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Effect on permeability and shear strength with the variation of grain size of sand

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Abstract: Permeability and shear strength are very important properties of a soil which are affected by grain size of soil particles. For the improvement of soft soil sometimes sand pile are used. The main objective is to investigate which type of sand is more suitable for sand pile economically. in this project, an attempt is made to relate permeability and frictional angle with the properties of grain size of soil such as effective size (d_{10}), mean particle size etc. the properties of grain size can be found out from gradation curve. The results of coefficient of permeability vary from 1× 10^{-3} to 15× 10^{-3}. The permeability increased significantly with the increase of mean particle size and effective size of sand. Frictional angle increased with the increase of permeability of soil but the variation is very insignificant. Shear strength also increased with the increase of mean particle size but the variation is also insignificant in this case. as the changes of value of frictional angle is negligible with the changes of size of sand from fine sand to coarse sand, local sand may be used with certain percentages of Kushtia sand in lieu of percentages of Sylhet sand in case of designing sand pile economically.

Keywords: *Permeability, Sand Drain, Shear Strength, Frictional Angle, Local Sand*

1. Introduction:

Most of the people are now willing to migrate to urban area for an improved life standard. This is making urban area more demanding, resulting in non-availability of land for building construction. A building of heavy weight requires heavy foundation, which warrants costly foundation system, if the soil is of low bearing capacity like Khulna. For the improvement of soft soil sometimes sand pile is used. The effectiveness of this pile depends mainly on the pore water dissipation rate, which may be variable with the size of granular fills (sand).In this project works, it will be under investigation that which type of sand is more suitable for sand pile economically. Granular materials are preferred for structural fill because they are strong, drain water rapidly, and settle relatively little. An important application of granular materials is backfill in mechanically stabilized earth (MSE) walls and reinforced soil (RS) slopes. For these applications, the friction angle of the sand generally is the most important property. In geotechnical engineering, the porous medium is soils and the fluid is water at ambient temperature. Generally, coarser the soil grains, larger the voids and larger the permeability.

Sand piling is a cost-effective method of ground improvement by compaction which is commonly used to improve soft seabed soils prior to land reclamation works. The benefits of gravel drains are densification of surrounding non-cohesive soil, dissipation of excess pore water pressure and re-distribution of earthquake-induced or pre-existing stresses. The rate of drainage of water from soil depends on the permeability. Volume change under load takes place quickly in sands and gravel. Piles composed of particles of same size do not produce a stress depression, while piles composed of particles with varying size produce stress depression. The sand pile required high strength and high permeability sand.

2. Methodology

2.1 General

The materials and method was divided into four steps. In the first step, three different sand were collected and reconstituted sands were made by the mixture of collected sands in different proportions.
The second step included grain size distribution to determine D_{10}, D_{30} and D_{60} from particle size distribution curve of the samples. The third step consists of compaction test to determine optimum moisture content for wet samples in direct shear test.
Lastly, permeability and direct shear test were done for determining coefficient of permeability and angle of friction of the samples respectively.

2.2 Preparation of Samples

2.2.1 Introduction

Three types of sand were collected. They are local sand, Kushtia sand and Sylhet sand.

2.2.2 Mixture of Local and Kushtia Sand

The local and Kushtia sand were first oven dried. Then the samples were prepared by mixing them in different proportion like 75% local and 25% Kushtia , 50% local and 50% Kushtia and 25% local and 75% Kushtia sand.

2.2.3 Mixture of Local and Sylhet Sand

The local and Sylhet sand were first oven dried. Then the samples were prepared by mixing them in different proportion like 75% local and 25% Sylhet, 50% local and 50% Sylhet and 25% local and 75% Sylhet sand.

2.2.4 Mixture of Kushtia and Sylhet Sand

The Kushtia and Sylhet sand were first oven dried. Then the samples were prepared by mixing them in different proportion like 75% Kushtia and 25% Sylhet, 50% Kushtia and 50% Sylhet and 25% Kushtia and 75% Sylhet sand.

