + water = 387g (W_1)

Weight of Pycnometer + water = 354 g(w_2)

wt. of soil 50 g (w_s)

Gs (at 30°C)= $\frac{W_s}{W_s - W_1 + W_2} = \frac{50}{50-387+354} = 2.9$

Gs (at 20°c) = Gs (at T°c) X $\frac{G_w \text{ (at Tc)}}{G_w \text{ (at 20°C)}}$

$$= \text{Gs (at 30°c)} \times \frac{G_w\ (at\ 30°c)}{G_w \text{ (at 20°c)}}$$

$$= 2.9 \times \frac{0.9957}{0.9982}$$

$$=2.89$$

4.2.5 Specific Gravity for Chapai Nawabganj Soil Sample

This sample is from Chapai Nawabganj and the specific gravity has been determined for it.

Weight of Pycnometer = 112 g

Weight of Pycnometer + soil = 162 g

Weight of Pycnometer + soil + water = 386g (W_1)

Weight of Pycnometer + water = 355 g(w_2)

wt. of soil 50 g (w_s)

Gs (at 30°C)= $\frac{\boldsymbol{W_s}}{\boldsymbol{W_s - W_1 + W_2}}$= $\frac{\mathbf{50}}{\mathbf{50-386+355}}$ = 2.63

Gs (at 20°c) = Gs (at T°c) X $\frac{\boldsymbol{G_w}\ \textbf{(at Tc)}}{\boldsymbol{G_w}\ \textbf{(at 20°C)}}$

= Gs (at 30°c) $\times \frac{G_w\ (at\ 30°c)}{G_w\ (\text{at } 20°\text{c})}$

= 2.63 X $\frac{0.9957}{0.9982}$

=2.62

4.2.6 Specific Gravity for BUET Campus Soil Sample

This sample has been collected from BUET to test and its specific gravity has been determined here.

Weight of Pycnometer = 111 g

Weight of Pycnometer + soil = 161 g

Weight of Pycnometer + soil + water = 386g (W_1)

Weight of Pycnometer + water = 355 g(w_2)

wt. of soil 50 g (w_s)

Gs (at 30°C) = $\frac{\boldsymbol{W_s}}{\boldsymbol{W_s - W_1 + W_2}}$= $\frac{\mathbf{50}}{\mathbf{50-386+355}}$ = 2.63

Gs (at 20°c) = Gs (at T°c) $\times \frac{\boldsymbol{G_w}\ \textbf{(at Tc)}}{\boldsymbol{G_w}\ \textbf{(at 20°C)}}$

= Gs (at 30°c) $\times \frac{G_w\ (at\ 30°c)}{G_w\ (\text{at } 20°\text{c})}$

= 2.63 X $\frac{0.9957}{0.9982}$

=2.62

4.3 Wash Sieve Analysis

Wash sieve analysis has been done for each sample. here are the tables of results for the sample down below.

Table 4-1: Wash sieve data for JU (Geology department) soil sample

Sieve no	Opening (mm)	Sieve wt.(gm)	Sieve +soil wt.(gm)	Wt. of soil retrained	Percent of retrained	Cumulative percent retrained	Percent finer
1	2	3	4	5	6	7	8
4	4.75	401	403	2	9.52	9.52	90.48
8	2.36	293	293	0	0	9.52	90.48
16	1.18	289	290	1	4.76	14.28	85.72
30	0.60	298	299	1	4.76	19.04	80.96
50	0.297	295	307	12	57.14	76.18	23.82
100	0.149	250	254	4	19.04	95.22	4.78
200	0.075	305	306	1	4.76	99.98	0.02
pan		305	305	0	0	99.98	100
total				=21			

Table 4-2: Wash sieve data for JU (Shapla Chattor) soil sample

Sieve no	**Opening (mm)**	**Sieve wt.(gm)**	**Sieve +soil wt.(gm)**	**Wt. of soil retrained**	**Percent of retrained**	**Cumulative percent retrained**	**Percent finer**
1	2	3	4	5	6	7	8
4	4.75	401	403	2	8.69	8.69	91.31
8	2.36	293	293	0	0	8.69	91.31
16	1.18	289	290	1	4.34	13.03	86.97
30	0.60	298	299	1	4.34	17.37	82.63
50	0.297	295	308	13	56.52	73.89	26.11
100	0.149	250	255	5	21.74	95.63	4.37
200	0.075	305	306	1	4.34	99.97	0.03
pan		305	305	0	0	99.97	0.03
total				=23			

Table 4-3: Wash sieve data for Barobazar (Ashulia) soil sample

Sieve no	Opening (mm)	Sieve wt.(gm)	Sieve +soil wt.(gm)	Wt. of soil retrained	Percent of retrained	Cumulative percent retrained	Percent finer
1	2	3	4	5	6	7	8
4	4.75	401	401	0	0	0	100
8	2.36	293	293	0	0	0	100
16	1.18	289	290	1	4	4	96
30	0.60	298	298	0	0	0	100
50	0.297	295	308	13	52	52	48
100	0.149	250	260	10	40	92	8
200	0.075	305	306	1	4	96	4
pan		305	305	0	0	96	4
total				=25			

Table 4-4: Wash sieve data for Uptown (Ashulia) soil sample

Sieve no	Opening (mm)	Sieve wt.(gm)	Sieve +soil wt.(gm)	Wt. of soil retrained	Percent of retrained	Cumulative percent retrained	Percent finer
1	2	3	4	5	6	7	8
4	4.75	401	401	0	0	0	100
8	2.36	293	293	0	0	0	100
16	1.18	289	289	0	0	0	100
30	0.60	298	298	0	0	0	100
50	0.297	295	306	11	64.70	64.70	35.3
100	0.149	250	255	5	29.41	94.11	5.89
200	0.075	305	306	1	5.88	99.99	0.01
pan		305	305	0	0	99.99	0.01
total				=17			

Table 4-5: Wash sieve data for Chapai Nawabganj soil sample

Sieve no	**Opening (mm)**	**Sieve wt.(gm)**	**Sieve +soil wt.(gm)**	**Wt. of soil retrained**	**Percent of retrained**	**Cumulative percent retrained**	**Percent finer**
1	2	3	4	5	6	7	8
4	4.75	401	401	0	0	0	100
8	2.36	293	293	0	0	0	100
16	1.18	289	289	0	0	0	100
30	0.60	298	298	0	0	0	100
50	0.297	295	305	10	62.5	62.5	37.5
100	0.149	250	254	4	25	87.5	12.5
200	0.075	305	306	1	6.25	93.75	6.25
pan		305	306	1	6.25	100	0
total				=16			

Table 4-6: Wash sieve data for BUET Campus soil sample

Sieve no	**Opening (mm)**	**Sieve wt.(gm)**	**Sieve +soil wt.(gm)**	**Wt. of soil retrained**	**Percent of retrained**	**Cumulative percent retrained**	**Percent finer**
1	2	3	4	5	6	7	8
4	4.75	401	401	0	0	0	100
8	2.36	293	293	0	0	0	100
16	1.18	289	289	0	0	0	100
30	0.60	298	298	0	0	0	100
50	0.297	295	307	12	66.67	66.67	37.5
100	0.149	250	254	4	22.22	88.89	12.5
200	0.075	305	306	1	5.56	94.45	6.25
pan		305	306	1	5.56	100.01	0
total				=18			

4.4 Hydrometer Analysis

Hydrometer Analysis are shown down below for each sample. Test time about 48hr (2880 min) for each sample.

Table 4-7: Hydrometer Analysis for JU (Geology department) soil sample

Date	Clock time	Elapsed time (min)	Temp C	Observed Hydrometer reading Ra	Hyd. Corr. Only for meniscus RL	Effective depth L cm	Unit wt. of water γw	Viscosity of water η poise	Grain diameter D mm	Temp correc-tion CT	Corrected Hyd. Reading RC	% Finer (% of portion finer than #200 sieve only) N	% Finer (combined) N'
1	2	3	4	5	6	7	8	9	10	11	12	13	14
31.04.24	25s	0.416	29	21	21	12.8	0.9960	0.00818	0.0717	+3.05	21.05	41.3	0.083
31.04.24	50s	0.83	29	20	20	13.01	0.9960	0.00818	0.0512	+3.05	20.05	37.2	0.074
31.04.24	1:01PM	1	29	18	18	13.3	0.9960	0.00818	0.0247	+3.05	18.05	37.2	0.074
31.04.24	1:02PM	2	29	16	16	13.7	0.9960	0.00818	0.0338	+3.05	16.05	35.1	0.070
31.04.24	1:04PM	4	29	15	15	13.8	0.9960	0.00818	0.0240	+3.05	15.05	31	0.062
31.04.24	1:08PM	8	29	14	14	13.9	0.9960	0.00818	0.0170	+3.05	14.05	28.9	0.058
31.04.24	1:16PM	16	29	12	12	14.3	0.9960	0.00818	0.0122	+3.05	12.05	24.8	0.050
31.04.24	1:32PM	32	29	11	11	14.5	0.9960	0.00818	0.0087	+3.05	11.05	22.7	0.045
31.04.24	2PM	60	29	9	9	14.8	0.9960	0.00818	0.0064	+3.05	9.05	20.7	0.041
31.04.24	3PM	120	29	7	7	15.1	0.9960	0.00818	0.0046	+3.05	7.05	20.7	0.041
31.04.24	5PM	240	29	6.5	6.5	15.2	0.9960	0.00818	0.0032	+3.05	6.55	18.6	0.037
01.04.24	1:01PM	1440	29	6	6	15.3	0.9960	0.00818	0.0013	+3.05	6.05	16.6	0.033
02.04.24	1:01PM	2880	29	6	6	15.3	0.9960	0.00818	0.0009	+3.05	6.05	16.6	0.033

