PREDICTING THE PERMEABILITY OF SANDY SOILS FROM GRAIN SIZE DISTRIBUTION INDICES

MOHD IRFAN WAR
M. TECH
RIMT university

ANUJ SACHAR
Assistant professor
RIMT university

ABSTRACT

Permeability is one of the most important and frequently used properties of soils. Grain size distribution and density are two important factors influencing the permeability of sandy soils. Although the relationships between grain size distribution and permeability has been quantified in previous studies, the influenced of density has not been quantified. The objective of this project is to investigate the quantitative relationships between permeability and grain size distribution indices such as effective particle size (D_{10}), coefficient of uniformity (C_u), coefficient of curvature (C_c), percentage of coarse sand fraction by weight of sample (%C), percentage of medium sand fraction by weight of sample (%M), and percentage of fine sand fraction by weight of sample (%F) to determine whether these relationships could be used for reliable estimates of permeability. Six samples of sandy soils, ranging from well graded to poorly graded, will be tested in the laboratory to determine their grain size distribution. The D_{10}, C_u, $C_{c,}$ %C, %M, and %F values for each soil will be calculated from the grain size distribution plots. Five replicate samples of each soil will be prepared at varying density values and tested for permeability using the constant head permeability test.

INTRODUCTION

1.1 General

The purpose of this study is to investigate the effect of grain size distribution on the permeability of sandy soils and to model grain size distribution indices and density as predictors of permeability.

1.2 Background

Permeability, also known as hydraulic conductivity, is the property that represents the ease with which water flows through porous media (Jabro, 1992; Alyamani and Sen, 1993; Holtz et al., 2011; Salarashayeri and Siosemarde, 2012). It is one of the most important physical properties of soil used in geotechnical engineering. The rate of settlement of saturated soils under load, the stability of slopes and retaining structures, the design of filters made of soil, and the design of earth dams are some of the examples of applications of permeability in geotechnical engineering (Das, 2008). Additionally, information about permeability is necessary to estimate the quantity of seepage that will occur through earth dams and levees and through their foundations, to solve problems involving pumping seepage water from construction excavations, to determine spacing and depth of drains for lowering the water table under roads and highways, and to conduct stability analyses of earth structures and earth retaining walls when they are subjected to seepage forces (Das, 2008). However, permeability is also one of the most variable properties varying in both horizontal and vertical directions.

This is particularly true for glacial soils which are heterogeneous in nature. In a laboratory, permeability is usually measured on small samples which do not represent the heterogeneity of soils in the field (Holtz et al., 2011). No matter how many samples are tested in the laboratory, one cannot reliably estimate permeability. In addition, reliability of laboratory test results depends on the quality of undisturbed soil samples collected in the field (Holtz et al., 2011). Since undisturbed samples cannot be obtained for granular soils, the accuracy of permeability test results for such soils depends on how well the soil structure and density of laboratory samples represent the natural state of soil in the field (DeGroot et al., 2012). To overcome this problem, field pumping tests are generally used for major engineering projects. However, performing a series of field pumping tests is both expensive and time consuming (Shepherd, 1989; Jabro, 1992). Also, in situ methods usually measure horizontal permeability (DeGroot et al., 2012). Because of these limitations of laboratory and field methods, many researchers (Hazen, 1892; Kozeny, 1927 and Carmen, 1956; Terzagi and Peck, 1964; Kenney et al., 1984; Alyamani and Sen, 1993) have attempted to develop empirical equations for predicting permeability from grain size distribution parameters.

1.3 Factors affecting Permeability

Permeability is a complex property that is controlled by physical properties of both the soil and the permeating fluid (DeGroot et al., 2012). At constant temperature of 20°C, the common room temperature, the viscosity and unit weight of water remain constant. Therefore, the properties such as , density, grain size distribution,void ratio, and soil texture and structure affect the magnitude of permeability.

1.3.1 Effect of Grain Size and Grain Size Distribution

Grain size distribution of granular soils affects their permeability (Freeze and Cherry, 1979). There are several ways to characterize grain size distribution of a granular soil. Commonly used indices include D10, coefficient of uniformity(Cu), coefficient of curvature(Cc), %C,%M,%F Cu is an important shape factor that represents the degree of sorting of a soil and indicates the slope of the grain size distribution curve (Mitchell and Soga, 2005). Larger Cu values indicate well-graded soils and smaller Cu values indicate uniformly-graded soils (Holtz et al., 2011). Poorly-graded soils have higher permeability and porosity values than well-graded soils in which smaller grains tend to fill the voids between larger grains. Cc is another important shape factor representing the grain size distribution that takes into account three points on the grain size distribution curve, reducing the possibility of considering a gap-graded soil as well-graded.

