DETERMINATION OF IN SITU SOIL DENSITY BY SAND CONE METHOD USING LOCALLY AVAILABLE SANDS

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ABSTRACT

In Bangladesh Ottawa sand is used to find out in situ soil density using Sand Cone Method. Ottawa sand is very expensive and it is always imported from abroad. Usually it requires much time to import this item. Instead of Ottawa sand, Sand Cone Method might use locally available sand as an alternative material for determining in situ soil density. In Bangladesh, local sand is available in abundance and compared with Ottawa sand it is also much cheaper in price.

In this research the quality and suitability of locally available sand in and around Khulna district are assessed for determining in situ density using Sand Cone Method. Five samples of sand named by Sylhet sand, Kushtia sand, Fultala sand, Bogjhuri sand and Mongla sand were collected from nearby business centers. Original sand and some graded sands of each sample were under investigation to ascertain their suitability of use in lieu of Ottawa sand in determining in situ soil density. Four gradations were considered and those were (i) passing # 16 and retained in # 30, (ii) passing # 30 and retained in # 40, (iii) passing # 40 and retained in # 50 (iv) passing #30 and retained in # 50 sieve. Each of the original samples has been characterized by determining its index properties, Grain size distribution. Specific gravity and density are determined for each sample of original and graded sands. These properties are compared with those recommended by ASTM (1989) for selecting suitable sand in Sand Cone Method.

From this study it was found that original sands of all selected places in Bangladesh did not satisfy the ASTM (1989) criteria for Ottawa sand. In case of graded sands, Sylhet sand satisfied all the required ASTM criteria for four gradations, while Kushtia and Fultala sands satisfied fully for three gradations except the gradation passing # 16 and retained in # 30 sieve. Bogjhuri and Mongla sands did not satisfy all the required criteria. So, the above graded sands that satisfy the criteria of Ottawa sand as mentioned in investigation can be used in sand cone method in lieu of costly Ottawa sand.

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NOTATIONS

AASHO	American Association of State Highway & Officials
ASTM	American Society for Testing and Materials
C_u	Uniformity coefficient
D_{10}	Diameter of the particles at 10 percent finer
D_{60}	Diameter of the particles at 60 percent finer
F.M.	Fineness modulus
Rc	Relative compaction
P_{max}	Maximum porosity
V	Volume of mold
V_w	Volume of displaced water
γ_d	Filed dry density
γ_{dmax}	Laboratory maximum dry density
γ_p	Density of paraffin wax
(-)	Passing sieve
(+)	Retained sieve

CHAPTER 1
INTRODUCTION

1.1 General

Compaction generally increases the shear strength of the soil, and hence the stability and bearing capacity. For this reason compaction of soil is required for the construction of earth dams, canal embankments, highways, retaining walls, runways and in many other engineering applications. Field compaction is measured quantitatively by determining the dry density of soil in situ. There are various methods of determining the field density of soils. The prominent are sand cone method, core cutter method, water displacement method and the rubber balloon method. The core cutter method is a convenient and quick method but it is best suited only for fine-grained cohesive soils which can be easily penetrated by the core cutter and which can be retained in it on excavation. Water replacement method can only be used on cohesive soil. The sand replacement or sand cone method, though relatively slow, can be widely used on any type of soil. In this project work the measurement of field density of sand by sand cone method was under consideration because sand cone method is widely used in our country. But in this method, ASTM (1989) has specified the use of Ottawa sand for the determination of in situ density, which is very costly. In this project it is under investigation that whether low cost locally available sand can be used in lieu of Ottawa sand in the measurement of field density or not.

Ottawa sand is usually specified for the determination of in situ volume and hence the soil density in sand cone method. Ottawa sand consists of pure siliceous materials and is practically all of one size and approximately white in colour. The specification of this test requires that the sand must be uniformly graded and rounded in shape to ascertain its free fall. In Bangladesh sands are available in abundance and it is expected that some of them might meet the specification requirements for density determination. If so the use of local sand would be less costly and can be used instead of expensive Ottawa sand due to its nominal cost, Furthermore, the local sand can be afforded to left in place after performing the test, which will shorten the testing time.

1.2 Objectives of the Study

The present project work is performed with a view to ascertain the suitability of selected local sands of Bangladesh for the determination of in situ soil density. Sand sample would be collected from some local business centers in and around Khulna district of Bangladesh. Test samples would be prepared by making numerous gradation of a sample. After performing field and laboratory tests the data would be analyzed to ascertain its statistical acceptability.

The major objectives of the study are:

i) To determine the desired density of graded and in place local sands from selected locations of Bangladesh.

ii) To compare the results of local sand with those of Ottawa sand in order to suggest the suitability of using local sand in the determination of in situ soil density.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Since most building sites start out as raw land, the first step in site construction work usually involves the grading of the site. Grading is defined as any operation consisting of excavation, filling, or combination thereof. The most common method of assessing the quality of the field compaction is to calculate the relative compaction (R_C) or degree of compaction of the fill, defined as:

$$R_C = 100 \frac{\gamma_d}{\gamma_{d\max}}$$

where, $\gamma_{d\ max}$ = laboratory maximum dry density and γ_d = field dry density.

The maximum dry density, $\gamma_{d\ max}$ is obtained from the laboratory compaction curve. In order to determine γ_d in the above equation, a field density test must be performed. The maximum dry density sought to be achieved in-situ is specified usually a certain percentage of the value obtainable in the laboratory compaction test. Thus control of compaction in the field requires the determination of in-situ density of the compacted fill and also the moisture content.

In this chapter the literature on the methods of field density measurement are briefly reviewed. A comparative study among them is also made in order to determine the suitability of these methods. The salient features of these methods are described in the following articles. An elaborate review of the literatures on sand density is also made.

2.2 In Situ Density Determination Methods

There are a number of methods for the determination of in place density of soil. Following methods are widely used:

(a) Sand cone method
(b) Core cutter method
(c) Rubber balloon method and
(d) Water displacement method

The methods are discussed briefly in the following articles.

2.2.1 Sand Cone Method

This method covers the determination of the in place density of soils. This method can be used to determine in place density of aggregates, soil mixtures or other similar materials. It is widely used to determine the density of compacted soils used in the construction of earth embankments, road fill and structures backfill.

The sand cone method is an indirect means of obtaining the volume of the hole. The sand used (often Ottawa Sand) is generally material passing No. 20 sieve but retained on the No. 30 sieve. Although (-) No. 30 and (+) No. 40 or (-) No. 30 and (+) No.50 sieve material can be used. It is generally desirable to have uniform or "one-size" sand with rounded grains to avoid segregation problems. The use of rounded particles instead of angular particles reduces particle packing. Sand characteristics should be such that of sand was poured through the cone apparatus into a hole and then completely recovered and then a second sand container is used the volume of the hole would be approximately the same (Bowles, 1992).

According to ASTM (1989), use of this method is generally limited to soil in an unsaturated condition. This method is not recommended for soils that are soft or friable (crumble easily) or in moisture condition such that water seeps into the hand excavated hole. The accuracy of the test may be affected for soils that deform easily or that may undergo a volume change in the excavated hole from standing or walking near the hole during the test.

The most commonly used sand cone apparatus uses a 3785 ml glass or plastic jug with sufficient material to fill a hole of not over 3700 ml and results depend on how full the jug prior to the test. In general, the field test holes will be quite small. Thus the error multiplier is large. It is absolutely essential that no soil be lost during excavation and that the volume determination not be done in any way that gives an apparent hole volume that is too large (or too small). Standard test procedure and method can be found in ASTM (1989). Details of the sand cone apparatus are shown in Fig. 2.1.

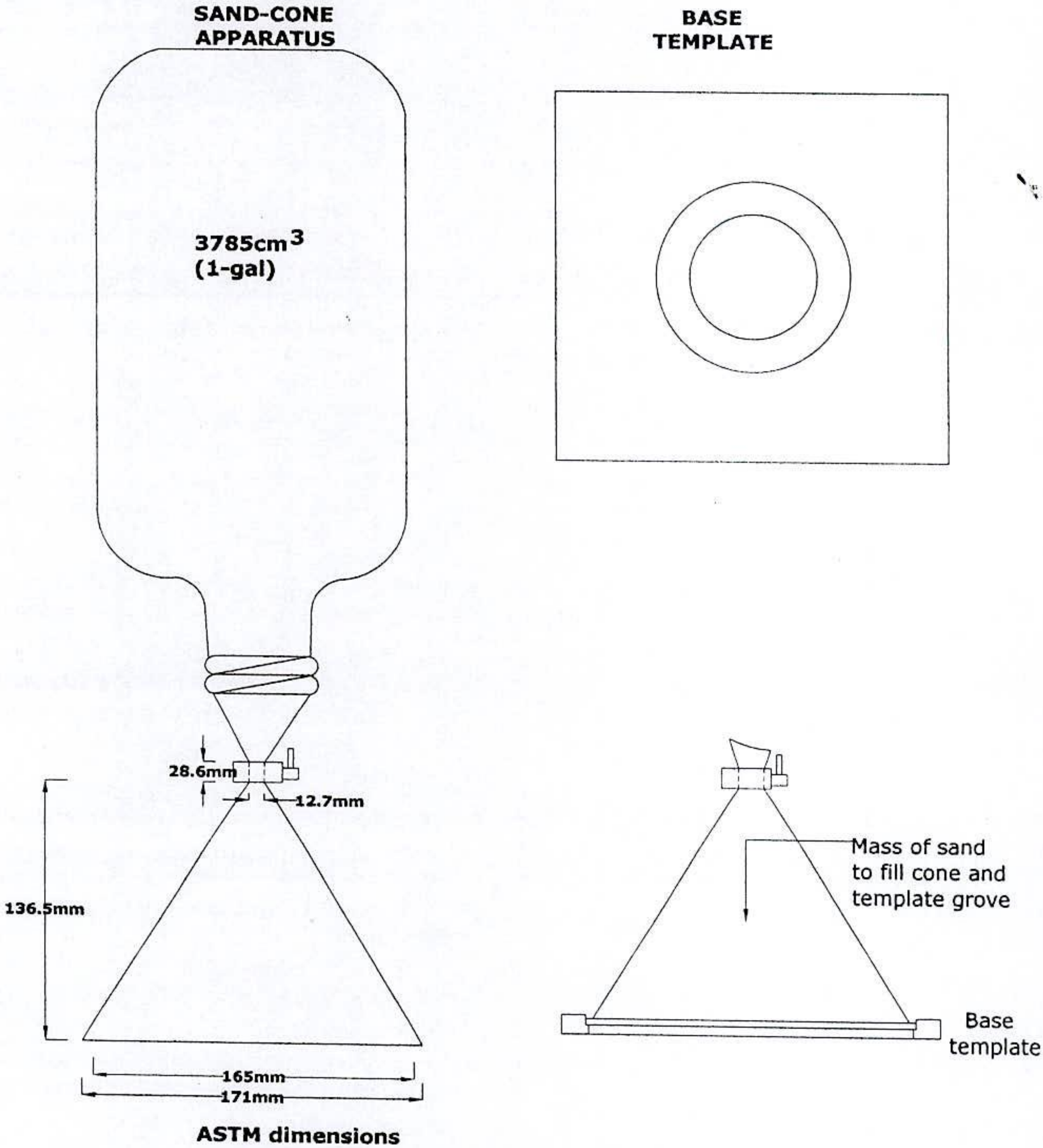

Fig. 2.1 General Line Details of the Sand Cone Apparatus.

2.2.1.1 Properties of Sand Used in Sand Cone Method

According to ASTM (1989) properties and requirements of sand that can be used in Sand Cone Method for determining in situ soil density are described below:

(i) Sand should be clean, dry, uniform uncemented, durable and free flowing.

(ii) Any gradation may be used that has uniformity coefficient ($C_u = D_{60} / D_{10}$) less than 2, a maximum particle size less than 2.00 mm (No. 10 sieve) and less than 3% by weight passing 250 μm (No. 60 sieve)

(iii) Uniform sand is needed to prevent segregation during handling, storage and use. Sand free of fines and fine sand particles is needed to prevent significant bulk density changes with normal daily changes in atmospheric humidity.

(iv) Sand comprised of durable, natural surrounded or rounded particles is desirable. Crushed sand or sand having angular particles may not be free flowing, a condition than can cause bridging resulting in inaccurate determinations.

(v) In selecting a sand from a potential source, five separate bulk density determinations shall be made on each container or bag of sand. To be acceptable sand, the variation between any determination and average shall not be greater than 1% of the average.

(vi) Before using sand in density determinations it shall be dried. Then allowed to reach an air dried state in the general location where it is to be used.

(vii) Sand shall not be reused without removing any contaminating soil, checking the gradation and drying.

(viii) Bulk density tests shall be made at intervals not exceeding 14 days, always after any significant changes in atmospheric humidity, before reusing and before using a new batch from a previously approved supplier.

2.2.1.2 Bulk Density of Sand

The bulk density of sand to be used in the filed test depends on how densely the sand is packed and it follows that for a material of a given specific gravity the bulk density depends on the grain size distribution and shape of the particles. All particles of one size can be packed to a limited extent but smaller particles can be added in the voids between the larger ones, thus increasing the bulk density of the packed material. The shape of the particles greatly affects the closeness of packing that can be achieved.

The actual bulk density of sand depends not only on the various characteristics of the material which determine the potential degree of packing but also on the actual compaction achieved in a given case. The test purposes, the degree of compaction has to be specified BS 812: Part 2: 1975 recognizes two degrees: loose (or uncompacted) and compacted. The test is performed in a metal cylinder of prescribed diameter and depth, depending on the maximum size of the materials and also on whether compacted or uncompacted bulk density is being determined.

It is suggested by Kolbuszewski (1948) that the following procedures be used for obtaining limiting porosities of sands:

1. Loose: 1000 gms of dry and thoroughly mixed sand should be placed in 2000 c.c. glass cylinder and a rubber stopper should be put on the cylinder. The cylinder with the sample should be shaken a few times and turned upside down, then very quickly turned over again. Taking volume of the sample, porosity can be calculated (P_{max}).

2. Dense: Compaction cylinder (proctors type) should be placed in the water tank and sand sample should be vibrated in 3 layers (15 minutes each layer) with pneumatic or electric hammer ("Kango hammer" type).

   1/30 cft sample should be thus obtained and then from it porosity can be calculated (P_{min}) .

2.2.2 Core Cutter Method

The apparatus in the core cutter method consists of:

(a) A cylindrical steel cutter having 10 cm internal diameter and 17.5 cm height, with a wall thickness of 3 mm, and bevelled at one end to form a cutting edge.

(b) A high steel dolly of 10 cm internal diameter and 2.5 cm height and 11.5 cm outside diameter fitted with a lip to enable it to be located at top of the cutter.

(c) A steel rammer having a tamping foot of 14 cm diameter and 7.5 cm height, fitted with a handle making a total height of about 1m.

Besides this balance accurate to 1 gm, pallete knife, straight edge, spade, pick-axe, trowel, apparatus for water content determination are required. The apparatus is shown in Fig. 2.2.

This method is used for clay, which is neither very stiff nor strong. The procedure for finding the field density by core cutter method is discussed below:

(i) The inside dimensions of the core cutter is measured (accurate to 0.5 mm) and then volume of the cutter is calculated.

(ii) The weight of the cutter is weighed without dolly.

(iii) The top soil of the site is cleaned. Then the dolly is placed over the cutter and rammed it gently into the soil by means of rammer until about 10 mm of the dolly protrudes above the surface.

(iv) The cutter is taken out containing the soil from the ground and the dolly is removed.

(v) Extra soil is trimmed off extruding from the ends and the cutter with full of soil is weighed.

(vi) Then the soil is removed from the cutter.

(vii) By dividing the weight of the soil by volume of the core cutter; bulk density of soil can be found out

(viii) Moisture content is also measured from representative sample of soil.

