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Engineering Properties and Cost Comparison among Sylhet sand, Khustia Sand and Local Sand in the Context of Foundation

Humayun Kabir[1*], Ikramul Hoque[2] , Tanbibur Rahman[3]

[1, 2, 3] Department of Building Engineering and Construction Management, Khulna University of Engineering & Technology, Khulna-9203.
Email: humayun2k13kuet@gmail.com

Abstract. Sand pile technology has been used widely in Bangladesh for various kind of soft soil improvement. But the effectiveness of sand pile varies with the change of grain size of sand use for piling. In these research, relations with different factors such as effective particle size (D10), mean particle size (D50)are discussed. For the purpose of experimental analysis, samples are prepared from mixing different proportions of available sands and then tested in the laboratory. Particle size distribution curve was used for finding out mean particle size (D50) & effective particle size (D10).Permeability value of different composition of sands varies from 1x10-3 to 10x10-3(cm/s). Frictional angle value changed very little with particle size variation. Market analysis was performed in the local area (Khulna) for cost comparison. 60% Sylhet sand with 40% Kushtia sand was found the most economical sand composition and it will save near about 8.89% of the total purchase cost of sand for sand piling. But it showedthe permeability value4.70 (cm/s) and frictional angle 40.91 degree, which are comparatively lower than 100 % Sylhet sand. In case of using decision, regional geotechnical expert's decisions will be considered strongly.

Keywords: Sand pile, Permeability, Shear strength, Grain size, Economic sand.

1. Introduction

Development of the life standard is caused by migration to urban location. This makes urban region more traumatic, tough and consequences no land reachable for building construction. A building of heavy weight requires heavy foundation, which warrants highly-priced foundation system, if the soil is low bearing capability like Khulna.

The definitions of soft soils have been made substantially through a scientific studies and geotechnical experience through the years. By way of definition smooth soils are low strength, excessive compressibility and very sensitive. For the improvement of soft soil occasionally sand pile are used. The performance of this pile depends particularly on pore water dissipation rate, which can be variable with the dimensions of granular fills (sand). Improved floor through sand compaction pile approach is powerful now not only in opposition to excessive earthquakes along with the 1995 Hyogo-ken Nambu Earthquake however also against earthquakes having long length time(Kinoshita, Harada, Nozu, & Ohbayashi, 2012). In this venture works, it is going to be underneath investigation that which kind of sand is more suitable for sand pile economically. Granular materials are favored for structural fill because they may be strong, drain water unexpectedly and settle especially little. The most useful moisture content material is more dependent on the mean particle size rather than the soil gradation(Gupta, 2008).An vital utility of granular substances is backfill in robotically stabilized earth (MSE) walls and reinforced soil (RS) slopes. For those packages, the friction angle of the sand normally is the maximum considerable property. In geotechnical engineering, the porous medium is soil and the fluid is water at ambient temperature. Typically, coarser the soil grains, large the voids and larger the permeability.

The advantages of gravel drains are densification of surrounding non-cohesive soil, dissipation of extra pore water pressure and re-distribution of earthquake-caused or pre-existing stresses. The rate of drainage of water from soil relies on the permeability. Volume change under load takes place speedy in sands and gravels. Piles composed of particles of equal size do not produce a stress depression, whilst piles composed of particles with various size produce stress depression. The sand pile required excessive strength and high permeable sand.Piles that are governed by gravitation, the grains always move downhill (Puhl, 1992). The finite-size effects can become important in determining the nature of the avalanches in a sand pile only if the length of the pile becomes so small that the addition of a single grain of sand takes the pile from an angle below the angle of repose to an angle greater than the maximum angle of stability(Puhl, 1992).

The sand compaction pile (SCP) technique is an approach of enhancing soft ground by way of installing well-compacted sand piles in the floor. It combines such essential concepts of ground development as densification and drainage. It may be implemented to all kinds of soils, from sandy to clayey soils, and it has consequently been broadly used in Bangladesh for development of soft ground.

Sand piling is a cost-effective approach of ground improvement through compaction that is typically used to improve soft seabed soils prior to land reclamation works.The Sand Compaction Pile (SCP) method is considered to be a displacement type pile method(Asaoka, Kodaka, & Nozu, 1994).