1.3.2 Effect of Soil Texture and Structure

Texture and structure relate to size, shape, and arrangement of particles in a soil mass. Particle shape has an important effect on permeability as it influences the size and shape of interconnection between particles (Figure 1.2). The more angular the grains are, the smaller the voids and more tortuous the flow paths were (Figure 1.3). This is because edges and corners of angular grains can fit into voids; i.e. there is a greater degree of interlocking (Holtz et al., 2011).

1.3.3Effect of Density and Void Ratio

Dry density (p) is the ratio of the mass of the solids in a soil to its total volume, the sum of volume of solids and volume of voids. Void ratio (e) is defined as the ratio of the volume of voids to the volume of solids (Das, 2008). Density and void ratio are inversely related. Permeability decreases as density increases or void ratio decreases.

METHODOLOGY

3.1 Sample Collection and Preparation

Six sandy soils, exhibiting different grain size distribution curves, were collected for this project from locations around Sumbal and Ganderbal. All soil samples were oven dried at 105°C for 24 hours.

3.2 Laboratory Investigations

Laboratory tests performed on the six soils included grain size distribution and constant head permeability tests. All tests were conducted according to Indian Standards.

3.2.1 Grain Size Distribution Test

This test was used to determine the percentages of different grain sizes present in each of the six soils in order to establish the grain size distribution curves and determine the grain size distribution indices such as effective grain size (D10), coefficient of uniformity (Cu), and coefficient of curvature (Cc).

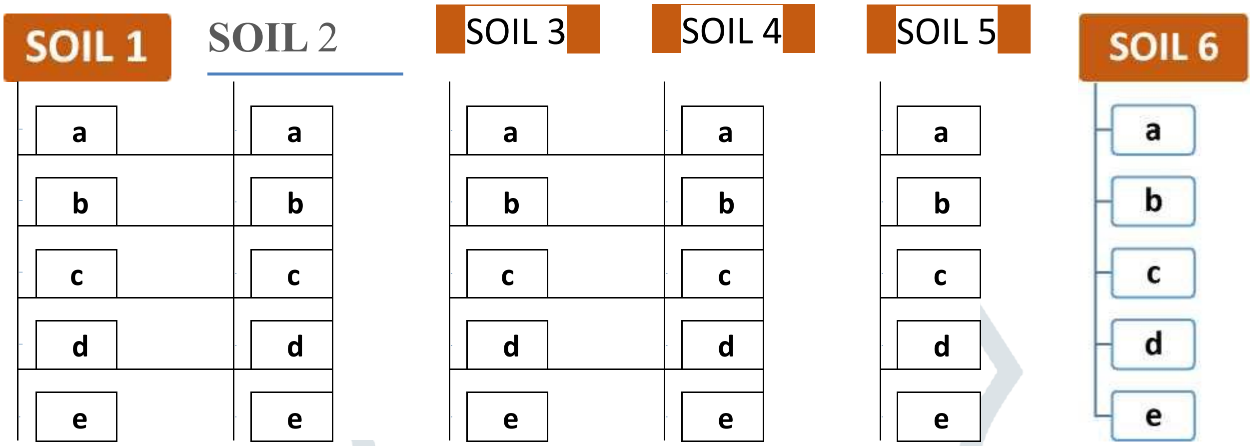
3.2.2 Constant Head Permeability Test

The constant head permeability test was used to determine the permeability of the six soils. Five or six samples of each sandy soil were compacted at different density values and tested for permeability. The quantity of water passing through the sample in 5 minutes (300 seconds) was collected in a graduated cylinder to compute permeability in accordance with Darcy’s law (Holtz, et al., 2011). The test were repeated five times for each sample and average permeability values were computed and reported in cm/sec.

Sample Testing scheme

Sample 1 to 6 are soils of different gradation. Each of the samples was tested for permeabilit

TEST RESULTS



This chapter presents the laboratory test data for the properties given below for the six soils used in the study: effective grain size (D_{10}), coefficient of uniformity (C_u), coefficient of curvature (C_c), percentage of coarse sand fraction by weight of sample (%C), percentage of medium sand fraction by weight of sample (%M), percentage of fine sand fraction by weight of sample (%F), dry density (ρ_d), and permeability (k) values.