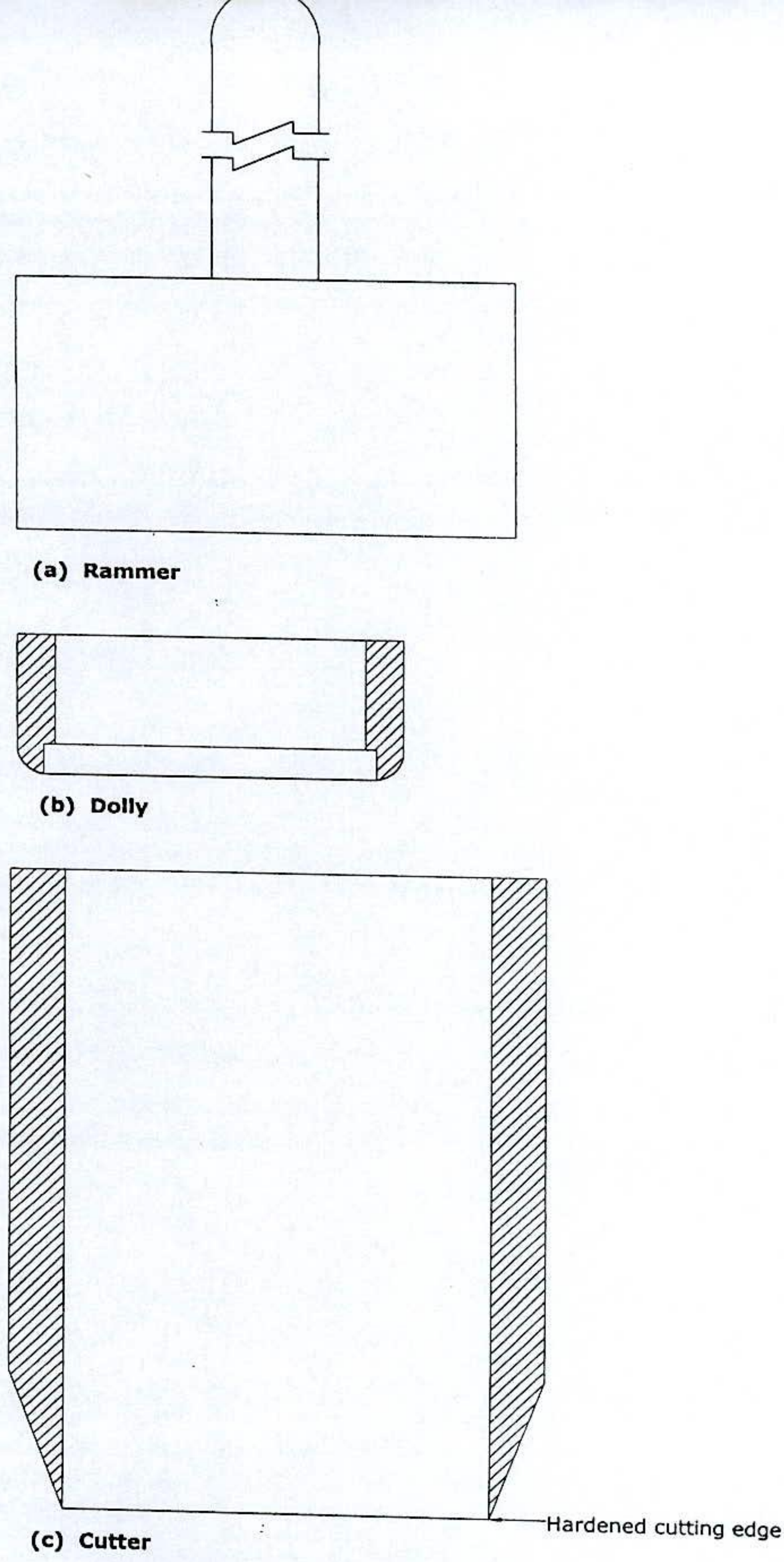

Fig. 2.2 Elevation of Core Cutter, Dolly and Rammer.

2.2.3 Rubber Balloon Method

Basically both the sand cone method and rubber balloon method use the same principle. That is one obtains a known mass of damp to wet soil from a small excavation of somewhat irregular shape of hole in the ground. If the volume of the hole is determined, the wet density can be easily computed. The volume of excavated hole is found by direct measurement of the volume of water pumped into a rubber balloon that fills the hole. This volume is read directly from a graduated cylinder that forms the reservoir for the balloon. The apparatus consists of the following parts:

(i) A graduated cylinder partially filled with water.

(ii) Air tight aluminium case which encloses the graduated cylinder.

(iii) Tray (density plate) with central circular hole of 10 cm diameter, which is sealed by a rubber balloon.

(iv) A pump is attached to the cylinder. For details of the method AASHO (1966) and ASTM (1989) can be consulted. The elevation of the apparatus are shown in the following Fig. 2.3.

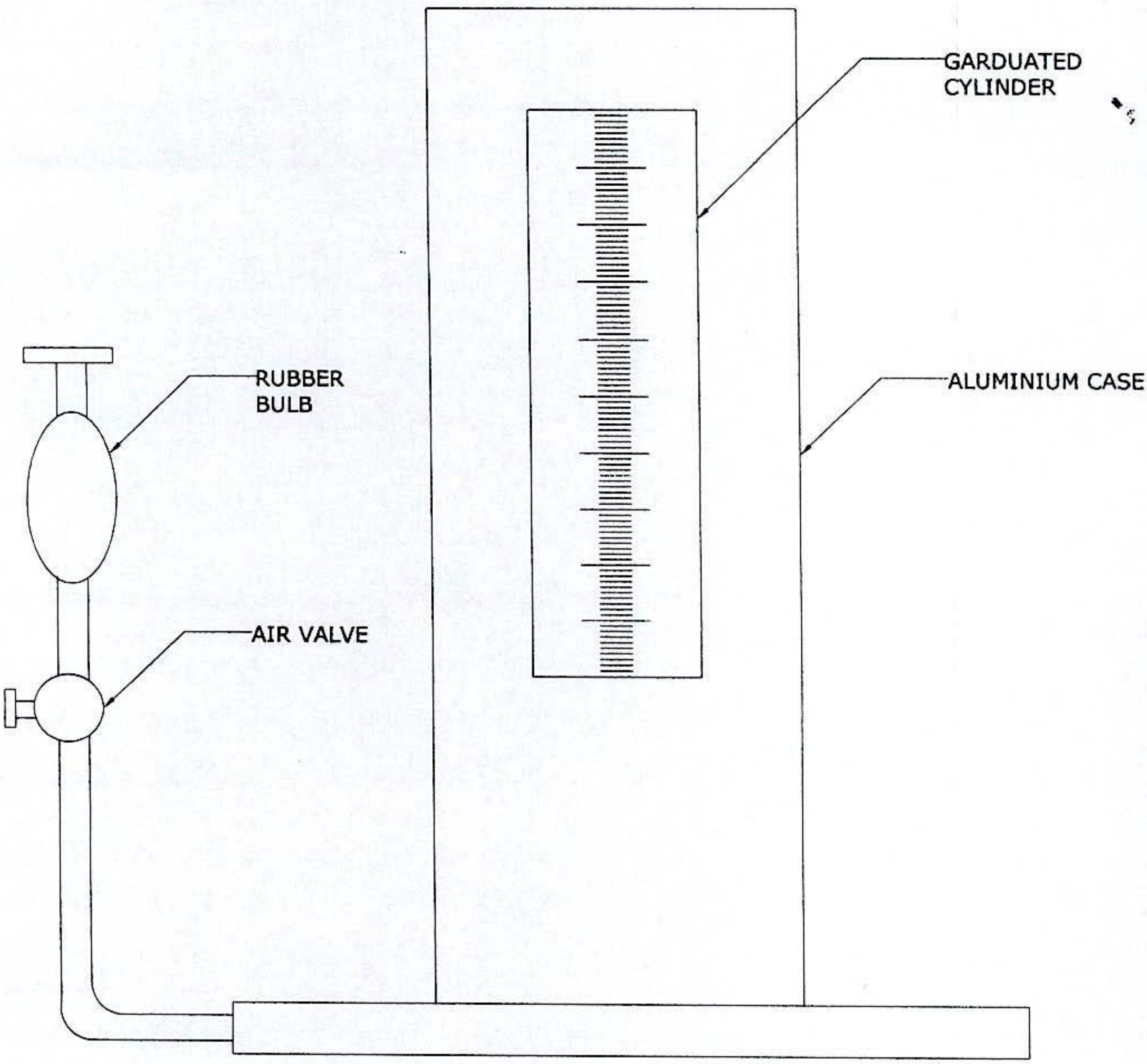

Fig. 2.3 Elevation of the Rubber Balloon Apparatus

Firstly, the tray is placed over the ground surface, where the density is to be determined. Then the cylinder is placed centrally over the tray. Air is pumped into the cylinder by opening air valve until the balloon is fully inflated against the surface of the soil in the opening to tray.

At this stage water level is read in the cylinder. The cylinder is then removed and hole is dug into the ground. The excavated soil is weighed. After that the cylinder is placed over the opening in the tray. Air is forced in the cylinder after opening the air valve so that the bottom is inflated. This is done till the base of the instrument is raised off the tray at least by one cm. The air valve is closed and both feet are placed firmly on the base plate so that the balloon into any irregularities in the hole. At this stage, again the level of water is read in the cylinder. The volume of the hole is found from the difference between the initial and final water levels in the cylinder. Once the volume and weight is known, then the bulk density of soil can be determined.

2.2.4 Water Replacement Method

This method has been found to be suitable for cohesive soils only. In this method a small specimen of soil is trimmed from a large sample or lump of soil having more or less regular shape (preferably cylindrical or cubical) and weighed it

Let the weight of the small specimen be W_1. Then the soil specimen is then coated completely by repeated dipping in molten paraffin wax. The waxed specimen is allowed to cool and weighed equal to W_2. The metal container should be filled with water up to overflow level and then the waxed specimen be immersed in water. The measurement of volume of displaced water should be done accurately. Let the volume of displaced water be V_w. The volume of the specimen can then be calculated by the following formula:

$$V = V_w - (W_2 - W_1) / \gamma_p$$

Where γ_p = Density of paraffin wax = 0.908 gm/cc.

The bulk density γ and the dry density γ_d are respectively given by:

$$\gamma = W_1/V \quad (gm/cc)$$

and $$\gamma_d = \gamma / (1+w) \quad (gm/cc)$$

Where, w = moisture content of the specimen o be determined by oven drying a small specimen.

2.3 Comparative Study of the Methods

The sand cone and balloon density methods for determining soil density, use the same principle. That is, one obtains a known weight of damp to wet soil from a small excavation of some what irregular shape hole in the ground. If the volume of the hole is determined the weight density can be easily computed. From these two methods the sand cone method is an indirect means of obtaining the volume of the hole. On the other hand by core cutter method the bulk density can be easily calculated from dividing the weight of bulk soil in the cutter by the volume of the cutter. Water displacement method has limited use. It can be used only for cohesive soil. For simplicity of the test, the sand cone method is widely used to determine the density of compacted soils. More over, other methods are not suitable for coarse-grained soil.

2.4 Previous Works on Local Sands in Bangladesh

Mohsin (1994) investigated the suitability of sand collected from Sylhet, Gazaria, Mymenshingh, Chandpur and Savar in lieu of Ottawa sand for the determination of field density in sand cone method. ASTM (1989) recommended some criteria for Ottawa sand. Regarding this criteria Mohsin (1994) found that original sand of all the collected locations did not satisfy the ASTM criteria. Only some graded sand of Sylhet and Gazaria satisfied all the criteria recommended by ASTM (1989). The satisfied grading of sands were:

(a) (-) No. 16 and (+) No. 30 (acceptable only for Sylhet)

(b) (-) No. 30 and (+) No. 40

(c) (-) No. 40 and (+) No. 50

(d) (-) No. 30 and (+) No. 50

Where (-) means passing and (+) means retaining sieve no.

CHAPTER 3

LABORATORY INVESTIGATION

3.1 General

For suitability of using locally available sands for determining in place soil density, Sylhet sand, Kushtia sand, Fultala sand, Bogjhuri sand and Mongla sand were selected. The samples of sands were collected from some locations of Jessore, Satkhira, Rupsha and Mongla. The selected type of sands and their designations are pointed out in Table 3.1.

Table 3.1 Type of Sands and Designations:

SL. No.	Types of Sand	Designation of Sample
1.	Sylhet	S-1
2	Sylhet	S-2
3.	Sylhet	S-3
4.	Kushtia	K-1
5.	Kushtia	K-2
6.	Kushtia	K-3
7.	Fultala	F-1
8.	Bogjhuri	B-1
9.	Mongla	M-1

Each of the collected samples was characterized by determining their index properties. Grain size distribution curve and specific gravity for each of the sample were determined according to standard procedure. Preparation of samples, determination of grain size distribution, specific gravity and density are described in the following Articles.

3.2 Preparation of Sample

The following procedures were carried out for the preparation of each sample:

a) Each sample was air dried for at least seven days.

b) With (ASTM) standard set of sieves (containing # 16, # 30, # 40, # 50, # 100) each air dried sample was graded. The gradations are shown in Table 3.2.

Table 3.2 Gradation of Sand

Sl. No	Description	Quantity of Sand collected	Purpose of Collection
1.	Sample passing sieve # 16 and retained in sieve # 30	6.0 kg.	Density determination
2.	Sample passing sieve # 30 and retained in sieve # 40	6.0 kg.	,,
3.	Sample passing sieve # 40 and retained in sieve # 50	6.0 kg.	,,
4.	Sample passing sieve # 30 and retained in sieve # 50	6.0 kg.	,,
5.	Sample passing sieve # 50 and retained in sieve # 100	6.0 kg.	,,
6.	Representative sample of all locations (original sand)	6.0 kg.	Determination of density, specific gravity and grain size distribution.

3.3 Properties of Sand Sample

3.3.1 Grain Size Distribution

Sieve analysis was carried out following the procedure of ASTM (1989).

The size of the grains of sands one of the factors affecting some of its physical properties of direct importance to the engineers and permeability. Grain size analysis was done by identification and classification of soils. It is done to determine the size of the soil grains and the percentage by weight of soil particles of different particle size comprising a soil sample.

The grain size distribution curves can be used to understand certain grain size characteristics of soils. Allen Hazen (1892) has shown that the permeability of clean filter sands in loose state can be correlated with numerical values designated D_{10}, the effective grain size. The effective grain size is corresponding to 10 percent finer particles. Hazen found that the sizes smaller than the effective size affected the functioning of filters more than did the remaining 90% percent of the sizes. To determine whether a material is uniformly graded, Hazen (1892) proposed the following equation:

$$C_u = \frac{D_{60}}{D_{10}} \tag{3.1}$$

Where D_{60} = particle size such that 60% of the total soil mass is finer than this size,

and D_{10} = particle size such that 10% of the total soil mass is finer than this size. When the uniformity coefficient, C_u is about one, the grain size distribution curve is almost vertical. For all practical purposes the following values can be considered for granular soils (Murthy, 1996).

$C_u < 5$	the soil is uniform
C_u = 5 to 15	the soil is medium graded
$C_u > 15$	the soil is well graded

In this study, grain size distribution curves were drawn after sieve analysis on each of the collected samples. The value of D_{10} and D_{60} were determined from these curves.

3.3.2 Specific Gravity

The specific gravity of a soil particles is the ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of distilled water at a temperature of 4°C. The specific gravity of a soil is often used in relating a weight of soil to its volume. Thus knowing the void ratio, the degree of saturation, and the sp. gravity, the unit weight of a moist soil can be computed.

Although specific gravity is employed in the identification of minerals, it is of limited value for identification or classification of soils, because the specific gravity of most soils falls within a narrow range.

In this study specific gravity of all sand samples collected from various places were carried out essentially for the identification of minerals (Lambe, 1969).

3.4 Determination of Bulk Density of Sand in the Laboratory

The following procedure was used to determine the density of the graded sand as well as original sand for each of the samples as shown in Table 3.2:

a) Determination of Weight of Sand in Cone:

i) The sand cone jug full of sand was weighed. Then the sand cone was turned upside down into a plane surface.
ii) The valve was opened and the sand was allowed to fill the cone. When the sand ceased to pour then valve was closed. The jug was then weighed again after used.
iii) The difference between the above two weights was the weight of sand in cone.

b) Determination of Weight of Sand in Mold and Cone

i) A mold of known volume (925.36 cm^3) with base plate and a template as a collar that makes the top surface of mold as a plane surface was taken. This mold could be thought of as the hole, which is dug in the field for density determination.
ii) The sand cone jug was weighed with full of sand before use.
iii) The sand cone was turned upside down and was placed on the template over the mold.
iv) The valve was opened and the sand was allowed to fill the mold as well as cone. When the sand ceased to pour, the valve was closed.
v) Then the jug was again weighed.
vi) The difference between the two weights was the weight of the sand in mold and cone.

3.4.1 Details Calculation of Density

The test procedures as described in Article 3.4(a) and 3.4(b) were followed for the calculation of weight of sand in cone and weight of sand in cone as well as mold. Both the calculations are mentioned below in (a) and (b) respectively.

a) i) Weight of jug + Cone + Sand (before use) = M_1 gm

ii) Weight of jug + Cone + Sand (after use) = M_2 gm

Weight of sand in cone = $(M_1 - M_2)$ gm

b) i) Weight of jug + cone + sand (before use) = M_3 gm

ii) Weight of jug + Cone + Sand (after use) = M_4 gm

Weight of sand in cone + mold = $(M_3 - M_4)$ gm

Therefore, weight of sand in mold = $(M_3 - M_4) - (M_1 - M_2)$ gm

Volume of mold = V cm^3 (known)

$$\text{Density of sand used} = \frac{(M_3 - M_4) - (M_1 - M_2)}{V} \text{ gm/cm}^3 \qquad (3.2)$$

The bulk densities of all the graded and original sands were measured by using above procedures and the results were shown in Chapter 4.

CHAPTER 4

TEST RESULTS AND DISCUSSIONS

4.1 General

In order to ascertain the suitability of local sand for determining in place soil density by Sand Cone Method, the test results of index properties of local sand, such as grain size distribution, uniformity coefficient, specific gravity and bulk density obtained for various sands are compared with the recommended ASTM (1989) index properties of sand. In this chapter all the test results are presented and discussed.

4.2 Grain Size Distribution and Specific Gravity Analysis

According to standard test procedure (ASTM 1989) sieve analysis and specific gravity test were performed on collected sand samples. Grain size distribution curves for original sands are shown in Fig. 4.1 to Fig. 4.9 and grain size distribution curve for Ottawa sand is shown in Fig. 4.10. The values of fineness modulus (F.M), D_{10}, D_{60}, C_u and specific gravity for each original sample were predicted from all the Grain size distribution curves. All the values are shown in Table 4.1. The grain size distribution curves for graded sands are also shown in Fig. 4.11 to Fig. 4.22. The values of D_{10}, D_{60} and C_u of graded sands are shown in Tables 4.2 and 4.3.

