Suitability of Rupganj Soil for Earth Construction

A thesis submitted by

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In partial fulfillment of the requirement for the degree of

BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING

Under the supervision of

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February 2021

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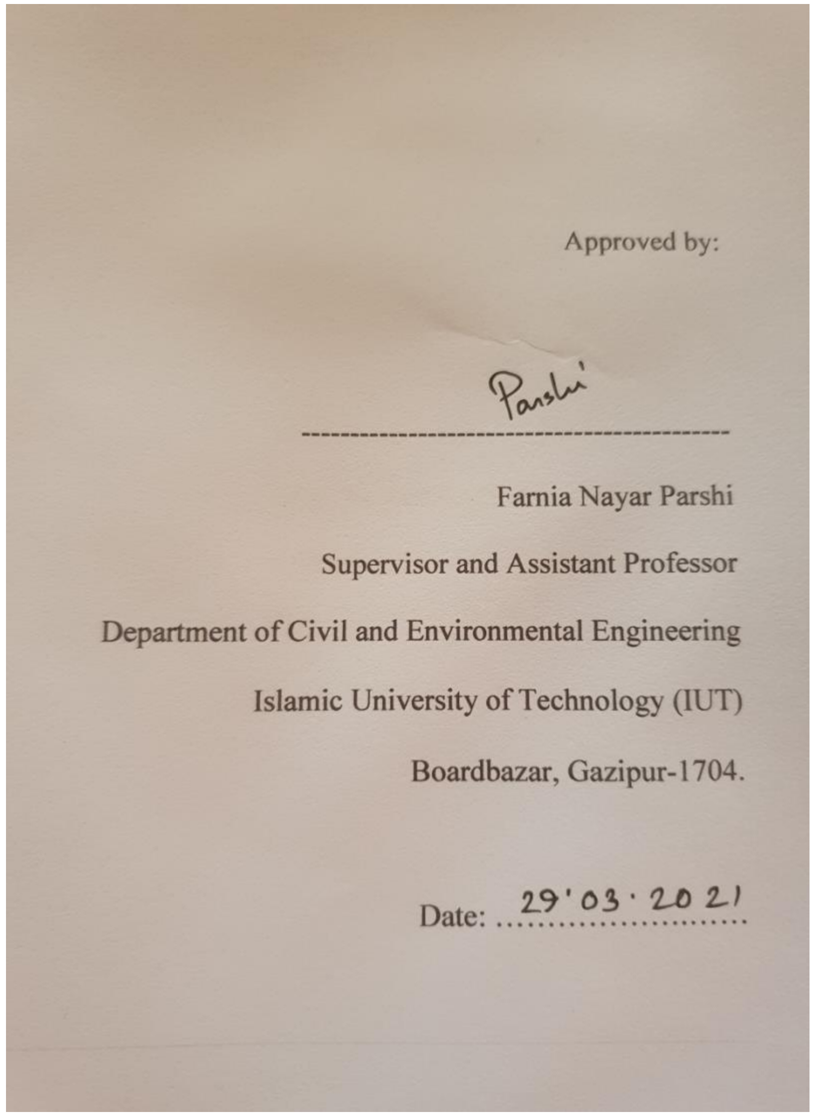

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DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Assistant Professor Farnia Nayar Parshi and this work has not been submitted elsewhere for any purpose.

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ACKNOWLEDGMENTS

We are really grateful because we managed to complete our graduation thesis on ‘Suitability of Rupganj Soil for Earth Construction.’ Within the given time by the University.

This undertaking couldn't be completed without the effort and cooperation of our group members. Who worked tirelessly through the unfortunate event of the Corona Virus Outbreak.

We also thank our supervisor, Mrs. Farniya Nayar Parshi, for the guidance and encouragement in finishing this paper and also for teaching us the relevant courses.

We also would like to acknowledge and thank the Prosoil Organization for their help by providing us with various data, which were indispensable for this paper.

We also thank all of our teachers for the knowledge, support and encouragement they have given us for so long. We are forever indebted.

Last but not the least we would like to thank our family and friends for their constant source of inspiration.

ABSTRACT

In order to use the soil as a construction material for earth construction, we need to check the suitability of the said soil. For which, its geotechnical properties are required to be examined. The purpose of this study was to determine the suitability of Rupganj soil by reviewing previous studies on the suitability criteria and previously published similar soil samples. This study was conducted under the main reference of a previous review paper which compiled the necessary information and requirements for a soil to be deemed suitable for earth construction. We have conducted the study on 7 soil samples from different depths of the similar area and assessed them according to the chosen criteria. Five geotechnical properties were compiled and referred to and then analyzed. These properties are particle size distribution, specific gravity, maximum dry density, optimum moisture content and Atterberg limit.

Based on the values of soil properties found on the literature review, and other recommendations from previous studies, analysis was carried out and recommendations were made for the suitability of different samples. We have also analyzed the cost and environmental impact produced by the suggested soil methods.

It was noted that some of the soil samples passed one set of criteria while failing the others. For this, stabilization techniques and materials were suggested. Finally, the study concludes whether the soil of said region is suitable for earth construction, and if not then what methods need to be applied.

TABLE OF CONTENTS

ACKNOWLEDGMENTS vi

ABSTRACT vii

LIST OF TABLES x

LIST OF FIGURES xi

LIST OF PICTURES 11

LIST OF ABBREVIATIONS xi

CHAPTER 1
INTRODUCTION 1

- **Chapter 1.1 General** 1
- **Chapter 1.2 Background** 3
- **Chapter 1.3 Objectives** 4
- **Chapter 1.4 Methodology** 4
- **Chapter 1.5 Research Plan:** 5

Chapter 2
LITERATURE REVIEW 6

CHAPTER 3
METHODOLOGY 9

- **Chapter 3.1 Introduction** 9
- **Chapter 3.2 Outline of methodology** 10

Chapter 3.3 Selection of Site 10
Figure 3.3.d: Soil Texture map of Bangladesh 13
Chapter 3.4 Data collection 13
Chapter 3.5 Review of Previous Paper and Setting Criterias. 14
Chapter 3.5.1 Particle Size and Atterberg Limit 14
Chapter 3.5.2: Specific Gravity, Dry Density and Optimum Moisture Content 19

CHAPTER 4
RESULTS AND DISCUSSION 20
Chapter 4.1: Particle Size and Distribution 20
Table 4.1: Particle Size Distribution Table. 21
Chapter 4.2: Atterberg Limit 22
Chapter 4.3: Specific Gravity, optimum moisture content and maximum dry density 23
Chapter 4.4: Combined result: 25
Chapter 4.5: Cost Analysis 26
Chapter 4.6 Reduction of Carbon footprint: 28

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS 29
Chapter 5.1 General 29
Chapter 5.2: Soil Review 29
Chapter 5.3: Future study and Suggestions 30

REFERENCES 32

APPENDIX
Soil classification 37

LIST OF TABLES

Table 3.5.1	Degree of Plasticity Index	18
Table 4.1	Particle Size Distribution Table	20
Table 4.2	Atterberg Limits and Plasticity Index Table	22
Table 4.3	Specific Gravity, Optimum Moisture Content and Maximum Dry Density Table	25

LIST OF FIGURES

Figure 3.2 Flow Chart of study outline 10

Figure 3.3a A sattelite view of Rupganj 11

Figure 3.3b Sattelite view of Jalshiri Abashan 12

Figure 3.3c Sattelite view of Boruna Bazar 12

Figure 3.3d Soil texture map of Bangladesh 13

Figure 3.5.1a Atterberg limits of soil suitibility 15

Figure 3.5.1b Granularity nomograms of suitable soil 16

Figure 3.5.1c Texture chart 17

Figure 4.1 Gradation curves of sample soils 20

Figure 4.5 Cost Comparision of different types of materials 27

Figure 4.6 Comparison of Carbon emission by different materials 28

LIST OF ABBREVIATIONS

IUT	Islamic University of Technology
W_p	Plastic Limit
W_l	Liquid Limit
I_p	Plasticity Index
RE	Rammed Earth
CEB	Compressed Earth Blocks
ADO	Adobe Blocks
OR	Outside Recommendation
G_S	Specific Gravity
OMC	Optimum Moisture Content
MDD	Maximum Dry Density

CHAPTER 1

INTRODUCTION

Chapter 1.1 General

For shelter and alternative construction functions concrete is widely used round the world where industries hold no regard for the high costs of stuff, labor and transportation. As a low income country the people of Bangladesh will solely dream of building a good shelter for themselves at a low value. Therefore, a desire arises to search out possible alternative building materials that is not only regionally obtainable and economical, however is additionally a way towards property development.

