DETERMINATION OF IN-SITU SOIL DENSITY USING LOCAL SANDS

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A Project Thesis

by

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ABSTRACT

Sand Cone method is widely used to determine the density of compacted soils in the construction of earth embankments, road fills and structure backfills. This method can also be used to determine in place density of soil deposits, aggregates, soil mixtures or other similar materials.

In our country Ottowa sand is used for determining in-situ soil density using Sand Cone Method. Ottowa sand is very expensive and it is always imported from abroad. Usually it requires much time to import this item. Instead of Ottowa sand local sand could be used as an alternative material for determining in place soil density by Sand Cone Method. In Bangladesh, local sand is available in abundance and compared with Ottowa sand it is also much cheaper in price. Since local sand is readily available and much less expensive for large scale testing of determining in place density, use of local sand would be less costly. Moreover it will not be required to recollect the local sand after the test is done.

In this research the quality and suitability of local sand, collected from different places of Bangladesh are assessed for determining in-situ density using Sand Cone Method. Each of the sample is characterized by determining its index properties. Grain size distribution, specific gravity and density are determined for each sample. These properties are compared with those recommended by ASTM for selecting a suitable sand in Sand Cone Method. Finally those satisfy the properties, recommended by ASTM are suggested for alternative use of Ottowa sand.

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CONTENTS

CHAPTER 1

INTRODUCTION

1.1 General

Determination of in place soil density is important for many types of earth construction such as dams, retaining walls, highways, airports etc. There are various methods of determination of field density of soils. The prominents are Sand cone, rubber balloon, core cutter and nuclear methods. Of these, sand cone is perhaps the most widely used method for its simplicity.

Ottowa sand is usually specified for the determination of in-situ volume and hence the soil density in sand cone method. Ottowa sand consists of pure silicious materials and is practically all of one size and approximatley 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 Ottowa 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 Scope and Objectives of the research

In this study the suitability of selected local sand of Bangladesh will be assessed for its use in the determination of in-situ soil density. Sand sample will be collected from selected locations of Bangladesh. Test samples would be prepare by making numerous gradation of a sample. Laboratory tests would be performed and the data will be analysed to ascertain its statistical acceptability.

The specific objectives of the study are:

i) To determine the desired density of graded local sand from selected locations of Bangladesh.

ii) To compare the results with those of Ottowa 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

There are various methods of determining field density of soils. The commonly used methods are:

i) Sand cone method
ii) Rubber balloon method
iii) Core cutter method and
iv) Nuclear method

In this chapter the existing literature on these methods are briefly reviewed. A comparative study 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

2.2.1 Sand Cone Method

This method is widely used to determine the density of compacted soils used in the construction of earth embankments, road fills and structural back fills. This method can also be used to determine in place density of natural soil deposits, aggregates, soil mixtures or other similar materials.

The sand cone method is a indirect means of obtaining the volume of the hole. The sand used (often Ottowa 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 a uniform or "one-size" sand with rounded grains to avoid segregation problems. The use of rounded 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 than 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 a 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.

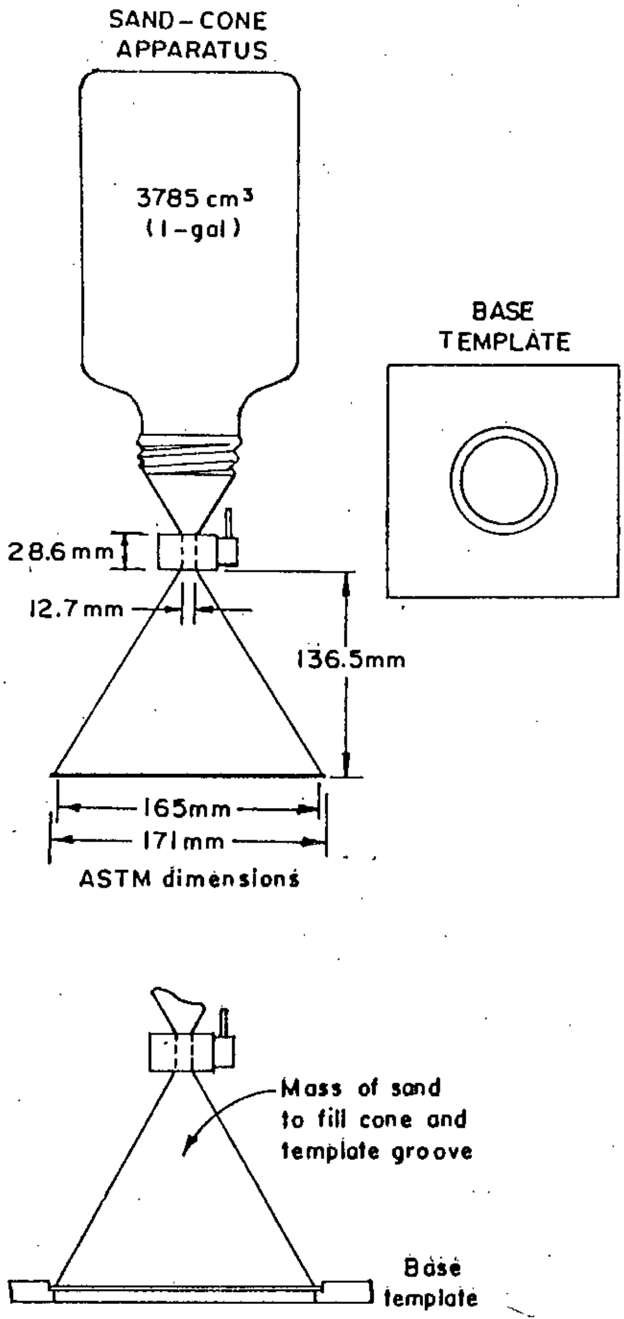

Fig. 2.1 General line details of the sand cone apparatus.

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 shall be clean, dry, uniform uncemented, durable and free flowing.

ii) Any gradation may be used that has a uniformity co-efficient ($Cu = D_{60}/D_{10}$) 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 subrounded 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 an acceptable sand, the variation between any determination and the 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.

Bulk Density of Sand

The bulk density depends on how densely the sand is packed and it follows that for a materials of a given specific gravity the bulk density depends on the size distribution and shape of the particles. Particles all 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 BS812: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.cs 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. Volume of the sample should be read and porosity 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 cu.ft. sample should be thus obtained and porosity calculated (P_{min}).

2.2.2 Rubber Balloon Method

Basically both the sand cone method and balloon density methods use the same principle. That is one obtains a known mass of damp to wet soil from a small excavation of somewhat irregular shape (a hole) in the ground. If the volume of the hole is determined, the wet density can be easily computed.

The volume of the excavated hole is found as a 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. This rapid means of finding the volume of the hole is often a distinct advantage in terms of test time over the sand cone method, which is more indirect.

The principal precaution with the balloon density test is to excavate a hole with regular sides so gravel protrusions do not rupture the baloon. As there should be no voids that the baloon can bridge. A zero reading must be obtained prior to using the device, after which, unless excessive evaporation occurs in the reservoir or the baloon ruptures, many hole volume readings can be taken before a new zero reading is required (Fig. 2.2).

For details of the method AASHO (1966) and ASTM (1989) can be consulted.

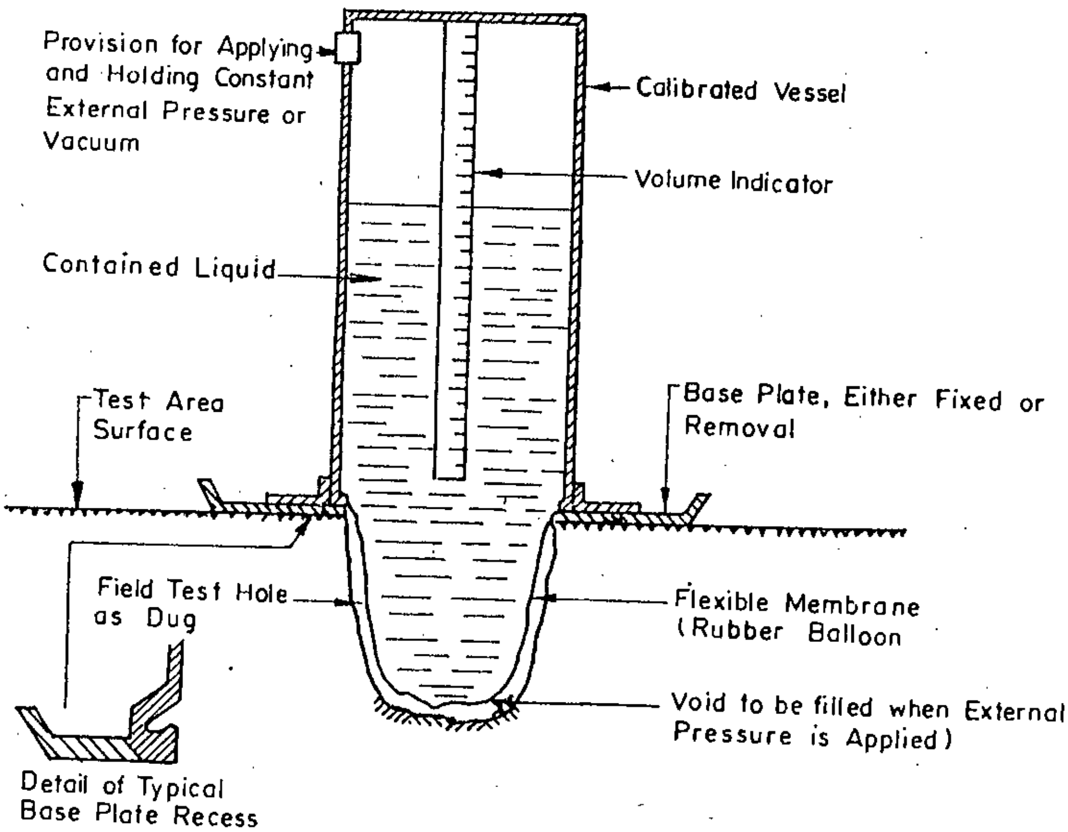

Fig. 2.2 Schematic drawing of calibrated vessel indicating principle.

2.2.3 Core Cutter Method

A core cutter consisting of a steel cutter, 10 cm in diameter and about 13 cm high, and a 2.5 cm high dolly is driven in the cleaned surface with the help of a suitable rammer till about 1 cm of the dolly protrudes above the surface. Schmatic diagram of the core cutter instrument is shown in Fig. 2.3. The cutter, containing the soil, is dug out of the ground, the dolly is removed and the excess soil is trimmed off. The weight of the soil in the cutter is found. By dividing it by the volume of the cutter the bulk density is determined. The water content of the excavated soil is found in the laboratory and the dry density is computed. A detailed description can be found in Punmia (1973).

2.2.4 Water Displacement Method

This method (Punmia, 1973) is suitable only for cohesive soil samples brought from the field. A small specimen is trimmed to a more or less regular shape, from a larger sample, and its weight W_1 is found. The specimen is covered with a thin layer of paraffin wax and the weight W_2 of the sealed specimen is taken. A metal container is filled above the over flow level and excess water is allowed to run off through the overflow outlet. The

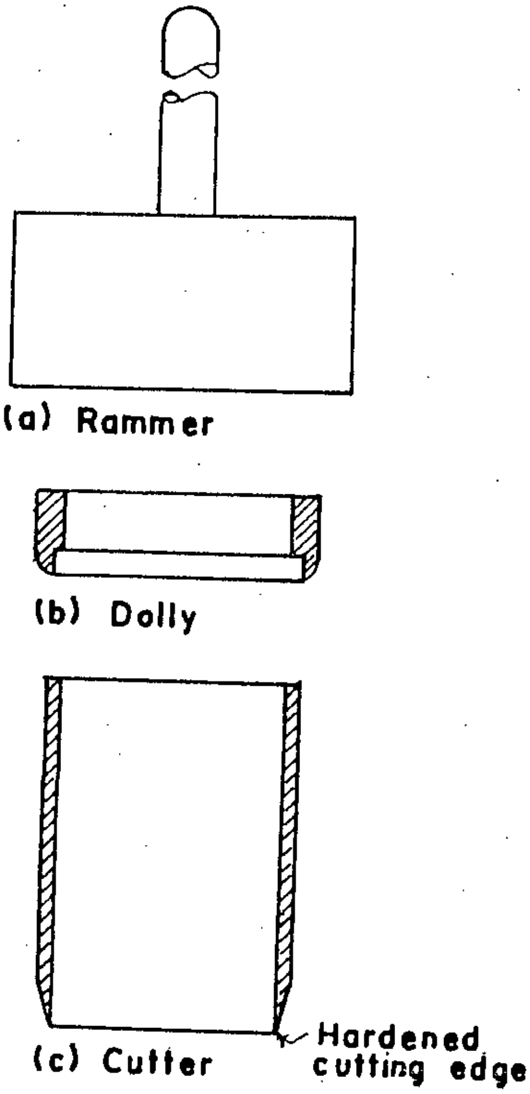

Fig. 2.3 Schematic drawing of core cutter apparatus

coated specimen is then slowly immersed in the container and the overflow water is collected in a measuring jar. The volume of the uncoated specimen is then calculated from the relation:

$$V = V_w - \frac{W_2 - W_1}{G_p} \qquad (2.1)$$

where G_p = density of paraffin wax (g/ml) in the absence of any other test, Gp may be taken as 0.908 g/ml.