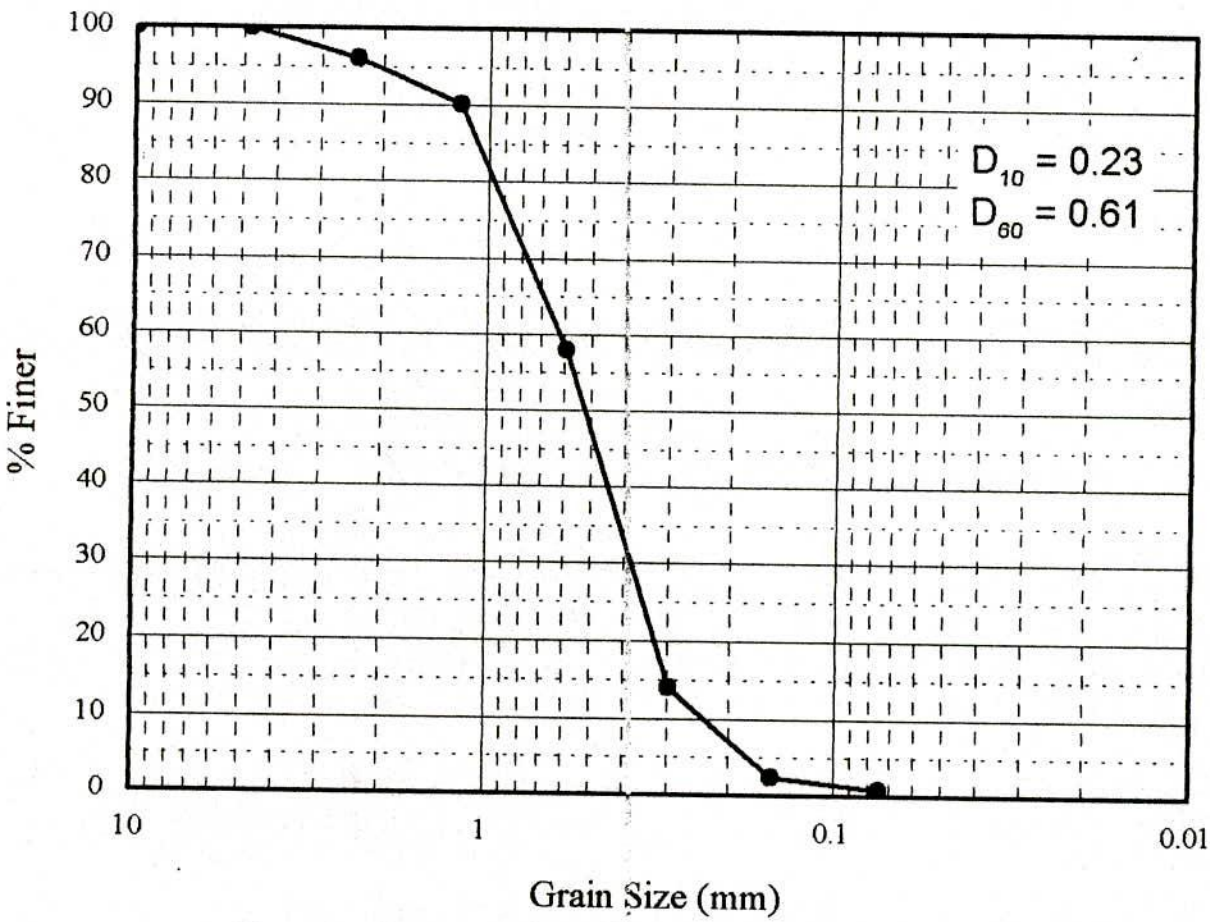

Fig 4.1 Grain Size Distribution of Sylhet Sand (S- 1)

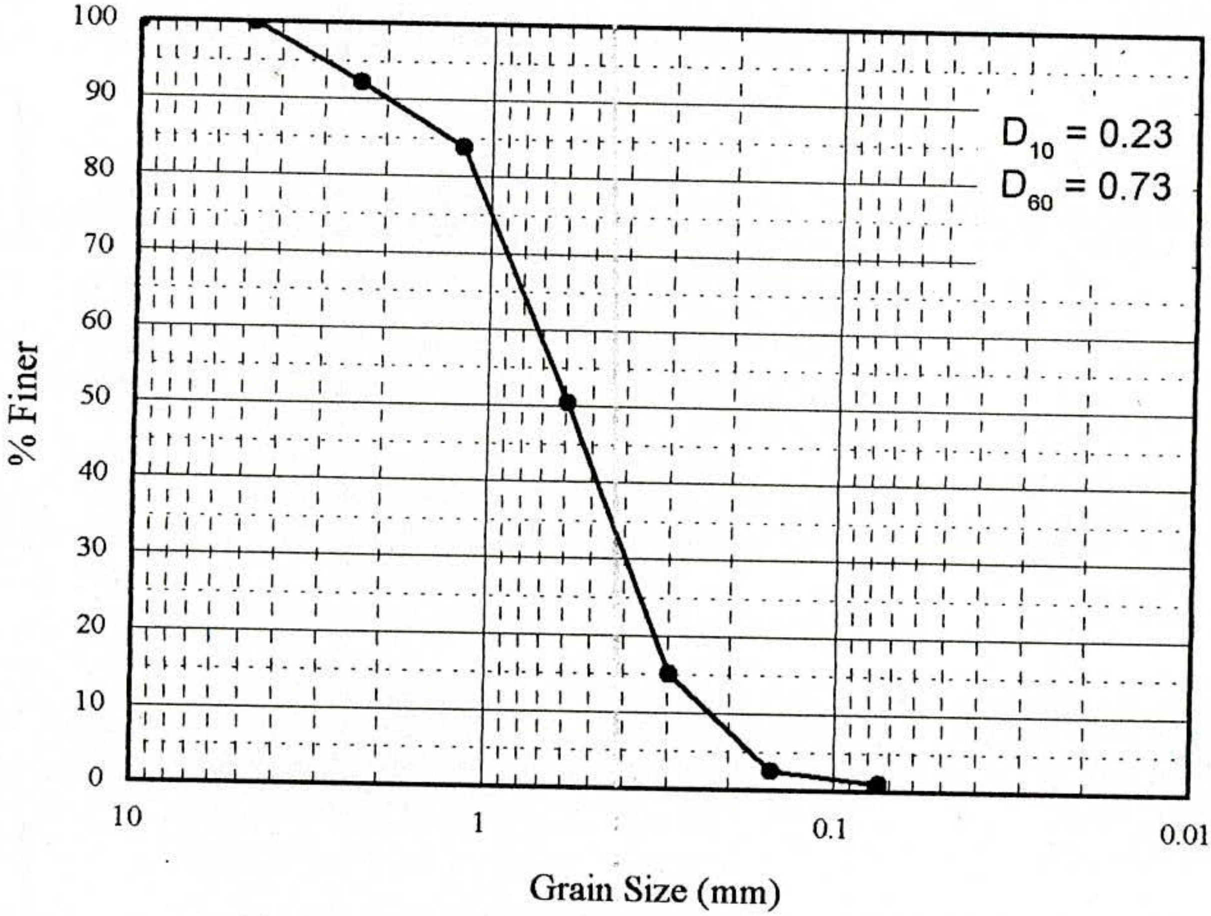

Fig 4.2 Grain Size Distribution of Sylhet Sand (S- 2)

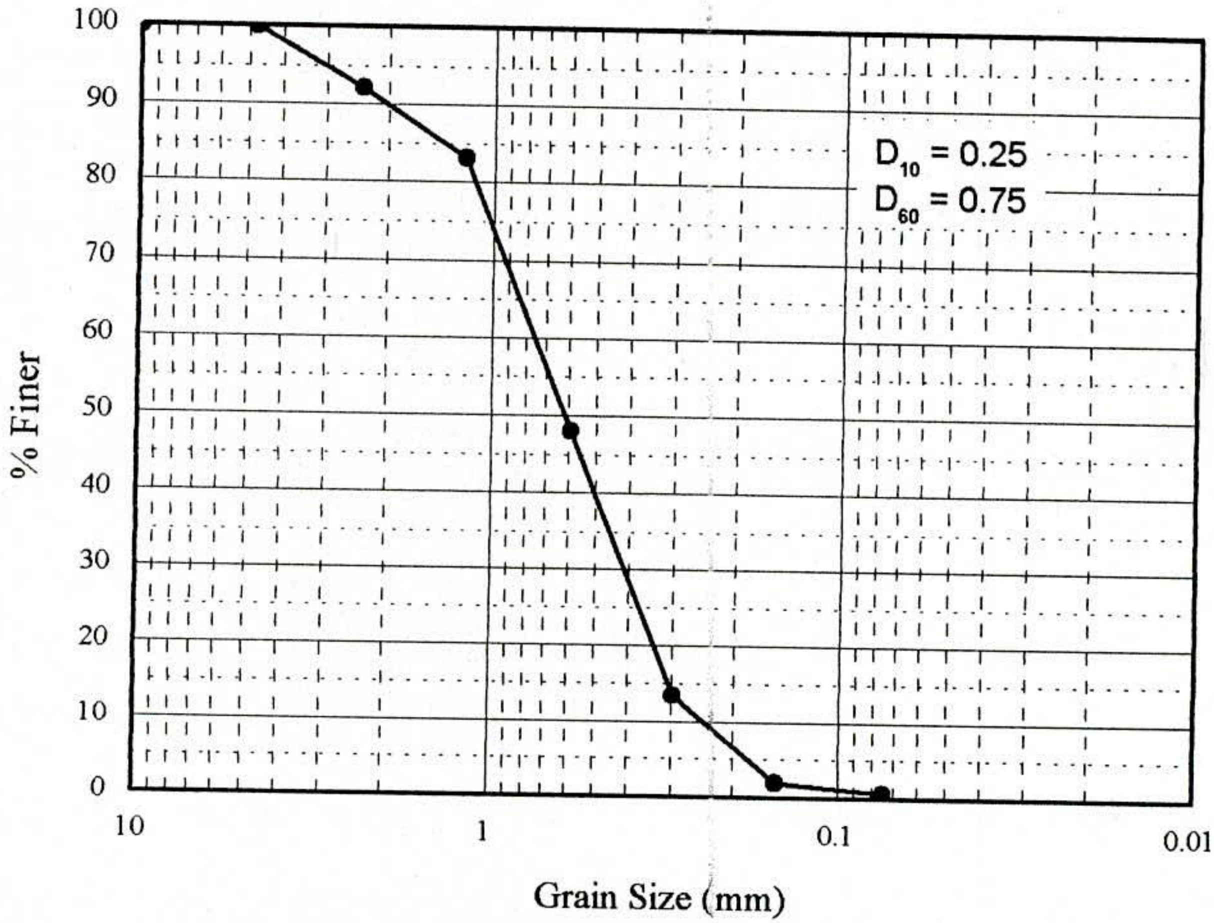

Fig 4.3 Grain Size Distribution of Sylhet Sand (S- 3)

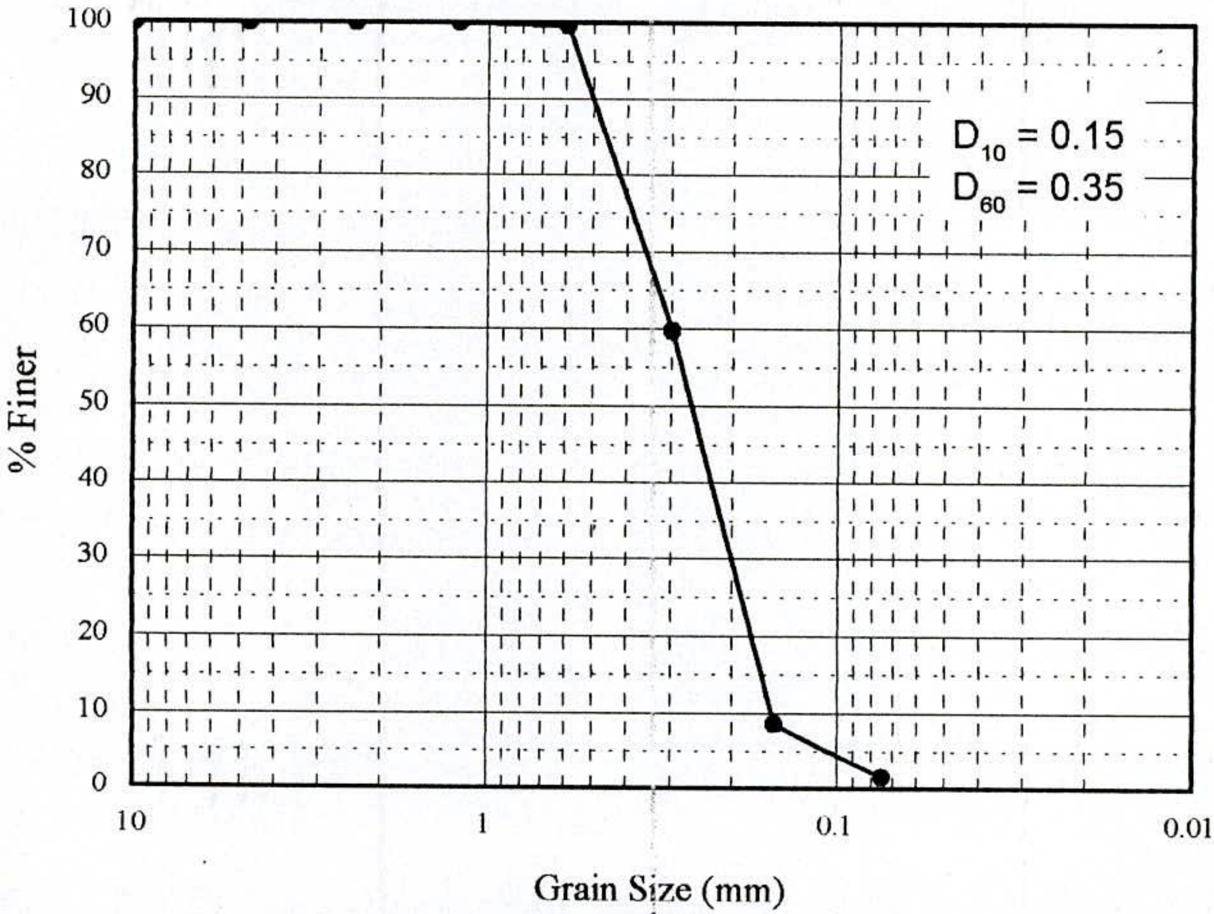

Fig 4.4 Grain Size Distribution of Kustia Sand (K- 1)

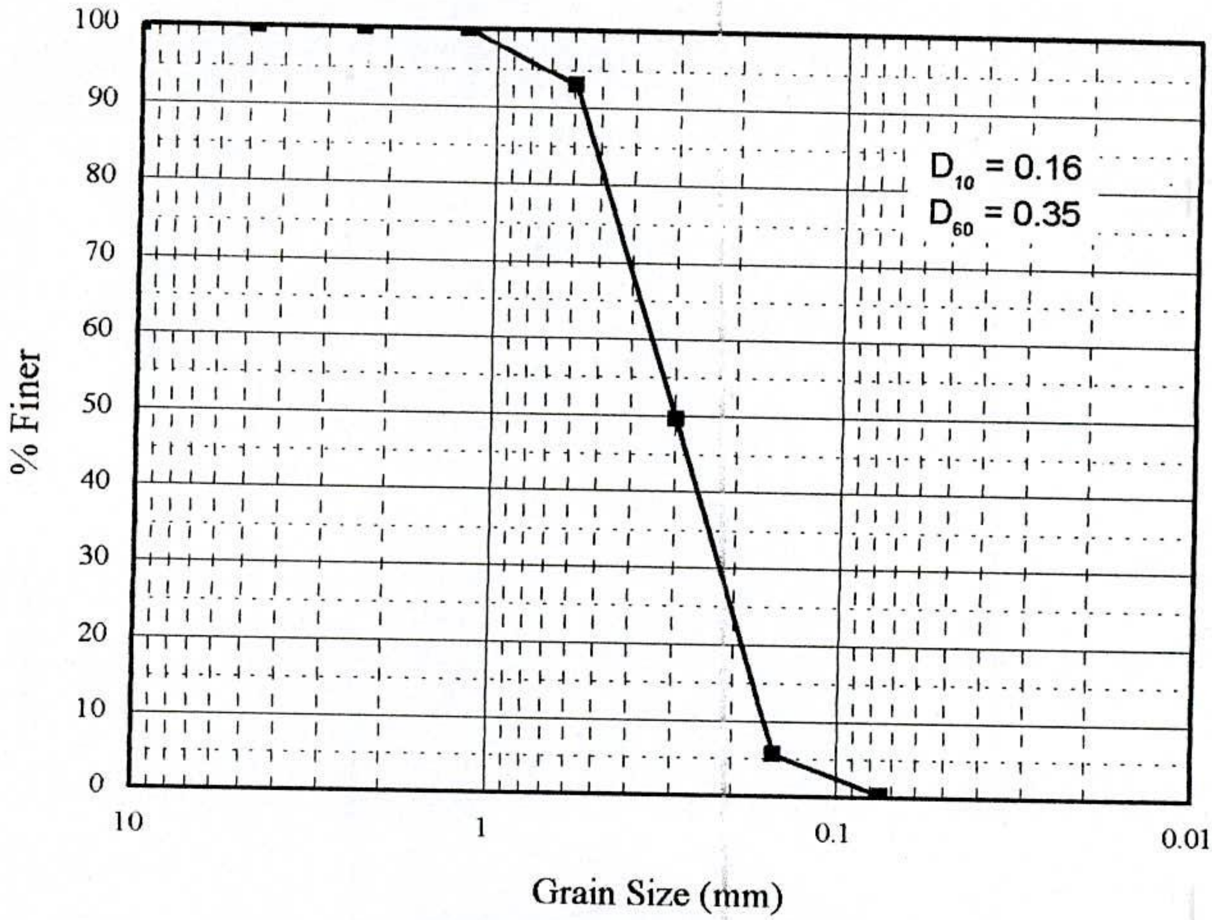

Fig 4.5 Grain Size Distribution of Kustia Sand (K- 2)