History always helps for developing new technology. So it is wise to look back. From primitive age man is dependent on housing. The history of civilization is synonymous to the history of housing. Ever since man learnt to build homes and cities around 10000 years ago, earth has undoubtedly been one of the most widely used construction materials in the world. Still today 50% of the population in developing countries, including the majority of the rural population and at least 20% of the urban and suburban population, live in earthen dwellings. (Houben H, 1994)

Clay bricks are some of the oldest building materials to be manufactured and used by man. They are still popular as building materials mainly because of their structural properties, easy availability, relatively low cost and easy architectural workability. Traditionally, clay bricks are considered as solid and sustainable materials under normal weather conditions. Where clay deposit is available, bricks can be manufactured locally, which makes them easily available at relatively low cost (Chan, 2011).

However, there are few undesirable properties like loss of strength once saturated with water, erosion because of wind or driving rain and poor dimensional stability. sturdiness and strength is also major downside. Another severe drawback is its vulnerability to earthquake loading. Various researches are dispensed round the world. These researchers have developed many solutions of structural reinforcement to earthen house. however most of the cases these solutions are neither low-cost nor straightforward to use in construction.

Clays having low strength and high compressibility, can cause severe damage to civil engineering construction. Therefore, these soils must be treated before commencing the construction operation to achieve desired properties. Different methods are available to improve the engineering properties of problematic soils such as densification, chemical stabilization, reinforcement and techniques of pore water pressure reduction.

People all over the world have been using various fiber with soil during earth construction. The chemical stabilization of clays using lime is also one of the commonest methods that can be used to upgrade the soils of poor properties to provide a workable platform to construction projects.

But not all clayey soil can be directly used for such research. Thus the purpose of this particular paper was to test the different parameters of a regional soil and compare them with the idealistic values of workable soil and derive whether they are suitable or not. And to see if they can be made suitable using the guidelines found available through the review papers.

So using the reviews and previous studies, this paper set to find out the suitability or how to make a certain area's soil suitable for earthen work such as using it for compressed earth blocks or direct mud housing. We have also checked the impact towards the environment and the cost effectiveness of the above mentioned soil.

Chapter 1.2 Background

- . Earth as a building material has low environmental impact and high availability.
- Utilization of locally available soil for the construction will optimize the cost and reduce the environmental impact. (Tharaka DGS, 2012)
- Earth building techniques are simple and easy to use, making it workable for local labors. (Ciancio D, 2013)
- Resources for concrete construction are slowly running out.
- Finding a new resource has become a new challenge and stable earth construction can solve that. (Laborel Préneron A, 2016)
- Naturally not all soil consists of suitable composition for building structures.
- Testing soil before using it as a construction material is necessary. (H. Danso, 2018)

Chapter 1.3 Objectives

- Identify the soil properties
- Evaluating the acquired values for identifying the suitability of the soil
- Pointing out the stabilizers according to the lacking of particular soil.
- Assessing environmental impact.
- Alternative usage of soils which are not suitable for earth works.

Chapter 1.4 Methodology

This research work conducted in the following way:

- Study of referential papers:

A total of 18 papers and 3 books and 5 websites were studied and taken reference of to find the ideal approach to judge the suitability of a certain soil. The research papers were properly reviewed and compared and one set of conclusion was chosen as the set answer.

- Selection of site and collection of data:

The site selection was an important part of the research. Because, we needed to choose a site that had prior history of clay or mud housing, had accessible and abundance of samples to make use of, the soil was similar or at least look similar to the reviewed examples and finally a soil that has low microbial content. So Rupganj was selected as the study area.

And the data was all collected from Prosoil foundation consultant.

- Study and analysis of the acquired data:

The data collected were then put through the analysis as we compared and deduced whether the samples met the criteria.

- Recommendation of stabilizers

After the analysis ended, the prior criteria were taken into account and proper stabilization methods and stabilizers were commented and recommended for the soils that were outside the ideal criterion.

Chapter 1.5 Research Plan:

The following is the breakdown of the entire research project:

a) Study of previous research to find the criteria defining a suitable soil.

b) Gathering the data.

c) Studying and analyze the acquired data.

d) Compare and deduce the analyzed results and recommend proper stabilization.

In this context, Chapter 2 includes the use of soil in infrastructure all over the world and recent relevant researches on soil as a building material. Also, the definition, classification, advantages, disadvantages of soil is explained.

The methodology is discussed in Chapter 3. The physical properties of each type of soil are described here. The criteria of this study is shown here.

The results of the experiments are mentioned in Chapter 4. Figures, graphs, and tables are used to discuss the outcomes of the test parameters.

Regarding this study, Chapter 5 provides some recommendations. Finally, scopes for further research work are listed in the last portion. This is the concluding phase of this research project.

Chapter 2

LITERATURE REVIEW

A soil is a material that is widely available in almost everywhere in the world and can be used in many types of earth construction, such as cob, rammed earth or stabilized mud blocks (SSF soil testing manual, 2014). Major geotechnical problems in construction involving silty-clayey soils

are due to their low strength, durability and high compressibility of soft soils, and the swell-shrink nature of the over-consolidated swelling soils (Stavridakis, 2006). The poor conditions of soils on their properties can often be a significant impediment to successfully implementing green infrastructure projects (United States Environmental Protection Agency, 2011). A major problem prior to the decision to use soil as the walling material on a construction project is to identify a sufficient supply of soil suitable for economic stabilization (AJ, 1988). Earthen construction has been one of the most largely used construction techniques in different historical ages (Parisi F, 2015). Earthen materials are still widely used worldwide because of their low-cost, abundance, availability and low environmental impact (Araya Letelier G, 2018). Earth as a building material is increasingly being studied for its low environmental impact and its availability (Laborel Préneron A, 2016). Utilization of locally available soil for the construction will optimize the cost and reduce the environmental impact (Tharaka DGS, 2012). The will of reducing environmental and social impact from the construction industry has led to a renewed interest in earth construction (Hamard E, 2016). Due to the ease and simplicity of earth building techniques, a local unskilled labour force can be readily employed, supplying job opportunities to remote communities and reduction in the cost of accommodation and transport of labour brought from distance (Ciancio D, 2013). Earth building techniques make use of raw earth as a material for constructing walls, and that evaluation of soils is a primary issue because not all soils are adequate in properties for earth buildings (Delgado MCJ, 2007). Geotechnical properties of soils influence the stability of civil engineering structures, and most of the geotechnical properties of soils influence each other (Roy S, 2017).

Laborel Préneron et al. (Laborel Préneron A, 2016) reviewed the state of the art of research on the influence of various natural and renewable resources in unfired earth materials such as compressed earth blocks, plasters, and extruded and stabilized blocks based on 50 major studies. Their study included the characterization of the particles and treatments, recapitulative tables of the material compositions, the physical, mechanical, hygrothermal and durability performances of earth based materials. Danso et al. (Danso H, Performance characteristics of enhanced soil blocks: A quantitative review., 2015) reviewed 56 published studies on the effect of stabilization on the performance characteristics of soil blocks and found that few studies have been conducted on durability properties of enhanced soil blocks as compared with physicomechanical properties. Delgado and Guerrero (Delgado MCJ, 2007) reviewed more than 20 technical documents including standards from National Standards bodies, analyzed the provisions they offered concerning soil suitability for the use of unestablished earth and analyzed the different approaches and kinds of recommendation offered. Finally, Humphrey Danso (H, Experimental Investigation on the Properties of Compressed Earth Blocks Stabilised with a Liquid

Chemical, 2017)analyzed the review work of more than 50 researchers and came up with a plausible way to find out the suitability of a soil, for using in earthen work.

To check the suitability of soil to be used as a foundation or as construction materials, its properties are required to be assessed (www.ejge.com, n.d.). The evaluation of basic engineering properties of soils through laboratory testing is very important in understanding and interpreting how soils will behave in the field (Zhang J, 2018). The physical and engineering properties of existing soils are intrinsic and can be used as a frame of reference for the behavior of strength characteristics of soil (www.ijetsr.com, n.d.). Different kinds of soil exist worldwide with different characteristics which are likely to have effects on the performance of the structures that are constructed with the soil. It is imperative to identify the characteristics of any obtainable soil before using it for construction purposes. Natural soil exists in the distinct composition of sizes, for which certain proportions of these sizes can make a good material for building structures. This presents the need for testing any given soil before it is used in the construction industry as a filling or structural material. The issue is that, given the fact that not all soils are suitable, and some classes are better depending on the technique used, it is necessary to use some way for evaluating them (Delgado MCJ, 2007). This study, therefore, reviews and analyses soil properties of the collected sample data in order to determine their suitability for earthen construction using the preordained analysis data from the literature reviews.

CHAPTER 3

METHODOLOGY

Chapter 3.1 Introduction

This chapter gives an outline of the research methods that were followed in the study. The systematic process from selecting the location of soil to analysis of the data.