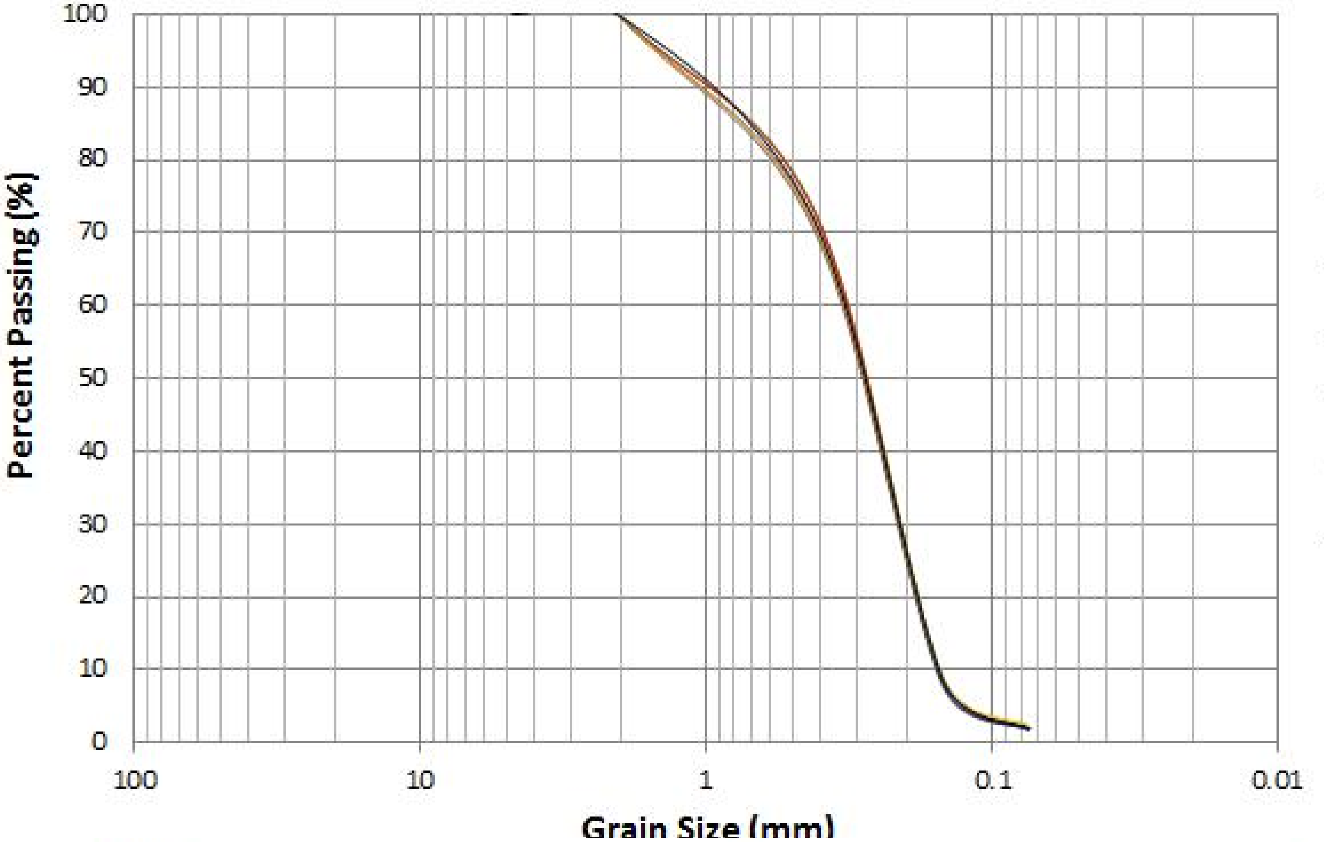
3.1 Grain Size Distribution

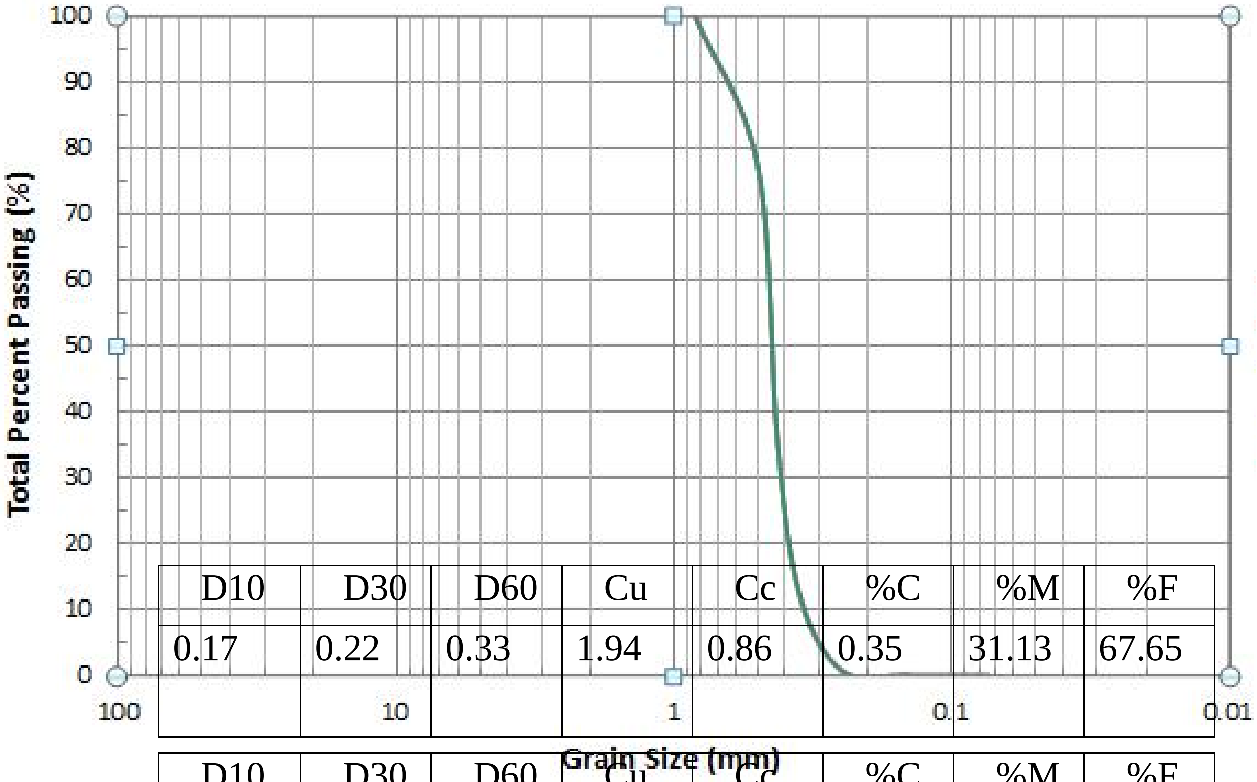
Grain size distribution tests of the soil samples will be used to classify the soils according to the Unified Soil Classification System (USCS) and to determine grain size distribution indices for each soil.

3.1.1 Grain Size Distribution by Sieve Analysis

The average grain size distribution curves for the six soils, based on seive analysis data, are shown in Figure 3.1. Replicates of grain size distribution for each sample are shown provides a summary of the grain size distribution indices including D_{10}, D_{30}, D_{60}, C_c, C_u, %C, %M, and %F.