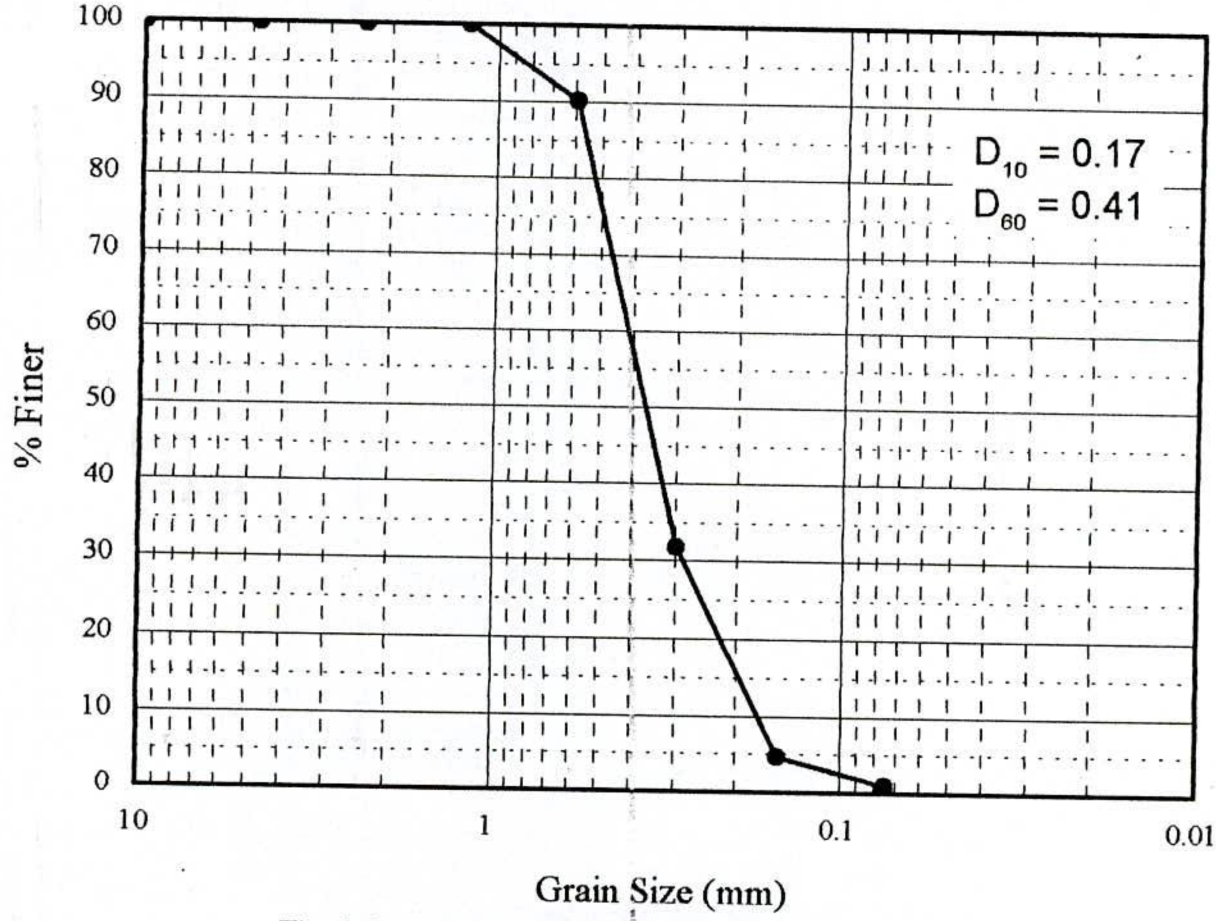

Fig 4.6 Grain Size Distribution of Kustia Sand (K- 3)

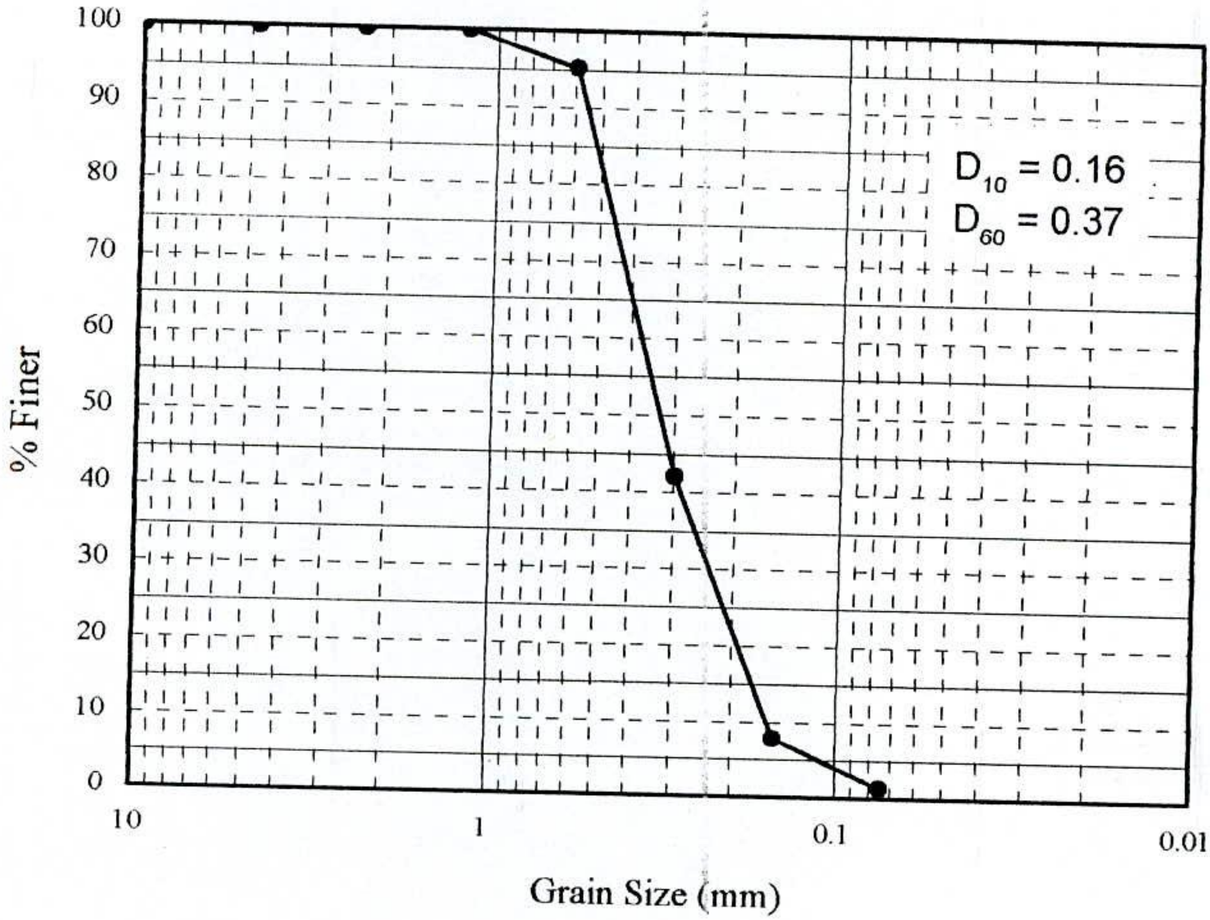

Fig 4.7 Grain Size Distribution of Fultala Sand, sample-1

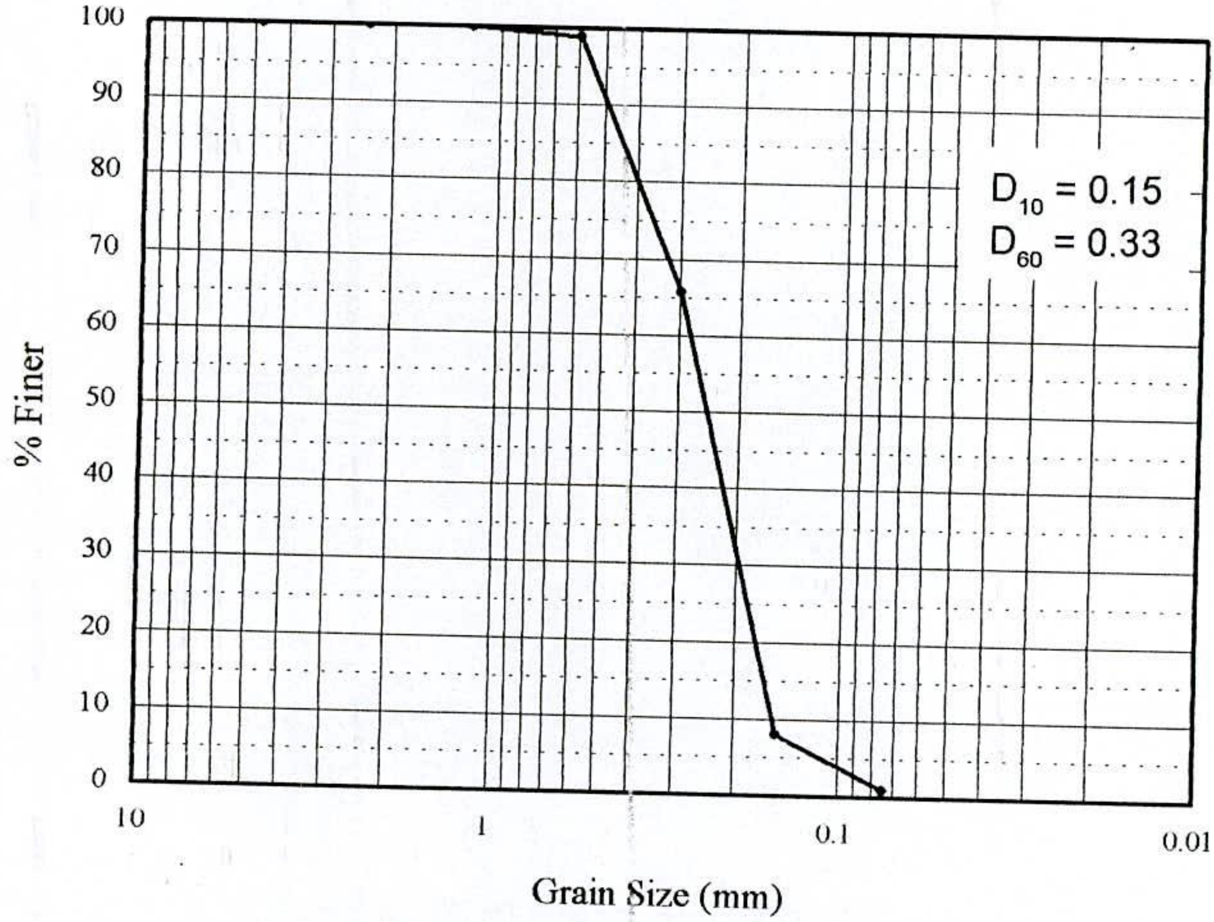

Fig 4.8 Grain Size Distribution of Bagjhuri Sand (B- 1)

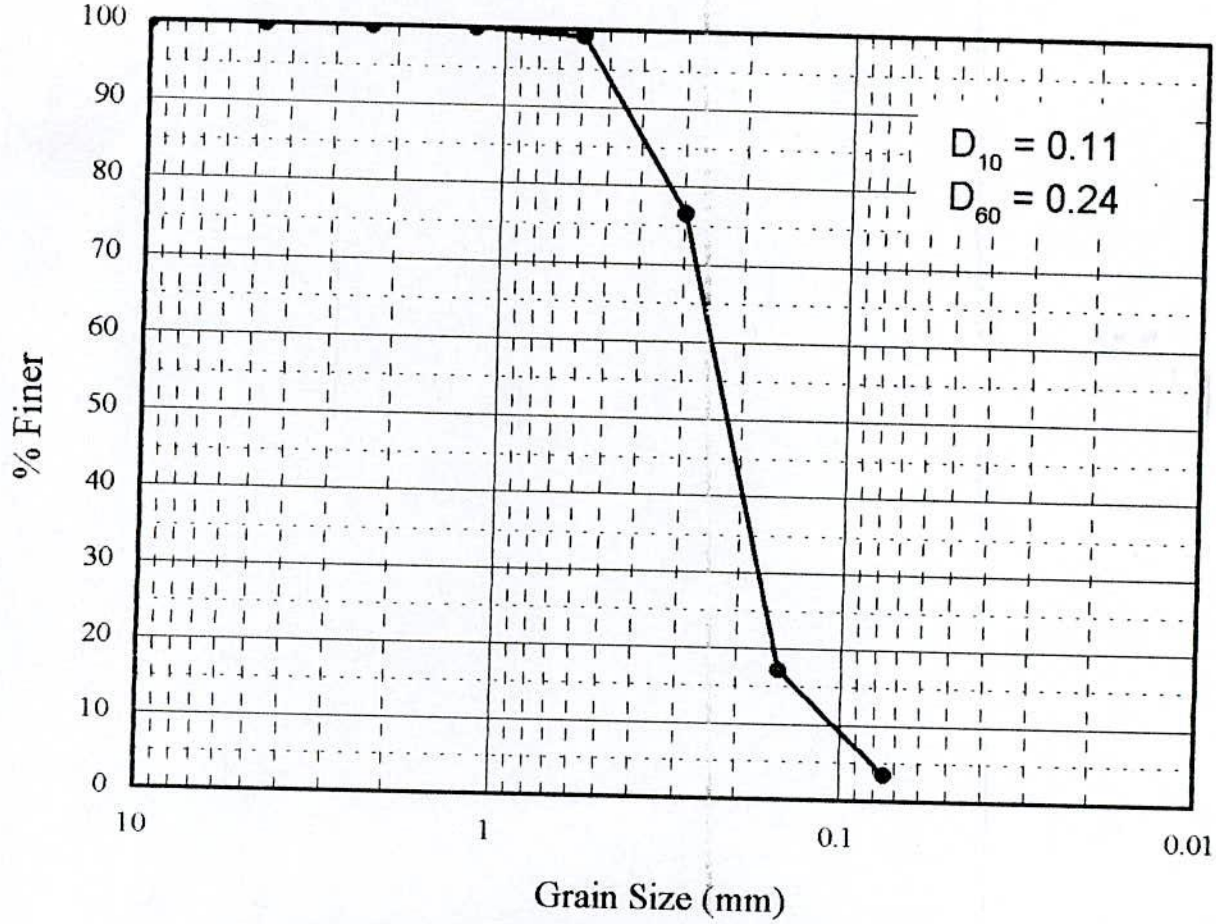

Fig 4.9 Grain Size Distribution of Mongla Sand (M- 1)

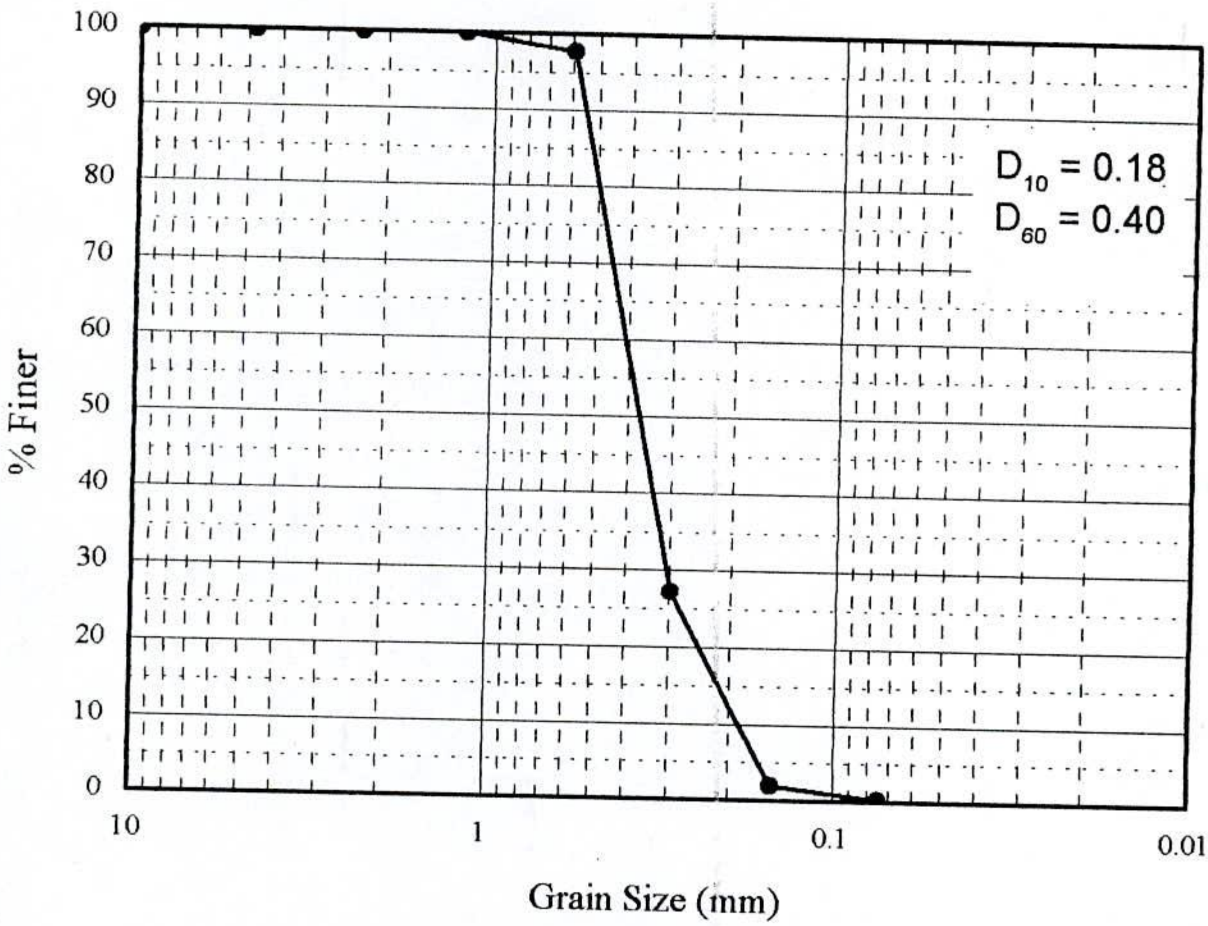

Fig 4.10 Grain Size Distribution of Ottowa Sand (O- 1)