This study adopted the approach of the research of Humphrey Danso (H, Influence of compacting rate on the properties of compressed earth blocks. , 2016) as a base and worked its way up from there. As the papers reviewed had already given a certain direction to analyze the sample soil, the reviews and conclusions of previous studies were taken as reference points. And were used to derive the data of this study. The geotechnical properties of soil samples used in previous studies were compiled and compared with various criteria and requirements to ascertain their suitability for construction purposes. Eighty-nine (89) studies in all were consulted and useful data were found in fifty-two (52) of them. Five geotechnical properties of soil were compiled and analyzed. These properties are particle size distribution, Atterberg limits, specific gravity, maximum dry density and optimum moisture content. A wide range of properties exists for determining the characteristics of soil for construction purposes (Danso H, Performance characteristics of enhanced soil blocks: A quantitative review., 2015). However, these properties were selected because they are the main properties used in most previous studies to characterize the soil samples.

Chapter 3.2 Outline of methodology

Our paper being a referential study we went through different phases. These are as follows:

1. We initially went through various published papers in the related areas then selected one as a base for our paper.
2. Then we went and searched for suitable locations/sites for our paper and collected data sample from “Prosoil Foundation Consultant”.
3. After getting our desired data we went to study and analysis of our acquired data to get the required information for our study.
4. Then we determined the suitability of the soil for our required purposes.
5. We recommended various stabilizers for the soil depending on their characteristics.
6. Finally, we made different recommendations for making earth blocks using that soil.

Here is a flow chart showing the progression of our study:

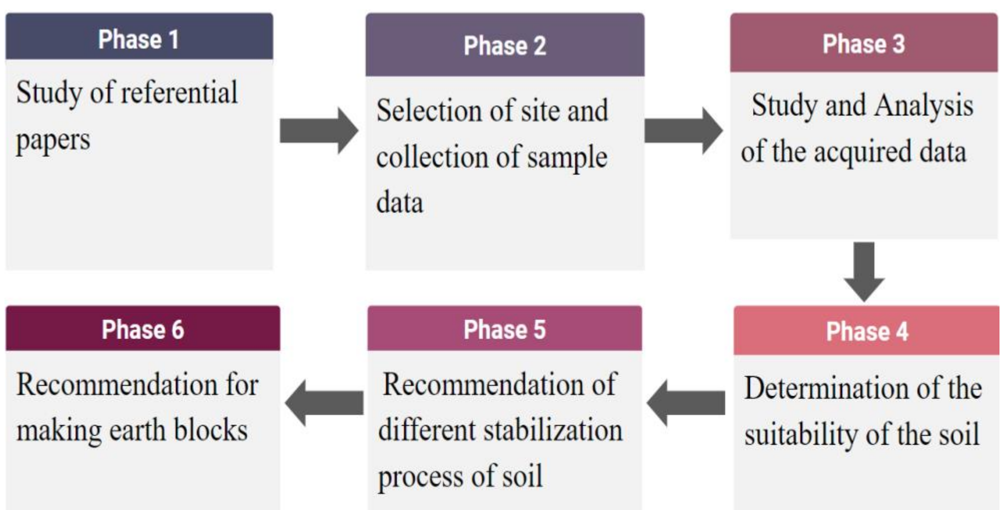

Figure 3.2: Flow Chart of Study Outline

Chapter 3.3 Selection of Site

Bangladesh is blessed with soils of various types and many of them are suitable for construction, as seen prior in many research papers. And so to select the site we had taken help from a website called Banglapedia. (Banglapedia.com, n.d.).figure 3.3.d shows a soil texture map of Bangladesh.

And finally after reviewing, we had chosen Rupganj as the study area. Because,

- It Falls under clayey soil region which is perfect for this study.
- Has prior history of mud construction. We have found out that there are signs of people living in mud houses in this area.
- Accessible to sample. There is abundance of soil which seem easy to be made use of.

Figure 3.3.a: A Sattelite view of Rupganj

An image of the Rupganj region is shown on figure (). From this region two spots were chosen to take data from. They were, Boruna Bazar and Jalshiri Abashan respectively.

Figure 3.3.b: Satellite view of Jalshiri Abashan

Figure 3.3.c: Satellite view of Boruna Bazar

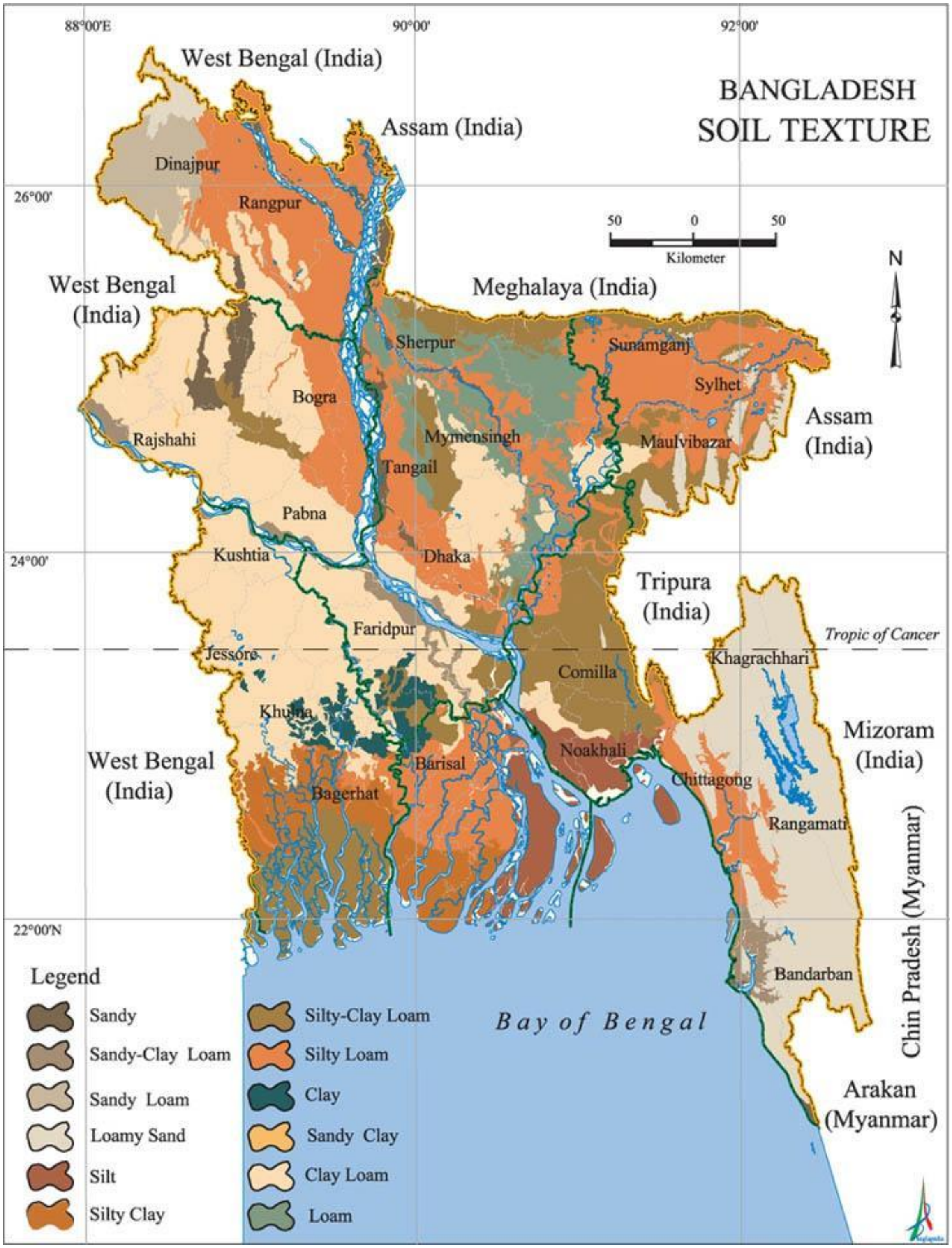

Figure 3.3.d: Soil Texture map of Bangladesh

Chapter 3.4 Data collection

Data were collected from Prosoil Foundation Consultant. The data came from two boreholes and they were directly used for the following study.

Chapter 3.5 Review of Previous Paper and Setting Criteria.

Many papers of prior research on similar subject were reviewed to find out the proper criteria to compare the found data on. Following are the set criteria based on our findings.

Chapter 3.5.1 Particle Size and Atterberg Limit

For particle size distribution and Atterberg limits of soil samples used in previous studies, their values and the techniques used were compiled in tables and then compared with the upper limits of various criteria and requirements. Out of the comparison, a suitable soil application technique of the soil samples based on the requirements were recommended. This helped in determining the suitability of the soil for earth construction. Figure 1 shows the upper limits of Atterberg limit values proposed as a guide to recommend soil samples used in previous studies for determining their suitability for earth construction based on different criteria by Doat et al. (Doat P, 1979), Spence and Cook (Spence RJS, 1983) and Delgado and Guerrero (Delgado MCJ, 2007) From Figure 3.5.1a, it can be seen that the study used upper limits of 50% and 30%, respectively for the liquid limit (WL) and plasticity index (PI).