The bulk density and the dry density of the specimen are determined from the relations

$$= \frac{W_1}{V} \quad \text{and} \quad = \frac{\tau}{1 + w} \qquad (2.2)$$

where w is the water content of the specimen to be determined by oven drying a small specimen.

2.2.5 Nuclear Methods (Shallow Depth)

This method uses nuclear equipment to determine the density of soil and soil-aggregate in place. In general, the total or wet density of the material under test is determined by placing a gamma source and a gamma detector either on, into adjacent to the material under test. These variations in test geometry are presented as the back scatter, direct transmission or optional air gap approaches. The intensity of radiation detected is dependent in part upon the density of the material under test. The radiation intensity reading is converted to measured wet density by a suitable calibration curve. It should be noted that the density determined by these methods is not necessarily the average density within the volume involved in the measurement and that the equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken ASTM (1989).

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 a 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 use only for cohesive soil. Nuclear method has limited use due to the sopsticated nuclear equipments need. The equipment utilize the radioactive materials which may be hazardous to the health of user unless proper protection are taken. For simplicity of the test, the sand cone method is widely used to determine the density of compacted soils.

CHAPTER 3

LABORATORY INVESTIGATION

3.1 General

In order to ascertain the suitability of using local sands for determining in place soil density, samples were collected by the author personally from Sylhet, Gazaria, Mymensingh, Chandpur, and Savar. Some of these samples were also collected from the various places of Narayanganj district such as Pagla, Dapa and Katchpur. Location of sample collected from various places are given in Table 3.1.

Table 3.1 Locations of Collected Sands

Sl.No.	Types of sand	Sample No.	Place of Collection
1.	Sylhet	I	Khaglarchar, Vill. Shoalla, Taherpur, Sylhet.
2.	Sylhet	II	Pagla, Narayanganj
3.	Sylhet	III	Dapa, Narayanganj
4.	Gazaria	I	Gazaria, Munshigonj
5.	Gazaria	II	Pagla, Narayanganj
6.	Gazaria	III	Katchpur, Demra, Dhaka
7.	Mymensingh	I	Gafargaon, Mymensingh
8.	Chandpur	I	Courtchandpur, Chandpur
9.	Savar	I	Gabtali, Dhaka

Each of the above sample was characterized by determining their index properties. Grain size distribution curve and specific gravity for each of the sample was determined. 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 procedure were carried out for the preparation of sample.

a) Air drying the sample for at least seven days and then.

b) With (ASTM) standard set of sieves (containing # 16, # 30,# 40, # 50, # 100) each sample was graded. The gradation 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	5.0 kg	Density determination
2.	Sample passing sieve # 30 and retained in sieve # 40	5.0 kg	"
3.	Sample passing sieve # 40 and retained in sieve # 50	5.0 kg	"
4.	Sample passing sieve # 30 and retained in sieve # 50	5.0 kg	"
5.	Sample passing sieve # 50 and retained in sieve # 100	5.0 kg	"
6.	Representative sample (original sand)	5.0 kg	Determination of density, specific gravity and grain size distribution

3.3 Properties of Sand Sample

3.3.1 Grain Size Distribution

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

The size of the grains of sand or soil is one of the factors affecting some of its physical properties of direct importance to the engineers, such as cohesion and permeability. Grain size analysis is done of 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 Hagen (1893) 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. Hagen 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, Hagen (1893) proposed the following equation:

$$C_u = \frac{D_{60}}{D_{10}} \qquad (3.1)$$

where D_{60} and D_{10} are the diameter of the particles at 60 and 10 percent finer respectively on the grain size distribution curve. When the uniformity coefficient, C_u, is about one, the grain size distribution curve is almost vertical. For all practicale purposes one considered the following values for granular soils (Punmia, 1973).

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 of each of the collected sample. From each curve C_u, D_{10}, D_{60} were calculated for respective sample.

3.3.2 Specific Gravity

The specific gravity of a soil 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, we can compute the unit weight of a moist soil.

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 fall within a narrow range.

In this study specific gravity of all sand sample collected from various places were carried out essentially for the identification of minerals (Lambe, 1954).

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 sample:

a) Determination of weight of sand in cone

i) The sand cone jug full of sand was weighed.

ii) Then the sand cone was turned upside down into a plane surface. 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 weight 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 can be thought of as the hole which is dug in the field for density determination.

ii) The sand cone jug was weighted with full of sand before use.

iii) The sand cone was turned upside down and was placed on the template over the mold. The valve was opened the sand was allowed to fill the mold and as well as cone. When the sand ceased to pour, the valve was closed. Then the jug again weighed.

iv) The difference between the two weights was the weight of the sand in mold and cone.

3.4.1 Details of Density Calculation

a) i) Weight of jug + cone + sand (before use) = A_1 gm

ii) Weight of jug + cone + sand (after use) B_1 gm

Weight of sand in cone = $(A_1 - B_1)$ gm

b) i) Weight of jug + cone + sand (before use) = A_2 gm

ii) Weight of jug + cone + sand (after use) = B_2 gm

weight of sand in cone + mold = $(A_2 - B_2)$ gm

Therefore, weight of sand in mold = $(A_2 - B_2) - (A_1 - B_1)$ gm

Volume of mold = V cm^3 (known)

$$\text{Density of sand used} = \frac{(A_2 - B_2) - (A_1 - B_1)}{V} \ gm/cm^3 \qquad (3.2)$$

CHAPTER-4

TEST RESULTS AND DISCUSSIONS

4.1 General

In order to acertain 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

Sieve Analysis and specific gravity test were performed, following the standard test procedure (ASTM (1989)) on collected sand sample. Grain size distribution curves for original sands are shown in Figs. 4.1 to 4.9.The value of fineness modulus,D_{10},D_{60},U and specific gravity for each original sample were calculated and are shown in table 4.1(a). The grain size distribution curves for graded sands are also shown in Figs. 4.10 to 4.22. The values of D_{10}, D_{60}, U of graded sand are shown in Tables 4.1(b) to 4.1(c).

The following observations were made after studying Figs. 4.1 to 4.22 and Tables 4.1(a), 4.1(b) and 4.1(c).

i) Average finess modulus of Sylhet and Gazaria sand were observed 2.64 and 1.71 respectively. but in case of Mymensingh, Chandpur and Savar sand those value were found 1.47, 0.96 and 1.18 respectively. So Mymensingh, Chandpur and Savar sand can be considered as fine sand, in comparison with Sylhet and Gazaria sand.

ii) From Table 4.1(a) it can be observed that the uniformity coefficient, of original Sylhet sand is greater than two. But in case of original Gazaria, Mymensingh, Chandpur and Savar sand this value was less than two. It also can be found from tables 4.1(b) and 4.1(c) the uniformity coefficient is less than two for all the graded sand. The ASTM (1989) recommendeds that the value of uniformity co-efficient for the sand, used in Sand Cone Method should be less than two.

iii) From Tables 4.1(a), 4.1(b) and 4.1(c) it can be observed that except the original Sylhet sand maximum particle size for all types of collected sand and also the graded sand 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 3 to 4 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(a) it was observed that in case of original sand this value varies from 3.50% to 80% In case of graded sand of passing No. 50 sieve and retained on No. 100 sieve it was observed that 65% by weight passing through 250 μm (Table 4.1(b)). But in case of all other graded sand 0% by weight passing 250 μm (Table 4.1(c)). So the graded sand of passing No. 50 sieve and retained on No. 100 sieve and all of the collected original sample fail to satisfy this criteria.

v) In case of Mymensingh, Chandpur and Savar sand it was observed that significant amount of mica was present in the collected 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 co-efficient are greater than two and maximum particle size is greater than 2 mm. In case of original Gazaria, Mymensingh, Chandpur, Savar 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 sand the uniformity coefficient is less than two, maximum particle size is less than 2 mm and less than 3% by weight pass through 250 μm which satisfy the ASTM (1989) criteria.

1) Sand passing No. 16 sieve and retained on No. 30 sieve.

2) Sand passing No. 30 sieve and retained on No. 40 sieve.

3) Sand passing No. 30 sieve and retained on No. 50 sieve.

4) Sand passing No. 40 sieve and retained on No. 50 sieve.

Table 4.1(a) Index Properties of Sands

Sl. No.	Location of sand	Sample No.	D_{10}	D_{60}	U	F.M.	Sp.Gr.	Maximum particle size, mm	% passing through 250 µm
1.	Sylhet	I	0.23	0.60	2.61	2.34	2.67	3.50	12.00
2.	Sylhet	II	0.28	0.70	2.50	2.62	2.65	3.00	7.00
3.	Sylhet	III	0.40	0.90	2.25	2.98	2.66	4.00	3.50
4.	Gazaria	I	0.21	0.39	1.85	1.68	2.72	1.50	15.00
5.	Gazaria	II	0.20	0.39	1.95	1.63	2.71	1.20	15.00
6.	Gazaria	III	0.27	0.43	1.59	1.81	2.70	0.85	8.00
7.	Mymensingh	I	0.16	0.29	1.81	1.47	2.87	0.85	22.00
8.	Chandpur	I	0.14	0.24	1.71	0.96	2.72	0.80	80.00
9.	Savar	I	0.16	0.27	1.69	1.18	2.73	0.70	50.00

Table 4.1(b) Index Properties of Graded Sands

Sl. No.	Gradation	D_{10}	D_{60}	U	Maximum particle	% passing through 250 µm
1.	(-) No 16 & (+) No. 30	0.64	0.85	1.30	1.18	0.00
2.	(-) No. 30 & (+) No.40	0.44	0.52	1.18	0.60	0.00
3.	(-) No. 40 & (+) No.50	0.32	0.39	1.22	0.42	0.00
4.	(-) No. 50 & (+) No.100	0.17	0.24	1.41	0.30	65.00

Table 4.1(c) Index Properties of Sand of Grade (-) No. 30 & (+) No. 50

Sl. No.	Location of sand	Sample No.	D_{10}	D_{60}	U	Maximum particle size, mm	% passing through 250 µm
1.	Sylhet	I	0.33	0.48	1.45	0.60	0.00
2.	Sylhet	II	0.34	0.48	1.41	0.60	0.00
3.	Sylhet	III	0.38	0.50	1.32	0.60	0.00
4.	Gazaria	I	0.32	0.46	1.44	0.60	0.00
5.	Gazaria	II	0.31	0.42	1.35	0.60	0.00
6.	Gazaria	III	0.33	0.45	1.36	0.60	0.00
7.	Mymensingh	I	0.32	0.40	1.25	0.60	0.00
8.	Chandpur	I	0.32	0.41	1.28	0.60	0.00
9.	Savar	I	0.31	0.40	1.29	0.60	0.00