2. Methodology

2.1 General

In this project work, there are some tests to find out the coefficient of permeability and angle of friction of sand to select the most effective size of sand for sand piling. The materials and method was divided into five steps. Three different sands were collected and reconstituted sands were made by the mixture of collected sands in different proportions. Then, laboratory works, such as Sieve Analysis, Constant-Head test and Direct Shear test was performed. There were also some technical works based on computer to find out the calculations and results of the project. The cost analysis was based on the market value analysis in the local region of Khulna. To find out the best option for sand piling, top options showing high permeability as well as high strength was considered for the calculation. Then the best one from them was taken as the result of the analysis.

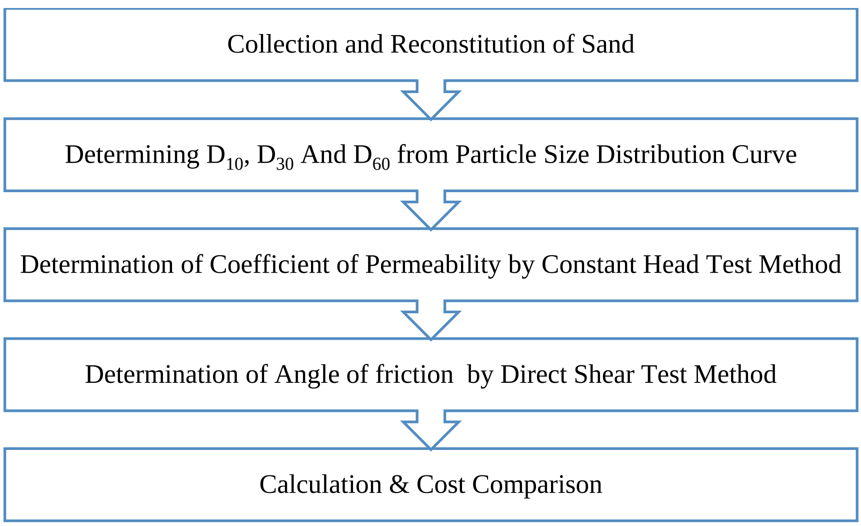

Fig.1. Methodology of different tests.

Figure 1 above indicates the sequences, how different tests & calculations had been done in the study. The total step mainly divided into sample collection, laboratory test & finally calculation with different comparisons.

2.2 Preparation of Samples

Three types of sand were collected. They are Local Sand, Kushtia Sand and Sylhet Sand. They were mixed in different proportions such as 1 (100%), 1:1 (50%:50%), 1:2 (33%: 67%), 2:3 (40%: 60%) for the different tests.

2.2.1 Mixture of Kushtia and local sand

The Kushtia and local sand was first oven dried. Then the samples had been prepared by mixing them in specific proportions like 33% Kushtia sand and 67% local sand (1:3), 50% Kushtia sand and 50% Local sand (1:2), 40% Kushtia sandand 60% local sand (2:3).

2.2.2 Mixture of Sylhet and local sand

The Sylhet and Local sand was first oven dried. Then the samples had been prepared by mixing them in specific proportions like 33% Sylhet sand and 67% local sand(1:3), 50% Sylhetsandand 50% Local sand (1:2), 40% Sylhet sand and 60% Local sand (2:3).

2.2.3 Mixture of Sylhet & Kushtia sand

The Sylhet and Kushtia sand was first oven dried. Then the samples had been prepared by mixing them in specific proportions like 33% Sylhetsandand 67%Kushtiasand (1:3), 50% Sylhetsandand 50% (1:2) Kushtiasand, 40% Sylhetsandand 60% Kushtiasand (2:3).

2.3 Particle Size Distribution

The percentage of various sizes of particles in a given dry soil sample is found by a particle size or mechanical analysis. Mechanical analysis means the separation of a soil into its different size fractions. The mechanical analysis is performed in two stages:

1). Sieve analysis
2). Wet analysis

The sieve analysis is the true representative of grain size distribution, since the test is not affected by temperature.

2.3.1 Sieve analysis

In the ASTM standards, the sieve sizes are given in terms of the number of the openings per inch. The number of the openings per square inch is equal to the square or the number of the sieve.The complete sieve analysis can be divided into two parts - the coarse analysis and fine analysis. An oven dried sample of the sample of the soil is separated into two fractions by sieving it through a 4.76mm ASTM sieve. The portion retains on it (+4.76mm) is termed as gravel portion and is kept for coarse analysis, while the portion passing through (-4.76mm) is subjected to fine analysis. The sieves used for fine analysis are: #8, #16, #30, #50, #100 and #200 ASTM sieves. Overloading of sieves has a considerable effect on the results of sieve analysis (Shergold, 1946).