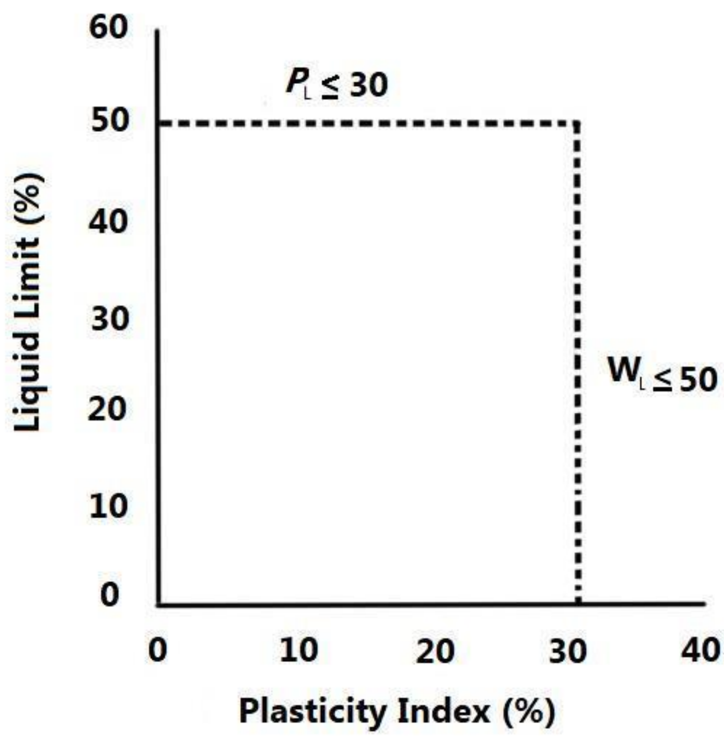

Figure 3.5.1a: Atterberg limits for soil suitability.

The particle size distribution test determines the amount, usually by mass, of the particles present in a soil sample (Jillavenkatesa A, 2001). Particle size distribution also known as grain size gives information on the soil's ability to pack into a dense structure [26]. The particle sizes are classified as gravel, sand (fine and coarse), silt and clay. There are different recommendations for soil particle sizes that are suitable for different techniques of earth building. Five of these recommendations are put together in a nomogram (see Figure 2) by Delgado and Guerrero (Delgado MCJ, 2007). Compressed earth block (CEB) was recommended by Houben and Guillaud (Houben H, 1994), CRATerre EAG (CRATerre EAG , 1998) and AFNOR (XP, 2001). While Adobe was recommended by Houben and Guillaud (Houben H, 1994) and CRATerre EAG (CRATerre

EAG , 1998), and rammed earth (RE) recommended by Houben and Guillaud (Houben H, 1994). Another source (Spence RJS, 1983) made a chart of soil particle size as shown in Figure 2. The shaded portion of the chart shows the recommended particle size suitable for soil stabilisation, which is in the range of 0% to 25% for clay, 0% to 25% for silt and 60 to 90% for sand constituents. In addition, a study by Bengtsson and Whitaker (Bengtsson LP, 1986) made recommendations for various techniques of soil particle sizes suitable for construction.

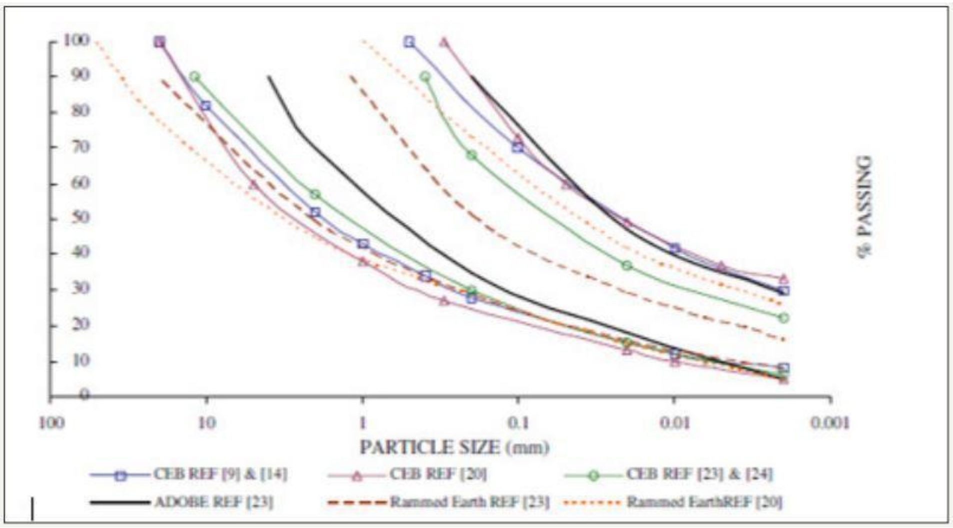

Figure 3.5.1b: Granularity nomograms of Suitable Soils

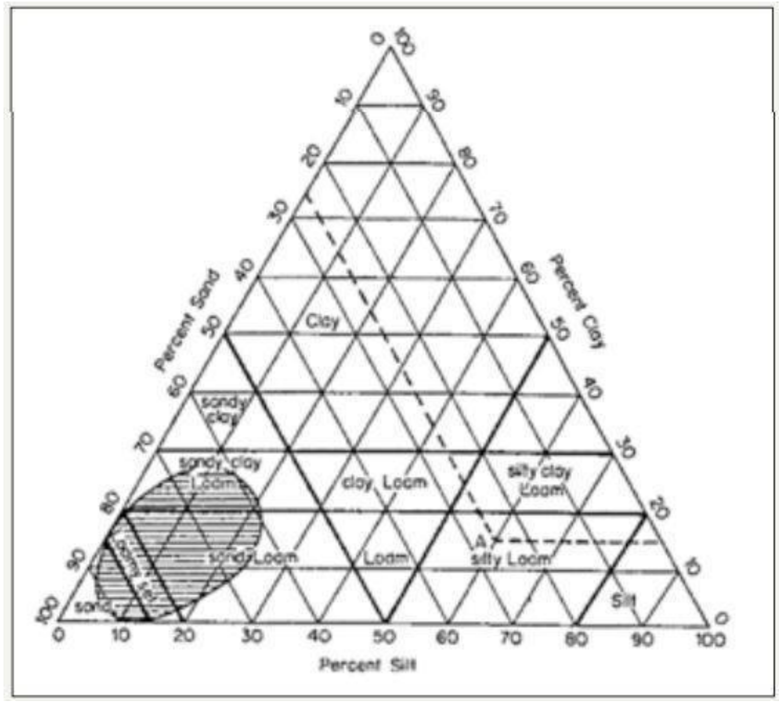

Figure 3.5.1c: Texture chart

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay. (Sowers, 1979.)

Water loss also contributes to the shrink of the clay fraction. For low clay mineral content (index plasticity below 20%), drying shrinkage showed a steady increase with the increase of clay content, but for a plasticity index beyond 25–30%, drying shrinkage increased rapidly as the clay content also increased. Soil with a plasticity index <20% is good for cement stabilization with cement content 10%. And, the commonly used drying shrinkage limit is from 0.008% to 0.10% . (F.V. Riza, 2015)

Sand as part of the mix seems to have significant influence in shrinkage, although sand content does not significantly affect the compressive strength as stated by Guettala (Guettala et al., 2002). However, (F.V. Riza, 2015) found out it can decrease plasticity, linear shrinkage and warping.

On the other hand, (Food and Agricultural Organization of the United Nations, n.d.) referred Plasticity Index on the basis of the liquid limit and the plastic limit. As the plasticity index (PI) can be defined as the numerical difference between them: PI = LL - PL

The plasticity index is expressed in percent of the dry weight of the soil sample. It shows the size of the range of the moisture contents at which the soil remains plastic. In general, the plasticity index depends only on the amount of clay present. It indicates the fineness of the soil and its capacity to change shape without altering its volume. A high PI indicates an excess of clay or colloids in the soil. Its value is zero whenever the PL is greater or equal to the LL. For this study the following chart will be referred to.

Plasticity Index (PI)	Degree of Plasticity
0-1	Non- Plastic
1-5	Slight Plasticity
5-10	Low Plasticity
10-20	Medium Plasticity
20-35	High Plasticity
35>	Very High Plasticity

Table 3.5.1: Degree of plasticity through Plasticity Index.