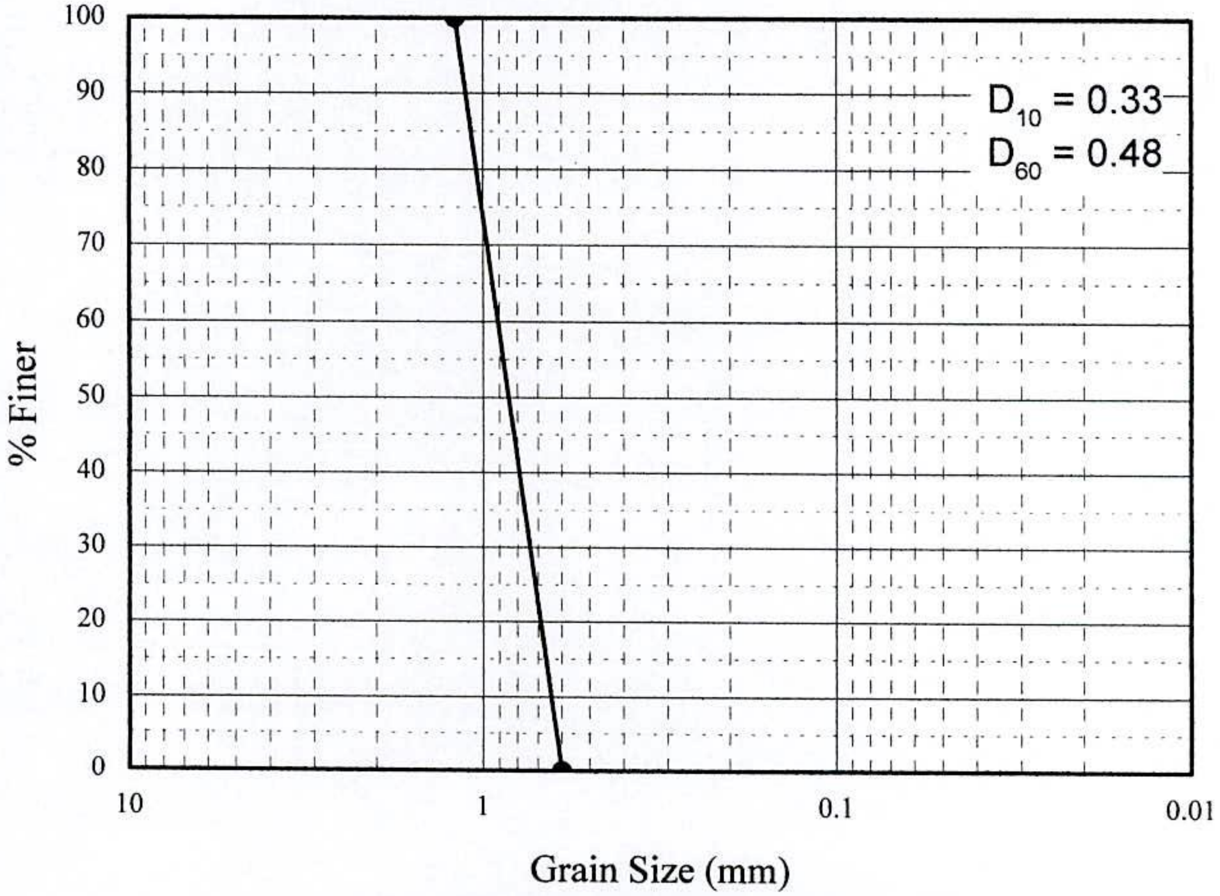

Fig 4.11 Grain Size Distribution of Graded Sylhet Sand (S-1) Grade (-) No. 16 and (+) No. 30

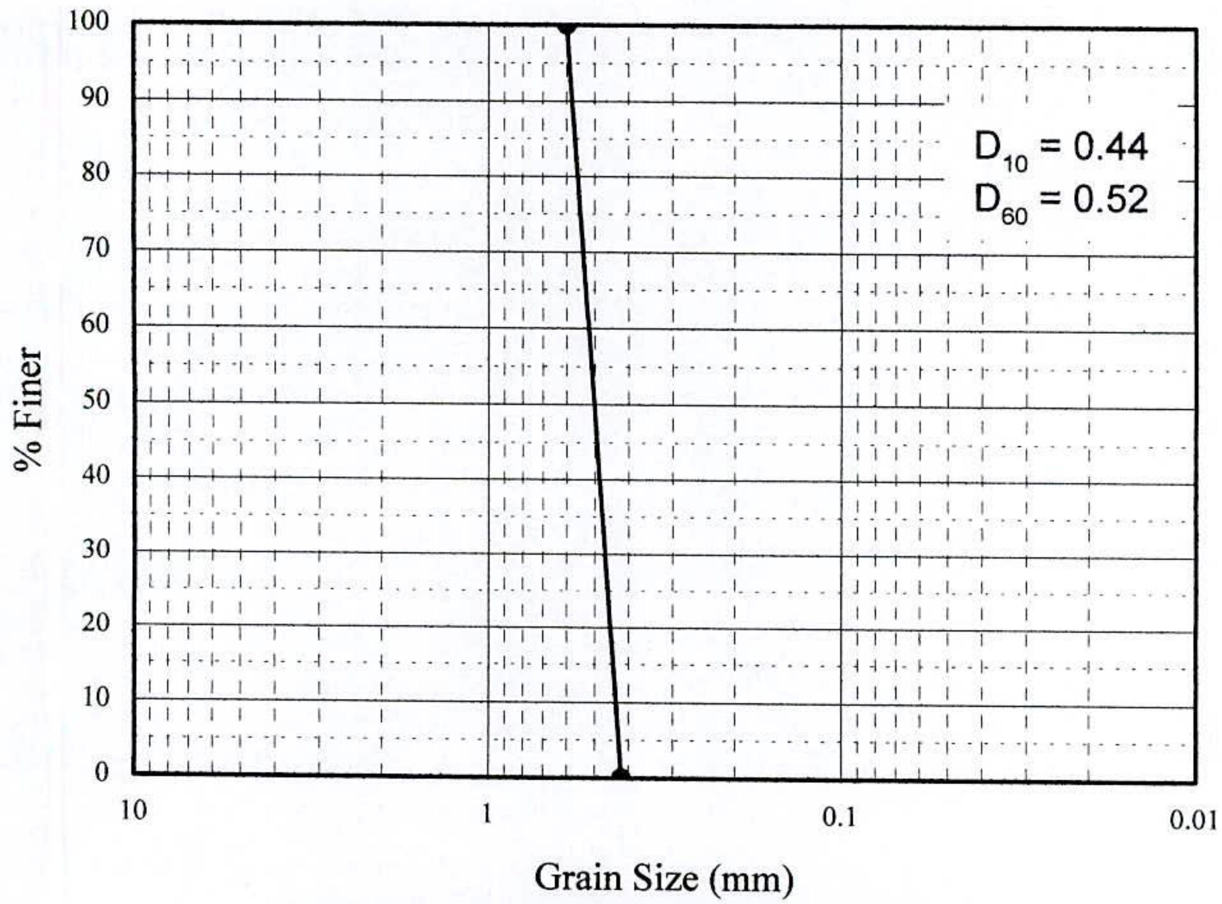

Fig 4.12 Grain Size Distribution of Graded Sylhet Sand (S-1) of Grade (-) No. 30 and (+) No. 40

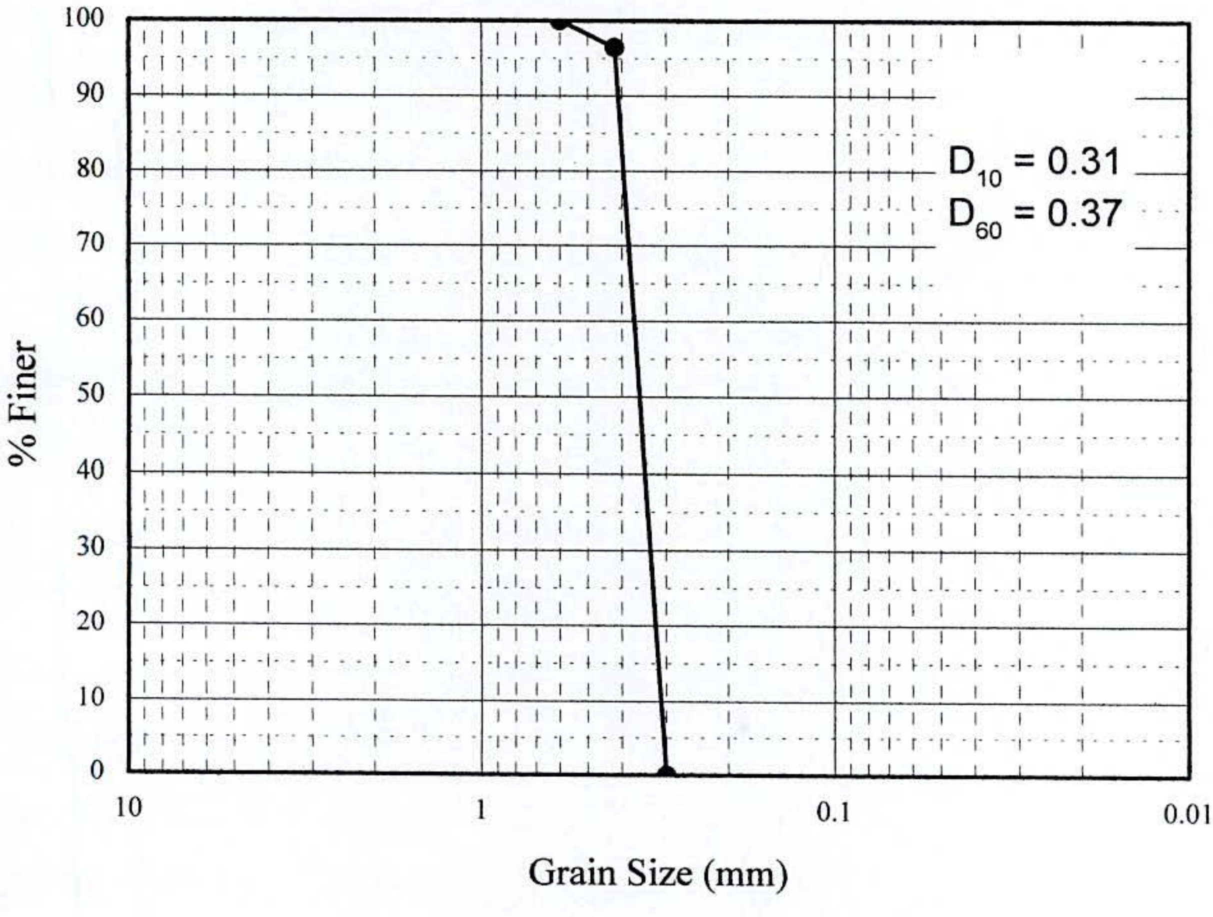

Fig 4.13 Grain Size Distribution of Graded Sylhet Sand (S-1)
Graded (-) No. 30 and (+) No. 50

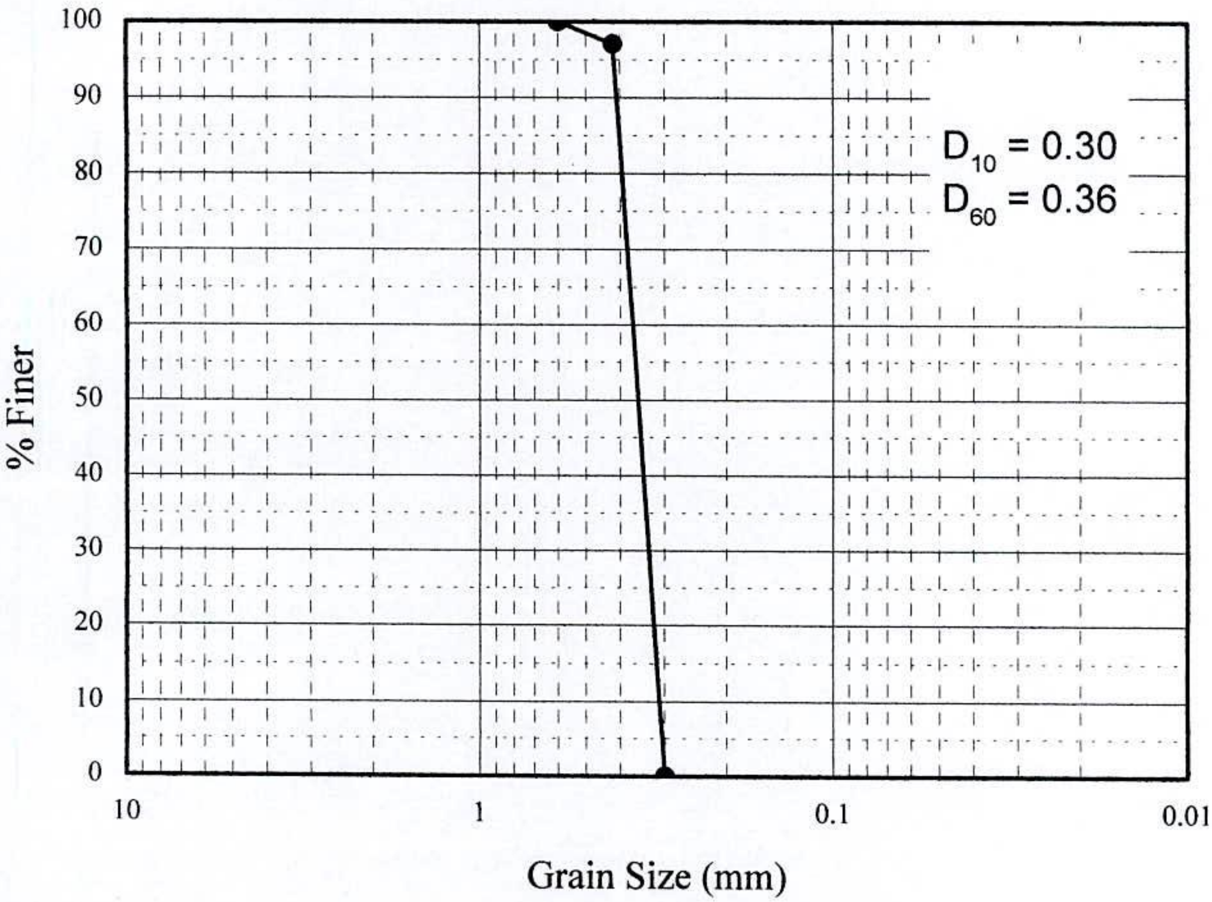

Fig 4.14 Grain Size Distribution of Graded Sylhet Sand (S-2)
Grade (-) No. 30 and (+) No. 50