Table 4-8: Hydrometer Analysis for JU (Shapla Chattor) soil sample

Date	Clock time	Elapsed time (min)	Temp C	Observed Hydrometer reading R_a	Hyd. Corr. Only for meniscus R_L	Effective depth L cm	Unit wt. of water γw	Viscosity of water η poise	Grain diameter D mm	Temp correction C_T	Corrected Hyd. Reading R_C	% Finer (% of portion finer than #200 sieve only) N	% Finer (combined) N'
1	2	3	4	5	6	7	8	9	10	11	12	13	14
31.04.24	25s	0.416	29	20	20	13	0.9960	0.00818	0.0723	+3.05	20.05	43.3	0.072
31.04.24	50s	0.83	29	18	18	13.3	0.9960	0.00818	0.0518	+3.05	18.05	41.3	0.069
31.04.24	1:01PM	1	29	18	18	13.3	0.9960	0.00818	0.0472	+3.05	18.05	37.2	0.062
31.04.24	1:02PM	2	29	17	17	13.5	0.9960	0.00818	0.0336	+3.05	17.05	33	0.055
31.04.24	1:04PM	4	29	15	15	13.8	0.9960	0.00818	0.0240	+3.05	15.05	31	0.052
31.04.24	1:08PM	8	29	14	14	13.9	0.9960	0.00818	0.0170	+3.05	14.05	28.9	0.048
31.04.24	1:16PM	16	29	12	12	14.3	0.9960	0.00818	0.0122	+3.05	12.05	24.8	0.041
31.04.24	1:32PM	32	29	11	11	14.5	0.9960	0.00818	0.0087	+3.05	11.05	22.7	0.038
31.04.24	2PM	60	29	10	10	14.6	0.9960	0.00818	0.0064	+3.05	10.05	18.6	0.031
31.04.24	3PM	120	29	10	10	14.6	0.9960	0.00818	0.0045	+3.05	10.05	14.5	0.024
31.04.24	5PM	240	29	9	9	14.8	0.9960	0.00818	0.0032	+3.05	9.05	13.5	0.023
01.04.24	1:01PM	1440	29	8	8	14.9	0.9960	0.00818	0.0013	+3.05	8.05	12.4	0.021
02.04.24	1:01PM	2880	29	8	8	14.9	0.9960	0.00818	0.0009	+3.05	8.05	12.4	0.021

Table 4-9: Hydrometer Analysis for Barobazar (Ashulia) soil sample

Date	**Clock time**	**Elapsed time (min)**	**Temp C**	**Observed Hydrometer reading Ra**	**Hyd. Corr. Only for meniscus RL**	**Effective depth L cm**	**Unit wt. of water γw**	**Viscosity of water η poise**	**Grain diameter D mm**	**Temp correction CT**	**Corrected Hyd. Reading RC**	**% Finer (% of portion finer than #200 sieve only) N**	**% Finer (combined) N’**
1	2	3	4	5	6	7	8	9	10	11	12	13	14
04.04.24	25s	0.416	30	16	16	13.7	0.9957	0.008	0.0654	+3.80	16.8	31.92	0.045
04.04.24	50s	0.83	30	15	15	13.8	0.9957	0.008	0.0465	+3.80	15.8	30.02	0.043
04.04.24	11:01AM	1	30	13	13	14.1	0.9957	0.008	0.0428	+3.80	13.8	26.22	0.037
04.04.24	11:02AM	2	30	13	13	14.1	0.9957	0.008	0.0302	+3.80	13.8	26.22	0.037
04.04.24	11:04AM	4	30	13	13	14.1	0.9957	0.008	0.0214	+3.80	13.8	26.22	0.037
04.04.24	11:08AM	8	30	10.5	10.5	14.5	0.9957	0.008	0.0153	+3.80	11.3	21.47	0.030
04.04.24	11:16AM	16	30	10	10	14.6	0.9957	0.008	0.0108	+3.80	10.8	20.52	0.029
04.04.24	11:32AM	32	30	10	10	14.6	0.9957	0.008	0.0077	+3.80	10.8	20.52	0.029
04.04.24	12PM	60	30	9	9	14.8	0.9957	0.008	0.0056	+3.80	9.8	18.62	0.026
04.04.24	1PM	120	30	7	7	15.1	0.9957	0.008	0.0040	+3.80	7.8	14.82	0.021
04.04.24	3PM	240	30	6.5	6.5	15.2	0.9957	0.008	0.0028	+3.80	7.3	13.87	0.020
05.04.24	11:01AM	1440	30	6	6	15.3	0.9957	0.008	0.0011	+3.80	6.8	12.92	0.018
06.04.24	11:01AM	2880	30	6	6	15.3	0.9957	0.008	0.0008	+3.80	6.8	12.92	0.018

Table 4-10: Hydrometer Analysis for Uptown (Ashulia) soil sample

Date	Clock time	Elapsed time (min)	Temp C	Observed Hydrometer reading R_a	Hyd. Corr. Only for meniscus R_L	Effective depth L cm	Unit wt. of water γw	Viscosity of water η poise	Grain diameter D mm	Temp correction C_T	Corrected Hyd. Reading R_C	% Finer (% of portion finer than #200 sieve only) N	% Finer (combined) N’
1	2	3	4	5	6	7	8	9	10	11	12	13	14
04.04.24	25s	0.416	30	17	17	13.5	0.9957	0.008	0.0673	+3.80	17.8	35.24	0.039
04.04.24	50s	0.83	30	16	16	13.7	0.9957	0.008	0.0480	+3.80	16.8	33.26	0.037
04.04.24	12:01PM	1	30	15	15	13.8	0.9957	0.008	0.0438	+3.80	15.8	31.28	0.035
04.04.24	12:02PM	2	30	15	15	13.8	0.9957	0.008	0.0310	+3.80	15.8	31.28	0.035
04.04.24	12:04PM	4	30	13	13	14.1	0.9957	0.008	0.0221	+3.80	13.8	27.32	0.030
04.04.24	12:08PM	8	30	12.5	12.5	14.2	0.9957	0.008	0.0157	+3.80	13.3	26.33	0.029
04.04.24	12:16PM	16	30	10.5	10.5	14.6	0.9957	0.008	0.0112	+3.80	11.3	22.37	0.025
04.04.24	12:32PM	32	30	9	9	14.8	0.9957	0.008	0.0080	+3.80	9.8	19.4	0.022
04.04.24	1PM	60	30	8.5	8.5	14.9	0.9957	0.008	0.0058	+3.80	9.3	18.41	0.020
04.04.24	2PM	120	30	5.5	5.5	15.3	0.9957	0.008	0.0042	+3.80	6.3	12.47	0.014
04.04.24	4PM	240	30	5	5	15.4	0.9957	0.008	0.0029	+3.80	5.8	11.48	0.013
05.04.24	12:01PM	1440	30	4	4	15.6	0.9957	0.008	0.0012	+3.80	4.8	9.5	0.011
06.04.24	12:01PM	2880	30	4	4	15.6	0.9957	0.008	0.0008	+3.80	4.8	9.5	0.011

Table 4-11: Hydrometer Analysis for Chapai Nawabganj soil sample

Date	Clock time	Elapsed time (min)	Temp C	Observed Hydrometer reading R_a	Hyd. Corr. Only for meniscus R_L	Effective depth L cm	Unit wt. of water γ_w	Viscosity of water η poise	Grain diameter D mm	Temp correction C_T	Corrected Hyd. Reading R_C	% Finer (% of portion finer than #200 sieve only) N	% Finer (combined) N'
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
30.04.24	25s	0.416	30	13	13	14.1	0.9957	0.008	0.0717	+3.80	13.8	27.87	0.037
30.04.24	50s	0.83	30	12	12	14.3	0.9957	0.008	0.0511	+3.80	12.8	25.85	0.035
30.04.24	10:01AM	1	30	12	12	14.3	0.9957	0.008	0.0465	+3.80	12.8	25.85	0.035
30.04.24	10:02AM	2	30	12	12	14.3	0.9957	0.008	0.0329	+3.80	12.8	25.85	0.035
30.04.24	10:04AM	4	30	11.5	11.5	14.4	0.9957	0.008	0.0233	+3.80	12.3	24.84	0.033
30.04.24	10:08AM	8	30	10.5	10.5	14.5	0.9957	0.008	0.0165	+3.80	11.3	22.82	0.031
30.04.24	10:16AM	16	30	10	10	14.6	0.9957	0.008	0.0117	+3.80	10.8	21.81	0.029
30.04.24	10:32AM	32	30	9	9	14.8	0.9957	0.008	0.0083	+3.80	9.8	19.79	0.027
30.04.24	11:01AM	60`	30	7	7	15.1	0.9957	0.008	0.0061	+3.80	7.8	15.75	0.021
30.04.24	12PM	120	30	5	5	15.4	0.9957	0.008	0.0044	+3.80	5.8	11.71	0.016
30.04.24	2PM	240	30	4	4	15.6	0.9957	0.008	0.0031	+3.80	4.8	9.69	0.013
01.05.24	10:01AM	1440	30	3	3	15.7	0.9957	0.008	0.0012	+3.80	3.8	7.67	0.010
02.05.24	10:01AM	2880	30	3	3	15.7	0.9957	0.008	0.0009	+3.80	3.8	7.67	0.010