The results of the mechanical analysis are plotted to get a particle size distribution curve with the percentage finer as the ordinate and the particle diameter as the abscissa, the diameter being plotted on a logarithmic scale. Particle size distribution and fines content influenced the strength, modulus and stress-strain relationship but had minimal effect on the failure strain and permeability of grouted sand(Ozgurel & Vipulanandan, 2005). A particle size distribution curve gives us an idea about the type and gradation of the soil. A curve situated higher up or to the left represents a relatively fine grained soil while a curve situated to the right represents a coarse grained soil. A soil sample may be either well graded or poorly graded. A soil is said to be well graded when it has good representation of particles of all sizes. On the other hand, a soil is said to be poorly grated if it has an excess of certain particles and deficiency of other or it has most of the particles of about the same size; in such, it is known as uniformly graded soil.

For coarse grained soil, certain particle sizes such as D10, D30, D50 and D60 are important. The D10 represents a size, in mm such that 10% of the particles are finer than this size, this is sometimes called the effective size. Similarly, the soil particles finer than D60 size are 60% of the total mass of the sample.

The uniformity co-efficient Cu is a measure of particle size range and is given by:

$$Cu=D60/D10 \quad (1)$$

Similarly, the shape of the particle size distribution curve is represented by the co- efficient of the curvature Cc is given by:

$$Cc=(D30)2/(D10xD60) \quad (2)$$

For a uniformly graded soil, C is nearly unity. For a well graded soil, Cc must be between one to three and in addition Cu must be greater than 4 for gravels and 6 for sands.

2.4 Determination of Coefficient of Permeability

The four most common laboratory techniques for figuring out the coefficient of permeability of soils are given below:

- Constant-head test
- Falling head test
- Indirect determination from consolidation test
- Indirect determination by horizontal capillary test.

Constant Head Test

The constant head test is appropriate for more permeable granular materials. Water flows from the overhead tank which includes three tubes: the inlet tube, the overflow tube and the outlet tube. The soil specimen is positioned inside a cylindrical mold, and the constant head loss, h, of water flowing through the soil is maintained by means of adjusting the supply. The outflow water is accumulated in a measuring cylinder; the period of the collection length is noted.

From Darcy's law, the total quantity of flow Q in time t can be given by:

$$Q=qt=kiAt \tag{3}$$

Where A= area of cross section of specimen. But,

$$i=h/L \tag{4}$$

Where, L is the length of specimen and so,

$$Q=k(h/L) \tag{5}$$

At Rearranging this gives,

$$K=QL/hAt \tag{6}$$

The values of Q, L, H, A, t can be determined from the test, and then the coefficient of permeability k for a soil can be calculated from Eq. (6) (Das, 2013).

Direct Shear Test

The shear strength parameters for a specific soil can be decided via laboratory tests on specimens taken from representatives samples of the in-situ soil. Basically, the device for this test includes a steel shear box into which the soil specimen is placed. The specimen can be square or round in plan, about three to four in2 (19.35 to 25.80 cm2) in area and 1 in (25.4mm) height. The box is break up horizontally into two halves. The sample is between two porous stones that are toothed or serrated to reduce the slippage at the interface between soils and shear box and to improve the transfer of the shear load to the soil. The porous stones are also used to drain water from saturated samples. The screws are used to adjust the spacing between the upper and lower parts of the shear box. Mounting pins keep the position of these two components throughout the sample fabrication and are removed earlier than the start of the shear phase. The base is fixed to the loading body and sometimes consists of water when the soil sample is to stay saturated. The normal load is implemented to the soil sample through a ball bearing and a rigid cap. The lateral load is carried out to the top component through the swan neck. Normal force on the specimen is implemented from top of the shear box through dead weights. The normal stress on the specimens acquired with the aid of the application of dead weights can be as high as a hundred and fifty lb/in2 (1035 kN/m2).

Shear force is carried out at the side of the top half of the container to cause failure inside the soil specimen. During the test, the shear displacement of the top half of the container and the alternate in specimen thickness are recorded by way of using horizontal and vertical dial gauges(Das, 2013).

3. Results and Discussions

Laboratory tests was performed to develop several relations among different properties. The table 1 below shows that the different proportion of mixing of Sylhet sand and Kushtia sand occupies maximum permeability and frictional angle. As it is known that the bearing capacity of soil increases with the increase of frictional angle as well as permeability.