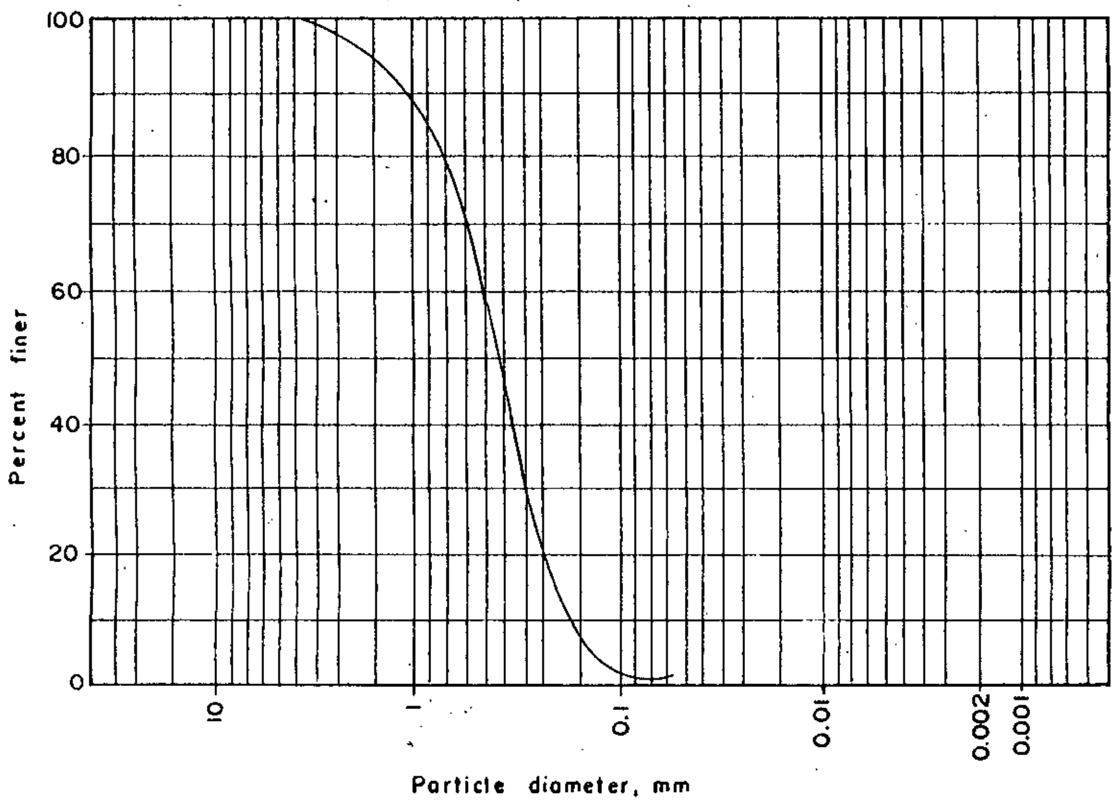

Fig. 4.1 Grain size distribution of Sylhet sand, sample-1

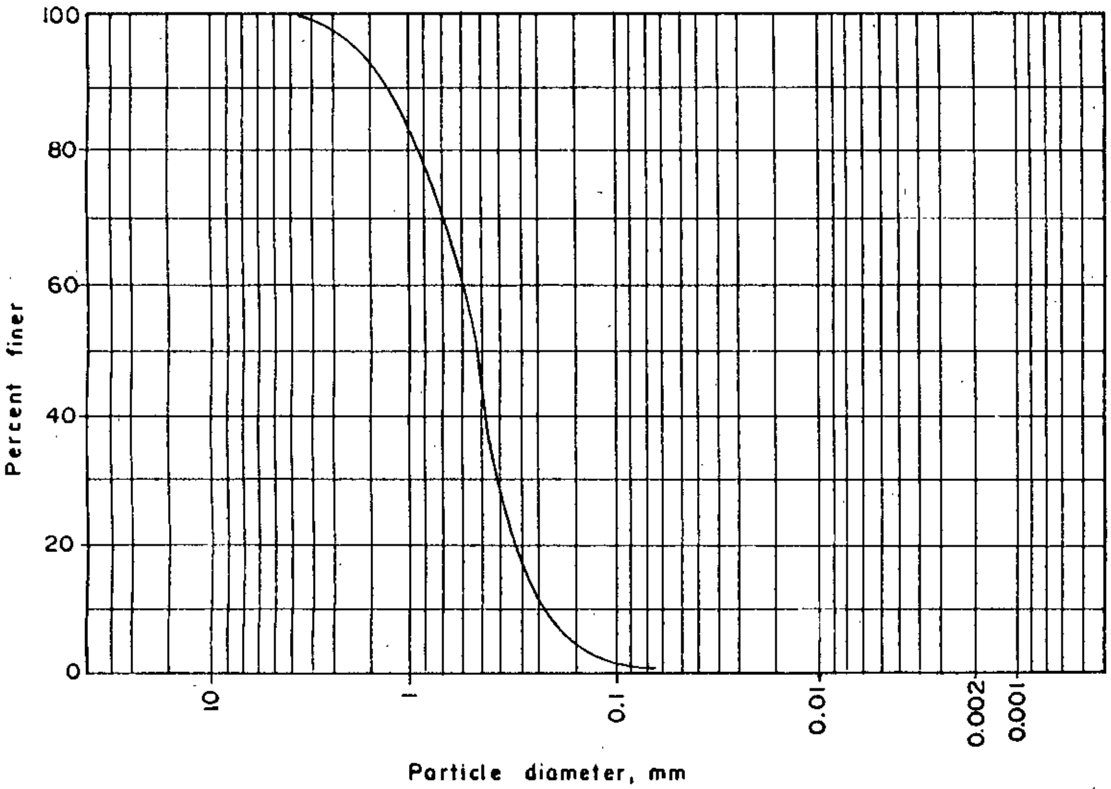

Fig. 4.2 Grain size distribution of Sylhet sand, sample-II

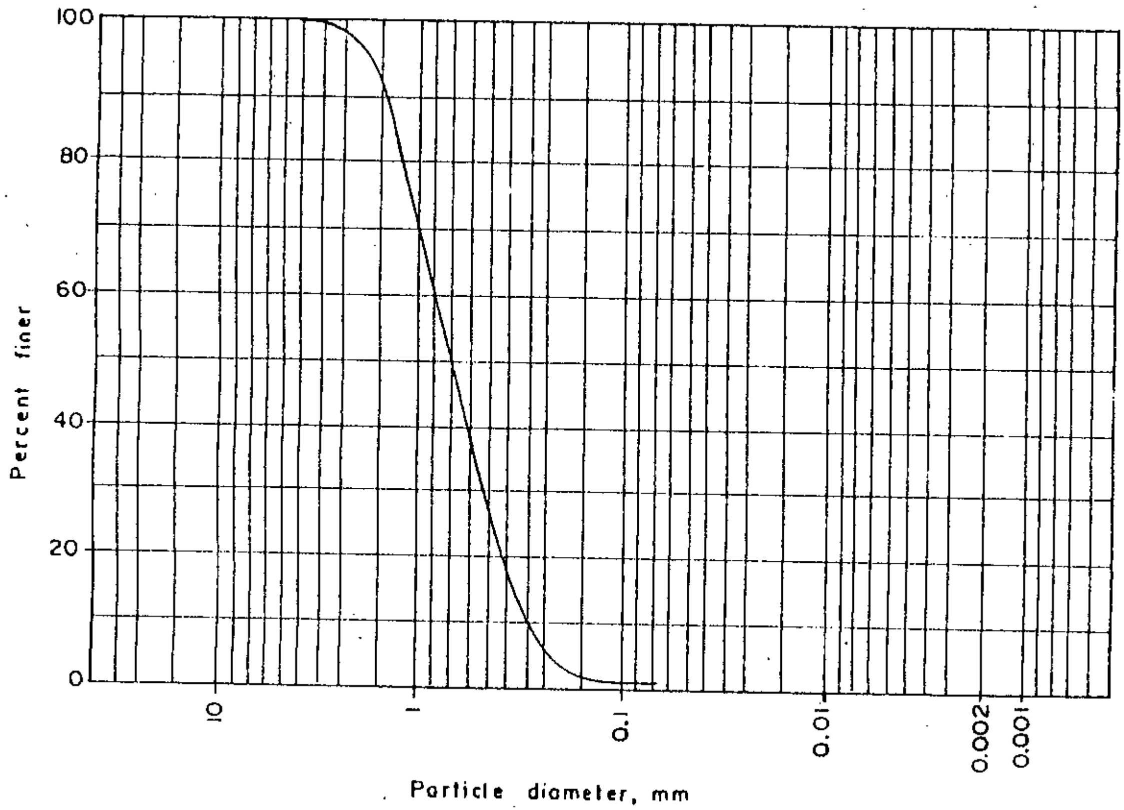

Fig. 4.3 Grain size distribution of Sylhet sand, sample-III

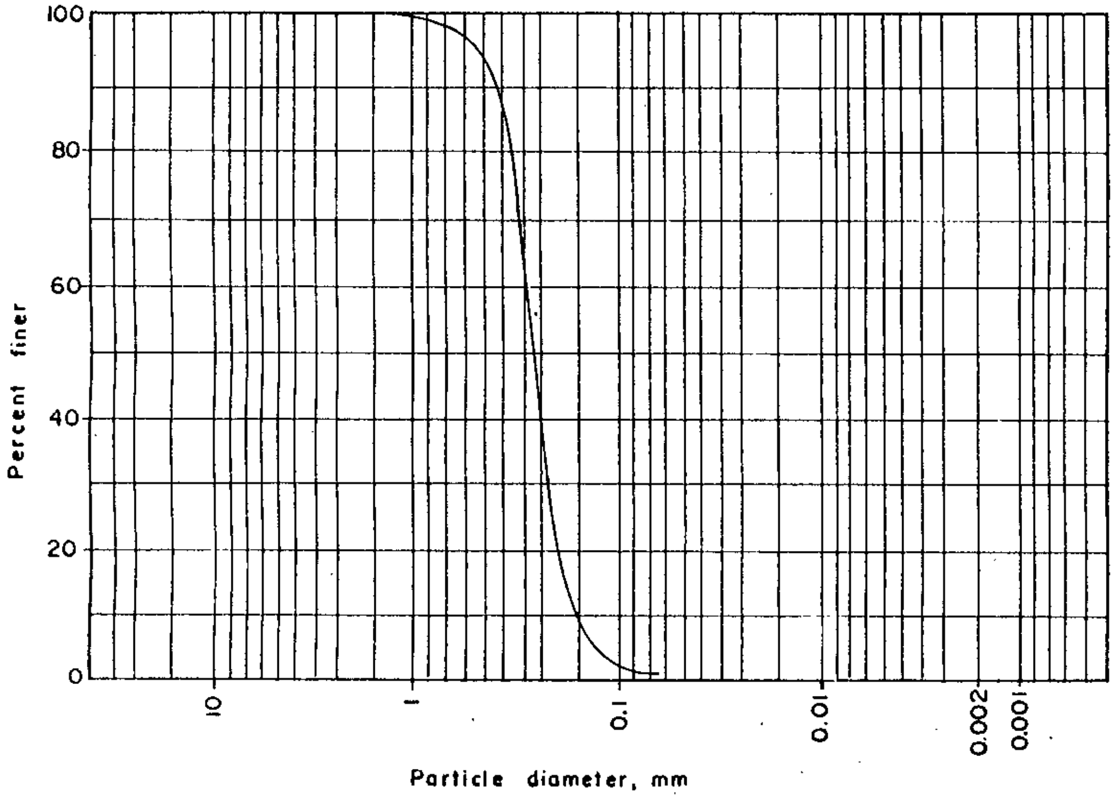

Fig. 4.4 Grain size distribution of Gazaria sand, sample-1

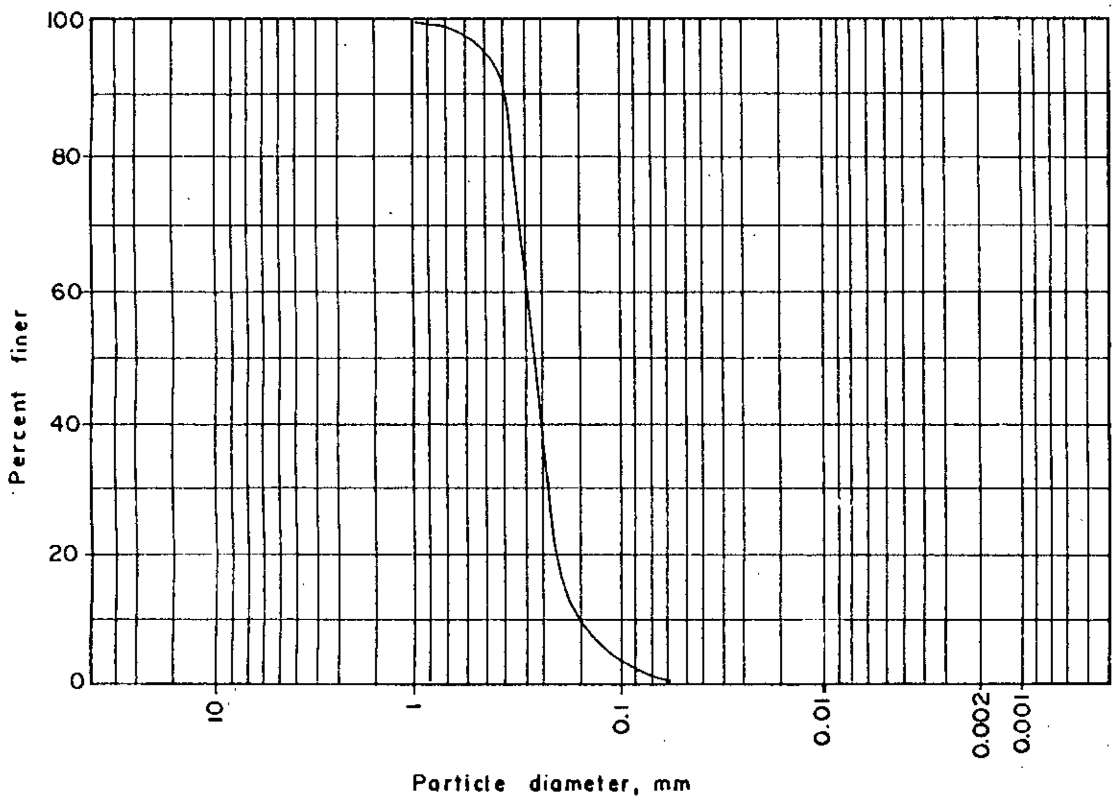

Fig. 4.5 Grain size distribution of Gazaria sand, sample – II