Table 4-12: Hydrometer Analysis for BUET Campus soil sample

Date	Clock time	Elapsed time (min)	Temp C	Observed Hydrometer reading R_a	Hyd. Corr. Only for meniscus R_L	Effective depth L cm	Unit wt. of water γ_w	Viscosity of water η poise	Grain diameter D mm	Temp correction C_T	Corrected Hyd. Reading R_C	% Finer (% of portion finer than #200 sieve only) N	% Finer (combined) N’
1	2	3	4	5	6	7	8	9	10	11	12	13	14
13.05.24	25s	0.416	30	16	16	13.7	0.9957	0.008	0.0706	+3.80	16.8	33.93	0.034
13.05.24	50s	0.83	30	12	12	14.3	0.9957	0.008	0.0511	+3.80	12.8	25.85	0.026
13.05.24	9:01AM	1	30	11	11	14.4	0.9957	0.008	0.0467	+3.80	11.8	23.83	0.024
13.05.24	9:02AM	2	30	10.5	10.5	14.5	0.9957	0.008	0.0331	+3.80	11.3	22.82	0.023
13.05.24	9:04AM	4	30	10	10	14.6	0.9957	0.008	0.0235	+3.80	10.8	21.81	0.022
13.05.24	9:08AM	8	30	10	10	14.6	0.9957	0.008	0.0166	+3.80	10.8	21.81	0.022
13.05.24	9:16AM	16	30	8	8	14.9	0.9957	0.008	0.0118	+3.80	8.8	17.77	0.018
13.05.24	9:32AM	32	30	5	5	15.4	0.9957	0.008	0.0085	+3.80	5.8	11.71	0.012
13.05.24	10:01AM	60	30	5	5	15.4	0.9957	0.008	0.0062	+3.80	5.8	11.71	0.012
13.05.24	11:01AM	120	30	3	3	15.8	0.9957	0.008	0.0044	+3.80	3.8	7.67	0.008
13.05.24	1PM	240	30	3	3	15.8	0.9957	0.008	0.0031	+3.80	3.8	7.67	0.008
13.05.24	5PM	480	30	3	3	15.8	0.9957	0.008	0.0022	+3.80	3.8	7.67	0.008
14.05.24	9:01AM	1440	30	2.5	2.5	15.9	0.9957	0.008	0.0013	+3.80	3.3	6.67	0.007
15.05.24	9:01AM	2880	30	2.5	2.5	15.9	0.9957	0.008	0.0009	+3.80	3.3	6.67	0.007

4.5 Hydrometer Analysis Graph

The comparison of Wash sieve analysis and Hydrometer analysis combined have been shown in semi-log graph for each sample.

4.5.1 Hydrometer Graph for JU (Geology Department) Soil Sample

The Hydrometer graph has been shown for the sample of JU (Geology Department)

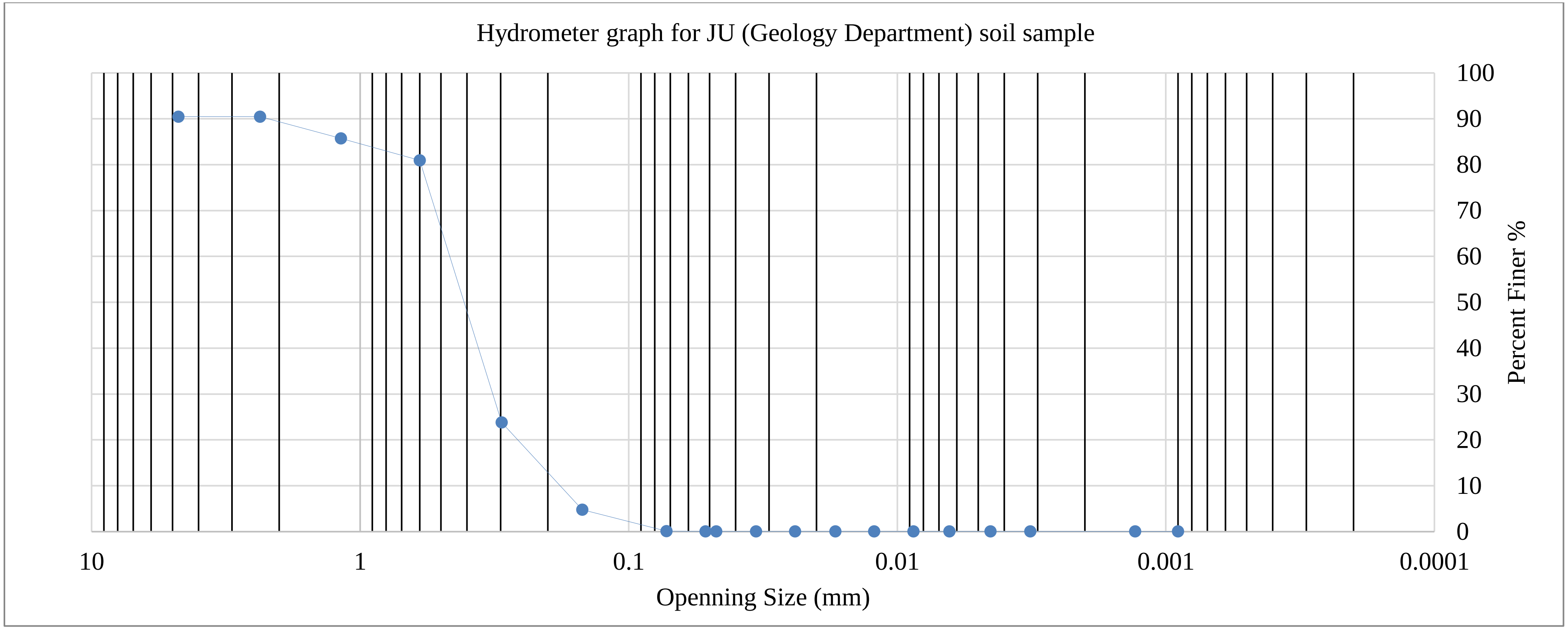


Figure 4-1: Hydrometer graph for JU (Geology Department) soil sample

4.5.2 Hydrometer Graph for JU (Shapla Chattor) Soil Sample

The graph has been shown for the sample of JU (Shapla Chattor)

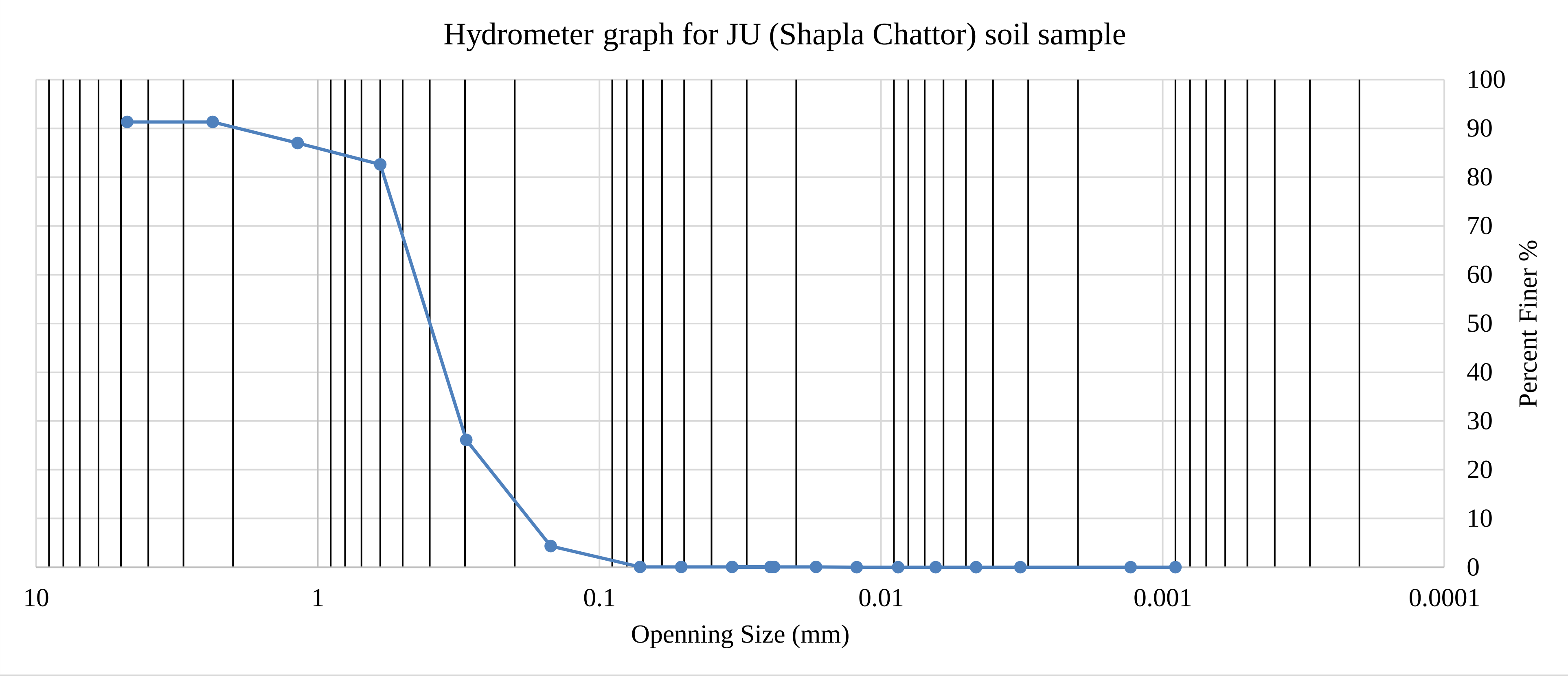


Figure 4-2: Hydrometer graph for JU (Shapla Chattor) soil sample

4.5.3 Hydrometer Graph for Barobazar (Ashulia) Soil Sample

The graph has been shown for the sample of Barobazar (Ashulia)