Chapter 3.5.2: Specific Gravity, Dry Density and Optimum Moisture Content

Similarly, specific gravity, maximum dry density and optimum moisture content of soil samples used in previous studies were also compiled and analyzed based on the various requirements and closely related spacing of the values of the soil properties. FM5- 472 [24] provides a different range of specific gravity values for different types of soil. It, however, provides a specific gravity of 2.00 and 2.80 for the lowest and highest, respectively for all types of soils. Therefore, the study adopted 2.00 and 2.80 as the lower and upper limits, respectively for the suitable specific gravity of soil samples for earth construction. There are no known criteria for acceptable optimum moisture content and maximum dry density for soil suitability for earth construction, therefore, the study considered values that are closely related as suitable optimum moisture content and maximum dry density.

CHAPTER 4

RESULTS AND DISCUSSION

Chapter 4.1: Particle Size and Distribution

Theoretically having higher clay content in soil with medium to high plasticity should be able to be used for earthen work if applied with high compaction pressure. As the clay particle's, inter particle cohesive bond acts as electrical charges of different intensities, depending on the inter particle distance. With a low humidity content clays form a coherent solid with high densities. [l] So by checking the grading curves on the Particle Size curve, we will be able to determine the suitability of the samples for earthen work by judging the clay amounts.

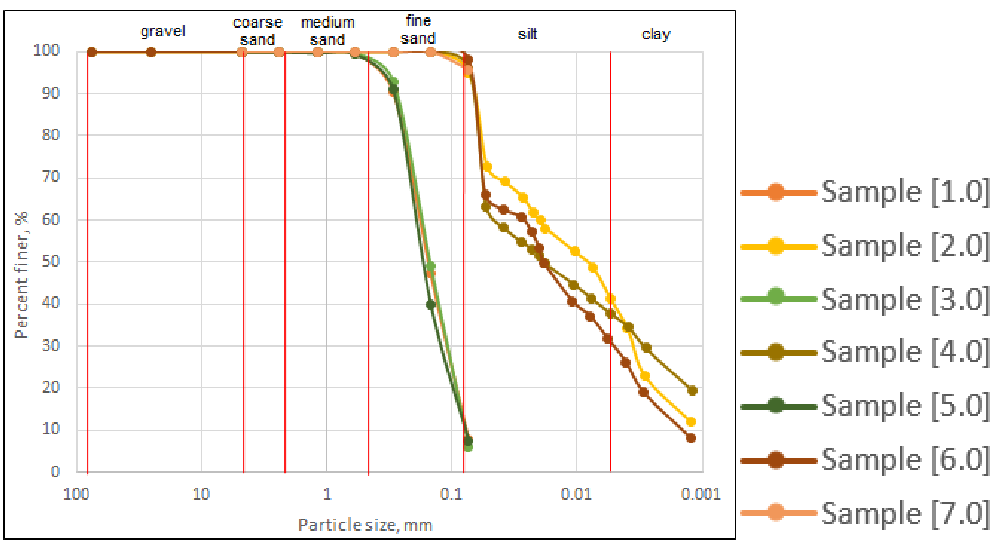

Figure 4.1 : Gradation Curves of the Sample Soils

Table 4.1: Particle Size Distribution Table.

Sample ID	Particle Sizes by Mass%							Soil Colour	USCS Classification
	Clay	Fines	Sand			Gravel	Colloid		
			Fine	Medium	Coarse				
[1.0]	0	7.64	86.61	5.69	0.07	0	0	Red clay	Poorly graded sand with silt
[2.0]	39.2	55.93	4.87	0	0	0	0	Red clay	Fat Clay
[3.0]	0	6.14	89.53	4.26	0.07	0	0	Red clay	Poorly graded sand with silt
[4.0]	36.91	58.98	4.11	0	0	0	0	Red clay	Fat Clay
[5.0]	0	7.47	87.18	5.28	0.07	0	0	Red clay	Poorly graded sand with silt
[6.0]	29.51	68.74	1.75	0	0	0	0	Red clay	Lean Clay
[7.0]	37.09	58.65	4.25	0	0	0	0	Brown clay	Lean Clay

Chapter 4.2: Atterberg Limit

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil: its shrinkage limit, plastic limit, and liquid limit. Depending on its water content, a soil may appear in one of four states: solid, semi-solid, plastic and liquid. It can provide a way to identify a soil for a particular area objectively and generally. The determination of the liquid and plastic limits is sufficient for construction purposes. The plastic limit can be defined as the moisture content at which, when rolled into a thread, a soil will begin to crumble. The thread is roughly 3mm in diameter. The liquid limit is the moisture content at which the soil transitions and starts to flow from plastic into liquid states. The difference between the plastic limit and the liquid limit is the plasticity index.

Sample ID	Atterberg Limits			Degree of Plasticity
	W_l (%)	W_p (%)	I_p	
[1.0]	50.4039	20.1326	30.2713	High plasticity
[2.0]	54.30776	22.11455	32.19321	High plasticity
[3.0]	48.625	23.067	25.558	Low plasticity
[4.0]	51.52001	21.78812	29.73189	High plasticity
[5.0]	50.4831	25.3054	25.1777	High plasticity
[6.0]	45.75918	21.24401	24.51517	Low plasticity
[7.0]	48.9	20.78	28.12	Low plasticity

Table 4.2: Atterberg Limits and Plasticity of the Sample Soil

Here, we have about 7 soil samples with their liquid limit, plastic limit and plasticity index. According USCS we have categorized all the samples into high plasticity and low plasticity. When the liquid limit is higher than 50, we considered it having high plasticity and when the liquid limit is lower than 50, we considered it having low plasticity.

From the table, we see [3.0,6.0,7.0] have low plasticity and [1.0,2.0,4.0,5.0,] have high plasticity.

[1.0,2.0,4.0,5.0] these soils have high amount of clay. Since clay ties the larger particles together, the clay content in the soil is a significant factor in earth building. Here these soils have more than 30 per cent clay. So they have ability to absorb moisture, have a very high shrinkage and swelling effect, which can result in the creation of cracks in the end product. So in order to use them in building structure we need to use stabilizers.

On the other hand, a relatively low amount of clay is present in the soil sample [3.0,6.0,7.0]. They will lead to weak bonding of other particles, which can lead to bonding failures in the final product. Therefore, in order to make them suitable for building purposes, soils with very low or very high content of clay and often silt may require the addition of stabilizers.

Chapter 4.3: Specific Gravity, optimum moisture content and maximum dry density

The specific gravity of a soil is the ratio of the mass of soil solids to the mass of an equal volume of water which provides an idea about the suitability of the soil as a construction material (Oyediran, 2011) and (Jain, 2002). Specific gravity (G_S) of a solid substance is the ratio of the weight of a given volume of material to the weight of an equal amount of water at 20 ^{o}C (www.globalsecurity.org, n.d.). In simple language, the specific gravity of soil tells how much heavier or lighter in weight the soil is than water. In many situations during construction processes, it is necessary for the soil to be compacted to its maximum dry density (Ren XC, 2015). Compaction is the process of mechanically densifying a soil by pressing the soil particles together into a closed state of contact so that the entrapped air can be expelled from the soil mass (www.bits.de, n.d.) and (H, Influence of compacting rate on the properties of compressed earth blocks. , 2016). The optimum moisture content (OMC) of soil is the water content at which a maximum dry unit weight can be achieved after a given compaction effort (en.wikipedia.org, n.d.). Maximum Dry density (MDD) of soil is the density that occurs at optimum moisture content.

The tables given below presents the data collected from the soil tests conducted by "Prosoil" a foundation consultant company for their project at Rupganj, Naraynganj. Forty-eight (48) data samples were collected from their tests which reported the values of specific gravity of soil. Table shows that all the samples have a specific gravity value of 2.725 which is within the recommended range of 2.00 to 2.80.

Tables also shows the optimum moisture content (OMC) values of the samples are mostly within the recommended range of 9.00 to 29.80 other than three exceptions. Of 33.98, 45.19, 30.11 values 45.19 is way out of recommendation. Also the tables provide the data of Maximum Dry Density (MDD) of the collected samples which are between 10.52 KN/m^3 to 20.1 KN/m^3. Critical observation of the values shows close relative spacing. Therefore, this provides the basis for recommendation for all the maximum dry density values in the table. Considering the results of the specific gravity, optimum moisture content and maximum dry density of the soil samples, it can be said that the influence of these are less in determining the suitability of the soil for earth construction compared to the particle size distribution and Atterberg limits.

Table 4.3: Specific Gravity, Optimum Moisture Content and Maximum Dry Density

Sample ID	G_s	OMC	MDD
[1.0]	2.725	25.44	12.85
[2.0]	2.725	17.7	12.4
[3.0]	2.725	26.88	13.68
[4.0]	2.725	19.2	12.43
[5.0]	2.725	28.94	11.41
[6.0]	2.725	18.6	12.5
[7.0]	2.725	33.98	11.87

Chapter 4.4: Combined result:

Stabilization of soil is an essential step in any construction project. In order to make our soil samples suitable for earth construction work we need to use various stabilizers such as cement, lime and fly ash etc. Criteria that are considered for the selection of suitable stabilizers are as follows-

Cement Stabilizer: Suitable for under 30% of clay amount, high control of moisture content although this method is not economic.