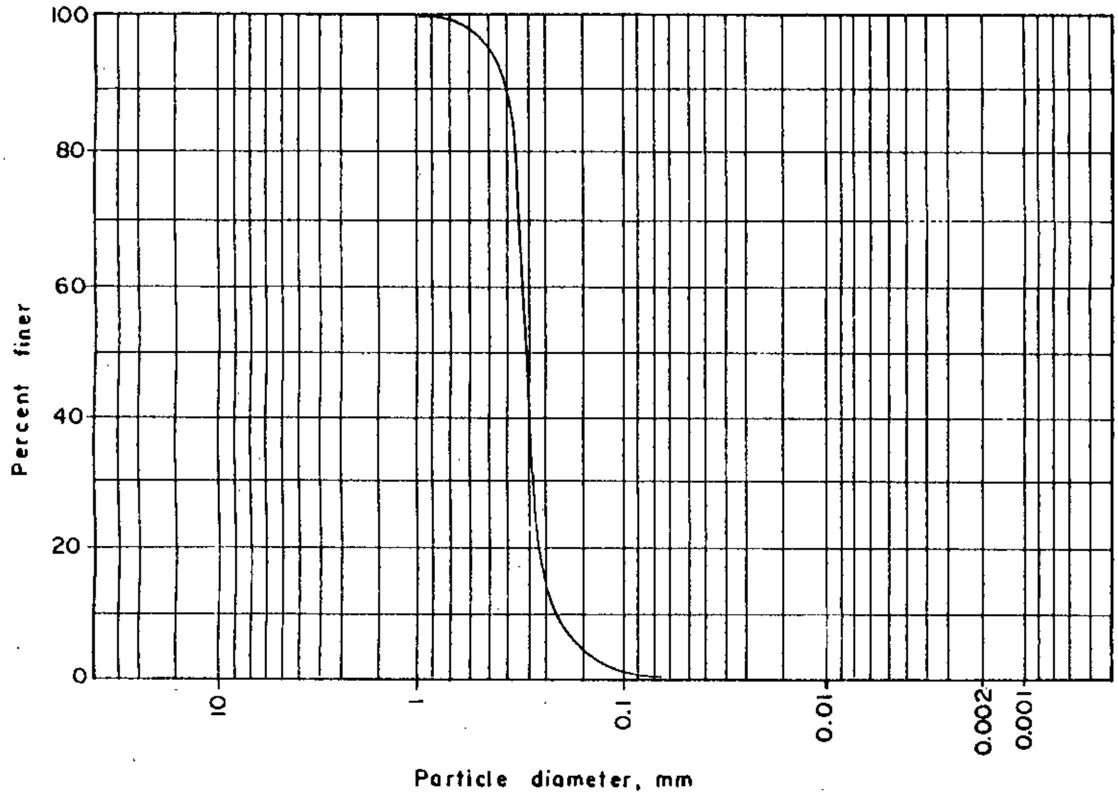

Fig. 4.6 Grain size distribution of Gazaria sand, sample–III

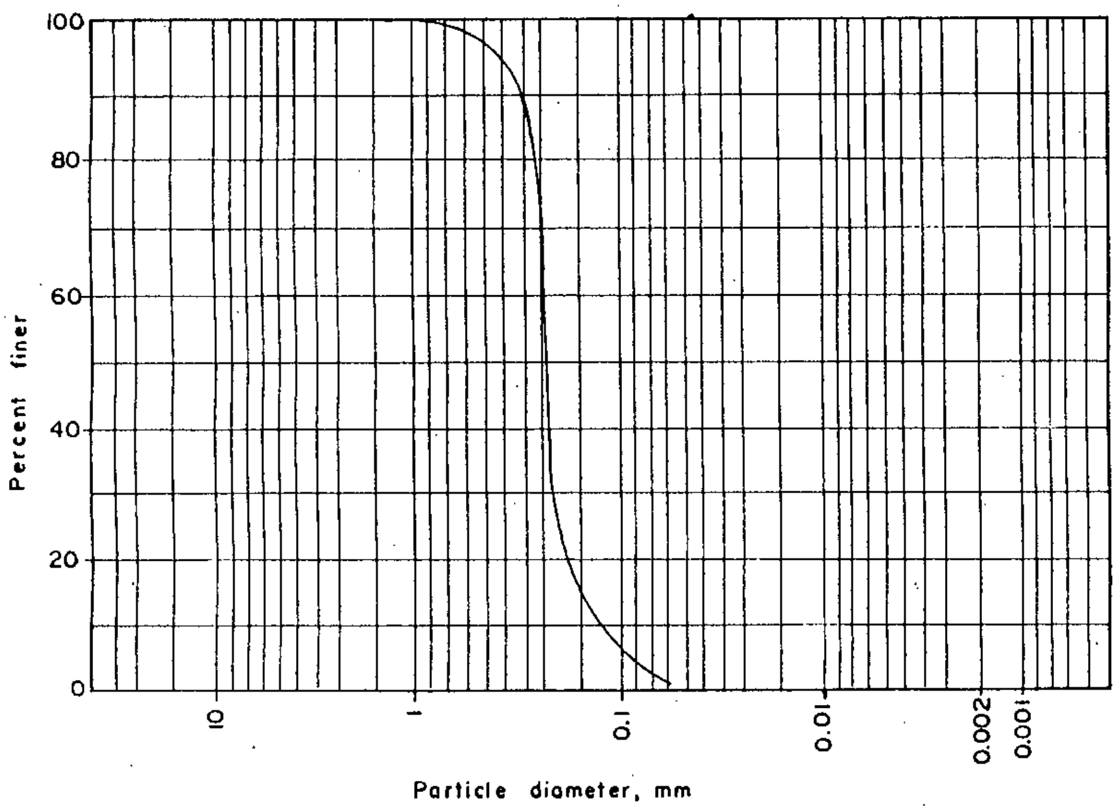

Fig. 4.7 Grain size distribution of Mymensing sand

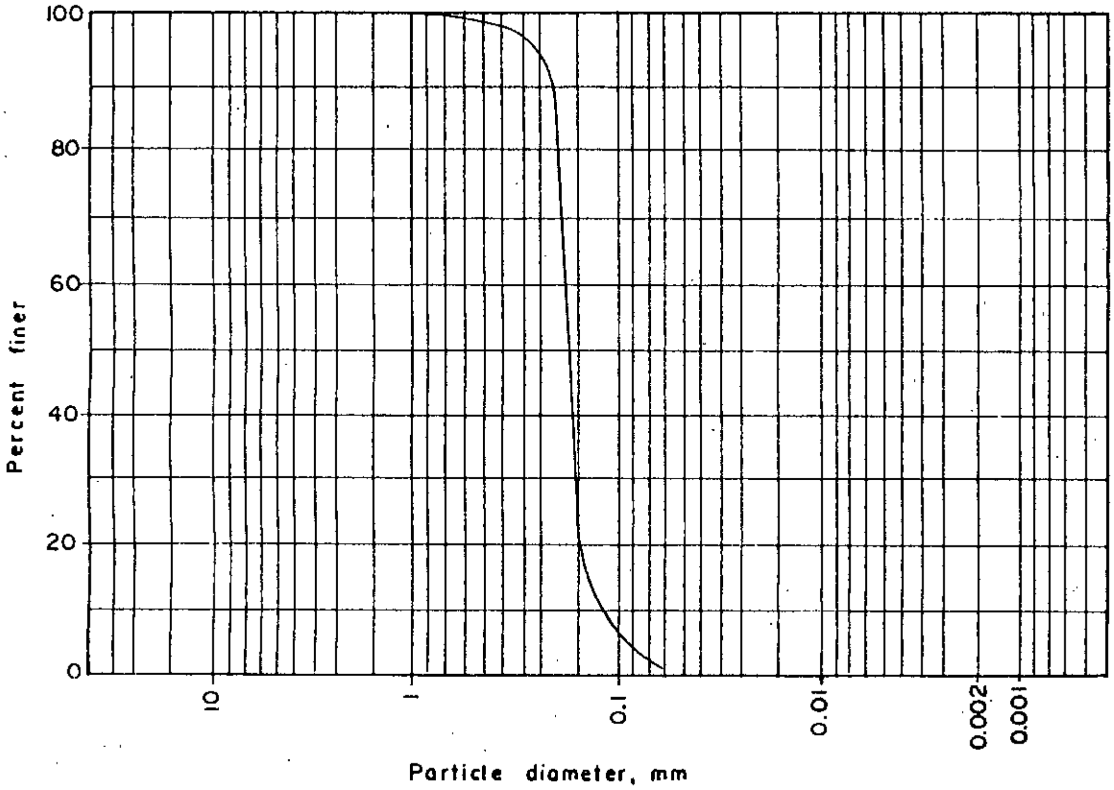

Fig. 4.8 Grain size distribution of Chandpur sand

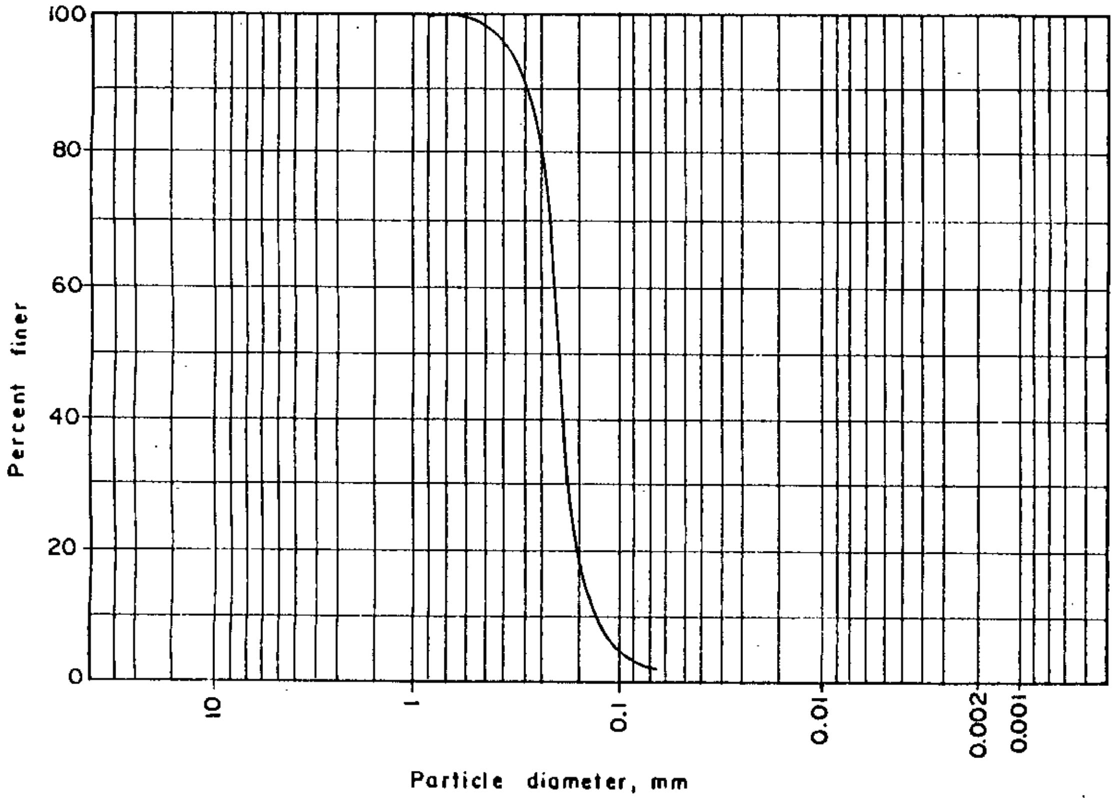

Fig. 4.9 Grain size distribution of Savar sand,

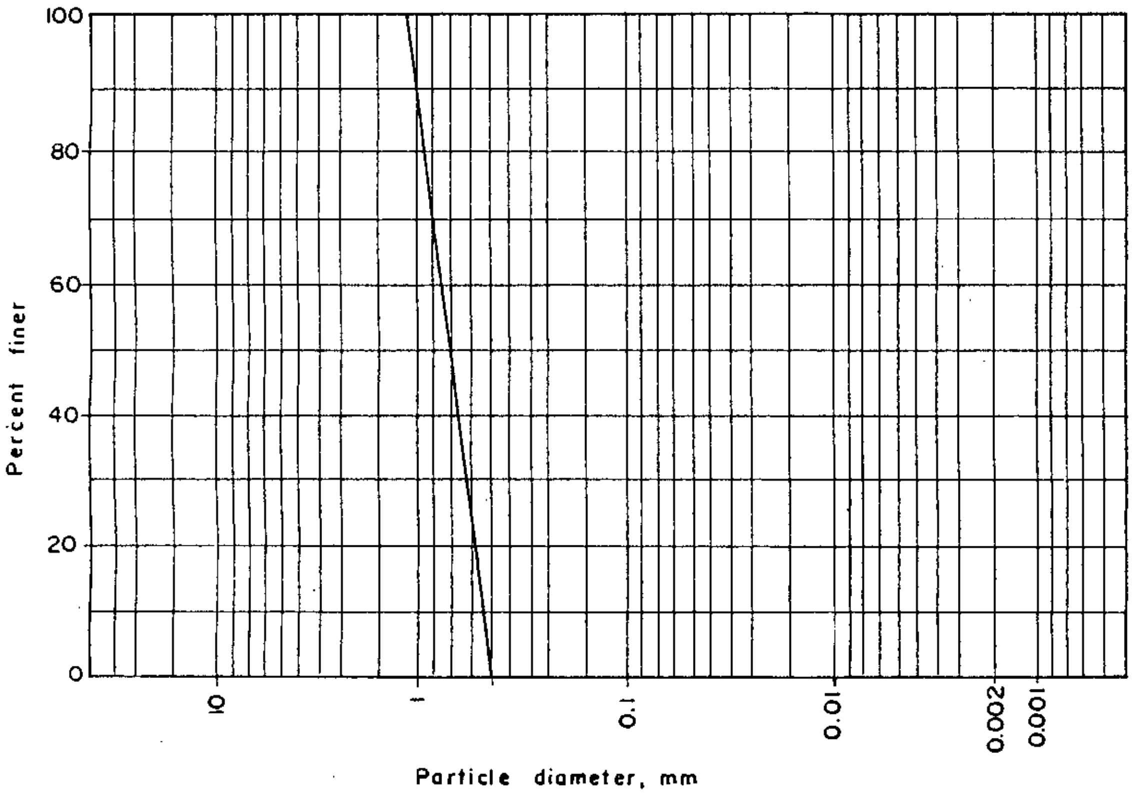

Fig. 4.10 Grain size distribution of Graded Sand of Grode (–) No. 16 and (+) No. 30