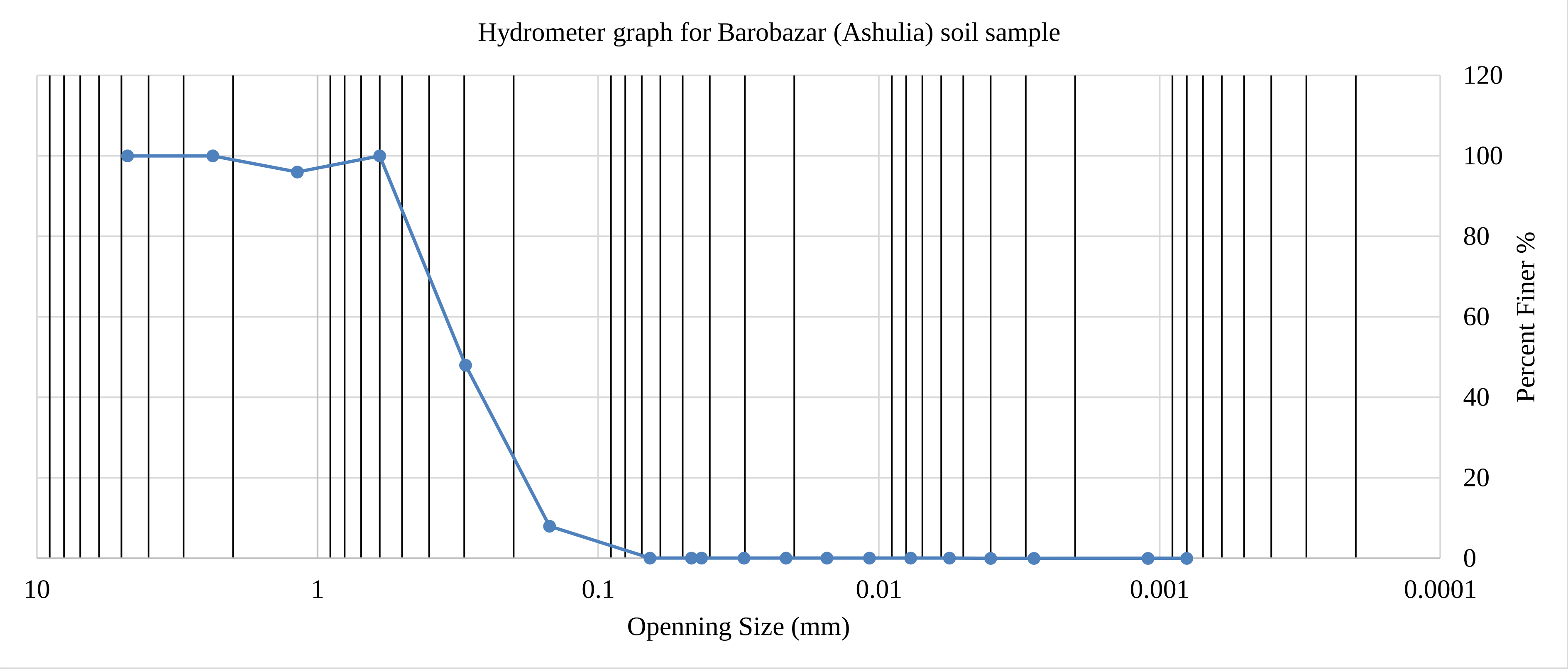


Figure 4-3: Hydrometer graph for Barobazar (Ashulia) soil sample

4.5.4 Hydrometer Graph for Uptown (Ashulia) SOIL SAMPLE

The graph has been shown for the sample of Uptown (Ashulia).

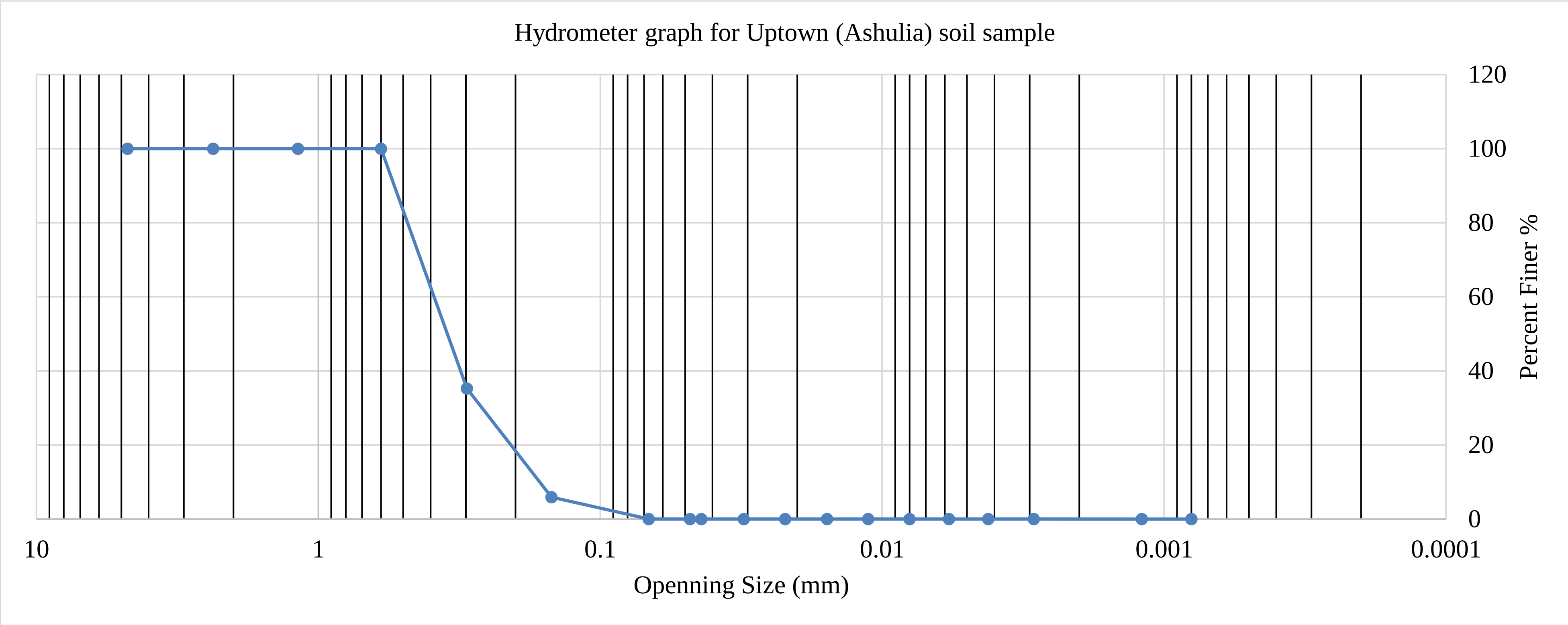


Figure 4-4: Hydrometer graph for Uptown (Ashulia) soil sample

4.5.5 Hydrometer Graph for Chapai Nawabgonj SOIL SAMPLE

The graph has been shown for the sample of Chapai Nawabganj.

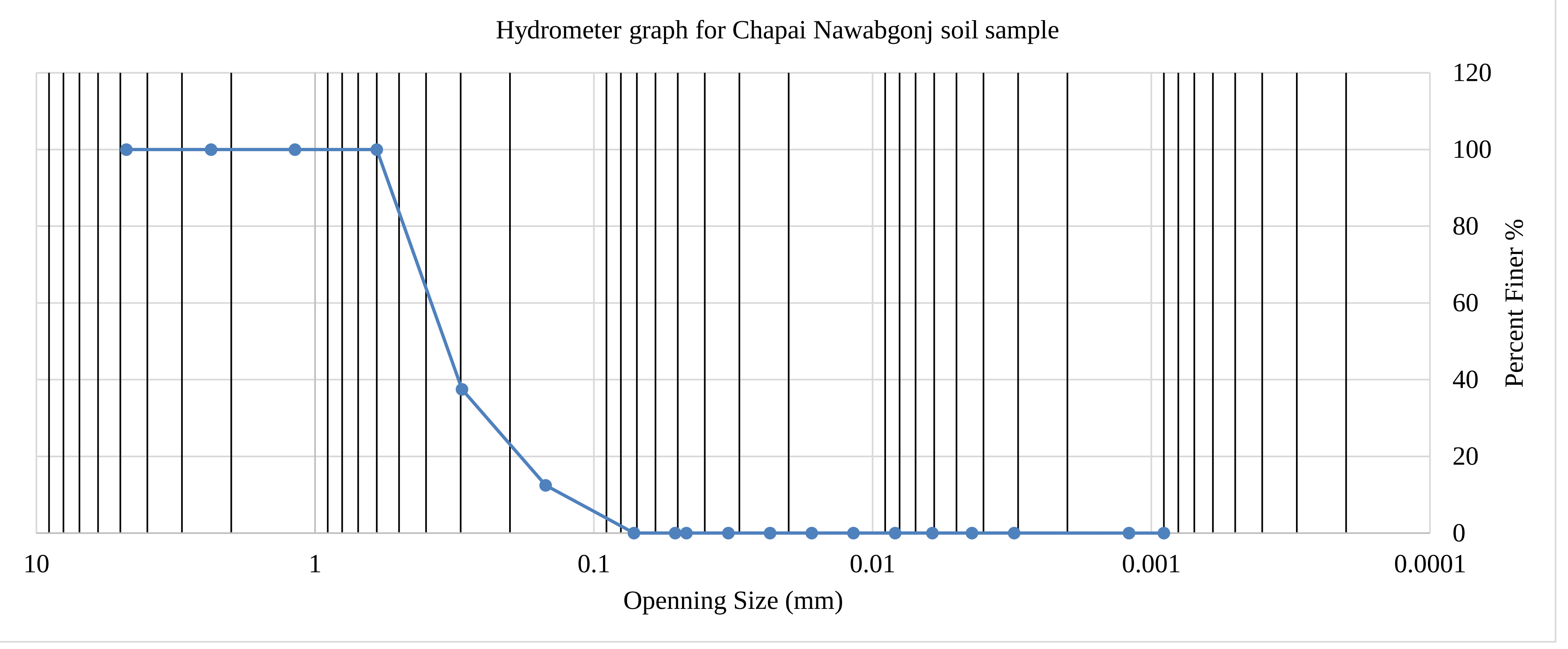


Figure 4-5: Hydrometer graph for Chapai Nawabgonj soil sample

4.5.6 Hydrometer Graph for BUET Campus Soil Sample

The graph has been shown for the sample of BUET Campus.