D10	D30	D60	Cu	Cc	%C	%M	%F
0.19	0.34	0.93	4.89	0.65	18.18	43.81	36.37

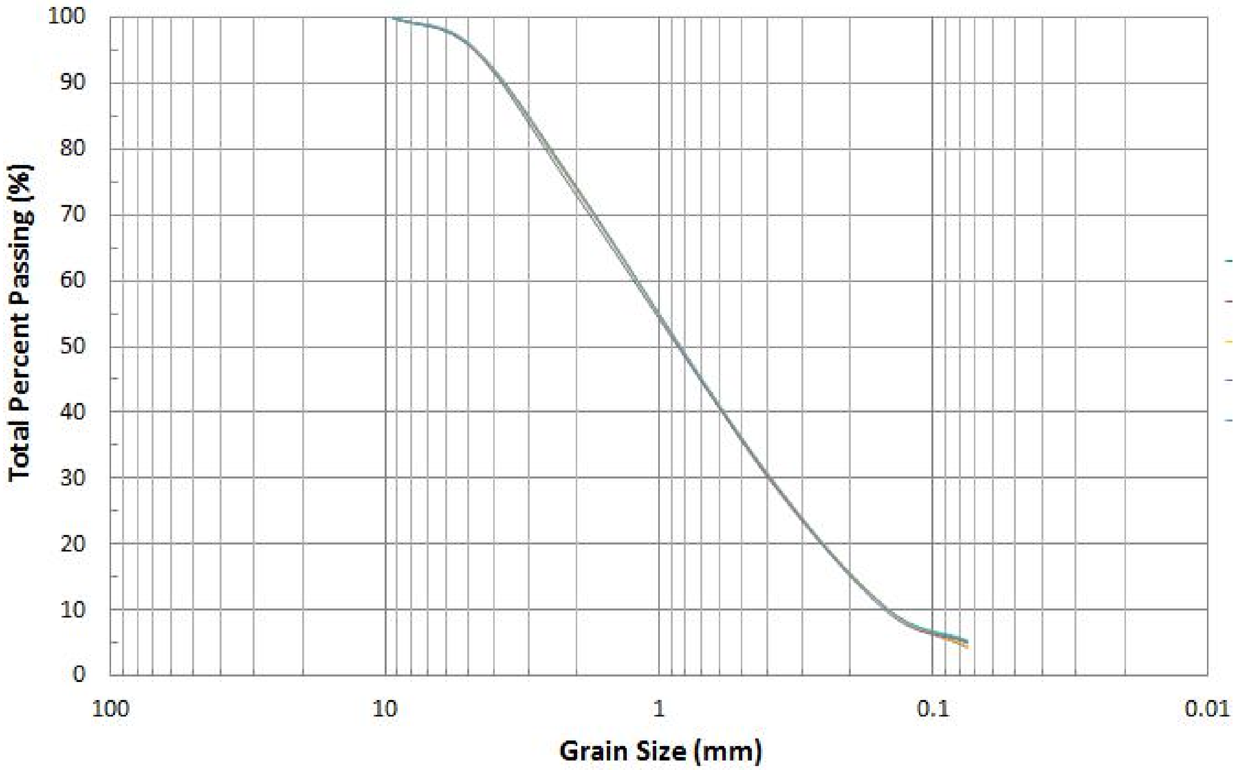