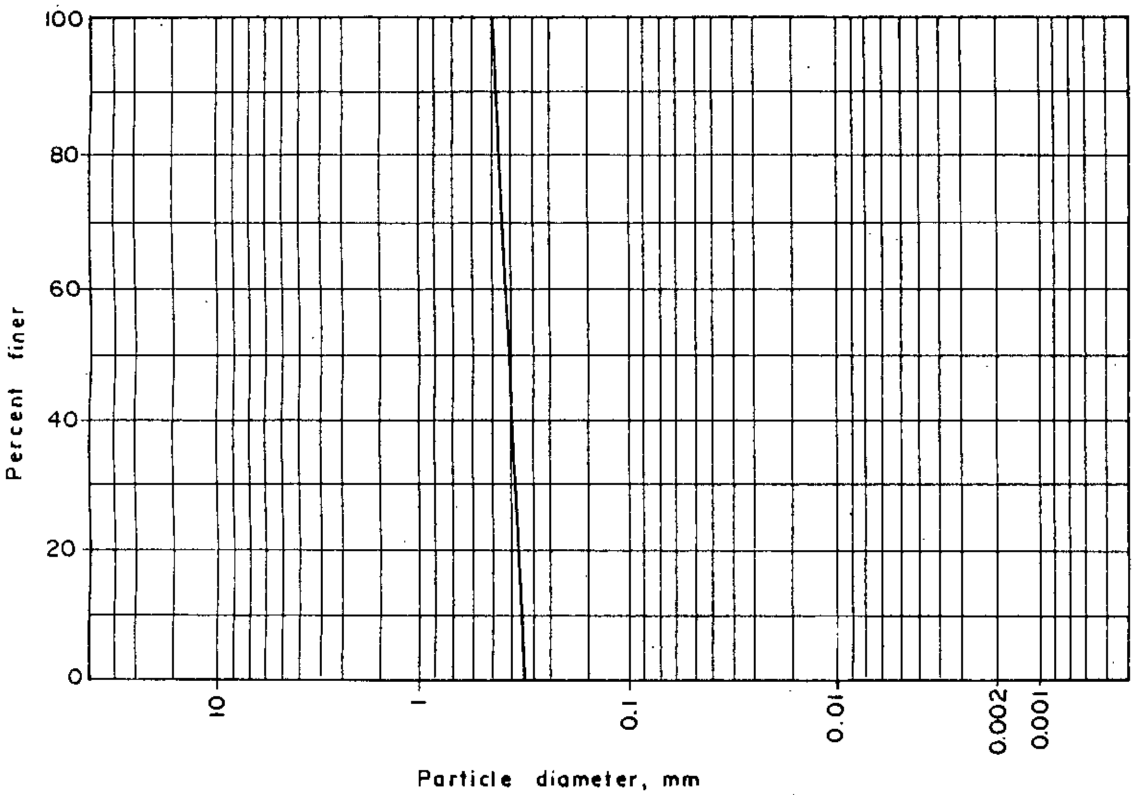

Fig. 4.11 Grain size distribution of Graded Sand of Grade (—) No. 30 and (—) No. 40

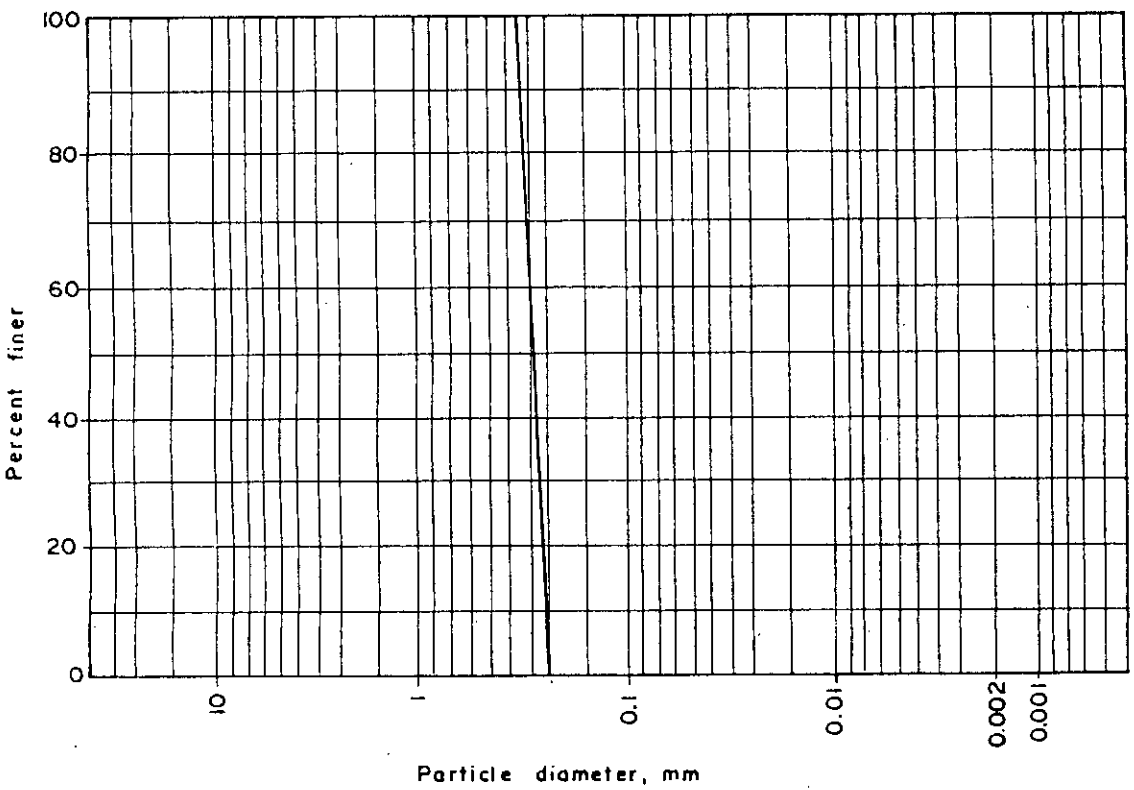

Fig. 4.12 Grain size distribution of Graded Sand of Grade (−) No. 40 and (+) No. 50

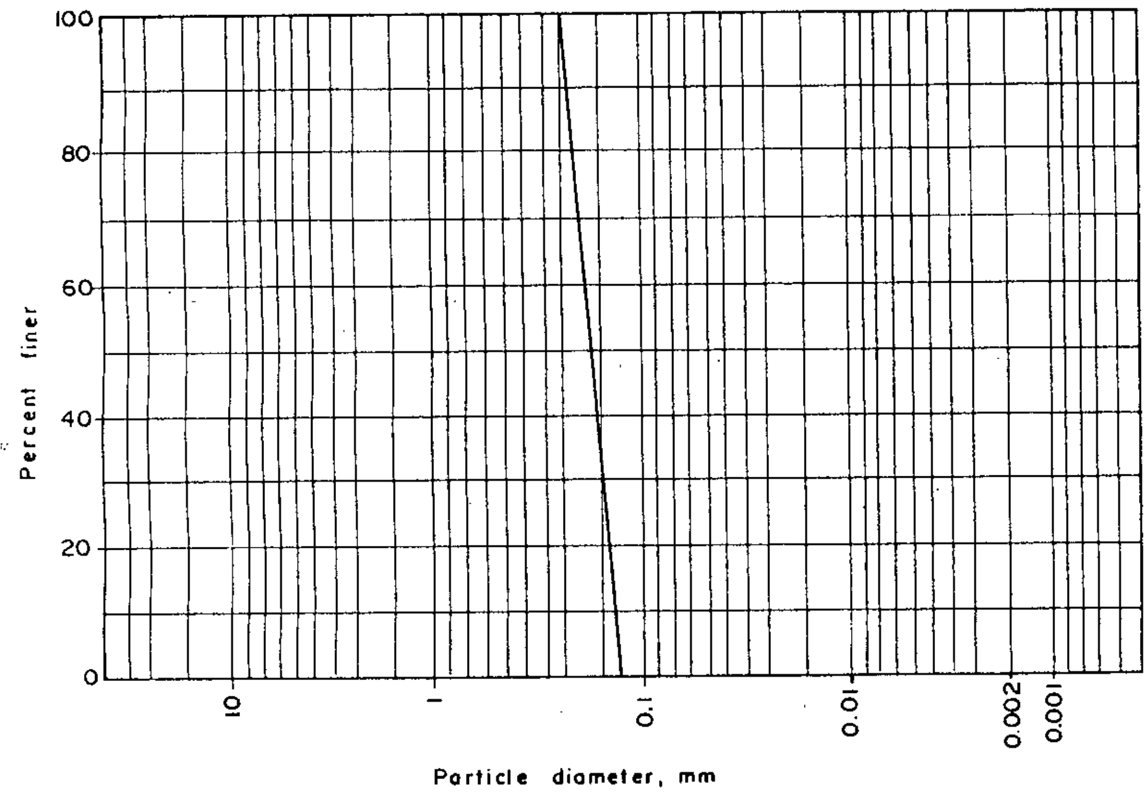

Fig. 4.13 Grain size distribution of Graded Sand of Grade (−) No. 50 and (+) No. 100

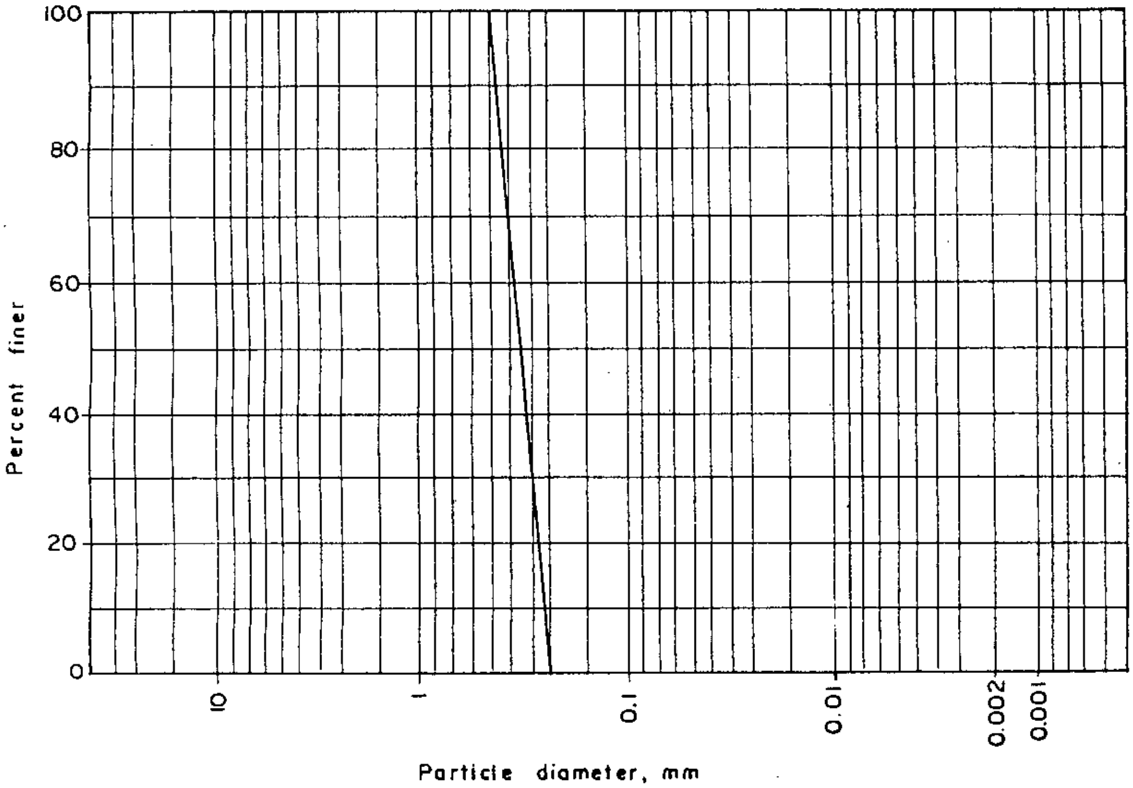

Fig. 4.14 Grain size distribution of Graded Sylhet Sand — I of Grade (−) No. 30 and (+) No. 50