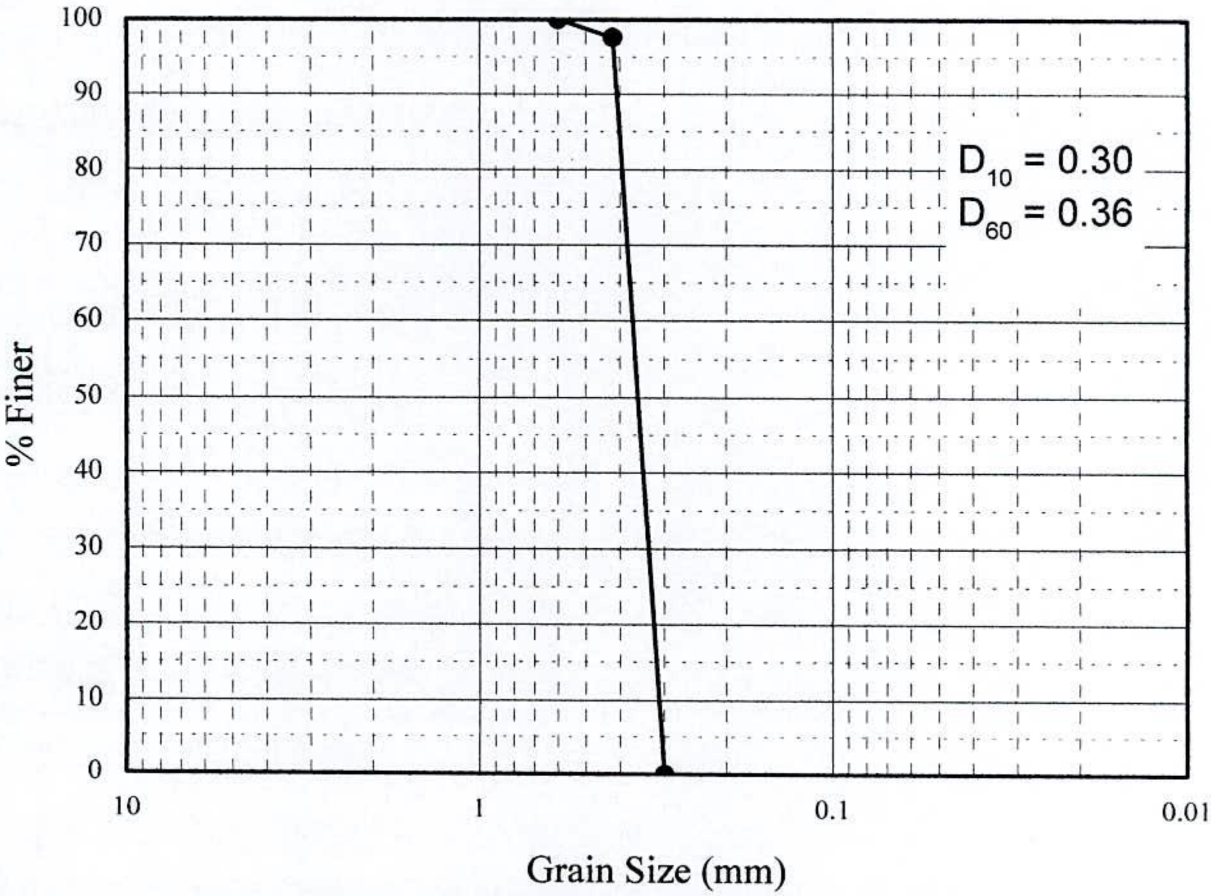

Fig 4.15 Grain Size Distribution of Graded Sylhet Sand (S-3)
Grade (-) No. 30 and (+) No. 50

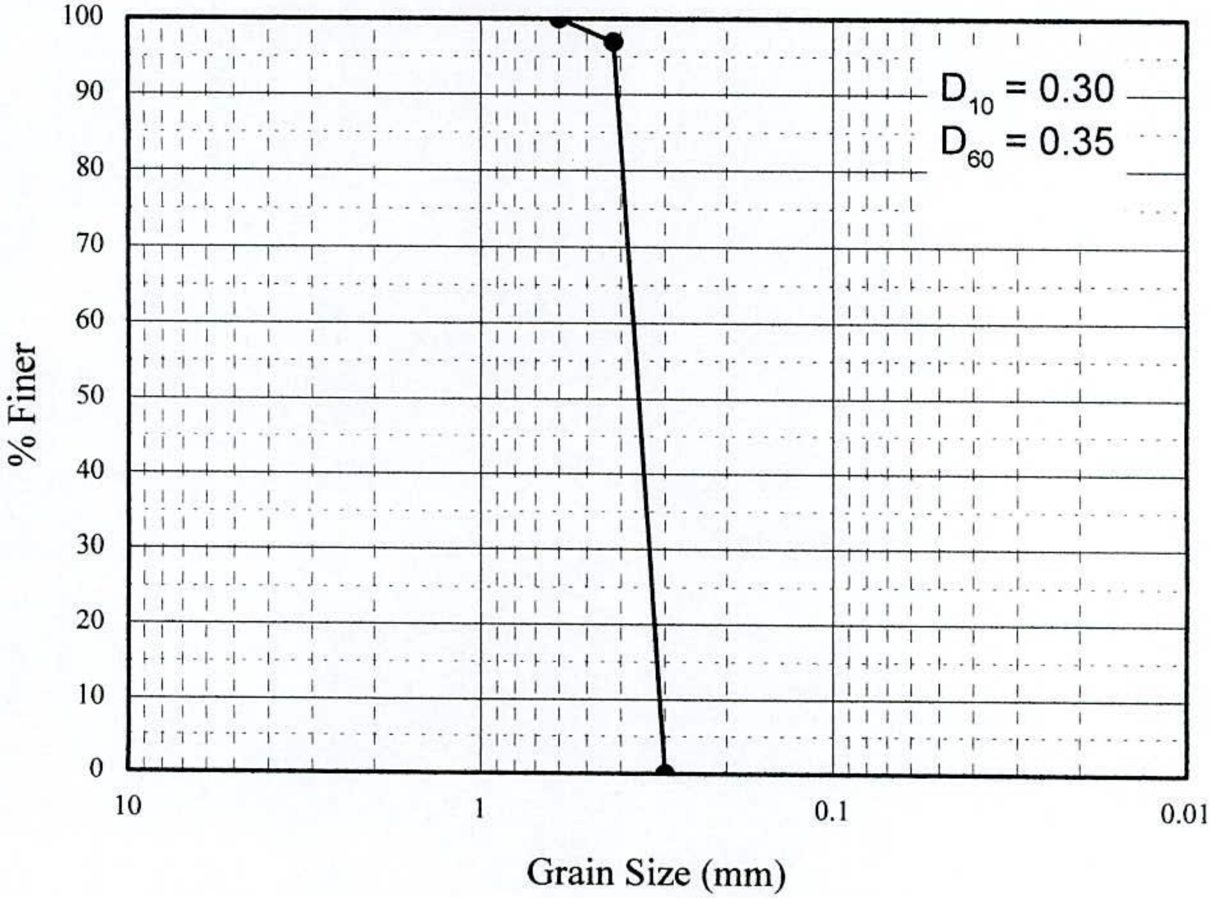

Fig 4.16 Grain Size Distribution of Graded Kustia Sand (K-1)
Grade (-) No. 30 and (+) No. 50

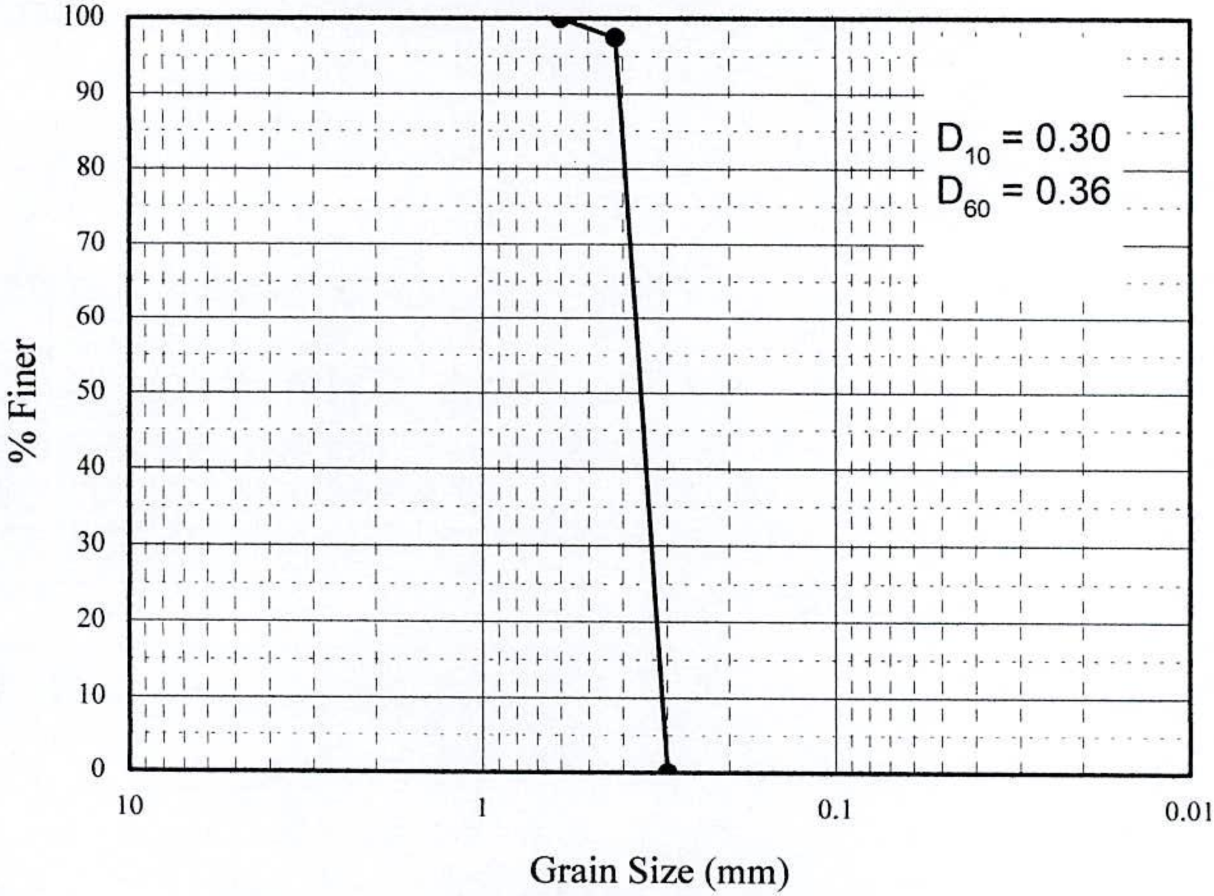

Fig 4.17 Grain Size Distribution of Graded Kustia Sand (K-2)
Grade (-) No. 30 and (+) No. 50

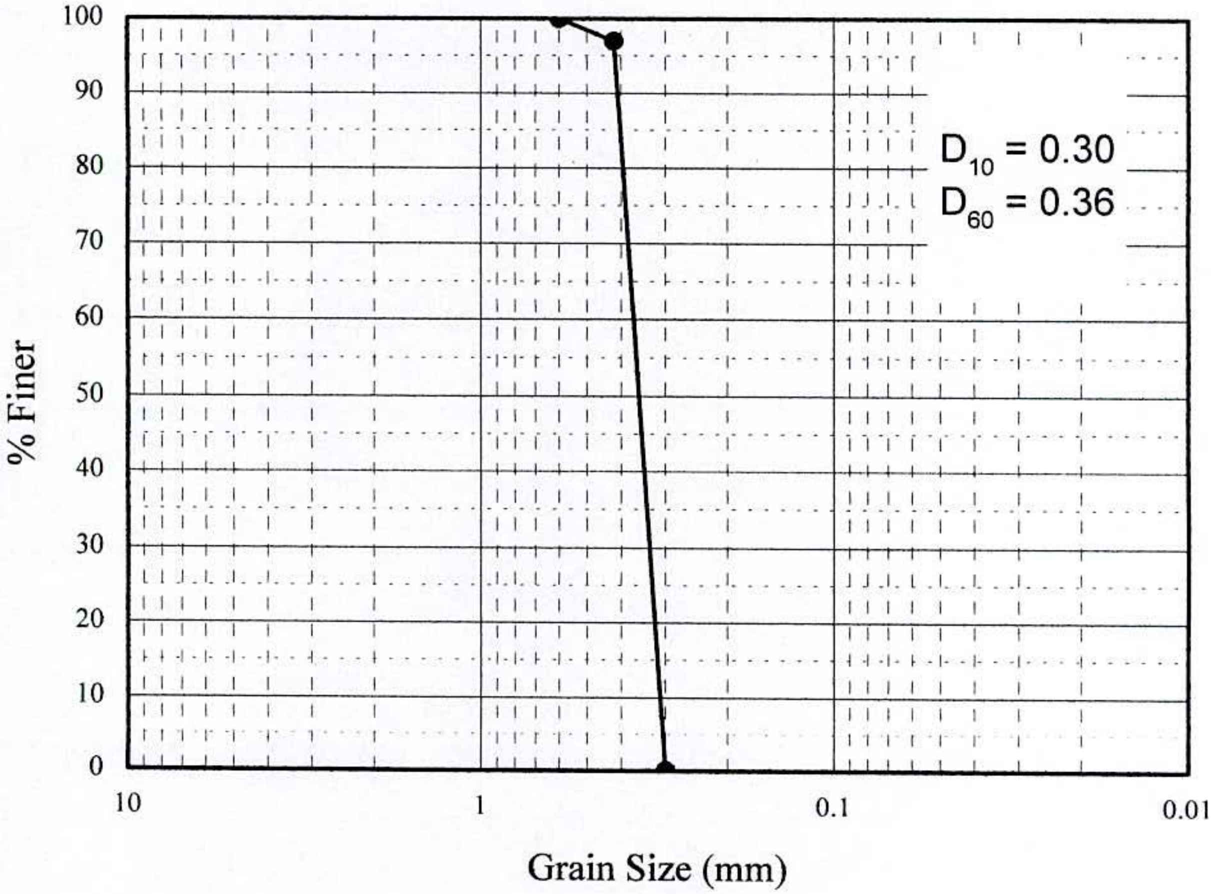

Fig 4.18 Grain Size Distribution of Graded Kustia Sand (K-3)
Grade (-) No. 30 and (+) No. 50

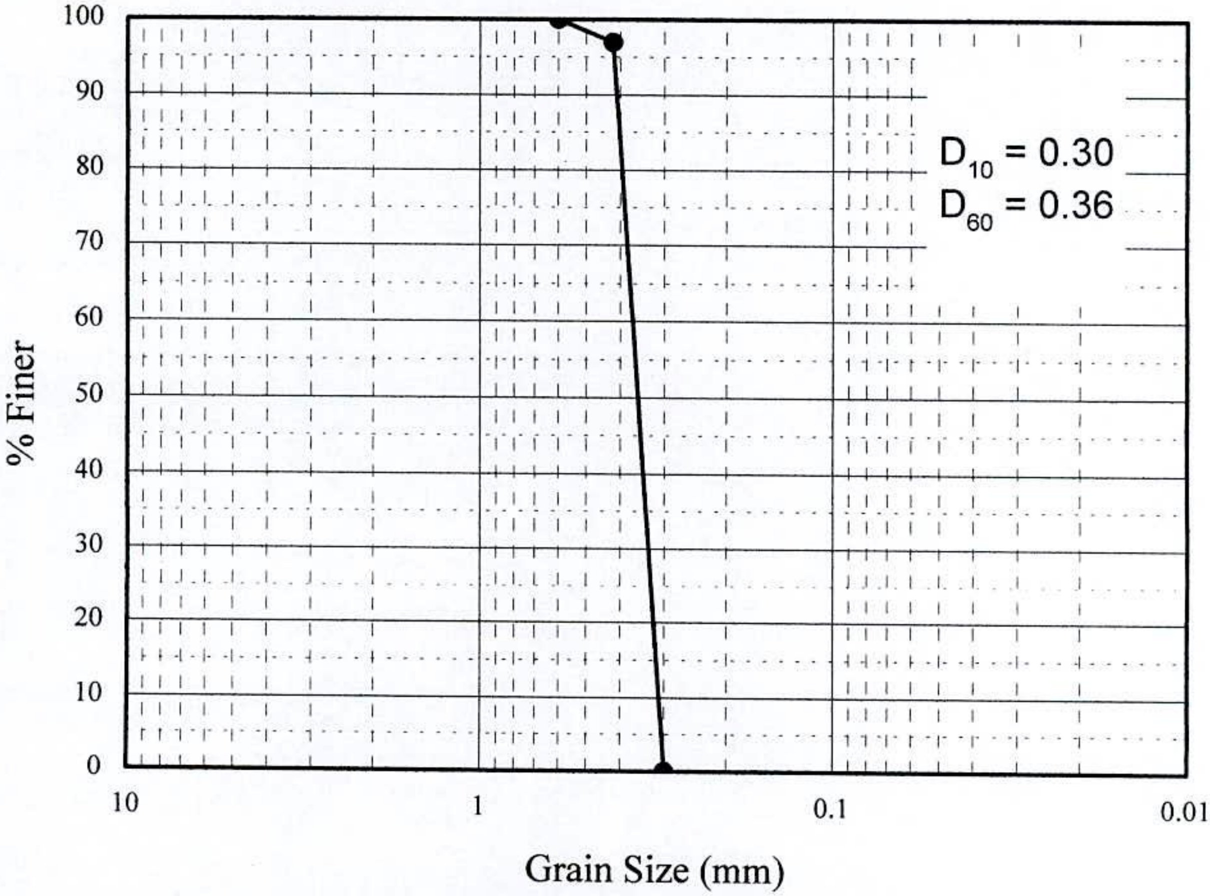

Fig 4.20 Grain Size Distribution of Graded Fultala Sand (F-1)
Grade (-) No. 30 and (+) No. 50