Table 1. A comparative study of samples for permeability and frictional angle.

Samples	Frictional Angle, Φ (deg)	Permeability k, (x 10^{-3} cm/s)
100% Local sand	53.13	2.54
60% Kushtia Sand and 40% Local Sand	37.57	3.19
33% Kushtia Sand and 67% Local Sand	34.99	2.74
50% Kushtia Sand and 50% Local Sand	30.96	3.68
60% Local Sand and 40% Kushtia Sand	33.07	2.21

33% Local Sand and 67% Kushtia Sand	35.16	3.11
100% Sylhet Sand	41.01	7.20
60% Sylhet Sand and 40% Local Sand	36.59	2.00
33% Sylhet Sand and 67% Local Sand	43.53	2.62
50% Sylhet Sand and 50% Local Sand	53.59	3.11
60% Local Sand and 40% Sylhet Sand	33.25	2.62
33% Local Sand and 67% Sylhet Sand	36.21	2.00
100% Kushtia Sand	33.02	4.62
60% Kushtia Sand and 40% Sylhet Sand	36.71	5.56
33% Kushtia Sand and 67% Sylhet Sand	33.02	4.46
50% Kushtia Sand and 50% Sylhet	33.69	5.56
60% Sylhet Sand and 40% Kushtia Sand	40.91	4.70
33% Sylhet Sand and 67% Kushtia Sand	35.01	4.62

Here, some graphical representation of permeability with the change of particle size of sand samples.

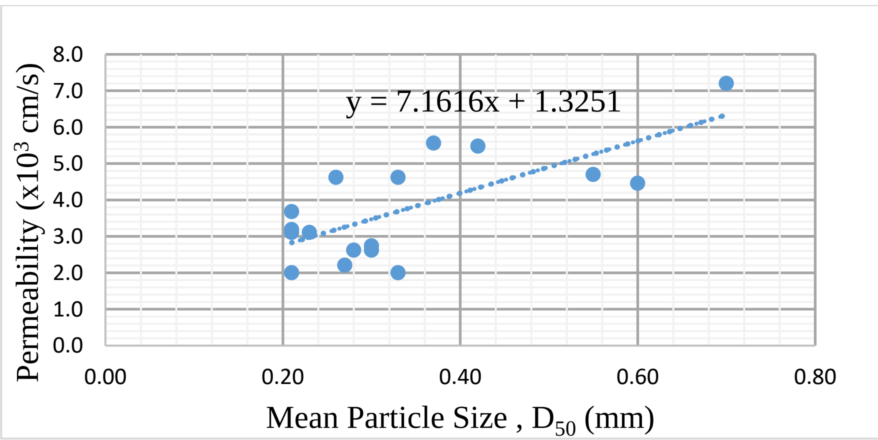

Fig.2. Variation of permeability with the mean particle size.

Permeability value changes greatly with the mean particle size (D50). Figure 2 indicates how permeability values make a relation with the mean particle size of sands.

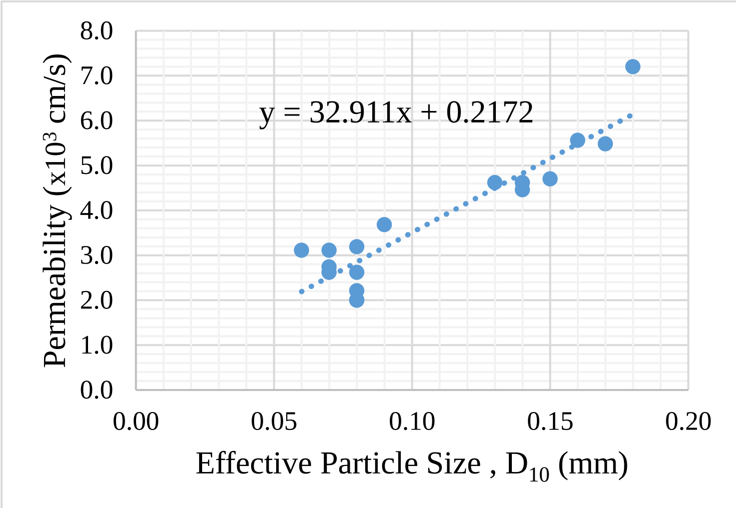

Fig.3. Variation of permeability with the effective particle size.