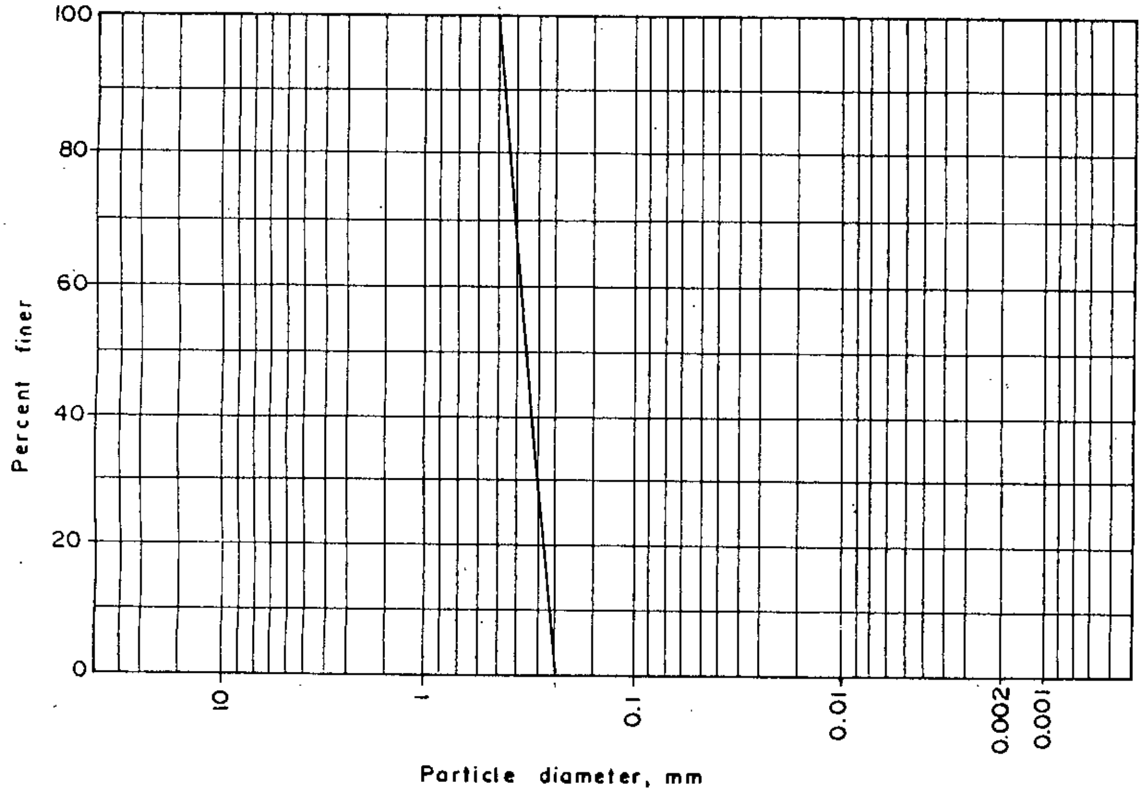

Fig. 4.15 Grain size distribution of Graded Sylhet Sand — II of Grade (–) No. 30 and (+) No. 50

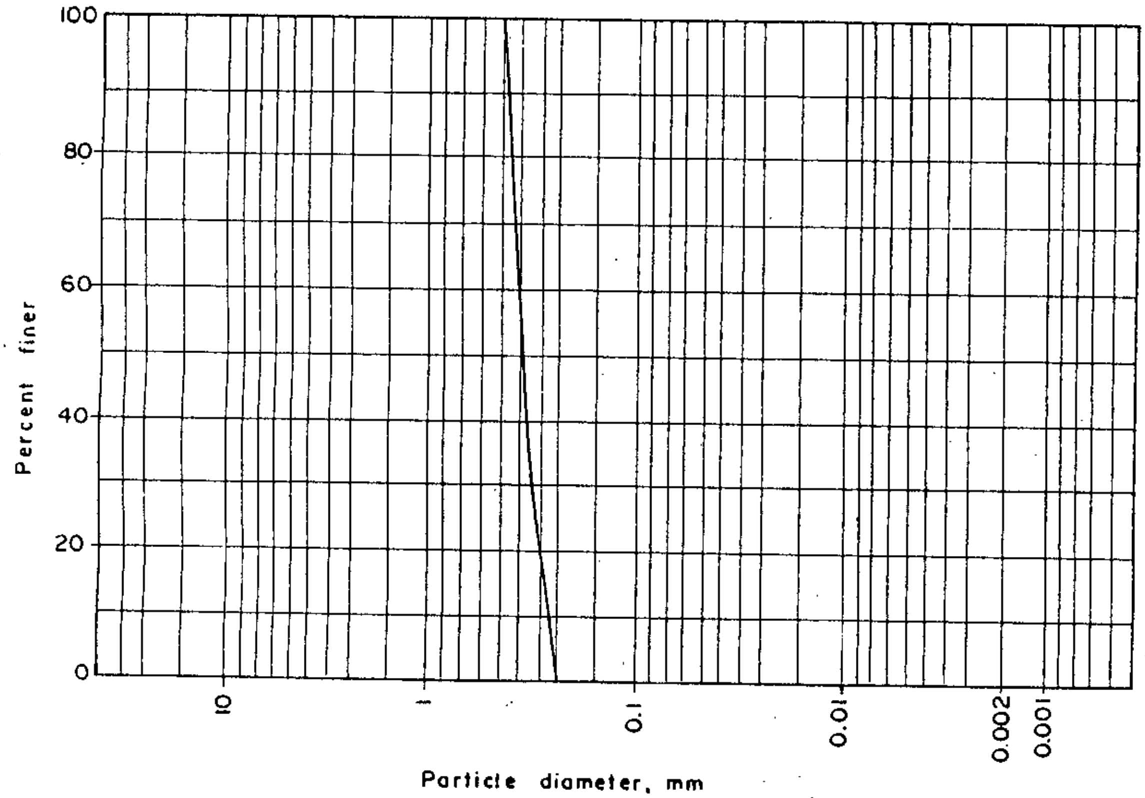

Fig. 4.16 Grain size distribution of Graded Sylhet Sand — III of Grade (−) No. 30 and (+) No. 80

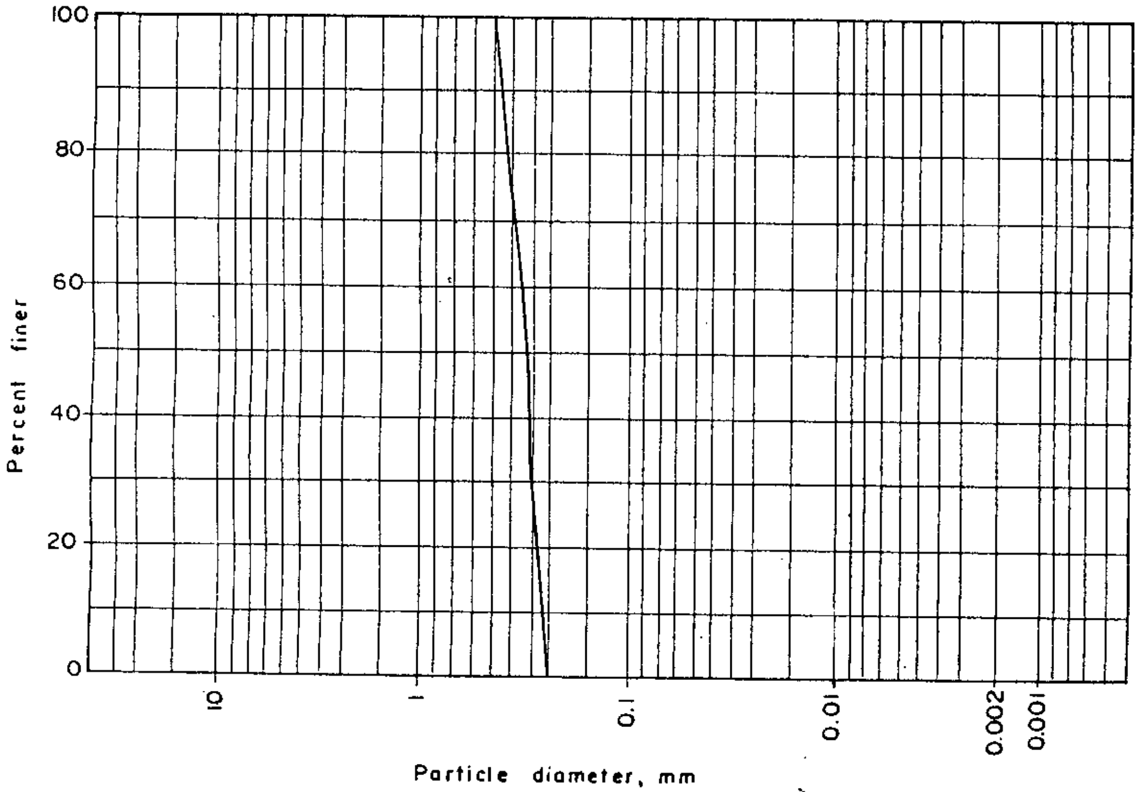

Fig. 4.17 Grain size distribution of Graded Gazaria Sand — I of Grade (−) No. 30 and (+) No. 80

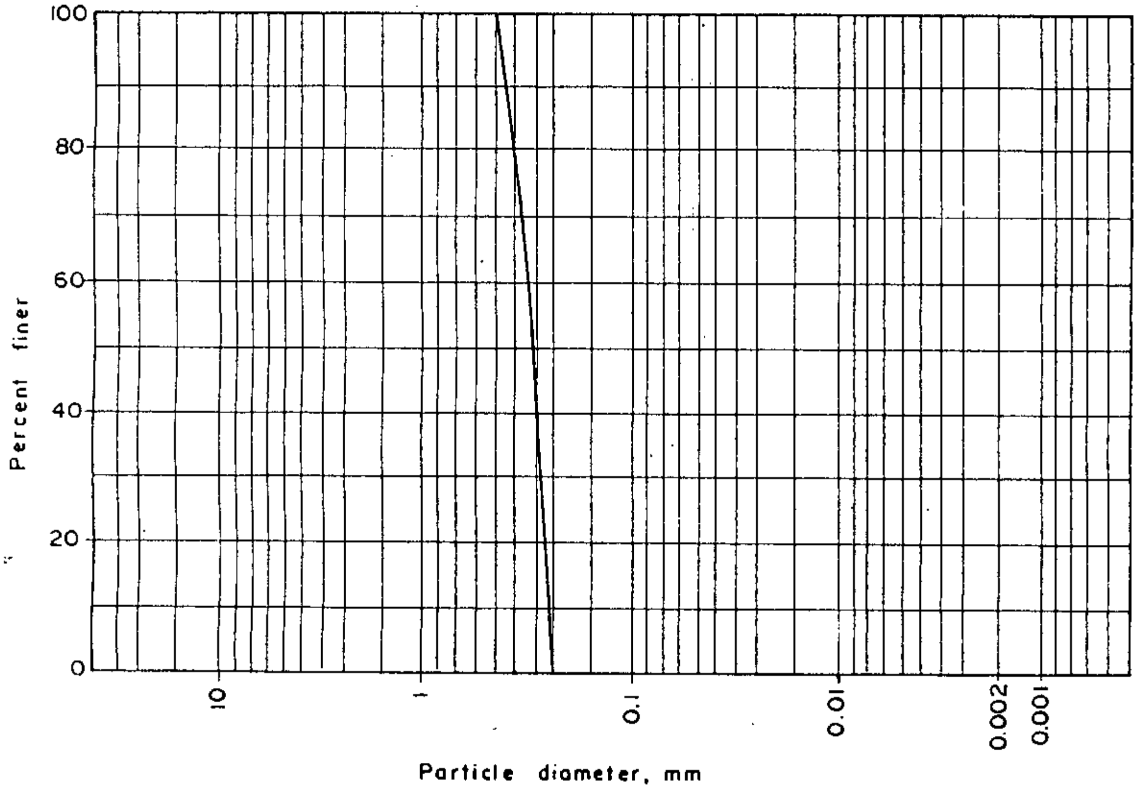

Fig. 4.18 Grain size distribution of Graded Gazaria Sand – II of Grade (–) No. 30 and (+) No. 50