2.3 Determination of Coefficient of Permeability

The four most common laboratory methods for determining the coefficient of permeability of soils are the following:

- 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 suitable for more permeable granular materials. Water flows from the overhead tank consisting of three tubes: the inlet tube, the overflow tube and the outlet tube. The soil specimen is placed inside a cylindrical mold, and the constant head loss, h, of water flowing through the soil is maintained by adjusting the supply. The outflow water is collected in a measuring cylinder, the duration of the collection period is noted.

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

$Q = qt = kiAt$ Where A= area of cross section of specimen But $i = h/L$ where L is the length of specimen, and so $Q = k\,(h/L)\,At$ Rearrenging this gives $k = QL/hAt$ … … … … … … … … … … (1)

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.(1) (B. M. Das, Advance)

2.4 Compaction Test

The laboratory test generally used to obtain the maximum dry unit weight of compaction and the optimum moisture content is called the Proctor compaction test (Proctor, 1933). The procedure for conducting this type of test is described in the following section:

Standard Proctor Test: In the Proctor test, the soil is compacted in a mold that has a volume of 943.3 cm3. The diameter of the mold is 101.6 mm. During the laboratory test, the mold is attached to a base plate at the bottom and to an extension at the top. The soil is mixed with varying amounts of water and then compacted in three equal layers by a hammer that delivers 25 blows to each layer. The hammer weighs 24.4 N (mass: 2.5 kg), and has a drop of 304.8 mm. For each test, the moist unit weight of compaction can be calculated as

$\gamma = W/ V(m)$

where

W = weight of the compacted soil in the mold
V(m) = volume of the mold =943.3 cm3

For each test, the moisture content of the compacted soil is determined in the laboratory. With known moisture content, the dry unit weight γd can be calculated as

$\gamma d = \gamma / 1+(w/100)$

The values of γd determined can be plotted against the corresponding moisture contents to obtain the maximum dry unit weight and the optimum moisture content for the soil. (Punmia, B.C. 1977)

2.5 Direct Shear Test

The shear strength parameters for a particular soil can be determined by means of laboratory tests on specimens taken from representatives samples of the in-situ soil.

Basically, the equipment for this test consists of a metal shear box into which the soil specimen is placed. The specimen can be square or circular in plan, about 3 to 4 in2 (19.35 to 25.80 cm2) in area and 1 in (25.4mm) height. The box is split horizontally into two halves. The sample is between two porous stones, which are toothed or serrated to minimize the slippage at the interface between soil 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. 'Two mounting pins maintain the position of these two parts during the sample fabrication and are removed before the beginning of the shear phase. The base is fixed to the loading frame and occasionally contains water when the soil sample is to remain saturated. The normal load is applied to the soil sample through a ball bearing and a rigid cap. The lateral load is applied to the upper part through the swan neck.

Normal force on the specimen is applied from top of the shear box by dead weights. The normal stress on the specimens obtained by the application of dead weights can be as high as 150lb/in2 (1035 kN/m2). Shear force is applied on the side of the top half of the box to cause failure in the soil specimen. During the test, the shear displacement of the top half of the box and the change in specimen thickness are recorded by the use of horizontal and vertical dial gauges. (B.M. Das, Advance)

3. Illustrations:
3.1 Tables

Table 1: Results of Coefficient of Permeability obtained from Constant Head Test

Sample	Coefficient of Permeability (10^{-3} cm/sec)
100% local sand	1.09
100% Kushtia sand	2.67
100% Sylhet sand	14.7
75% Kushtia sand & 25% local sand	1.74
50% Kushtia sand & 50% local sand	1.44
25% Kushtia sand & 75% local sand	1.31
25% local sand & 75% Sylhet sand	9
50% local sand & 50% Sylhet sand	2.77
75% local sand & 25% Sylhet sand	1.31
75% Kushtia sand & 25% Sylhet sand	3.05
50% Kushtia sand & 50% Sylhet sand	4.72
25% Kushtia & 75% Sylhet sand	12.1