Lime Stabilizer: Clayey soil, high amount of clay, plasticity index around 10 but this method can have impact on the environment and isn't suitable for the stabilization of silty soil.

Fly ash: For low moisture content, for coarse grain soil/sandy soil and must be used with cement.

From the above mentioned qualities we have recommended the stabilization methods of our soil samples:

Cement stabilization- [6.0]

Lime stabilization- [2.0], [4.0]

Fly ash with cement stabilization- [1.0], [3.0], [5.0]

Among our sample data some of the soil some soil properties are unsuitable for earth construction works but are rather suitable for other works such as pottery and use in concrete mix etc. We found that among our sample data [7.0], have high content of silt and clay as such these type of soil is very suitable for making earthen wears and pottery.

Chapter 4.5: Cost Analysis

Below shows the comparative cost analysis for the proposed stabilized earth blocks using the Rupganj Soil.

Compressed Stabilized Earth Blocks: BDT 35/unit (8% cement)

Unit Dimensions: (7 inch x 14 inch x 4 inch) = 0.227 cu ft.

Therefore, 1 cubic ft. = 154.18 BDT

Fire Clay Brick: BDT 10.5/unit

Unit Dimensions: (10 inch x5 inch x3 inch)” = 0.087 cu ft.

Therefore, 1 cubic ft. = 120.68 BDT

Price of concrete ranges depending on the PSI

1 cubic ft. = BDT 230 - BDT 300

So considering the price and environmental effects we can consider Compressed Stabilized Earth Blocks as a viable alternative to traditional building materials.

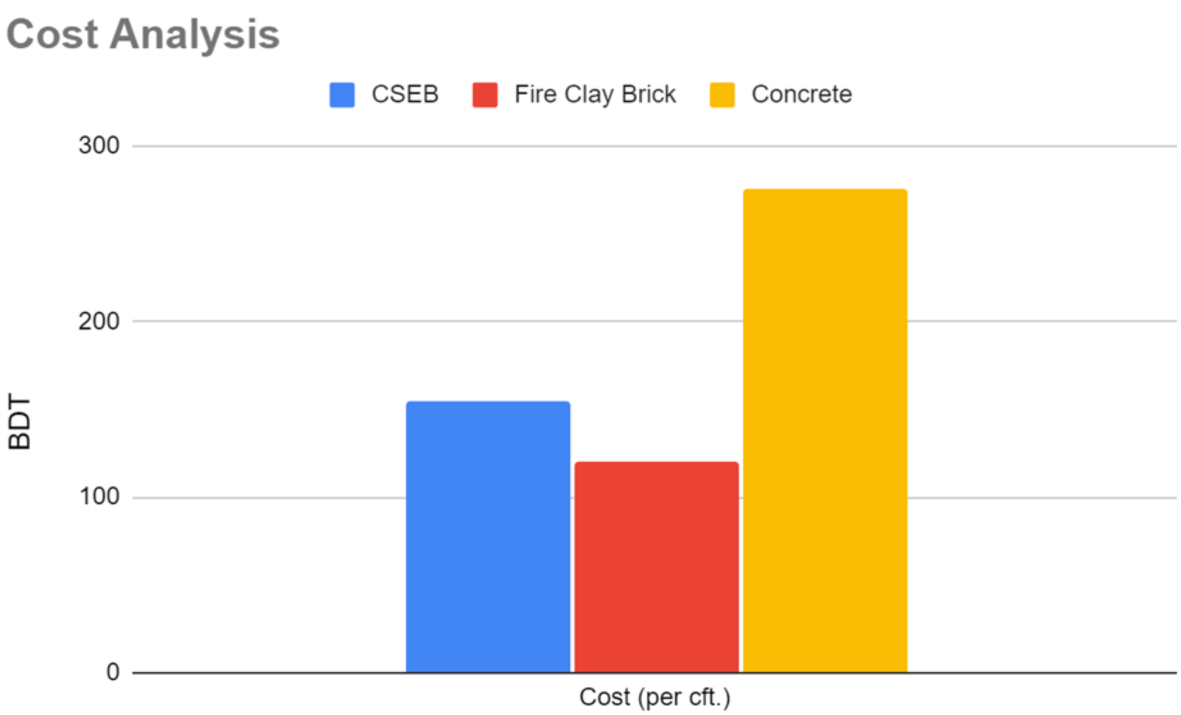

Figure 4.5: Cost comparison of different types of material

Chapter 4.6 Reduction of Carbon footprint:

Below shows the amount of carbon emission reduction due to choosing earth as a material,

60-70% less energy consumption compared to traditional burnt clay brick
For one unit (0.227cft) of earth
block, considering 8% cement,
We know, 0.01816 cft cement produces 0.667 kg of CO_2
Similar unit of concrete would emit about 1.52544 kg of CO_2

So we can see the reduction of carbon= {(1.5254-0.667)/1.5254} *100%
=56.26%

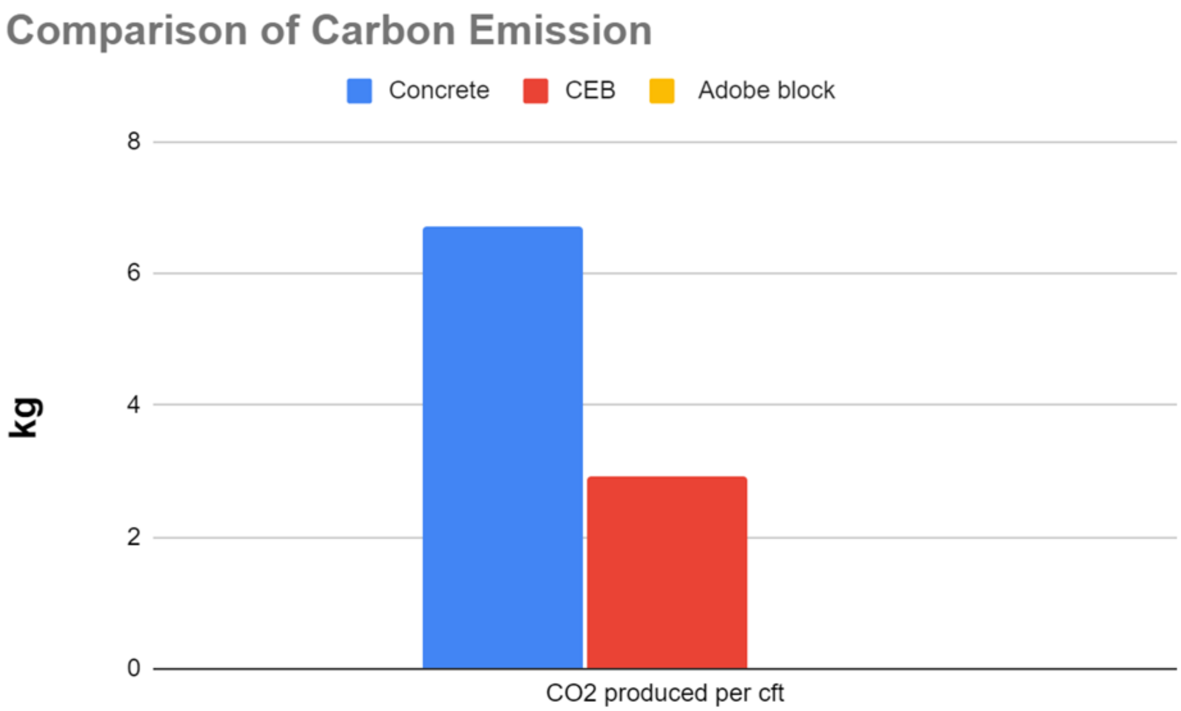

Figure 4.6: Comparison of carbon emission by different materials.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Chapter 5.1 General

Our research has finally led us to a conclusion that the soil properties of Rupganj soil are ideal for earthen construction. We can see that it is suitable for such construction based on the obtained values from various experiments and collected data. We were also able to identify specific stabilizers for the lack of a specific soil component. We also discovered soil's other uses. We also looked at the soil's impact on the environment.

Chapter 5.2: Soil Review

We discovered that the soil is mostly clay, with some sandy soils thrown in for good measure. One advantage that should be mentioned is that there was no organic material. In comparison to traditional burnt clay bricks, 60 percent to 70 percent less energy is consumed here. As a result, it is both cost-effective and environmentally friendly.

Unfortunately, the amount of data collected was insufficient for a conclusive study like the one we conducted here. We couldn't possibly consider all possible construction methods. We were only able to collect data from two locations, which we considered to be ideal samples. The use of the soil directly is limited because our research is based on referential papers. It can, however, be used as a reference point. As a result, other researchers can use our findings to determine the suitability of local soil. Future research can be based on our findings, and the interaction between fiber and various earth block materials can be easily determined.