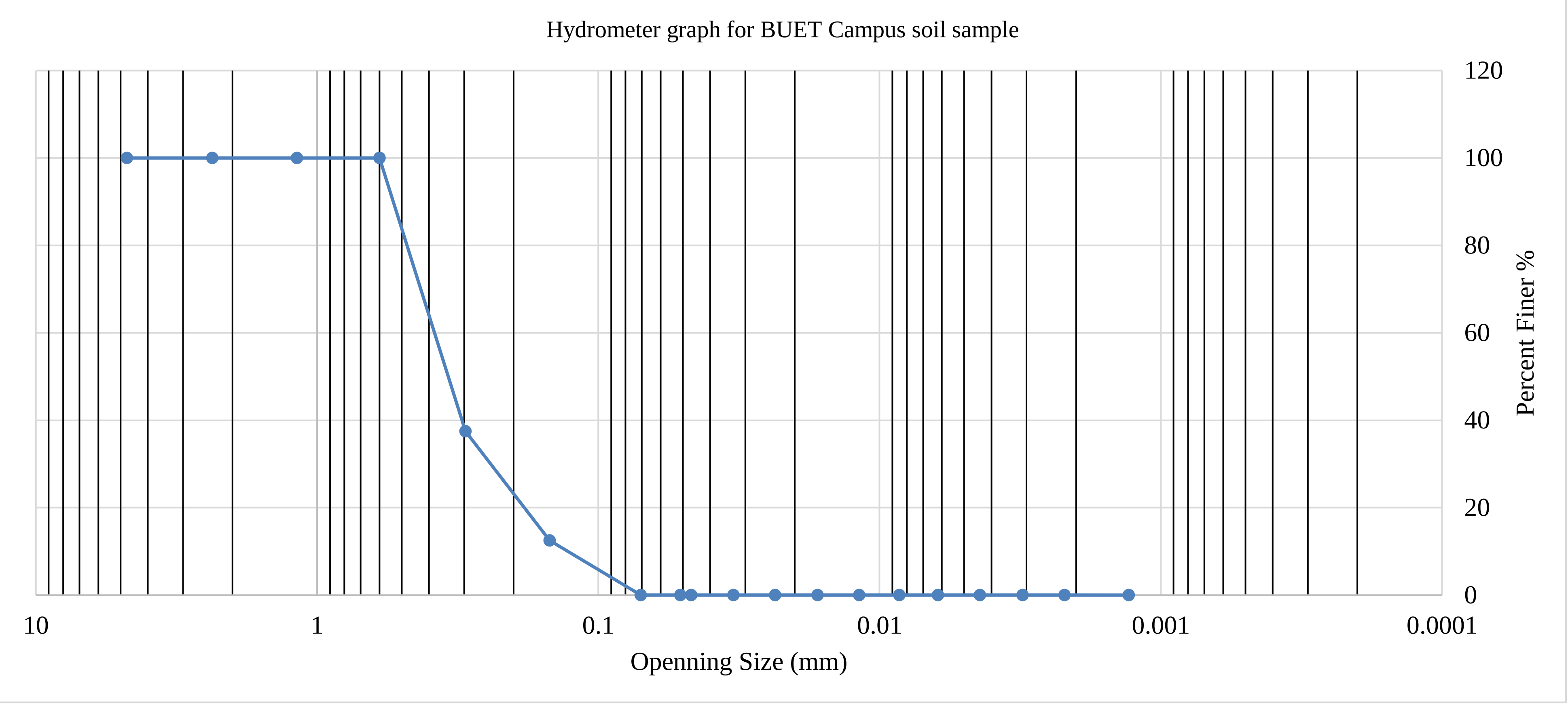


Figure 4-6: Hydrometer graph for BUET Campus soil sample

4.5.7 Combined Hydrometer Graph of Soil Sample

To compare all the sample together a combined graph has been made with all the values from above.

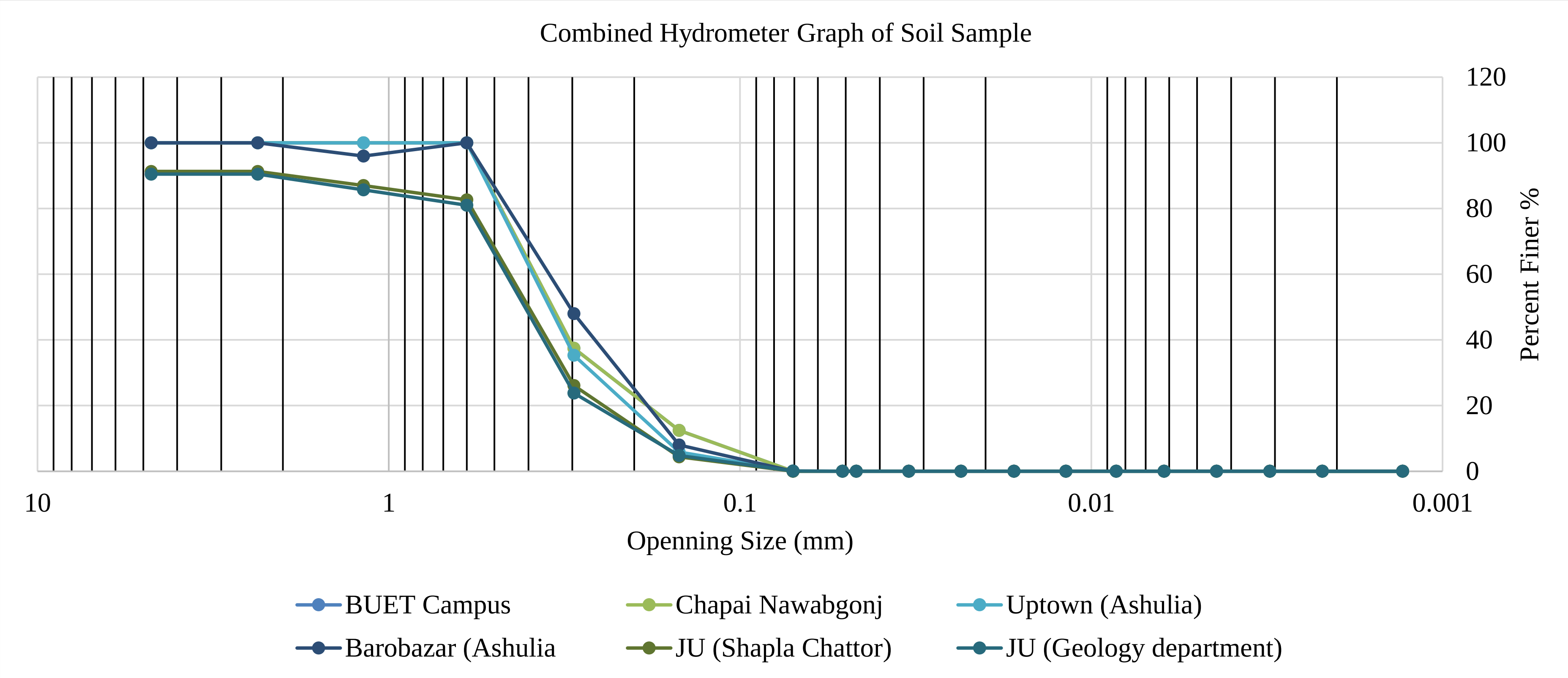


Figure 4-7: Combined hydrometer graph of soil sample

4.6 Percentage of Sand, Silt and Clay

4.6.1 General

Soils are made with three types of particle size. Namely, they are sand, silt, and clay. Usually, soil particles from 2.0 mm to 0.05 mm are sand. Soil particle sizes from 0.05 mm to 0.002mm are silt and particle sizes less than 0.002 mm are known as clay.

4.6.2 Percent of Sand, Silt and Clay for the Tested Samples

Here is the table of percent of sand, silt and clay for the samples for this test.

Table 4-13: Percent of sand, silt and clay

Soil Type	JU (Geology Department)	JU (Shapla Chattor)	Barobazar (Ashulia)	Uptown (Ashulia)	Chapai Nawabgonj	BUET
Sand	47.16	45.49	56.16	56.69	65.83	67.40
Silt	40.02	37.18	30.43	33.07	25.75	25.21
Clay	12.82	17.33	13.41	10.24	8.42	7.39

4.7 Liquid Limit by Casagrande Method

At this point the graph of liquid limit using Casagrande method has been shown for each sample.

4.7.1 JU (Geology Department)

This is the liquid limit graph for JU (Geology Department)

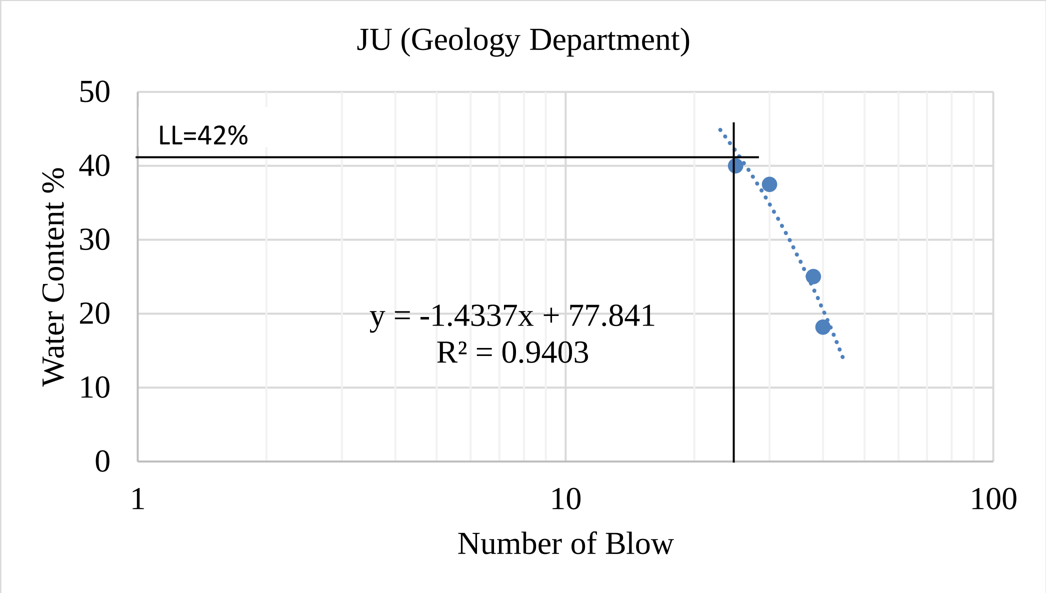


Figure 4-8: Graph of liquid limit by Casagrande method for JU (Geology Department)

4.7.2 JU (Shapla Chattor)

This is the liquid limit graph for JU (Shapla Chattor)