Table 2: Calculations of Mean Particle Size (D_{50}), Effective Size (D_{10}) and C_u

Sample	D_{50} (mm)	D_{10}(mm)	C_u
100% local sand	0.12	0.078	1.82
100% Kushtia sand	0.245	0.13	2
100% Sylhet sand	0.53	0.18	3.88
75% Kushtia sand & 25% local sand	0.2	0.09	2.67
50% Kushtia sand & 50% local sand	0.173	0.087	2.13
25% Kushtia sand & 75% local sand	0.16	0.084	2.02
25% local sand & 75% Sylhet sand	0.44	0.11	3.5
50% local sand & 50% Sylhet sand	0.249	0.09	3.33
75% local sand & 25% Sylhet sand	0.175	0.085	2.35
75% Kushtia sand & 25% Sylhet sand	0.449	0.16	3.75
50% Kushtia sand & 50% Sylhet sand	0.39	0.14	3.57
25% Kushtia & 75% Sylhet sand	0.31	0.12	3.42

Table 3: Results of Frictional angle obtained from Direct Shear Test

Sample	Frictional angle Φ(deg)	
	Dry	Wet
100% local sand	33.07	36.87
100% Kushtia sand	34.44	39.34
100% Sylhet sand	33.69	42.14
75% Kushtia sand & 25% local sand	33.69	33.48
50% Kushtia sand & 50% local sand	32.62	34.22
25% Kushtia sand & 75% local sand	33.02	36.87
25% local sand & 75% Sylhet sand	30.96	38.66
50% local sand & 50% Sylhet sand	32.62	36.87
75% local sand & 25% Sylhet sand	34.64	37.1
75% Kushtia sand & 25% Sylhet sand	32.15	36.87
50% Kushtia sand & 50% Sylhet sand	30.19	37.78
25% Kushtia & 75% Sylhet sand	29.25	38.045