Variation of permeability with effective particle size is also significant. Figure 3 indicates how variation of permeability changes with effective particle size (D10).

Here, some graphical representation of frictional angle with the change of particle size of sand samples.

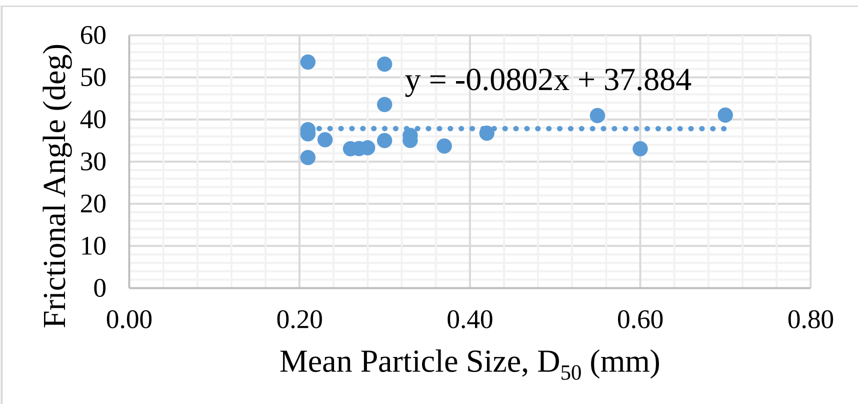

Fig.4. Variation of frictional angle with the mean particle size

Variation of frictional angle with mean particle size is very slow. In figure 4 the variation line is near about parallel to horizontal axis. It means that grain size effect has less impact on frictional angle.

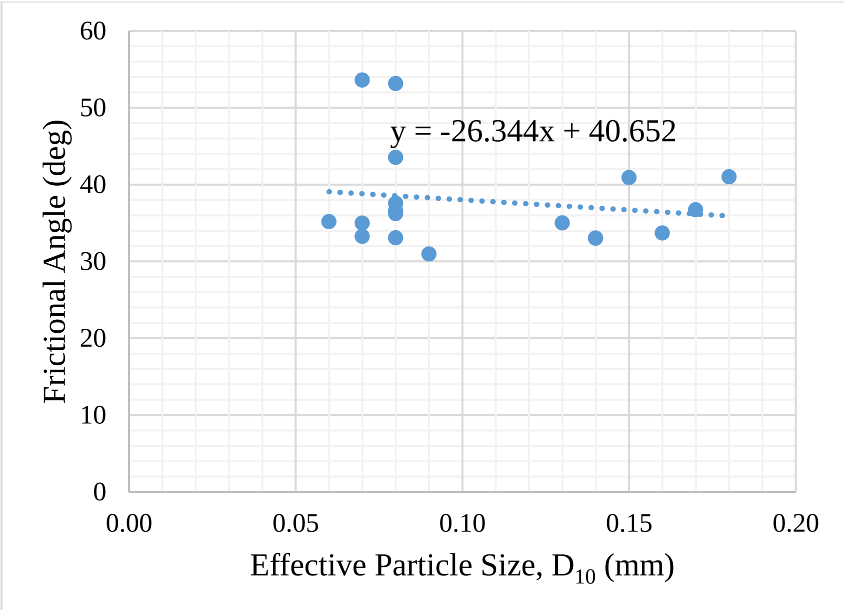

Fig. 5. Variation of frictional angle with the effective particle size.

Variation of frictional angle is also insignificant comparatively with effective particle size. In figure 5 the variation line is downgrading at a lower rate. It expresses that the effective particle size has a less impact on frictional angle.

Here, the graph below represent the variation of permeability with the change of frictional angle of sand samples. Figure 6 indicates that the changes of permeability with frictional angle is also very slower.