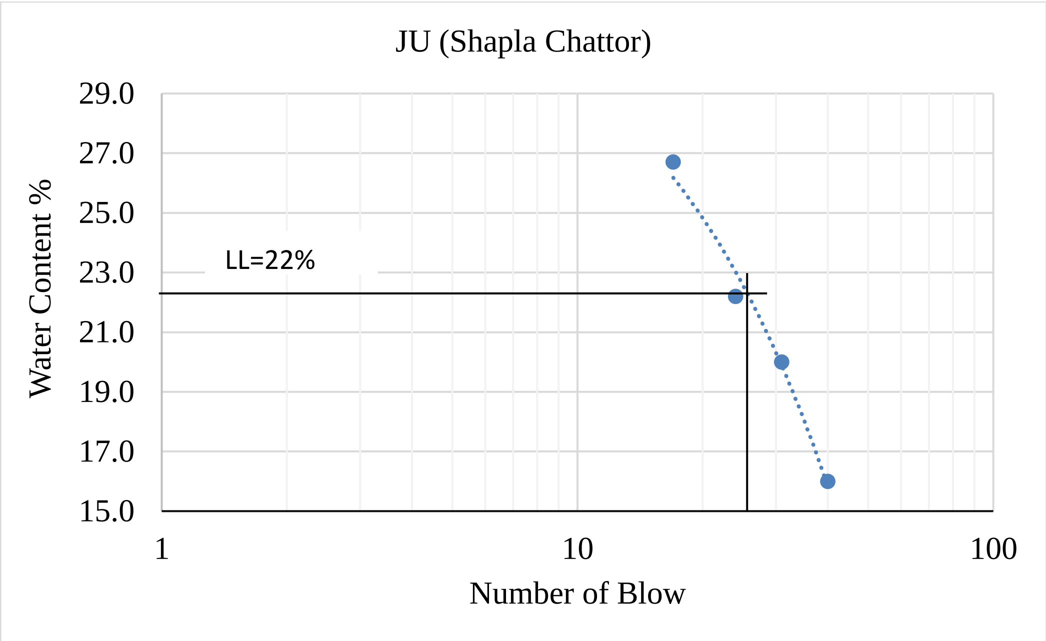


Figure 4-9: Graph of liquid limit by Casagrande method for JU (Shapla Chattor)

4.7.3 Barobazar (Ashulia)

This is the liquid limit graph for Barobazar (Ashulia)

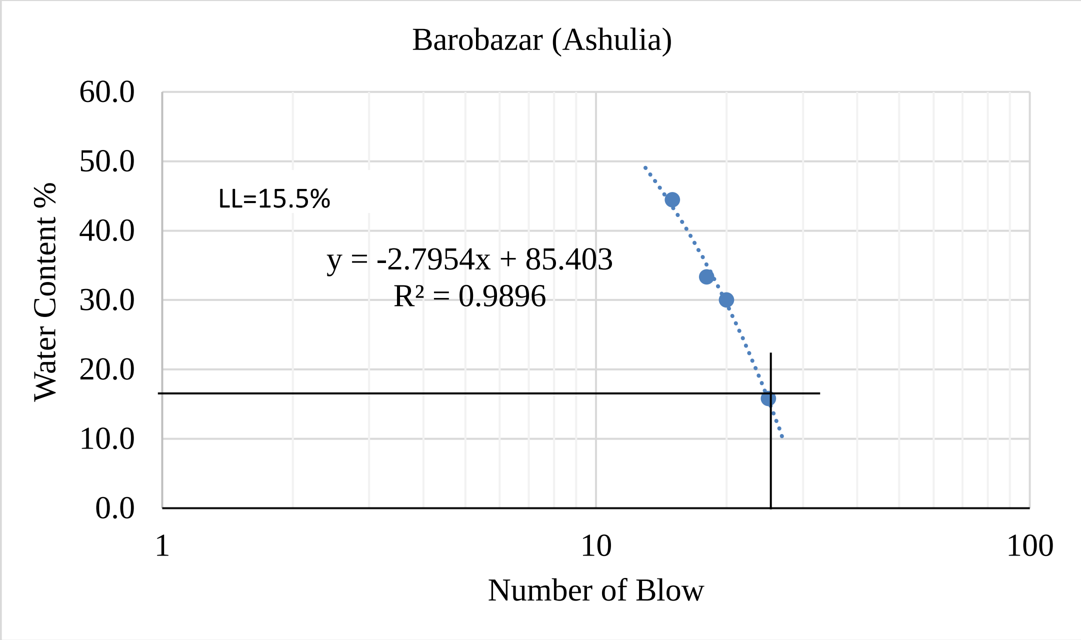


Figure 4-10: Graph of liquid limit by Casagrande method for Barobazar (Ashulia)

4.7.4 Uptown (Ashulia)

This is the liquid limit graph for Uptown (Ashulia)

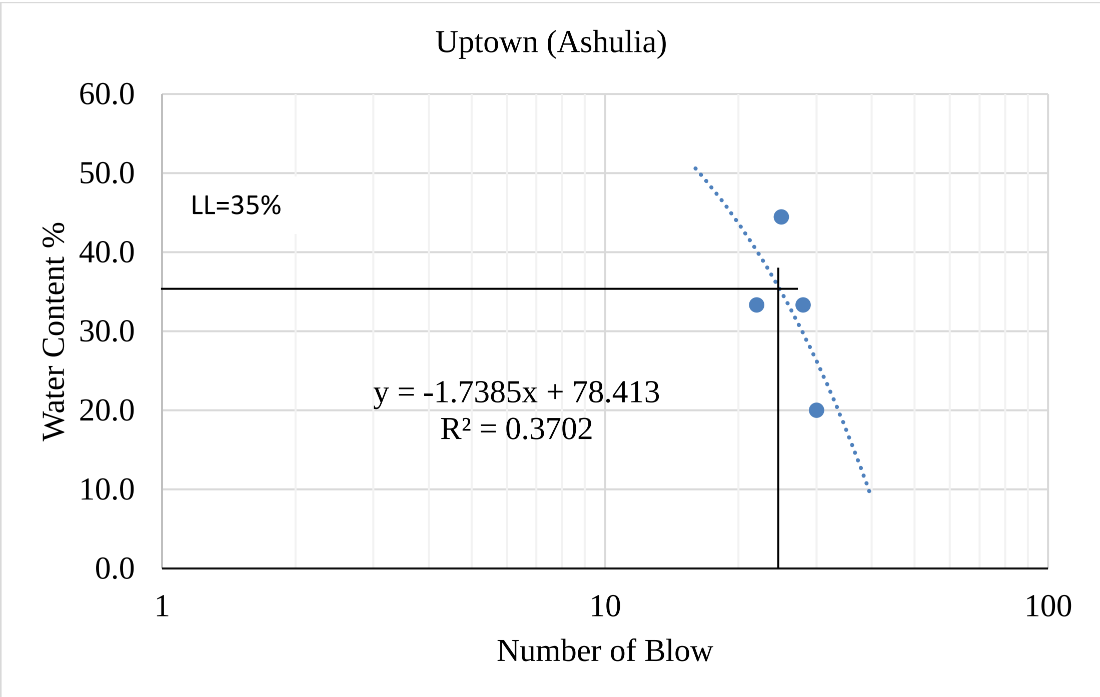


Figure 4-11: Graph of liquid limit by Casagrande method for Uptown (Ashulia)