Finally, but certainly not least, we attempted to use our findings as a foundation for any future research or work, so that it can be used to determine the suitability of the soil and to compare it to other studies in order to better understand its characteristics.

Chapter 5.3: Future study and Suggestions

Evaluation of soil quality may be one of the soil science community's most contentious topics ever debated. Our goal is to examine the current status and potential of the assessment of soil quality as a tool for monitoring the physical, chemical and biological effects of management decisions that may affect soil and water resources on the soil. Differences are identified and discussed between inherent and dynamic soil quality and different approaches for evaluation. In our research we got the value of particle size of soil, plastic limit, liquid limit, plasticity index, specific gravity, optimum moisture content, maximum dry density. From these values we can do the following future evaluation:

- For earthblock construction purpose it will help to compare between different soils of Bangladesh.
- Further research can be conducted on the soil that we tested as the values we got are suitable for construction.
- Similar research can be done on a bigger scale regarding different types of soil from different region.
- Research on fiber interaction can also be done as we have good data of soil investigation. We can do improvement also according to necessity.
- It will be beneficial on deciding to how to choose and use soil economically.
- A huge threat to our environment which is Carbon emission can be controlled by gaining knowledge from this research.
- It will help us by providing alternatives regarding building purpose also.

- Energy saving. The main manufacturing cost of the block involves only the cost of conveying the earth to the site, a routine procedure since earth is a material within easy reach of most building sites. Furthermore, if the earth comes from the excavation work on the site itself, two birds are killed with one stone, compounding the savings.Technically, moreover, it is a very advantageous material with great energy-saving potential in heating and cooling terms.
- The cheapness of the material will help to reduce homelessness. A study can be conducted on the population with a poorer income and find out if using earthen houses can be a solution to their predicament.

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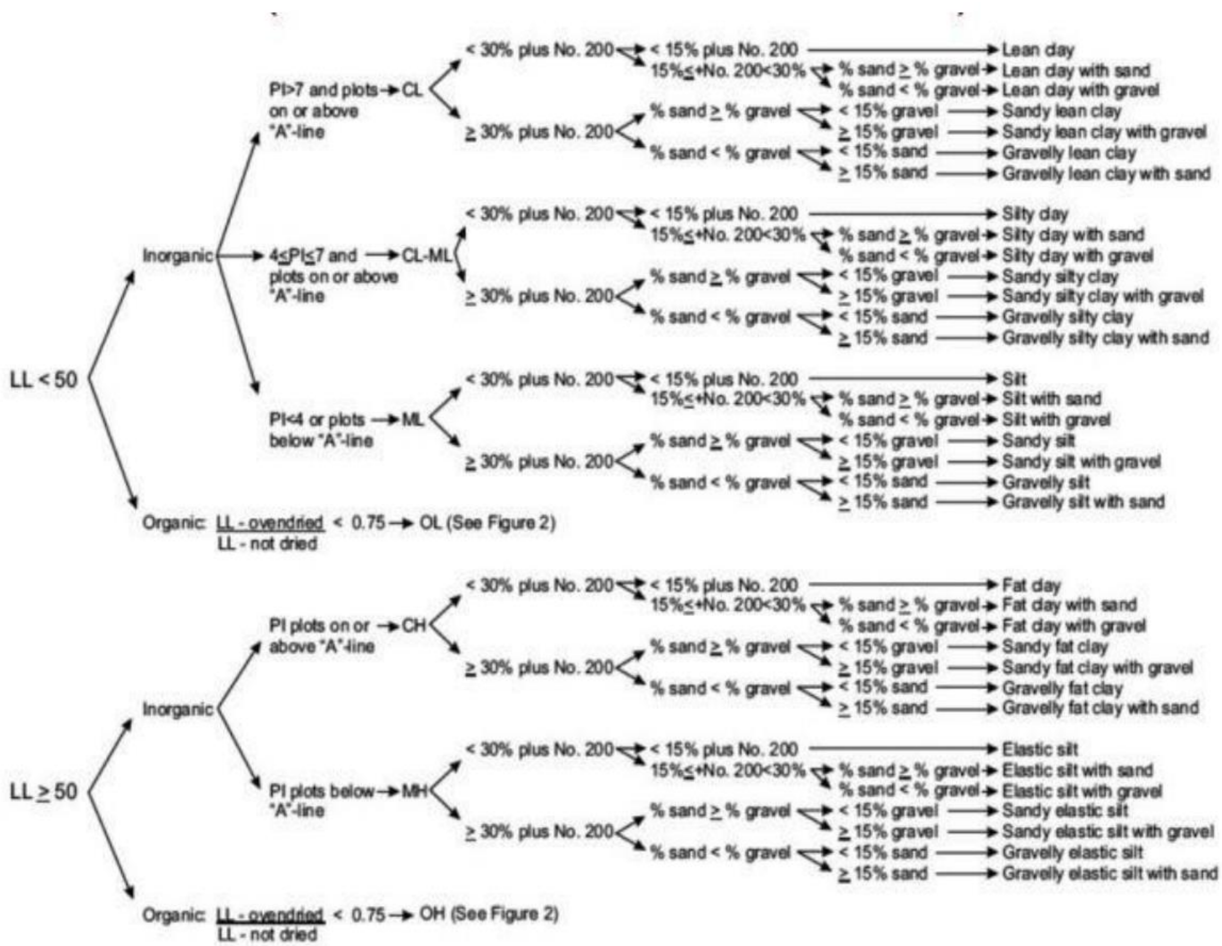
APPENDIX