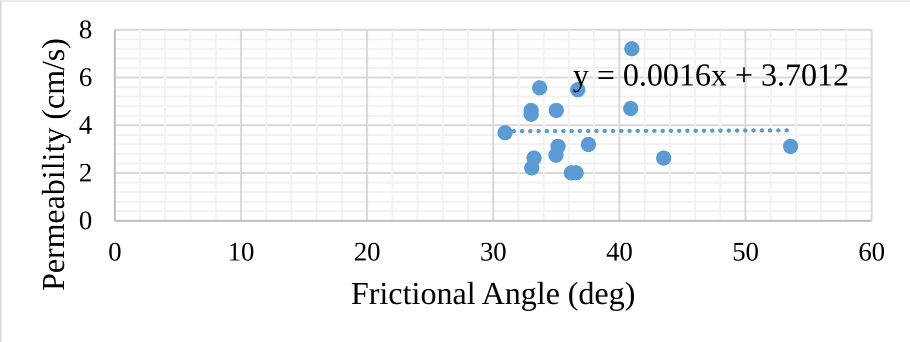

Fig. 6. Variation of permeability with the frictional angle of the samples

From the results it is shown that the coefficient of permeability varied from lx10-3 cm/sec to 10x10-3 cm/sec. Some equations were expressed by the author related to permeability which shown in Table 2

Table 2. Relation between (1) k vs. D50 (2) k vs. D10 (3) Φ vs. D10 (4) Φ vs. D50 (5) k vs. Φ

Sl. No	Relations	Equations
1	Permeability with the Mean Particle Size	$k = 7.1616\ D_{50} + 1.3251$
2	Permeability with the Effective Particle Size	$k = 32.911\ D_{10} + 0.2172$
3	Frictional Angle with Effective Particle Size	$\Phi = -0.0802\ D_{50} + 37.884$
4	Frictional Angle with Mean Particle Size	$\Phi = -26.344\ D_{10} + 40.652$
5	Permeability with Frictional Angle	$k= 0.0016\ \Phi + 3.7012$

The permeability equations indicated straight line which holds good for determining coefficient of permeability directly as particle size distribution is easier than permeability measurement rates.

The results showed a direct relation between grain size of particles and frictional angle. It is noted that there is increase in frictional angle with the increase of particle size.

Cost Comparison

Cost comparison was performed to find out the economic sand composition for sand piling based on engineering properties. Table 3 indicates the samples which showed the maximum permeability values with their cost per cubic feet (cft). Among the best five samples 100% Sylhet sand showed the maximum permeability value at a cost ৳ 45 per cubic feet.

Table 3. Sample with their cost per cft according to permeability

Samples	Permeability (cm/s)	Cost /cft (৳)
100% Sylhet Sand	7.20	45.00
60% Sylhet Sand and 40% Kushtia Sand	4.70	41.00
50% Kushtia Sand and 50% Sylhet	5.56	40.00
60% Kushtia Sand and 40% Sylhet Sand	5.48	39.00
33% Sylhet Sand and 67% Kushtia Sand	4.62	38.30

Table 4 indicates the top five samples which have highest frictional angle with their per cubic feet (cft) cost. From direct shear test we found the maximum value of frictional angle holds the 100% local sand sample with a minimum cost of ৳ 8 per cubic feet.

Table 4. Sample with their cost per cft according to frictional angle

Samples	Frictional Angle (deg)	Cost /cft (৳)
100% Local sand	53.13	8.00
33% Sylhet Sand and 67% Local Sand	43.53	20.21

50% Sylhet Sand and 50% Local Sand	53.59	26.50
100% Sylhet Sand	41.01	45.00
60% Sylhet Sand and 40% Kushtia Sand	40.91	41.00

Here in table 5 indicates the best two options with their permeability and frictional angle.

Table 5. Best options with their permeability, frictional angle and cost

Samples	Permeability (cm/s)	Frictional Angle (deg)	Cost /cft (Tk)
100% Sylhet Sand	7.20	41.01	45.00
60% Sylhet Sand and 40% Kushtia Sand	4.70	40.91	41.00

From above table 5 we can see that the 100% Sylhet sand sample has the highest permeability rate as well as higher frictional angle. But its cost per cft is 45 Tk, which is relatively higher. On the other hand 60% Sylhet sand and 40% Kushtia sand sample shows a higher frictional angle as well as higher permeability. Its cost per cft is 41 taka, which is relatively economic than 100% Sylhet sand. By using this 8.89% of the total purchase cost of sand for sand piling will be reduced.

4. Conclusions

From different analysis result, following observations can be drawn out: The permeability improved extensively with the increase of mean particle size and effective size of sand.Frictional angle improved with the growth of effective size as well as permeability of soil but the variation of frictional angle with permeability of soil is very insignificant.Shear strength also improved with the increase of mean particle size but the variation is also insignificant in this case.Using 60% Sylhet sand with 40% Kushtia sand will save near about 8.89% of the total purchase cost of sand for sand piling. But it will depend on the choice of regional geotechnical expert.

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