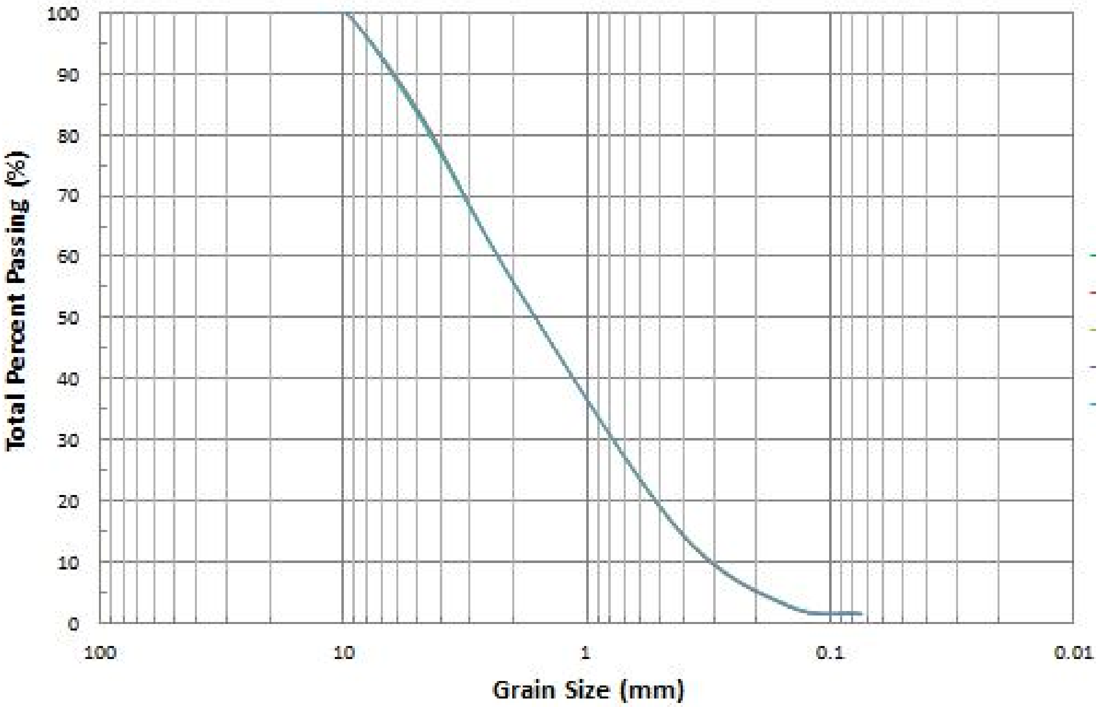


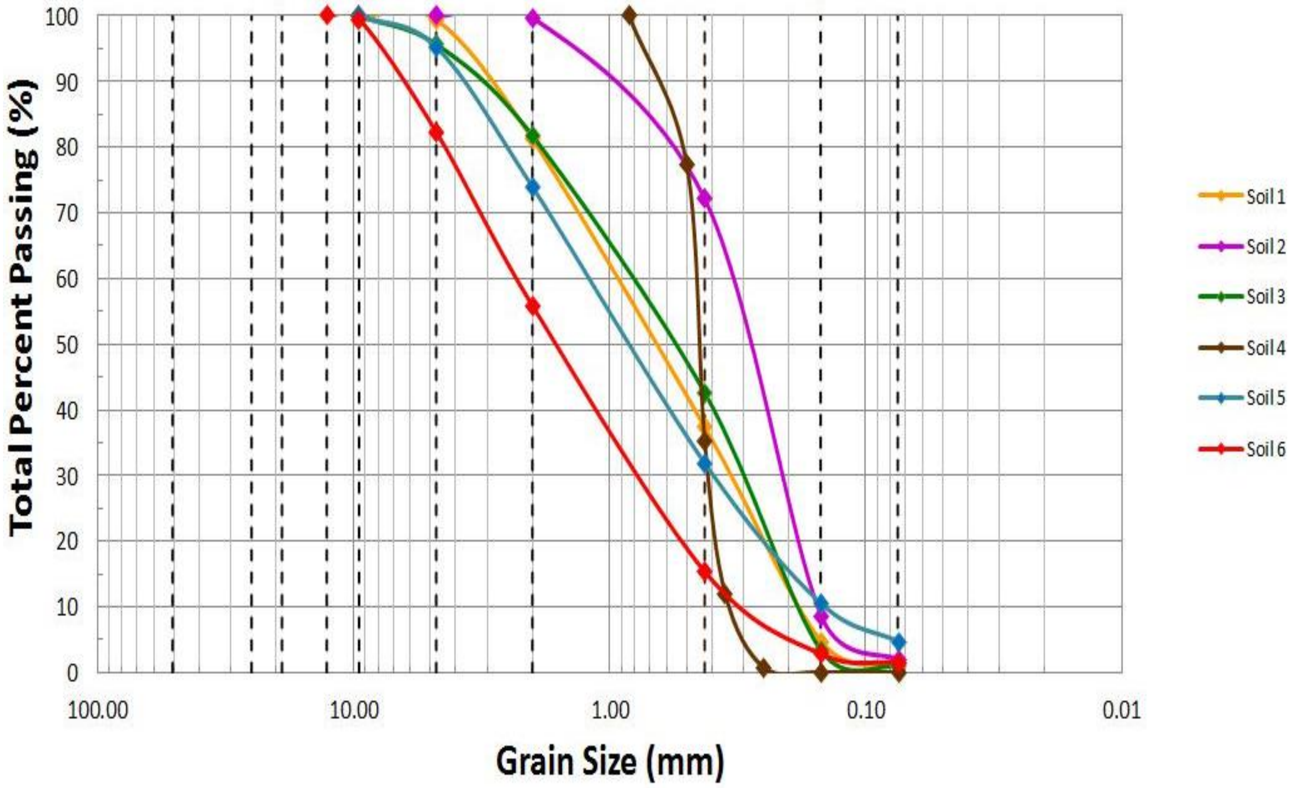
D10	D30	D60	Cu	Cc	%C	%M	%F
0.17	0.22	0.33	1.94	0.86	0.35	31.13	67.65