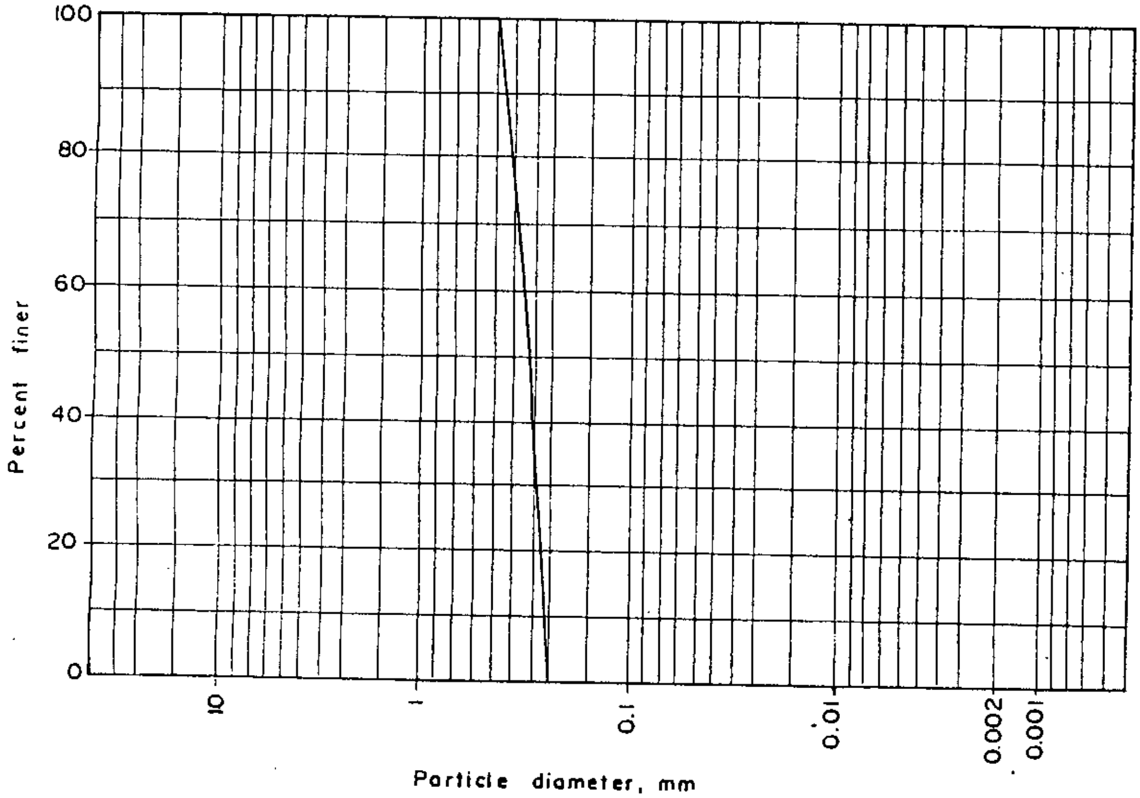

Fig. 4.19 Grain size distribution of Graded Gazaria Sand — III of Grade (−) No. 30 and (−) No. 50

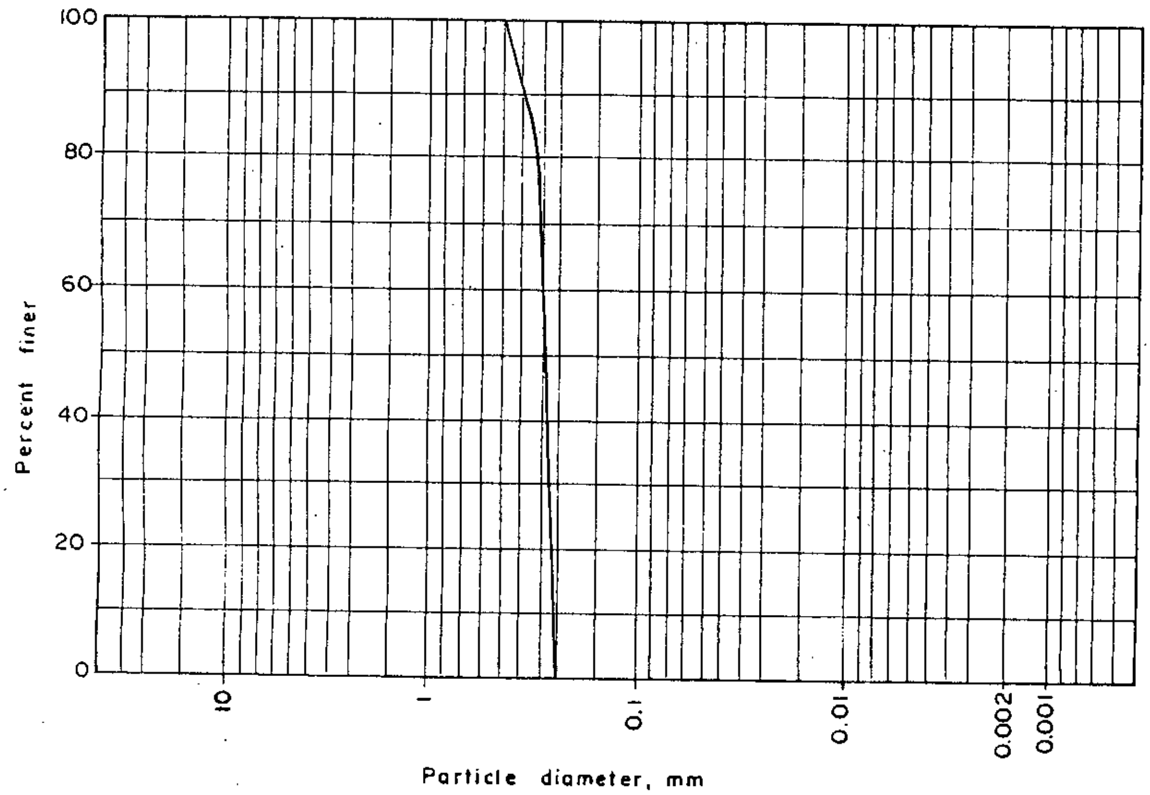

Fig. 4.20 Grain size distribution of Graded Mymensingh Sand of Grade (−) No. 30 and (+) No. 50

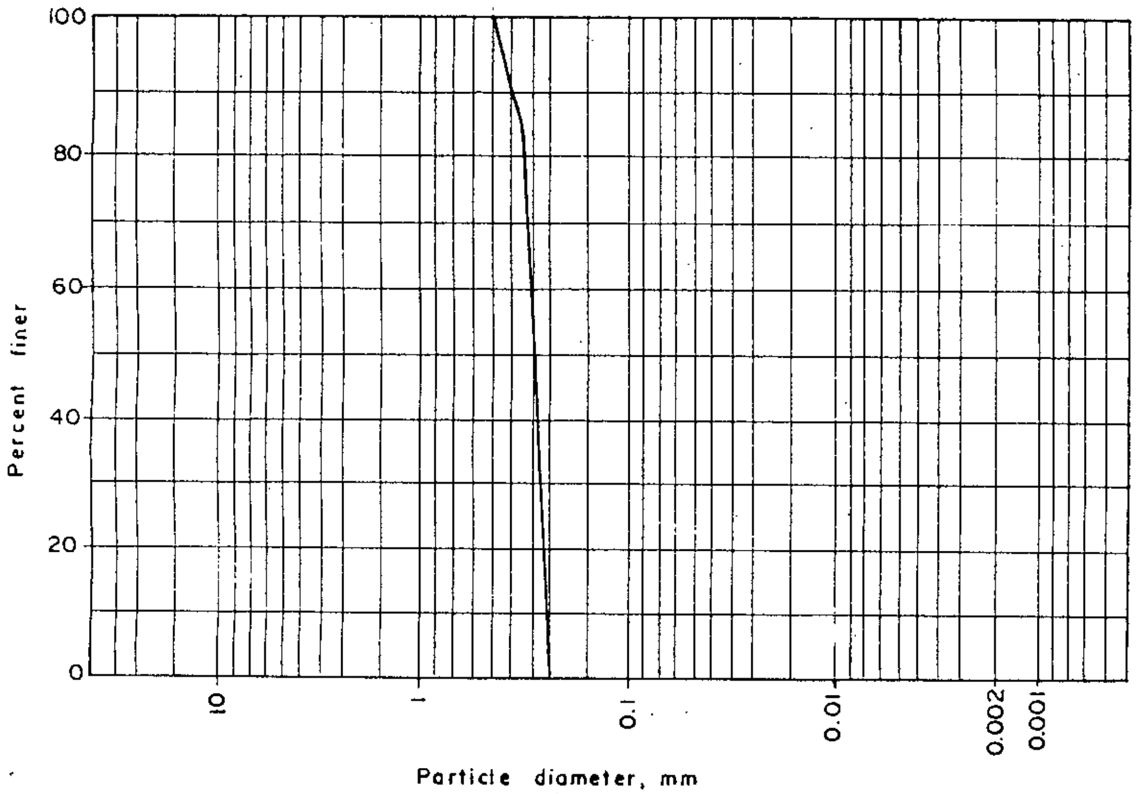

Fig. 4.21 Grain size distribution of Graded Chandpur Sand of Grade (–) No. 30 and (+) No. 50

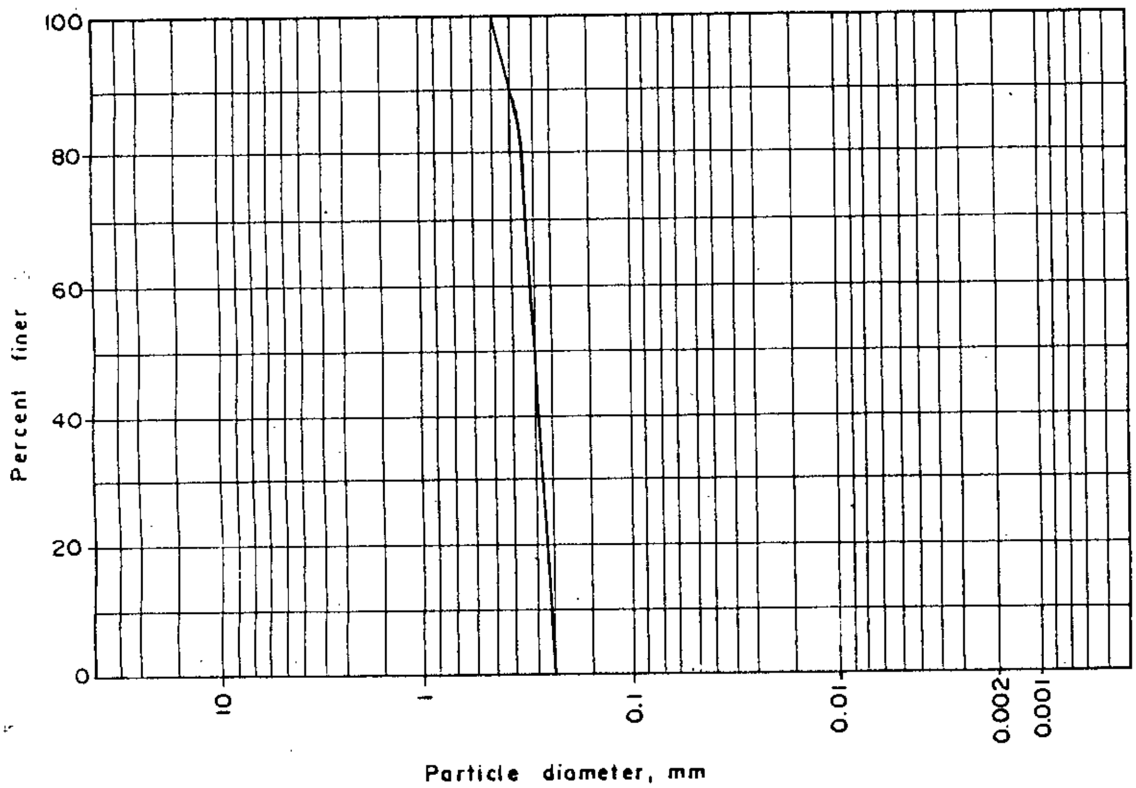

Fig. 4.22 Grain size distribution of Graded Savar Sand of Grade (−) No. 30 and (+) No. 50

4.3 Density Analysis of Sand

Determination of bulk density of graded sand as well as original sand were performed following the procedure described in Art. 3.4. Table 4.2 shows the density of graded Ottowa sand. From this table it is found that for any particular grade of sample the bulk density are almost same in each determination. Bulk density of graded Sylhet, Gajaria, Mymensingh, Chandpur and Savar sand are shown in Tables 4.3 to 4.7 respectively. From these tables it is observed that bulk density differs from one determination to another for each grade. In case of Mymensingh, Savar and Chandpur sand it observed that the bulk density of any grade differ significantly from that of Ottowa. Moreover from the Art. 4.2 it is found that these three types of sand are fine sand and sufficient coarse grade sample could not be found easily. So it can be concluded now that these three types of sand are not suitable as a materials for determination of in-situ soil density.