4.7.5 Chapai Nawabganj

This is the liquid limit graph for Chapai Nawabganj

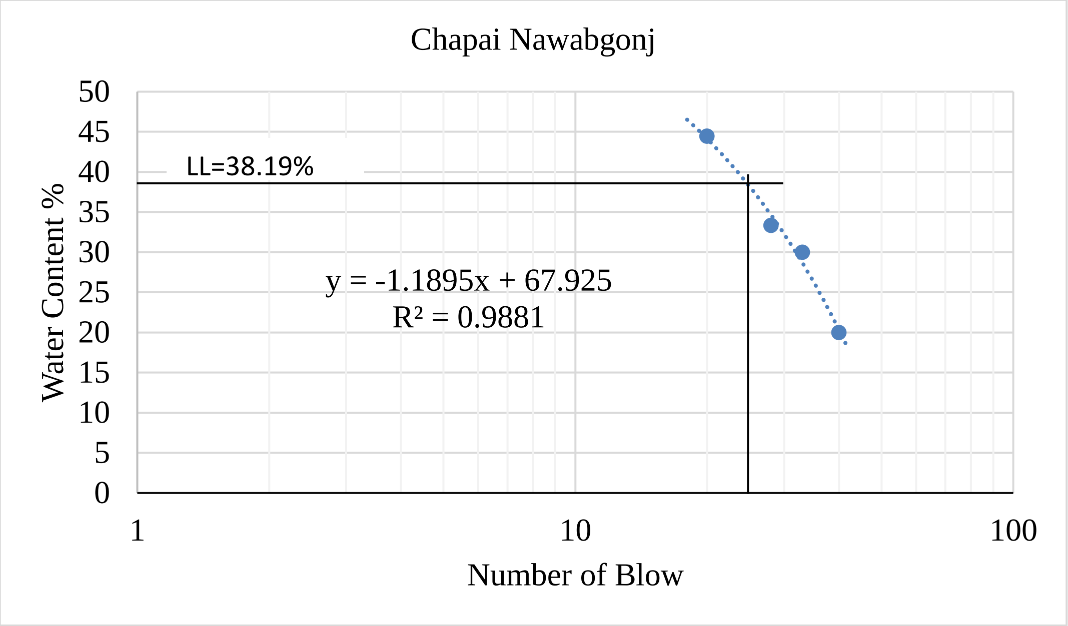


Figure 4-12: Graph of liquid limit by Casagrande method for Chapai Nawabganj

4.7.6 BUET Campus

This is the liquid limit graph for BUET Campus

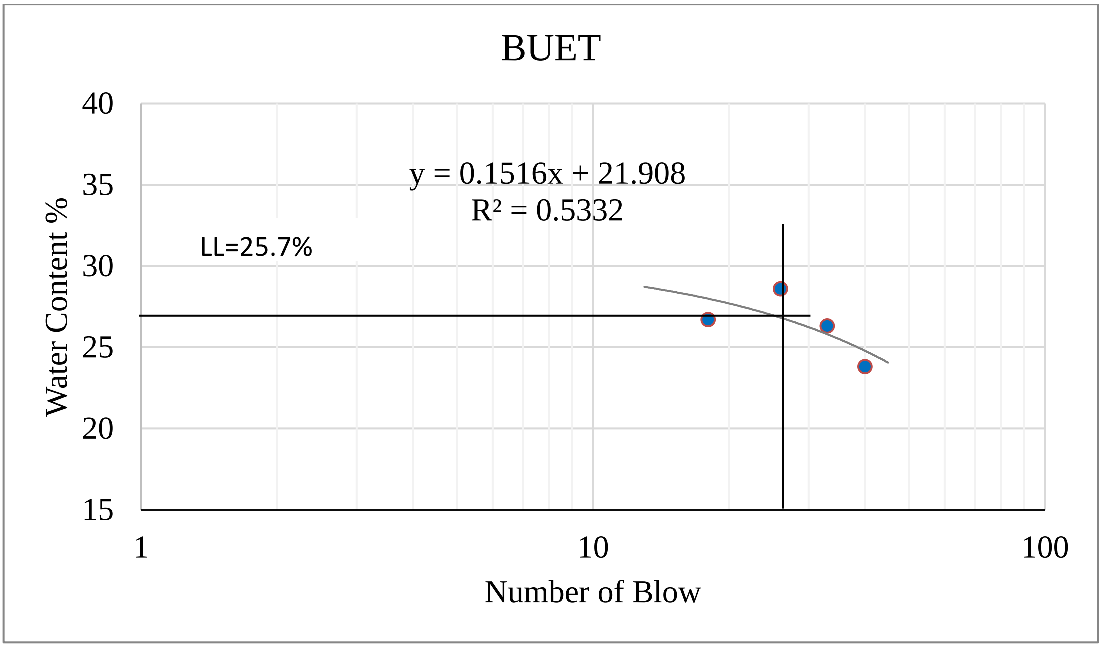


Figure 4-13: Graph of liquid limit by Casagrande method for BUET Campus

4.8 Plasticity Index

Here is the list of plasticity index of the tested sample. Here plasticity index is the difference of the value of liquid limit and plastic limit.

Table 4-14: Table of plasticity index and symbol

SI No.	LOCATION	LL	PL	PI	SYMBOL
1	JU (Geology department)	42	28	14.0	ML
2	JU (Shapla Chattor)	22	19	3.0	CL
3	Barobazar (Ashulia)	15.5	12	3.5	CL
4	Uptown (Ashulia)	35.5	22	13.5	CL
5	Chapai Nawabganj	38.19	29	9.2	ML
6	BUET	25.7	17	8.7	CL

4.8.1 Plasticity index Chart

Here is the plasticity index chart for all of the sample using Casagrande method.

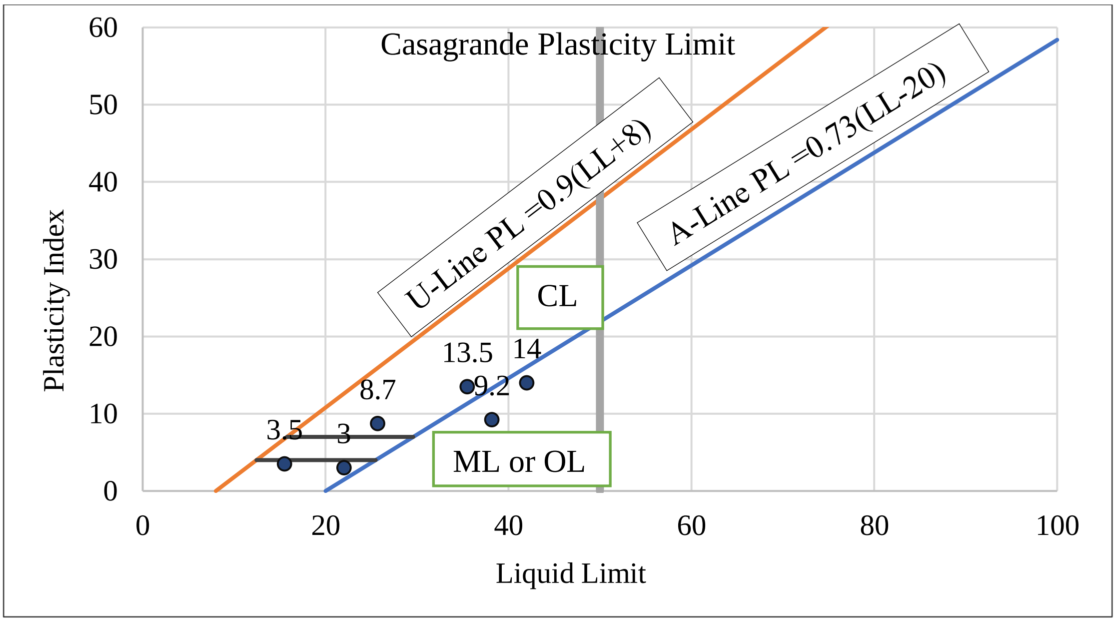


Figure 4-14: Plasticity Index Chart for samples.

4.9 Liquid Limit Using Cone Penetration Method

The graph of liquid limit using cone penetration method has been shown here in this section.

4.9.1 JU (Shapla Chattor)

The graph of liquid limit for JU (Shapla Chattor)

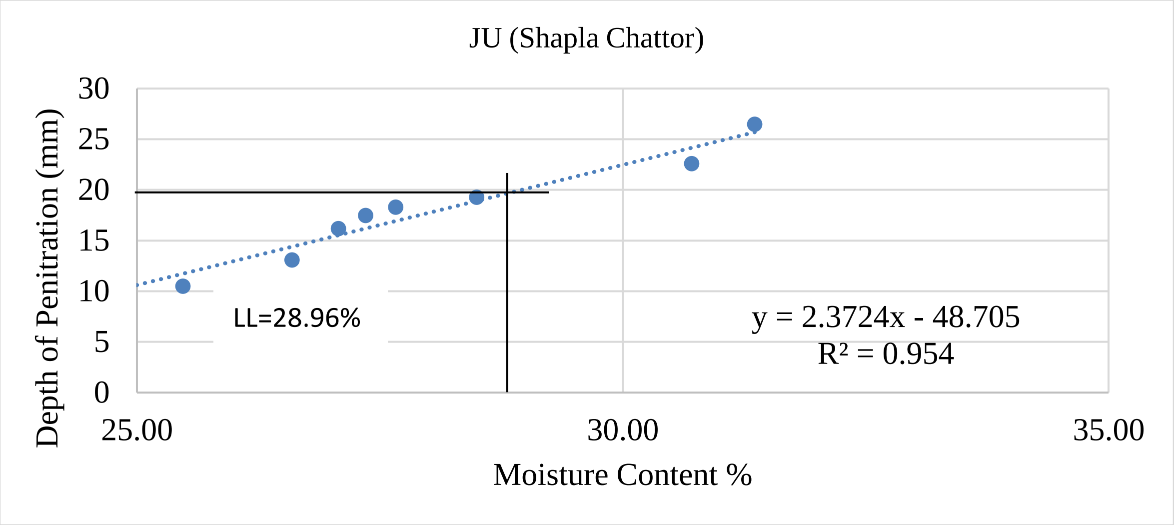


Figure 4-15: Graph of Liquid limit by Con Penetration Method for JU (Shapla Chattor)

4.9.2 Chapai Nawabganj

Graph of the sample of Chapai Nawabganj for liquid limit

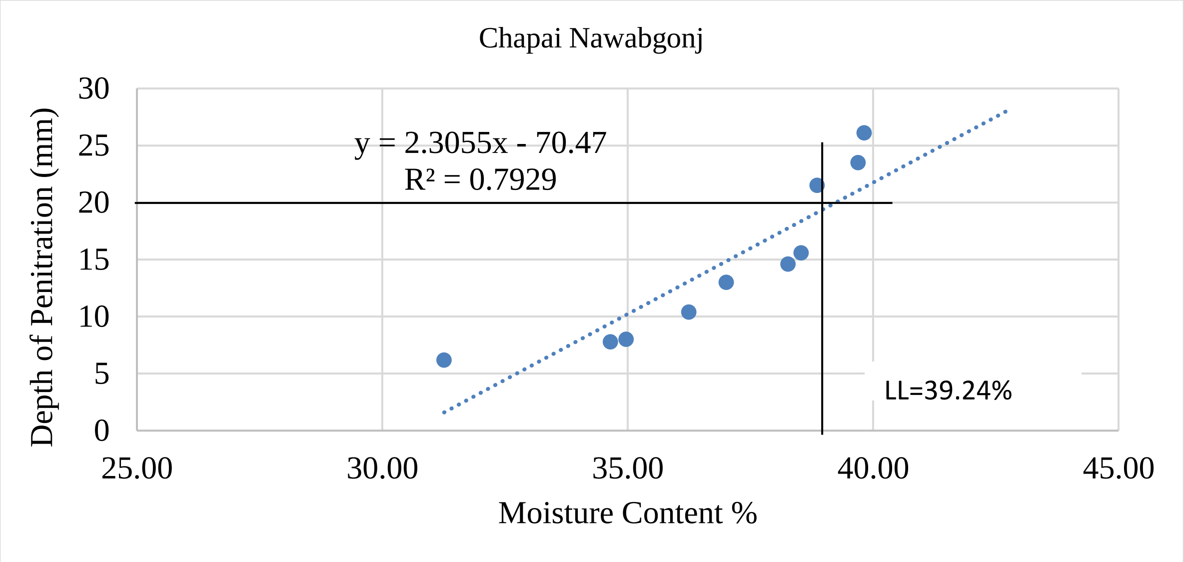


Figure 4-16: Graph of liquid limit by cone penetration method for Chapai Nawabganj