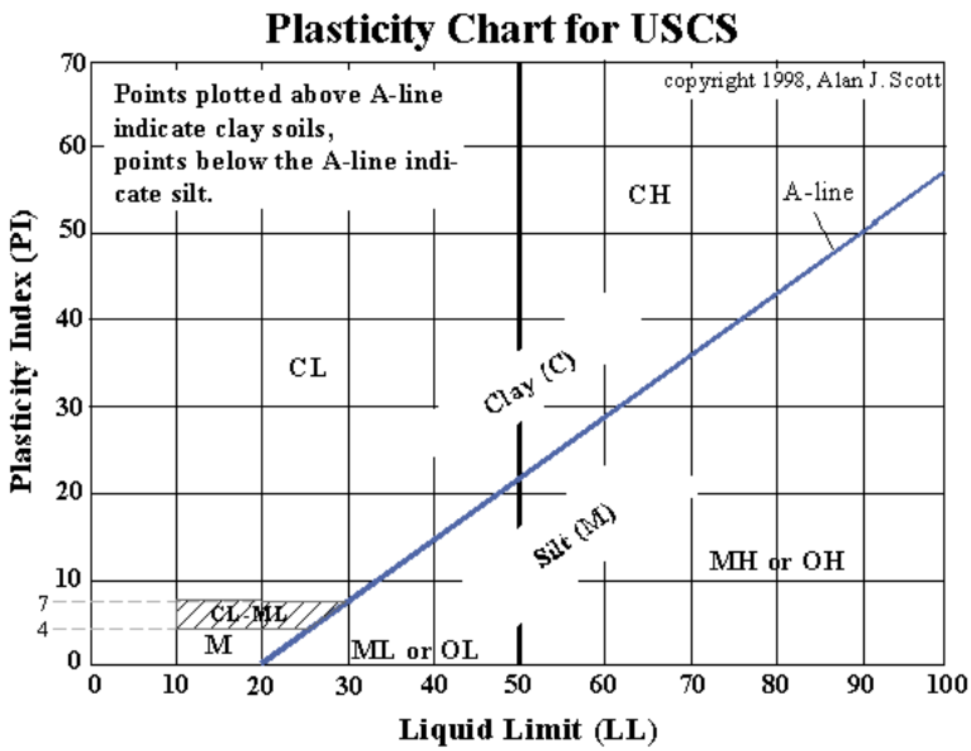
Soil classification

USCS Soil Classification System

For fine grained soil (≥50% passing #200 sieve



Plasticity Chart for USCS



Grain size Analysis

Bore Hole: SW-BH-103

Location: Boruna Bazar, Narayanganj

Depth (m): 4.0

Sample Type: Disturbed

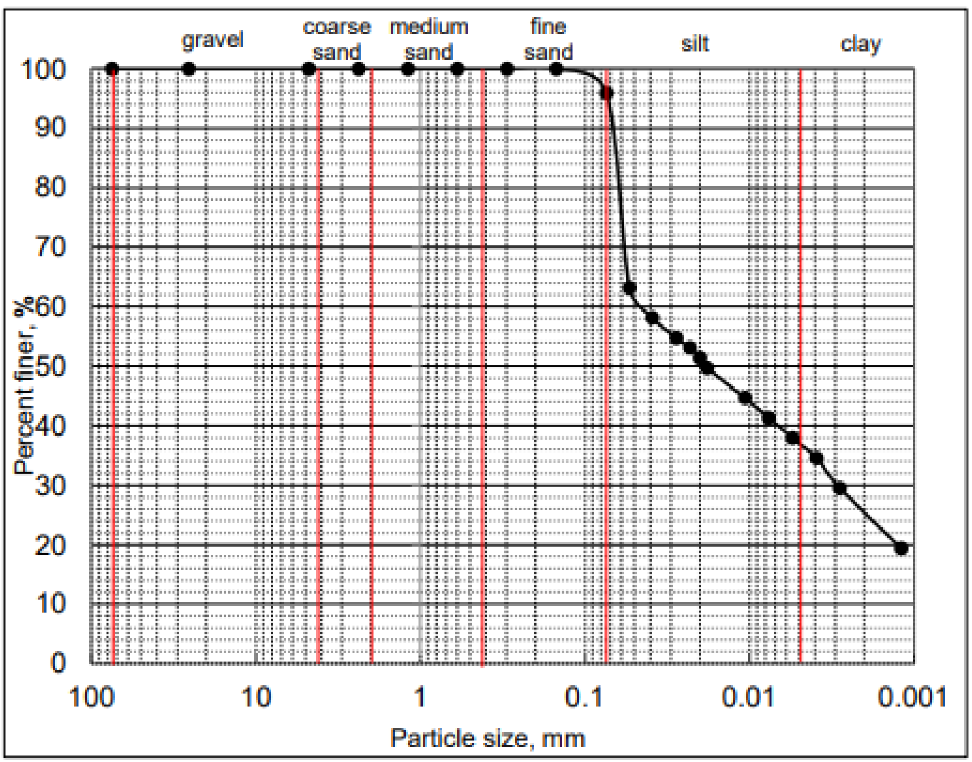
Date: 28-Sep

Size fractions

Gravel : 75.00 mm to 4.75 mm =	0.00 %
Coarse sand : 4.75 mm to 2.00 mm (Passing #4 and retained on #10) =	0.00 %
Medium sand : 2.00 mm to 0.425 mm (Passing #10 and retained on #40) =	0.00 %
Fine sand : 0.425 mm to 0.075 mm (Passing #40 and retained on #200) =	4.11 %
Silt size : 0.075 to 0.005 mm =	58.98 %
Clay size : smaller than 0.005 =	36.91 %
Colloid : smaller than 0.001 =	0.00 %
	100.0

Visual classification: Clay
USCS classification: Fat Clay

D10 (mm)	D30 (mm)	D50 (mm)	D60 (mm)	D95 (mm)	Sand (%)	Fines (%)	C_c	C_u	LL (%)	PI (%)	USCS
-	0.003	0.018	0.044	0.073	4.11	95.89	-	-	51.52	29.73	CH



% finer	openning (mm)
100.00	75.0000
100.00	25.5400
100.00	4.7600
100.00	2.3800
100.00	1.1900
100.00	0.5960
100.00	0.2970
100.00	0.1490
95.89	0.0740
63.19	0.0536
58.13	0.0388
54.76	0.0279
53.08	0.0229
51.39	0.0200
49.71	0.0180
44.65	0.0106
41.28	0.0076
37.91	0.0055
34.54	0.0039
29.49	0.0028

Liquid and Plastic Limit Test

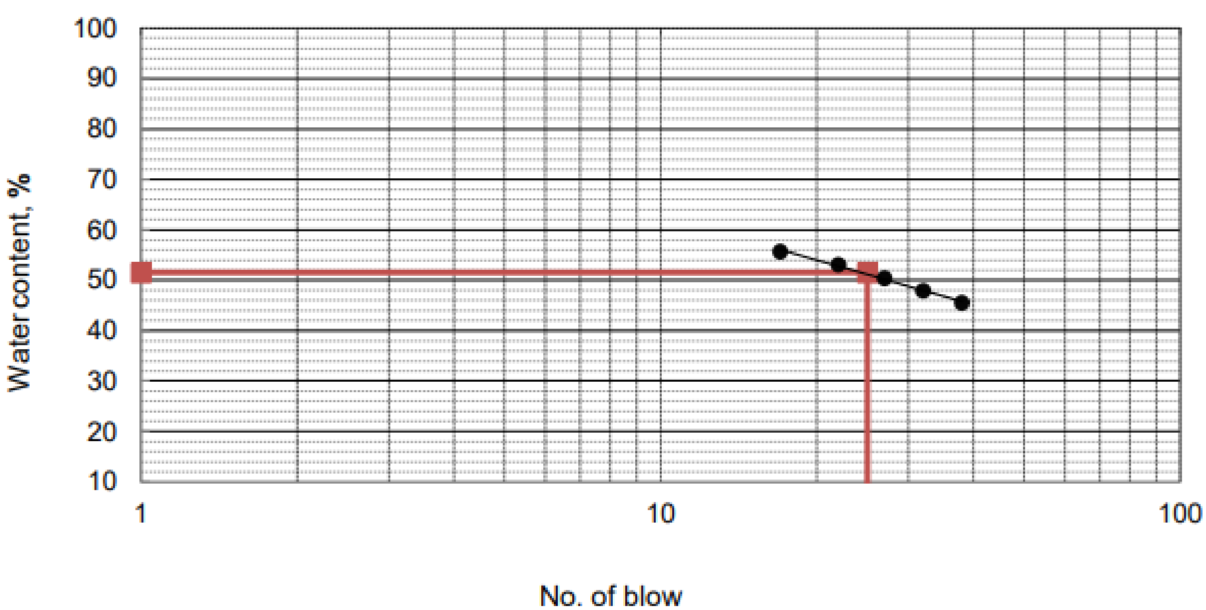
For Liquid Limit Analysis

No. of Blow	38	32	27	22	17
Wt. of bowl	20.24	20.20	20.44	20.49	23.65
Wt. of bowl+wet soil	30.18	32.42	30.16	31.59	34.63
Wt. of bowl+dry soil	27.07	28.46	26.90	27.74	30.70
Water content	45.53	47.94	50.46	53.10	55.74
Lquid Limit	*51.52*				

For Plastic Limit Analysis

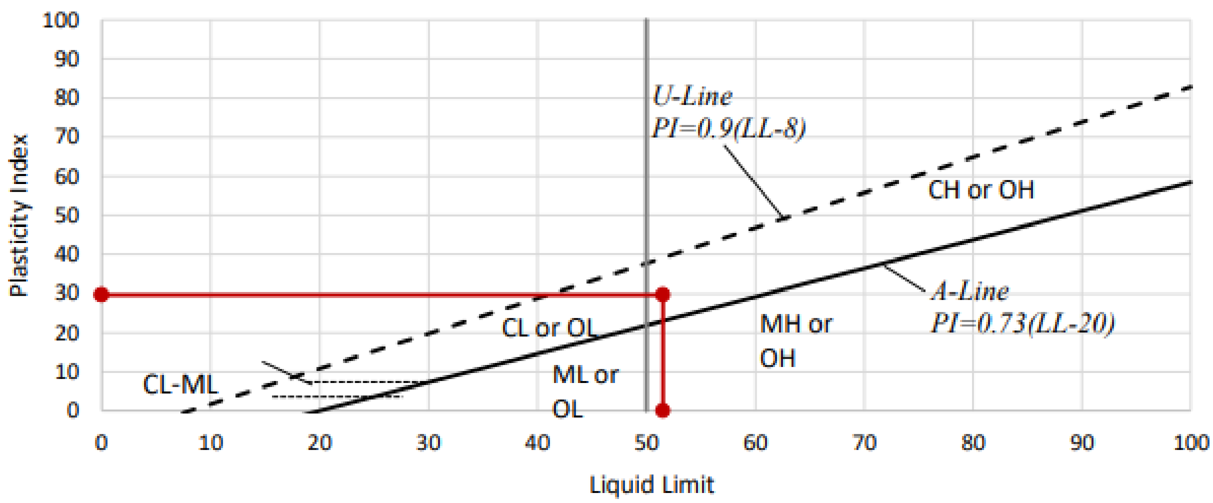
Wt. of bowl	20.32	23.80	18.21
Wt. of bowl+wet soil	22.79	25.58	20.48
Wt. of bowl+dry soil	22.33	25.27	20.08
Water content	22.89	21.09	21.39
Plastic Limit	*21.79*		

Graph for Liquid Limit (LL) Determination



Soil Classification by Cassagrande's chart

Soil Classification by using Aurther Casagrande's Plasticity Chart



Result Summary		
Liquid Limit, LL	**51.52**	%
Plastic Limit, PL	**21.79**	%
Plasticity Index, PI	**29.73**	
Soil Type	**CH (Clay with High Plasticity)**	

Note(s)

(1) Standard wet preparation and multipoint LL method has been used.

(2) If the plastic limit is equal to or greater than the liquid limit, soil is reported as as nonplastic, NP.