Hence any further investigation on these three samples were not carried out.

From Tables 4.3 and 4.4 it is observed that the bulk densities of Sylhet sand and Gazaria sand differs significantly in compared with of Ottowa sand (Table 4.2). In case of graded Sylhet sand it was observed that the bulk density differs significantly from grade passing # 16 sieve to retained in # 30 sieve with other grades. However in case of graded Gazaria sand it is observed that the variation of bulk density of various grades and mixed grades do not differ substantially.

Table 4.2 Density of Ottowa Sand (Test Condition)

	Density (gm/cm^3)				
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
1	1.550	1.533	1.498	1.516	1.480
2	1.550	1.533	1.499	1.516	1.485
3	1.550	1.533	1.499	1.516	1.481

Table 4.3 Density of Sylhet Sand, Sample No. I

	Density (gm/cm^3)				
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
1	1.329	1.270	1.248	1.277	1.271
2	1.326	1.260	1.246	1.274	1.260
3	1.329	1.260	1.243	1.271	1.274

Table 4.4 Density of Gazaria Sand, Sample No. I

Sl.	Density (gm/cm^3) (-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
1	1.332	1.338	1.335	1.337	1.300
2	1.325	1.344	1.317	1.328	1.309
3	1.323	1.340	1.327	1.339	1.308

Table 4.5 Density of Mymensingh Sand

Sl.	Density (gm/cm^3) (-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
1	1.197	1.311	1.308	1.318	1.327
2	1.185	1.304	1.314	1.324	1.330
3	1.185	1.318	1.304	1.318	1.321

Table 4.6 Density of Chandpur Sand, Sample No. I

	Density (gm/cm^3)				
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
1	-	-	-	1.084	1.280
2	-	-	-	1.094	1.290
3	-	-	-	1.093	1.284

- Sufficient course grade sample could not be found from the collected sample because of fine grained sand.

Table 4.7 Density of Savar Sand, Sample No. I

	Density (gm/cm^3)				
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
1	-	1.144	1.253	1.237	1.293
2	-	1.147	1.248	1.234	1.293
3	-	1.142	1.245	1.239	1.293

- Sufficient course 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 4.8, 4.9 and 4.10 show the bulk density of three types of graded Sylhet sand. These three types of sample were collected from three different places. From these 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 case 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 Ottowa sand for determining the in-situ soil density by sand cone method.

Table 4.8 Density of Graded Sylhet Sand, Sample No. I

	Density (gm/cm³)			
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
1	1.329	1.270	1.248	1.277
2	1.326	1.260	1.246	1.274
3	1.329	1.260	1.242	1.271
4	1.325	1.270	1.252	1.276
5	1.330	1.270	1.244	1.270
6	1.335	1.268	1.257	1.287
7	1.327	1.260	1.243	1.277
8	1.330	1.270	1.252	1.274
9	1.329	1.270	1.244	1.275
10	1.329	1.270	1.257	1.276
Mean:	1.329	1.267	1.249	1.276
Standard deviation σn:	0.003	0.004	0.005	0.004
Maximum deviation from mean:	0.45%	0.55%	0.64%	0.86%

Table 4.9 Density of Graded Sylhet Sand, Sample No. II

	Density (gm/cm^3)			
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
1	1.347	1.249	1.243	1.270
2	1.353	1.250	1.252	1.267
3	1.349	1.257	1.246	1.269
4	1.348	1.264	1.250	1.272
5	1.351	1.266	1.255	1.280
6	1.340	1.270	1.264	1.271
7	1.347	1.267	1.255	1.267
8	1.348	1.264	1.261	1.272
9	1.341	1.257	1.251	1.269
10	1.342	1.270	1.252	1.270
Mean:	1.347	1.261	1.253	1.270
Standard deviation σn:	0.004	0.007	0.006	0.004
Maximum deviation from mean:	0.45%	0.95%	0.88%	0.79%

Table 4.10 Density of Graded Sylhet Sand, Sample No. III

	Density (gm/cm³)			
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
1	1.360	1.279	1.270	1.297
2	1.356	1.288	1.265	1.307
3	1.346	1.290	1.270	1.298
4	1.358	1.294	1.270	1.302
5	1.348	1.279	1.260	1.311
6	1.349	1.278	1.260	1.298
7	1.352	1.286	1.268	1.297
8	1.348	1.279	1.269	1.308
9	1.346	1.281	1.270	1.297
10	1.355	1.288	1.268	1.302
Mean:	1.352	1.284	1.267	1.302
Standard deviation σn:	0.005	0.005	0.004	0.005
Maximum deviation from mean:	0.44%	0.78%	0.55%	0.46%

4.3.2 Density Analysis of Graded Gazaria Sand

Tables 4.11 to 4.13 show the bulk density of three different types of graded Gazaria sand. From these three tables it was 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. It was also visually observed that few mica also was present in this grade of Gazaria sand. But in case of following three grade of Gazaria sand it was observed the maximum variation in each determination from mean was within 1% which fullfill the specification given by the ASTM (1989). So the following three grade of Gazaria sand satisfy the maximum specifications as a 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 4.11 Density of Graded Gazaria Sand, Sample No. I

Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
	Density (gm/cm^3)			
1	1.332	1.338	1.335	1.337
2	1.325	1.344	1.317	1.328
3	1.323	1.340	1.327	1.338
4	1.333	1.350	1.319	1.337
5	1.338	1.338	1.335	1.340
6	1.334	1.355	1.330	1.340
7	1.332	1.338	1.327	1.338
8	1.333	1.340	1.325	1.335
9	1.323	1.342	1.330	1.337
10	1.325	1.340	1.330	1.340
Mean:	1.329	1.343	1.328	1.337
Standard deviation σn:	0.005	0.005	0.006	0.003
Maximum deviation from mean:	0.68%	0.56%	0.83%	0.67%

Table 4.12 Density of Graded Gazaria Sand, Sample No. II

	Density (gm/cm^3)			
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
1	1.323	1.343	1.317	1.345
2	1.295	1.336	1.318	1.349
3	1.308	1.334	1.323	1.343
4	1.307	1.340	1.320	1.345
5	1.314	1.346	1.320	1.348
6	1.306	1.327	1.328	1.337
7	1.315	1.336	1.323	1.349
8	1.325	1.334	1.318	1.345
9	1.308	1.343	1.317	1.347
10	1.307	1.346	1.320	1.338
Mean:	1.311	1.339	1.320	1.345
Standard deviation σ_n:	0.008	0.006	0.003	0.004
Maximum deviation from mean:	1.22%	0.89%	0.58%	0.59%

Table 4.13 Density of Graded Gazaria Sand, Sample No. III

	Density (gm/cm^3)			
Sl.	(-) No. 16 & (+) No. 30	(-) No.30 & (+) No.40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50
1	1.303	1.349	1.346	1.357
2	1.303	1.346	1.346	1.367
3	1.316	1.349	1.346	1.357
4	1.327	1.348	1.336	1.355
5	1.317	1.350	1.346	1.358
6	1.304	1.348	1.336	1.354
7	1.308	1.346	1.345	1.357
8	1.315	1.349	1.343	1.356
9	1.304	1.342	1.346	1.357
10	1.309	1.346	1.345	1.357
Mean:	1.311	1.347	1.343	1.358
Standard deviation σn:	0.008	0.002	0.004	0.003
Maximum deviation from mean:	1.22%	0.37%	0.52%	0.66%

4.3.3 Density Analysis of Original Sylhet Sand

In case of Sylhet sand it was observed that original Sylhet sand were not a free flowing materials. It cloged the valve of sand cone apparatus and segregation problem occured during fill up the jug. On the other hand maximum particle size of original Sylhet sand greater than 2 mm and uniformity coefficient also greater than two. So it can be concluded that original Sylhet sand can not be used as a materials for determination of in-situ soil density by sand cone method.

4.3.4 Density analysis of Original Gazaria Sand

From collected sample of Sylhet sand and Gazaria sand a few quantity of sand washed out and dried in each case. After drying bulk density of Gazaria sand determined following the procedure descrived in Art. 3.4. Bulk density of original Gazaria sand is shown in Table 4.14. From this table it is observed that the maximum variation of the average value from any determination is 0.58%. ASTM (1989) recommends this variation should be less than 1%. On the other hand the unformity coefficient of Gazaria sand found is also to be less than two. But more than 3% by weight of sand pass through 250 μm which do not fulfill the ASTM (1989) criteria. So the original Gazaria sand can not be used as an alternative materials of Ottowa sand for determining in-situ soil density by sand cone method.

Tabel 4.14 Density of Original Gazaria Sand (washed)

Sl No.	Density gm/cm^3
1	1.377
2	1.388
3	1.381
4	1.374
5	1.380
Mean:	1.380
Standard deviation	0.005
Maximum deviation from mean	0.58%

It is observed in the study that the bulk density increase about 1.69% in case of washed Sylhet sand of grade passing # 16 sieve and retained in # 30 sieve. But in case of Gazaria sand virtually no variation in density is observed between washed and unwashed sample (Table 4.15).

Table 4.15 Density on Wash & Unwashed Graded Sand

	Density (gm/cm^3)			
	Sylhet sand retained in # 30 sieve		Gazaria Sand Passing # 30 & Retained in # 50 sieve	
Sl. No.	Unwashed	Washed	Unwashed	Washed
1	1.360	1.379	1.325	1.327
2	1.356	1.382	1.330	1.326
3	1.358	1.382	1.332	1.323
Mean	1.358	1.381	1.329	1.325
Standard Diviation	0.002	0.001	0.003	0.002
Maximum variation from mean	0.15%	0.14%	0.30%	0.15%

4.4 Remarks

From the analyses and interpretation of test results presented in this chapter it is found that the graded Sylhet sands satisfies the major ASTM (1989) criteria for selecting the sand in sand cone method. However the original Sylhet sand does not satisfy those criteria. It also appears that the original Gazaria, Mymensingh, Chandpur and Savar sands are not suitable for determining in place soil density in sand cone method. However graded Gazaria sands except the grade passing # 16 sieve and retained in # 30 sieve are found to be suitable for determining in place soil density in sand cone method. Summary of the above findings are presented in Table 4.16. It is also found that the increase in bulk density of washed and unwashed sand do not differ substantially. Washed and unwashed sand can be used for this purpose.

Table 4.16 Suitability of using Local 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	% passing through 250 µm	Maximum variation from mean density	
			< 2	< 2mm	< 3%	< 1%	
1	Sylhet	Original	-	-	-	-	Not accaptable
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	Bazaria	Original	‡	‡	-	‡	Not Acceptable
7	Bazaria	(-) No 16 & (+) No. 30	‡	‡	‡	-	Not Acceptable
8	Bazaria	(-) No 30 & (+) No. 40	‡	‡	‡	‡	Acceptable
9	Bazaria	(-) No 40 & (+) No. 50	‡	‡	‡	‡	Acceptable
10	Bazaria	(-) No 30 & (+) No. 50	‡	‡	‡	‡	Acceptable
11	Mymenshingh	Graded/Original	‡	‡	-	-	Fine sand and sufficient coarse grade materials could not be founded easily. So not acceptable
12	Chandpur	Graded/Original	‡	‡	-	-	-Do-
13	Savar	Graded/Original	‡	‡	-	-	-Do-

- Do not satisfy the ASTM (1989) specification. ‡ Satisfy the ASTM (1989) specification.

CHAPTER-5

CONCLUSIONS

5.1 Conclusions

On the basis of the present investigation on the suitability of using local sand 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.

The following three types of Graded Gazaria Sand 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 above types of sand fulfill approximately 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

In this research only five types of sand samples were studied to find the suitability of using those in determining soil density in sand cone method. These five types of sand were collected from five selected locations of Bangladesh. The sand samples of other places of Bangladesh should also be studied. It is reported in ASTM (1989) that the effect of humidity on fine sand is significant. In this study the sand collected from Chandput, Mymnesingh, and Savar were found to be fine. Their susceptibility in density variation for humidity were not studied. The effect of angularity in density veriation were also not studied in this thesis work. So the effect of humidity and angularity on density of sand should be studied in future.

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