3.2 Figures and Graphs:

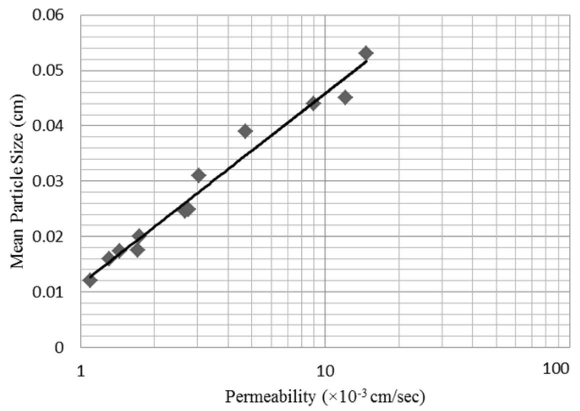

Figure 1: Variation of Permeability with the Mean Particle Size

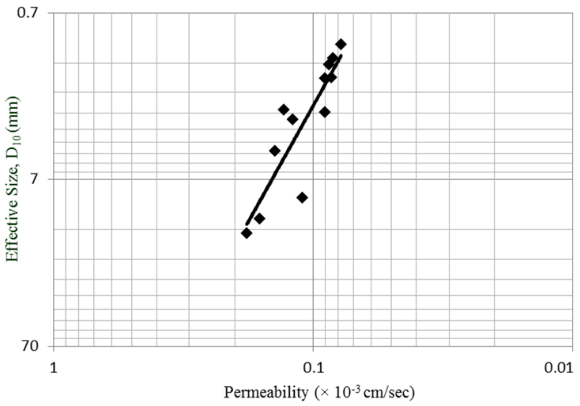

Figure 2: Variation of Permeability with the Effective size

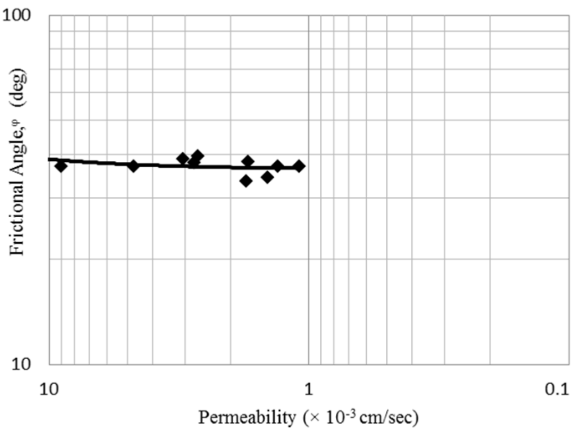

Figure 3: Variation of Frictional angle with Permeability

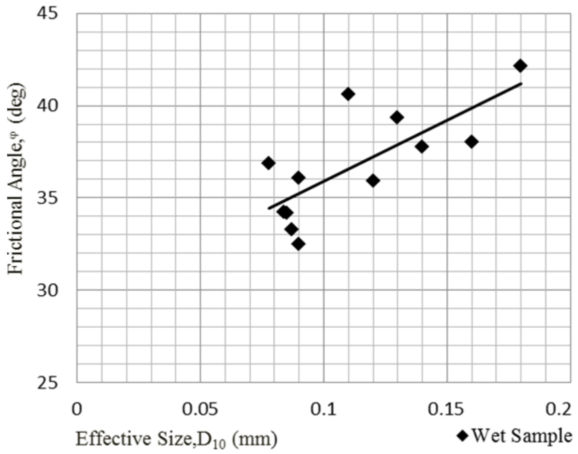

Figure 4: Variation of Frictional angle with Effective Size

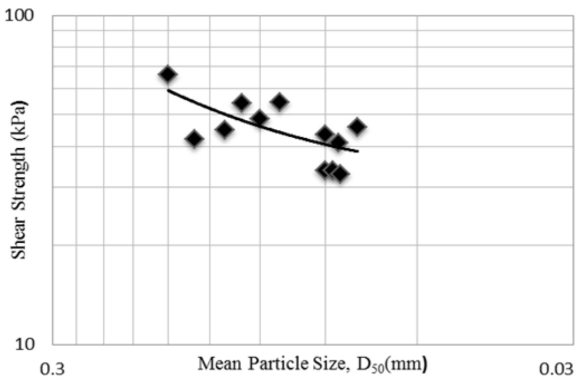

Figure 5: Variation of Shear Strength with the Mean Particle Size

From the results it is shown that the coefficient of permeability varied from 1×10^{-3} cm/sec to 15×10^{-3} cm/sec. Some equations were expressed by the author related to permeability which are shown in Table 4.5

Table 4: Relation between (1) K vs. D_{50} (2) K vs. D_{10} and (3) Su Vs. D_{50}

S. No	Relations	Equations
1	Permeability with Mean Particle Size	$\log(k)= 1.92\log(D_{50}) + 3.56$
2	Permeability with Effective Size	$k =1541(D_{10})^{2.787}$
3	Shear Strength with Mean Particle Size	$S_u=409.61(D_{50})^2+95.404 D_{50}+28.642$

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 and decrease in dry density for wet samples.

4. Conclusions:

From the observation of results, following conclusions can be drawn out:

1. The permeability increased significantly with the increase of mean particle size and effective size of sand.
2. Frictional angle increased with the increase of effective size as well as permeability of soil but the variation of frictional angle with permeability of soil is very insignificant.
3. Shear Strength also increased with the increase of mean particle size but the variation is also insignificant in this case.
4. As the changes of value of frictional angle is negligible with the changes of size of sand from fine sand to coarse sand, local sand may be used with certain percentages of Kushtia sand in lieu of percentages of Sylhet sand in case of sand pile.
5. So it can be suggested that there will be savings a lot of money due to use of local sand with certain percentage of Kushtia sand instead of very coarse sand.

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