4.9.3 BUET Campus

This is the liquid limit graph for BUET Campus

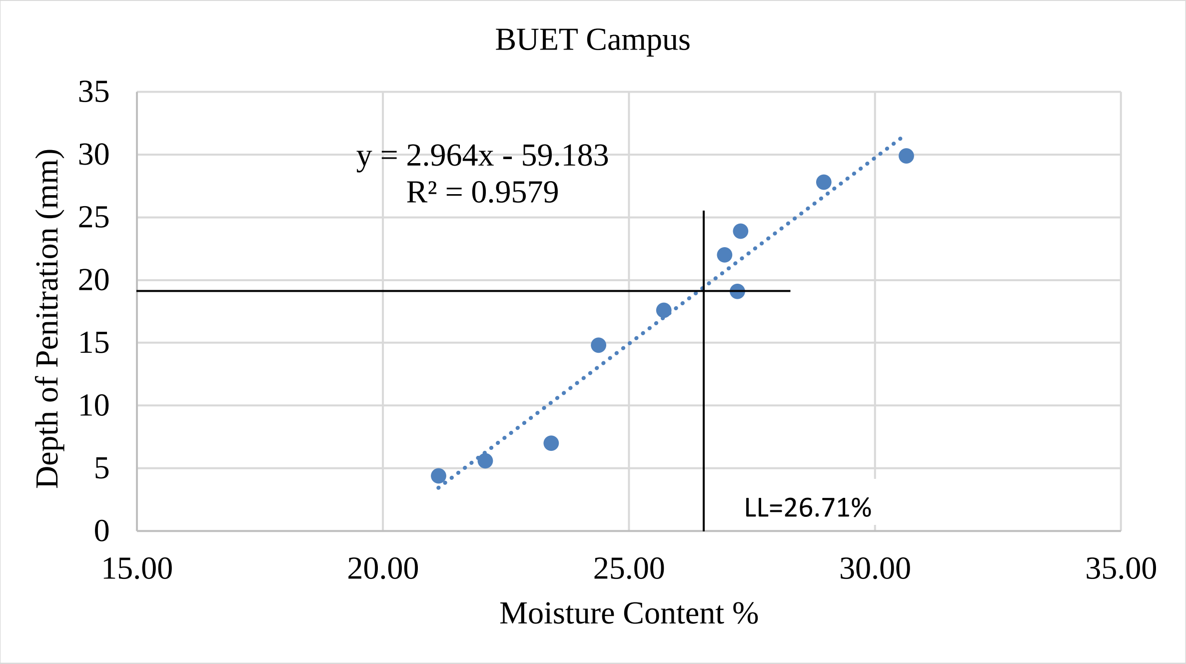


Figure 4-17: Graph of Liquid limit by cone penetration method for BUET Campus

4.9.4 Description

During conducting this test due to some limitations not all of the test could be done properly. There was no apparatus to test cone penetration so an arrangement had to done at a different lab. But due to the distance and time not all of the test was done. At most 3 of the tests were done successfully.

4.10 Variation of Liquid Limit Between Two Methods

At this point the variation of each method will be discussed. Here the point that should be mentioned is, the study has been done on six samples and liquid limit test has been tasted using the Casagrande Method for all of them. But due to the shortage of time and apparatus three of the sample were tasted liquid limit using cone penetration method.

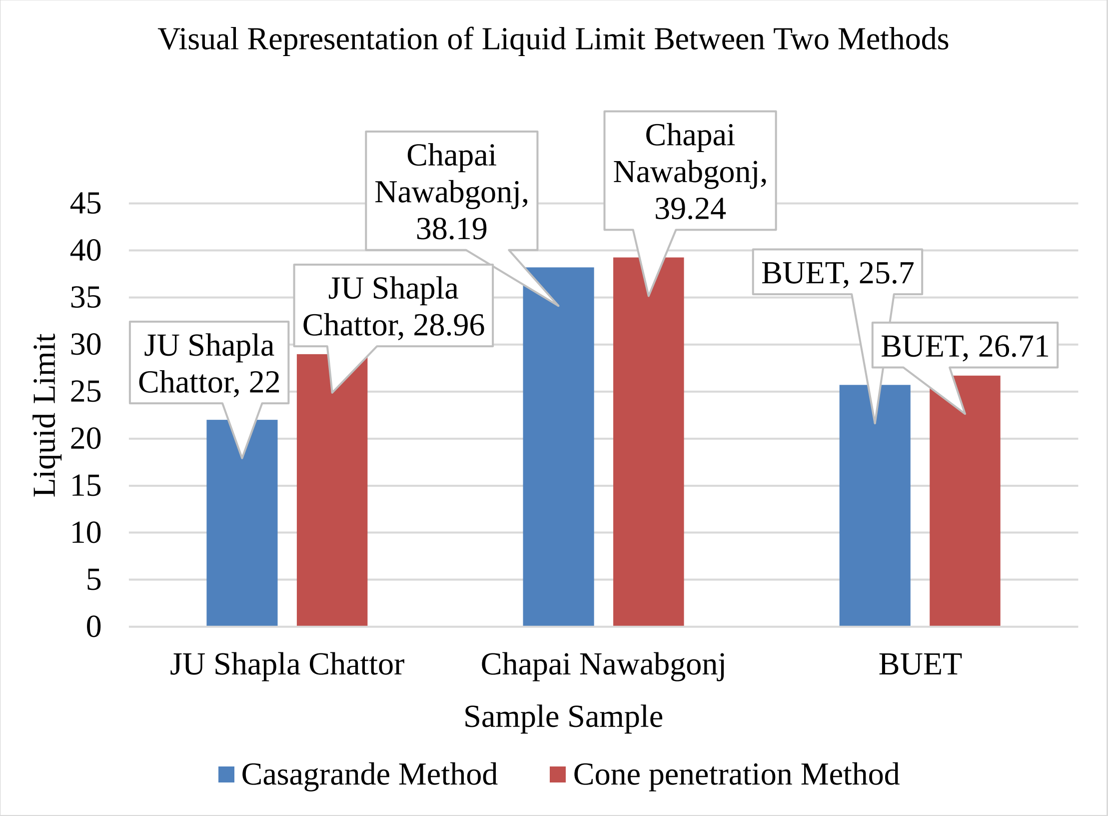


Figure 4-18: Variation of liquid limit between two methods

4.11 Discussion

The main purpose of the study was to find the variation of liquid limit between Casagrande and cone penetration method. To conduct the test six sample were taken. To make sure that the samples were clay the wash sieve has been performed for each sample. For each of the test liquid limit has been determined using Casagrande Method. Due to lake of apparatus cone penetration method was tasted at a different lab. The test was done for three samples. And the three of these samples were compared to determine the outcome of the study.

Chapter 5

CONCLUSION

5.1 General

The main purpose of the study was to compare and analyze the liquid limit with cone penetration and Casagrande method. And compare their values to each other. By comparing their values any discrepancies or variations can be identified for liquid limit and practical implications.

5.2 Conclusion

1. It is observed that the result for JU Shapla Chatter was 6.96%, BUET was 1.05%, and Chapai Nawabganj was 1.05% less using the Casagrande method compared to the cone penetration method.
2. It was found that while most of the tests showed some variations, the results were almost the same most of the time.
3. However, there were indeed some variations, with the cone penetration method yielding higher liquid limit values than the Casagrande method.

The study reveals that although there are minor variations in the results between the Casagrande method and the cone penetration method, the cone penetration method consistently shows higher liquid limit values. This suggests that while both methods are generally reliable, the cone penetration method may provide a more accurate measure of liquid limits in certain contexts. Further research could investigate the underlying reasons for these variations and determine the specific conditions under which each method performs best.

5.3 Recommendation

1. If it was possible to perform all of the tests for all of the samples.
2. It could have had a much clearer outcome of the test. While conducting further research the soil should be oven dried properly and should be grinded to the finest grain possible.

References

Belviso, R., Ciampoli, S., Cotecchia, V., and Federico, A. (1985). *Use Of The Cone Penetroe Eeeter To Deterreiine Consistency Lireiits.* Retrieved from https://cdn.ca.emap.com/wp-content/uploads/sites/13/1985/07/198507_Pages_21-22.pdf

Wood, D. M., Wroth, C. P (1978). *The use of the cone penetrometer to determine the plastic limit of soils*. Retrieved from https://trid.trb.org/View/80396: http://worldcat.org/issn/00174653

Das, B. M. (2002). *Principles of geotechnical engineering* . Retrieved from https://search.worldcat.org/: https://search.worldcat.org/title/Principles-of-geotechnical-engineering/oclc/46713278

Feng, T.W. (2001). *A linear log d – log w model for the determination of consistency limits of soils*. Retrieved from Canadian Science Publishing: https://doi.org/10.1139/t01-061

Feng, T.W. (2004). *Asce Library*. Retrieved from Using a Small Ring and a Fall-Cone to Determine : https://doi.org/10.1061/(ASCE)1090-0241(2004)130:6(630)

Harison, J. A. (1988). *Using The Bs Cone Penetrometer For The Determination Of The Plastic Limit Of Soils*. Retrieved from https://trid.trb.org/: https://trid.trb.org/view/289623

Houlsby, G. (1982). *Theoretical analysis of the fall cone test*. Retrieved from https://www.icevirtuallibrary.com/doi/abs/10.1680/geot.1982.32.2.111:https:// doi.org/ 10.1680/geot.1982.32.2.111

Methods of test for soils for civil engineering purposes - Classification tests. (1990). Retrieved from https://knowledge.bsigroup.com:https://knowledge. sigroup .com /products /methods-of-test-for-soils-for-civil-engineering-purposes-classification-tests?version=standard&tab=overview

Wasti, Y., and Bezirci, M. H. (1986). *Determination of the consistency limits of soils by the fall cone test*. Retrieved from Canadian Geotechnical Jurneal: https://doi.org/10.1139/t86-033

Wroth, C. P., and Wood, D. M. (1978). *The correlation of index properties with some basic engineering properties of soils*. Retrieved from Canadian Geotechnical Journal: https://doi.org/10.1139/t78-014