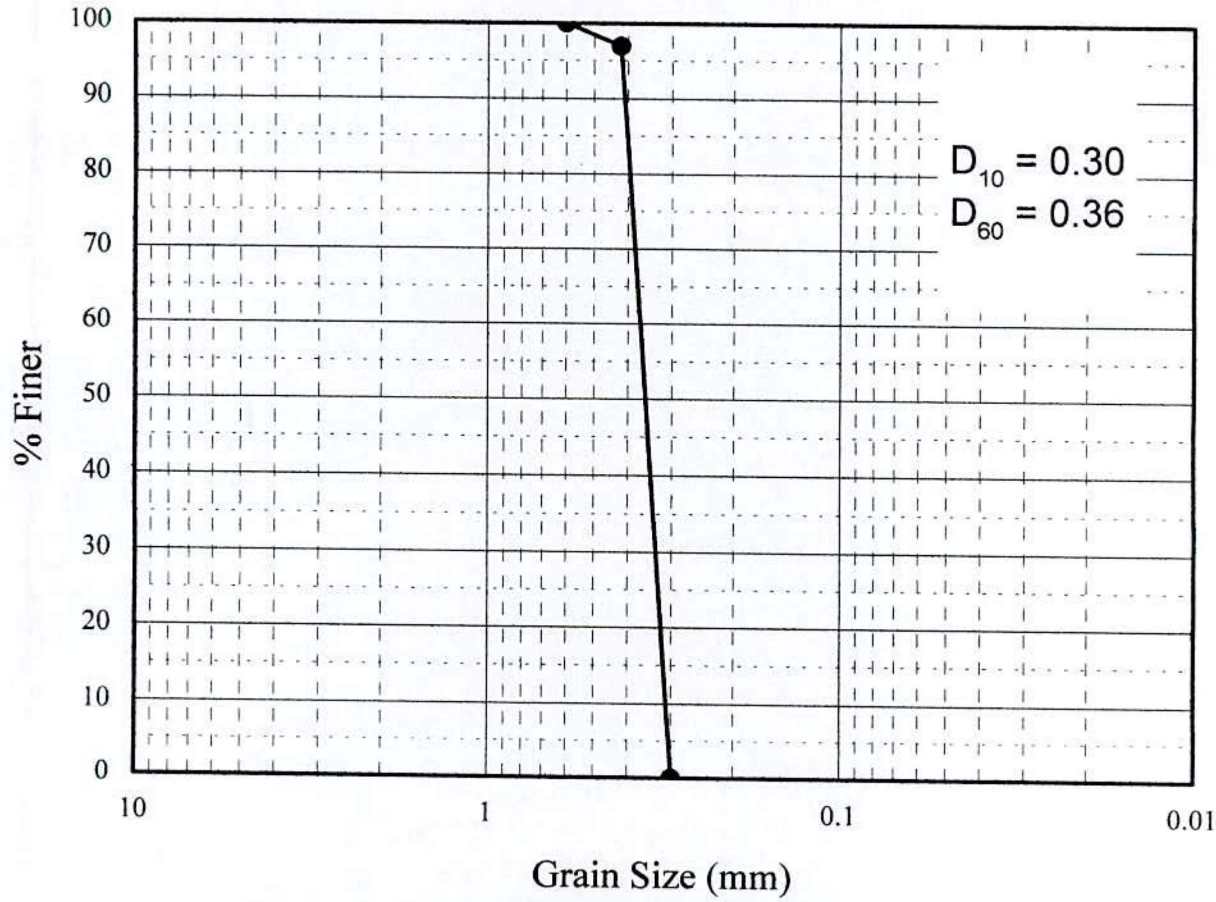

Fig 4.19 Grain Size Distribution of Graded Bogihuri Sand (B-1)
Grade (-) No. 30 and (+) No. 50

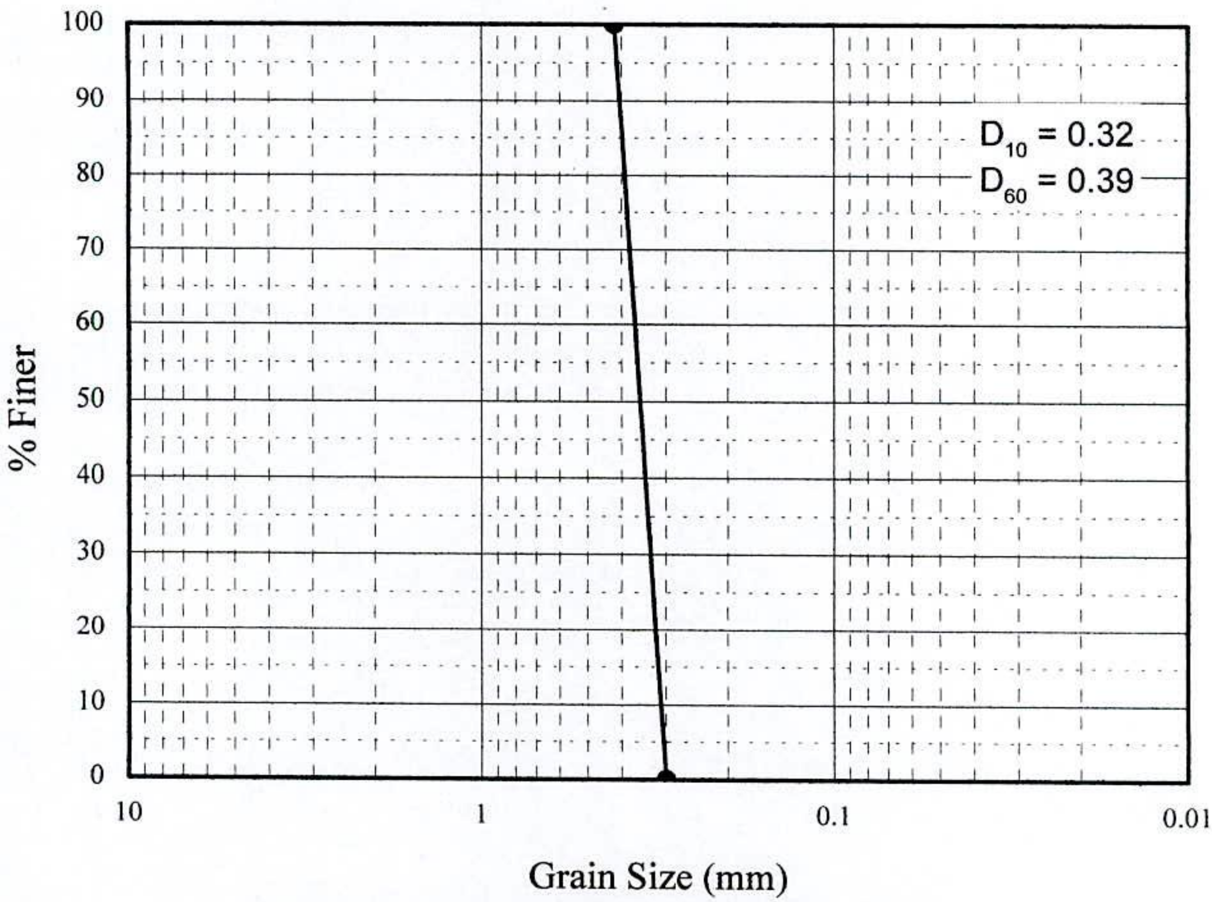

Fig 4.21 Grain Size Distribution of Graded Sylhet Sand (S-1)
Grade (-) No.40 and (+) No. 50

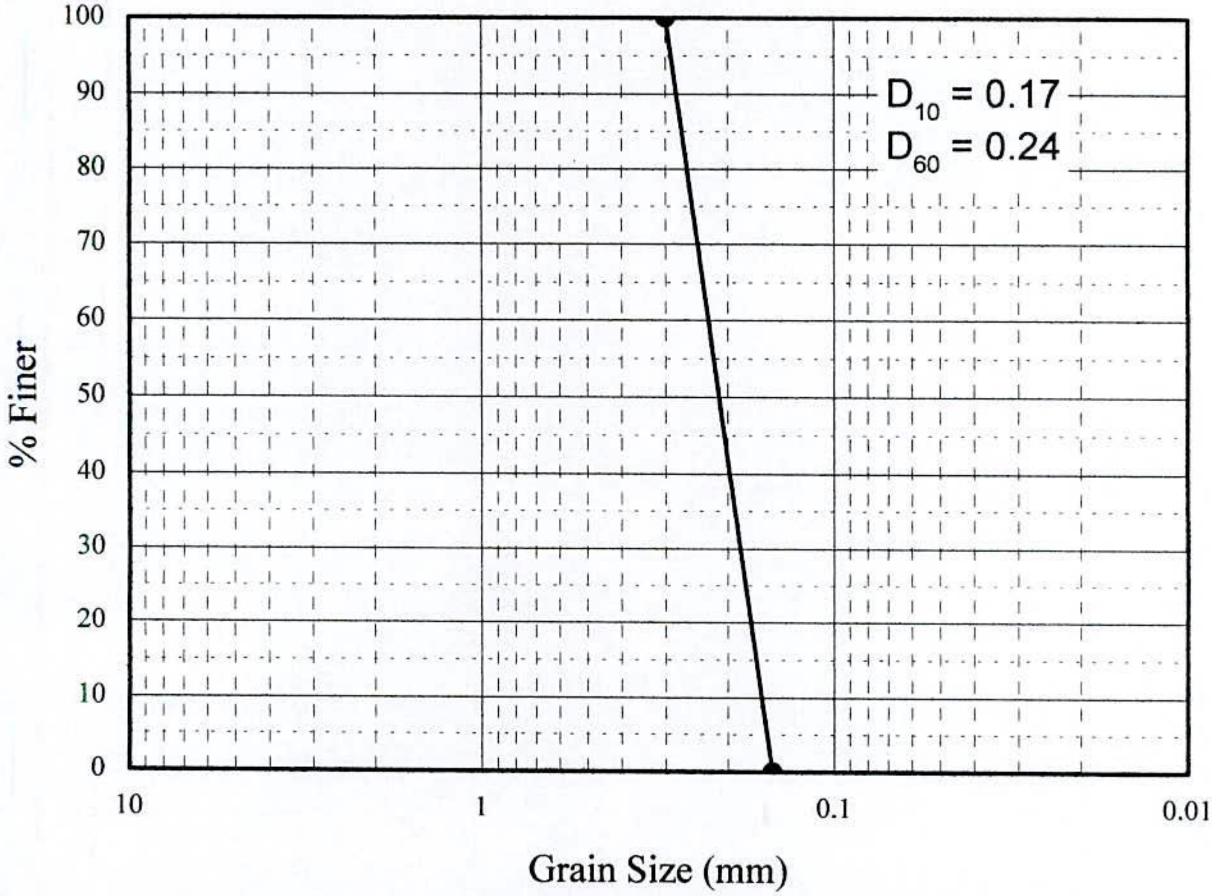

Fig 4.22 Grain Size Distribution of Graded Sylhet Sand (S-1)
Grade (-) No. 50 and (+) No. 100

Table 4.1 Index Properties of Original Sands

Sl. No.	Sample Designation	D_{10}	D_{60}	C_u	F.M.	Sp.Gr.	Maximum Particle Size (mm)	% Passing through 250 μm
1.	S-1	0.23	0.61	2.65	2.39	2.69	2.36	10.00
2.	S-2	0.23	0.73	3.17	2.56	2.71	2.31	8.00
3.	S-3	0.25	0.75	3.00	2.61	2.66	2.36	4.00
4.	K-1	0.15	0.35	2.33	1.32	2.72	1.52	13.00
5.	K-2	0.16	0.35	2.19	1.52	2.70	1.24	14.00
6.	K-3	0.17	0.41	2.41	1.74	2.72	1.50	9.00
7.	F-1	0.16	0.37	2.31	1.55	2.86	0.84	23.00
8.	B-1	0.15	0.25	2.20	1.27	2.72	0.76	82.00
9.	M-1	0.11	0.24	2.18	1.08	2.71	0.70	55.00

Table 4.2 Index Properties of Graded Sands

Sl. No.	Gradation	D_{10}	D_{60}	C_u	Maximum Particle (mm)	% Passing through 250 μm
1.	(-) No. 16 & (+) No.30	0.65	0.86	1.323	1.20	0.00
2.	(-) No. 30 & (+) No.40	0.45	0.56	1.244	0.62	0.00
3.	(-) No. 40 & (+) No.50	0.30	0.40	1.330	0.40	0.00
4.	(-) No. 50 & (+) No.100	0.18	0.25	1.390	0.32	66.00

Table 4.3 Index Properties of Sand of Grade (-) No. 30 & (+) No. 50

Sl. No.	Sample Designation	D_{10}	D_{60}	C_u	Maximum Particle Size (mm)	% Passing through 250 μm
1.	S-1	0.31	0.45	1.45	0.40	0.00
2.	S-2	0.32	0.45	1.41	0.40	0.00
3.	S-3	0.34	0.46	1.35	0.40	0.00
4.	K-1	0.32	0.46	1.44	0.40	0.00
5.	K-2	0.30	0.42	1.40	0.40	0.00
6.	K-3	0.33	0.45	1.36	0.40	0.00
7.	F-1	0.32	0.42	1.31	0.40	0.00
8.	B-1	0.31	0.40	1.29	0.40	0.00
9.	M-1	0.30	0.35	1.17	0.40	0.00

The following observations were made after studying Figs. 4.1 to 4.22 and Tables 4.1 to 4.3:

i) Average fineness modulus (F.M.) of Sylhet, Kushtia and Fultala sands were observed as 2.52, 1.53 and 1.55 respectively. But in case of Bogjhuri and Mongla sand, F.M. values were found as 1.27 and 1.08 respectively. So Bogjhuri and Mongla sand can be considered as fine sand, in comparison with Sylhet, Kushtia and Fultala sands.

ii) From Table 4.1 it can be observed that the uniformity coefficient, C_U of original Sylhet sand is greater than two, the values of C_U of original Kushtia, Fultala, Bogjhari and Mongla sands were also greater than two. It can also be found from Tables 4.2 to 4.3, the values of C_U less than two for all the graded sands. The ASTM (1989) recommended that the value of uniformity coefficient for the sand, used in Sand Cone Method should be less than two.

iii) From Tables 4.1 to 4.3 it can be observed that except the original Sylhet sand, maximum particle size for all types of collected sands as well as the graded sands were found to be less than 2.00 mm which satisfy the recommended value of ASTM (1989), In case of original Sylhet sand maximum particle size varies from 2.00 mm to 3.00 mm.

iv) ASTM (1989) recommends that less than 3% by weight of sand should pass through 250 μm. From grain size distribution curves and Table 4.1 it can be observed that in case of original sands this value varies form 4% to 80%. Table 4.3 shows that 66% by weight passes through 250μm in case of graded sands of passing No. 50 sieve and retained on No.100 sieve. But Table 4.2 shows that 0% by weight passes through 250μm in case of all other graded sands. So all the graded sands of passing No. 50 sieve and retained on No. 100 sieve including all original samples fail to satisfy the ASTM (1989) criteria.

v) In case of Bogjhuri and Mongla sands it was observed that significant amount of mica was present in the collected samples of sand and this is not desirable.

vi) In case of original Sylhet sand it was observed that this sand is not free flowing and uniform but in case of graded Sylhet sand this quality improved significantly.

From above discussions on grain size distribution it can be concluded that original Sylhet sand failed to satisfy the ASTM (1989) criteria because of its uniformity coefficient is greater than two and maximum particle size is greater than 2.00 mm. In case of original Kushtia, Fultala, Bogjhuri, Mongla sand and also sand passing No. 50 sieve and retained on No. 100 sieve, it was observed that more than 3% by weight of sand pass through 250 μm. So these types of original and graded sand do not satisfy the ASTM (1989) criteria. But in case of the following graded sands the uniformity coefficient is less than two, maximum particle size is less than 2.00 mm and less than 3% by weight pass through 250 μm, which satisfy the ASTM (1989) criteria.

(a) Sand passing No. 16 sieve and retained on No. 30 sieve.

(b) Sand passing No. 30 sieve and retained on No. 40 sieve.

(c) Sand passing No. 30 sieve and retained on No. 50 sieve.

(d) Sand passing No. 40 sieve and retained on No. 50 sieve.

4.3 Density Analysis of Sand

Determination of bulk density of graded sand as well as original sand was performed following the procedure described in Art. 3.4. Table 4.4 shows the density of graded Ottawa sand. From Table 4.4 it is observed that for any particular grade of sample the bulk density is almost same in each determination. Bulk density of graded Sylhet, Kushtia, Fultala, Bogjhuri and Mongla sands are shown in Tables 4.5 to 4.9 respectively. From these tables it is observed that the bulk density differs with the different locations for each grade.

In case of Bogjhuri and Mongla sands it was observed that the bulk density of any grade differs significantly from that of Ottawa. Moreover from the Article 4.2 it is found that these two types of sand are fine for which sufficient coarse grade sample could not be found easily. So it can be concluded that these two types of sand are not suitable as materials for determination of in situ soil density. Hence any further investigation on these two samples was not carried out.

From Tables 4.5 and 4.6 it is observed that the bulk densities of Sylhet Sand and Kushtia Sand differ significantly in compared with that of Ottawa sand. In case of graded Sylhet sand it was observed that the bulk density differs significantly from grade passing # 16 sieve to retaining in # 30 sieve with other grades. However in case of graded Kushtia sand it was observed that the variations of bulk densities of various grades and mixed grades do not differ substantially.

Table 4.4 Density of Ottawa Sand from Laboratory Test

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No. 40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.540	1.527	1.499	1.499	1.53
2.	1.550	1.527	1.498	1.498	1.53
3.	1.550	1.530	1.530	1.498	1.51

Table 4.5(a) Density of Graded Sylhet Sand (S-1)

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.322	1.229	1.228	1.250	1.247
2.	1.325	1.228	1.226	1.247	1.241
3.	1.324	1.227	1.225	1.248	1.251

Table 4.5(b) Density of Graded Sylhet Sand (S-2)

Density (gm/cm^3)					
Sl. No.	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.322	1.228	1.224	1.258	1.244
2.	1.325	1.224	1.225	1.256	1.242
3.	1.324	1.226	1.225	1.256	1.446

Table 4.5(c) Density of Graded Sylhet Sand (S-3)

Density (gm/cm^3)					
Sl. No.	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.323	1.234	1.228	1.265	1.250
2.	1.321	1.235	1.224	1.266	1.252
3.	1.318	1.237	1.226	1.262	1.251

Table 4.6(a) Density of Graded Kushtia Sand (K-1)

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.322	1.326	1.320	1.324	1.328
2.	1.325	1.340	1.344	1.336	1.338
3.	1.324	1.342	1.341	1.338	1.326

Table 4.6(b) Density of Graded Kushtia Sand (K-2)

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.267	1.309	1.284	1.320	1.276
2.	1.266	1.312	1.288	1.322	1.278
3.	1.268	1.308	1.282	1.318	1.274

Table 4.6(c) Density of Graded Kushtia Sand (K-3)

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.301	1.264	1.262	1.264	1.256
2.	1.306	1.269	1.264	1.268	1.264
3.	1.304	1.266	1.266	1.265	1.262

Table 4.7 **Density of Graded Fultala Sand**

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1.	1.323	1.234	1.228	1.265	1.250
2.	1.321	1.235	1.224	1.266	1.252
3.	1.318	1.237	1.226	1.262	1.251

Table 4.8 **Density of Graded Bogjhuri Sand**

	Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1	------	1.222	1.203	1.084	1.240
2	------	1.214	1.206	1.094	1.248
3	------	1.211	1.196	1.093	1.243

N. B.: Sufficient coarse grade sample could not be found from the collected sample because of fine-grained sand.

Table 4.9 Density of Graded Mongla Sand

Density (gm/cm^3)					
Sl. No.	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No. 40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50	(-) No. 50 & (+) No.100
1	------	-------	1.167	1.237	1.230
2	------	--------	1.163	1.234	1.231
3	-----	-------	1.161	1.239	1.229

N. B.: Sufficient coarse grade sample could not be found from the collected sample because of fine-grained sand.

4.3.1 Density Analysis of Graded Sylhet Sand

Tables 4.10 to 4.12 exhibit the bulk densities of three types (S-1, S-2 and S-3) of graded Sylhet sands. From the tables it can be observed that the following four grades of sample fulfill the criteria given by ASTM (1989).

i) Sand passing # 16 sieve and retained in # 30 sieve

ii) Sand passing # 30 sieve and retained in # 40 sieve

iii) Sand passing # 40 sieve and retained in # 50 sieve

iv) Sand passing # 30 sieve and retained in # 50 sieve

In each of the above cases the maximum variation in each determination from mean was less than 1%. So these four different grades of Sylhet sand can be used as an alternative materials of Ottawa sand for determining the in situ soil density by sand cone method.

Table 4.10 Density of Graded Sylhet Sand (S-1)

Density (gm/cm^3)				
Sl.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50
1	1.313	1.229	1.228	1.250
2	1.315	1.228	1.226	1.247
3	1.314	1.227	1.225	1.248
4	1.311	1.228	1.227	1.246
5	1.316	1.227	1.230	1.247
6	1.321	1.230	1.232	1.252
7	1.217	1.231	1.228	1.250
8	1.315	1.229	1.232	1.246
9	1.214	1.228	1.228	1.248
10	1.214	1.229	1.230	1.248
Mean:	1.214	1.227	1.225	1.246
Standard deviation on:	0.048	0.0013	0.0024	0.0019
Maximum deviation from mean:	0.55%	0.20%	0.29%	0.30%

Table 4.11 **Density of Graded Sylhet Sand (S-2)**

	Density (gm/cm^3)			
Sl.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
1	1.322	1.228	1.224	1.258
2	1.325	1.224	1.225	1.256
3	1.324	1.226	1.225	1.256
4	1.323	1.225	1.226	1.257
5	1.328	1.227	1.228	1.256
6	1.325	1.227	1.222	1.248
7	1.322	1.226	1.220	1.250
8	1.326	1.221	1.224	1.252
9	1.325	1.224	1.225	1.252
10	1.342	1.225	1.225	1.258
Mean :	1.322	1.221	1.22	1.248
Standard deviation on:	0.0058	0.0020	0.009	0.006
Maximum deviation from mean	0.32%	0.35%	0.20%	0.12%

Table 4.12 Density of Graded Sylhet Sand (S-3)

	Density (gm/cm^3)			
Sl.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50
1	1.323	1.234	1.228	1.265
2	1.321	1.235	1.224	1.266
3	1.318	1.237	1.226	1.262
4	1.319	1.236	1.229	1.266
5	1.318	1.238	1.227	1.270
6	1.317	1.239	1.228	1.268
7	1.318	1.228	1.232	1.265
8	1.320	1.232	1.234	1.264
9	1.322	1.234	1.228	1.264
10	1.320	1.232	1.230	1.266
Mean :	1.317	1.228	1.224	1.262
Standard deviation on:	0.002	0.0033	0.0029	0.0022
Maximum deviation from mean:	0.26%	0.53%	0.44%	0.35%

4.3.2 Density Analysis of Graded Kushtia Sand

Tables 4.13 to 4.15 show the bulk densities of three different types (K-1, K-2 and K-3) of graded Kushtia sand. From these three tables it is observed that in case of sand passing # 16 sieve and retained in # 30 sieve, the maximum variation in bulk density in any determination from mean varies more than 1% in two cases (K-2 and K-3). It was also visually observed that a few mica was also present in this grade of Kushtia sand. But in case of the following three grades of Kushtia sand, the maximum variation in each determination from mean was within 1% which fulfill the specification given by the ASTM (1989). So the following three grades of Kushtia sand satisfy all the specifications as material using for sand cone method given by ASTM (1989).

i) Sand passing # 30 sieve and retained in # 40 Sieve
ii) Sand passing # 40 sieve and retained in # 50 sieve
iii) Sand passing # 30 sieve and retained in # 50 sieve

Table 4.13 Density of Graded Kushtia Sand (K-1)

Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50
1	1.276	1.283	1.283	1.285
2	1.272	1.286	1.288	1.286
3	1.270	1.285	1.286	1.292
4	1.274	1.282	1.282	1.294
5	1.278	1.288	1.284	1.296
6	1.272	1.282	1.288	1.294
7	1.270	1.280	1.284	1.292
8	1.276	1.284	1.282	1.293
9	1.274	1.282	1.282	1.294
10	1.276	1.284	1.284	1.295
Mean :	1.270	1.280	1.282	1.285
Standard deviation on:	0.0027	0.0029	0.0023	0.0037
Maximum deviation from mean	0.33%	0.34%	0.29%	0.55%

Table 4.14 Density of Graded Kushtia Sand (K-2)

	Density (gm/cm^3)			
Sl.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50
1	1.267	1.309	1.284	1.320
2	1.266	1.312	1.288	1.322
3	1.268	1.308	1.282	1.318
4	1.269	1.312	1.286	1.320
5	1.270	1.314	1.288	1.323
6	1.272	1.316	1.290	1.316
7	1.274	1.308	1.284	1.324
8	1.275	1.310	1.292	1.320
9	1.268	1.308	1.290	1.322
10	1.266	1.310	1.292	1.316
Mean :	1.266	1.308	1.282	1.316
Standard deviation on:	0.007	0.0058	0.0035	0.0028
Maximum deviation from mean	1.20%	0.82%	0.43%	0.31%

Table 4.15 Density of Graded Kushtia Sand (K-3)

	Density (gm/cm^3)			
Sl. No.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50
1	1.301	1.264	1.262	1.264
2	1.306	1.269	1.264	1.268
3	1.304	1.266	1.266	1.265
4	1.300	1.264	1.264	1.262
5	1.302	1.262	1.262	1.265
6	1.302	1.264	1.262	1.266
7	1.300	1.265	1.264	1.264
8	1.306	1.268	1.261	1.266
9	1.302	1.266	1.264	1.264
10	1.301	1.264	1.230	1.264
Mean :	1.30	1.162	1.23	1.162
Standard deviation on:	0.006	0.0022	0.0112	0.0017
Maximum deviation from mean	1.18%	0.29%	0.24%	0.25%

4.3.3 Density Analysis of Graded Fultala Sand

Table 4.16 shows the bulk density of Fultala sand. From the table it can be observed that in case of sand passing # 16 sieve and retained in # 30 sieve, the maximum variation in bulk density in any determination from mean varies more than 1%. It was also visually observed that a few mica was present in this grade of Fultala sand. But in case of the following three grades of Fultala sand if can be observed the maximum variation in each determination from mean is within 1% which fulfill the specification given by the ASTM (1989). So the following three grades of Fultala sand satisfy the maximum specification as material using for sand cone method given by ASTM (1989)

i) Sand passing # 30 sieve and retained in # 40 Sieve

ii) Sand passing # 40 sieve and retained in # 50 sieve

iii) Sand passing # 30 sieve and retained in # 50 sieve

Table 4.16 Density of Graded Fultala Sand

Density (gm/cm^3)				
Sl. No.	(-) No. 16 & (+) No.30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No.50
1	1.323	1.234	1.228	1.250
2	1.321	1.235	1.224	1.252
3	1.318	1.237	1.226	1.251
4	1.311	1.228	1.227	1.246
5	1.316	1.227	1.230	1.247
6	1.321	1.230	1.232	1.252
7	1.217	1.231	1.228	1.250
8	1.315	1.229	1.232	1.246
9	1.214	1.228	1.228	1.248
10	1.214	1.229	1.230	1.248
Mean:	1.311	1.228	1.226	1.250
Standard deviation on:	0.008	0.0015	0.0026	0.0022
Maximum deviation from mean:	1.25%	0.22%	0.30%	0.33%

4.3.4 Density Analysis of Original Sylhet Sand

it was observed that original Sylhet sand is not a free flowing materials. It clogged the valve of sand cone apparatus and segregation problem occurred during fill up the jug. It was also observed for original Sylhet sand that maximum particle size is greater than 2.00 mm and uniformity coefficient is greater than two. So it can be concluded that original Sylhet sand can not be used as material for determination of in situ soil density by sand cone method.

4.3.5 Density Analysis of Original Kushtia Sand in Washed Condition

From collected samples of Kushtia sand a small quantity of sand was washed out and dried. Then bulk density of Kushtia sand was determined following the procedure described in Art. 3.4. Bulk density of original Kushtia sand is presented in Table 4.17. From the Table 4.17 it is observed that the maximum variation of the average value from any determination is 0.156% but ASTM (1989) recommends this variation should be less than 1%. Previously it was observed that the uniformity coefficient of Kushtia sand is less than two, which fulfills the ASTM (1989) criteria. On the other hand sand passing through 250 μm is more than 3% by weight, which does not fulfill the ASTM (1989) criteria. So the original Kushtia sand can not be used as an alternative material of Ottawa sand for determining in situ soil density by sand cone method.

4.3.6 Density Analysis of Graded Kushtia and Sylhet Sands in Washed and Unwashed Conditions

Densities of graded (passing # 30 and retained on # 50 sieve) Sylhet and Kushtia sands in washed and unwashed conditions are presented in Table 4.18. From Table 4.18 It is observed that the bulk density increases about 1.26% and 0.85% in case of washed Sylhet and Kushtia sands respectively. So, for both the samples of sand the variation in density is insignificant between washed and unwashed sample.

Table 4.17 Density of Original Kushtia Sand (Washed)

Sl. No.	Density (gm/cm^3)
1	1.282
2	1.280
3	1.282
4	1.284
5	1.282
Mean :	1.282
Standard deviation:	0.0014
Maximum deviation from mean :	0.156%

Table 4.18 Variation of Density on Washed & Unwashed Graded Sand

Density (gm/cm^3)				
	Sylhet Sand passing # 30 sieve & retained in # 50 sieve		Kushtia Sand Passing # 30 & Retained in # 50 sieve	
Sl. No.	Unwashed	Washed	Unwashed	Washed
1	1.265	1.282	1.285	1.301
2	1.263	1.279	1.286	1.297
3	1.268	1.281	1.292	1.299
Mean	1.265	1.281	1.288	1.299
Standard deviation	0.0025	.00153	0.0038	0.0023
Maximum variation from mean	0.24%	0.156%	0.31%	0.154%

4.3.7 Density Analysis of Original Fultala Sand

In case of Fultala sand if was observed that uniformity coefficient is greater than two. More than 3% by weight of sand pass through 250 μm, which do not fulfill the ASTM (1989) criteria. So the original Fultala sand can not be used as an alternative materials of Ottawa sand for determining in situ soil density by-sand cone method.

4.4 Remarks

From the analyses and interpretation of test results presented in this chapter it is found that the graded Sylhet sands satisfy the major ASTM (1989) criteria for selecting the sand in sand cone method. However, the original Sylhet sand does not satisfy those criteria. Similar results were found by Mohsin (1994) for original Sylhet sand. It is also observed that the original Kushtia, Fultala, Bogjhuri and Mongla sands are not suitable for determining in place soil density in sand cone method. However graded Kushtia & Fultala sands except the grade passing # 16 sieve and retained in # 30 sieve are found to be suitable for determining in place soil density. Summary of the above findings are presented in Table 4.19. It is also found that the increase in bulk density of washed and unwashed sands does not differ substantially. Washed and unwashed graded sands may be used for this purpose.

Table 4.19 Suitability of Using Locally available Sands in Sand Cone Method

Sl. No.	Location	Gradation	Major ASTM (1989) Criteria for the sand used in the Sand Cone Method				Remarks
			Uniformity coefficient	Maximum Particle Size, mm	X passing through 250μm	Maximum variation from mean density	
			<2	<2mm	<3%	<1%	
1	2	3	4	5	6	7	8
1	Sylhet	Original	-	-	-	-	Not acceptable
2	Sylhet	(-) No 16 & (+) No. 30	+	+	+	+	Acceptable
3	Sylhet	(-) No 30 & (+) No. 40	+	+	+	+	Acceptable
4	Sylhet	(-) No 40& (+) No. 50	+	+	+	+	Acceptable
5	Sylhet	(-) No 30 & (+) No. 50	+	+	+	+	Acceptable
6	Kushtia	Original	-	+	-	+	Not acceptable
7	Kushtia	(-) No 16 & (+) No. 30	+	+	+	-	Not acceptable
8	Kushtia	(-) No 30 & (+) No. 40	+	+	+	+	Acceptable
9	Kushtia	(-) No 40 & (+) No. 50	+	+	+	+	Acceptable
10	Kushtia	(-) No 30 & (+) No. 50	+	+	+	+	Acceptable
11	Fultala	Original	-	+	-	-	Not acceptable.
12	Fultala	(-) No 16 & (+) No. 30	+	+	+	-	Not acceptable
13	Fultala	(-) No 30 & (+) No. 40	+	+	+	+	Acceptable
14	Fultala	(-) No 30 & (+) No. 50	+	+	+	+	Acceptable
15	Fultala	(-) No 40 & (+) No. 50	+	+	+	+	Acceptable
16	Bogjhuri	Graded/ Original	-	+	-	-	Not acceptable
17	Mongla	Graded/ Original	+	+	-	-	Not acceptable

N.B.: (1) In column 4 to 7 – (minus) sign indicates not satisfy the ASTM (1989) criteria & + (plus) sign indicates satisfy the ASTM (1989) criteria.
(2) In column 3 (-) & (+) signs indicate passing & retaining sieves respectively.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the present study some properties of locally available sands have been investigated to compare with those of Ottawa sand as mentioned by ASTM (1989), which must be fulfilled to use in sand cone method. Attempts have been made to justify the suitability of local sands in lieu of Ottawa sand to find out in situ density by sand cone method. With original local sands, some graded sands were also selected for the investigation of suitability. The main findings have been outlined into following sections.

(a) In the determination of in situ density the following four types of Graded Sylhet sands are found to be suitable:

(i) Sand passing # 16 sieve and retained in # 30 sieve.
(ii) Sand passing # 30 sieve and retained in # 40 sieve.
(iii) Sand passing # 40 sieve and retained in # 50 sieve.
(iv) Sand passing # 30 sieve and retained in # 50 sieve.

(b) The following three types of Graded Kushtia Sands are also found to be suitable for determining the in situ soil density by sand cone method:

(i) Sand passing # 30 sieve and retained in # 40 sieve.
(ii) Sand passing # 40 sieve and retained in # 50 sieve.
(iii) Sand passing # 30 sieve and retained in # 50 sieve.

(c) The following three types of Graded Fultala Sands are also found to be suitable for determining the in situ soil density by sand cone method:

(i) Sand passing # 30 sieve and retained in # 40 sieve.
(ii) Sand passing # 40 sieve and retained in # 50 sieve.
(iii) Sand passing # 30 sieve and retained in # 50 sieve.

The types of sand mentioned in above three sections [(a), (b) and (c)] fulfill all the criteria recommended by the ASTM (1989) for determination of in situ soil density in sand cone method.

5.2 Recommendations for Future Study

Several aspects of the work presented in this project work require further study. Some of the important areas of further research may be listed as below:

- In this research only five types of selected sand samples were studied to find out the suitability of using those in determining soil density in sand cone method. This research may be extended to other sands those are available in Bangladesh.
- It is reported in ASTM (1989) that the effect of humidity on fine sand is significant. In this study sands collected from Bogjhuri and Mongla were found to be fine. Their susceptibility in density variation for humidity was not studied. So the effect of humidity on density of sand should be studied in future.
- The effects of angularity in density variation were not studied in this thesis work. So the effect of angularity on density of sand should also be studied in future.

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