D10	D30	D60	Cu	Cc	%C	%M	%F
0.34	0.42	0.46	1.35	1.13	0	64.83	35.17

D10	D30	D60	Cu	Cc	%C	%M	%F
0.14	0.40	1.25	8.93	0.91	21.29	42.08	27.21

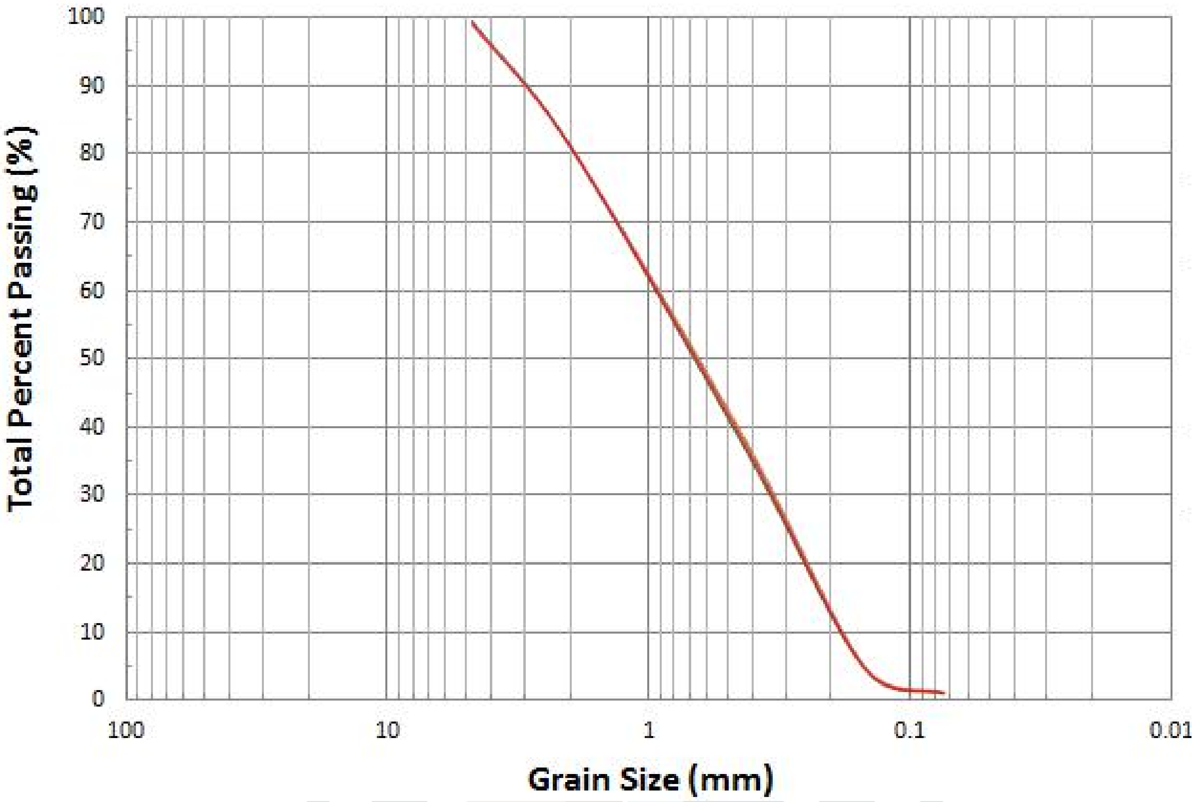

Total Percent Passing (%)
100
90
80
70
60
50
40
30
20
10
0
100
10
1
0.1
0.01
Grain Size (mm)


Total Percent Passing (%)
100
90
80
70
60
50
40
30
20
10
0
100
10
1
0.1
0.01
Grain Size (mm)



D10	D30	D60	Cu	Cc	%C	%M	%F
0.31	0.80	2.35	7.33	0.97	26.48	40.49	13.88

D10	D30	D60	Cu	Cc	%C	%M	%F
0.19	0.34	0.93	4.89	0.65	18.18	43.81	36.37



SOIL	D10	D30	D60	Cu	Cc	%C	%F	%M
1	0.19	0.34	0.93	4.89	0.65	18.18	43.81	36.37
2	0.17	0.22	0.33	1.94	0.86	0.35	31.13	67.65
3	0.19	0.30	0.80	4.21	0.59	13.64	39.09	40.91
4	0.34	0.42	0.46	1.35	1.13	0	64.83	35.17
5	0.14	0.40	1.25	8.93	0.91	21.29	42.08	27.21
6	0.31	0.80	2.35	7.33	0.97	26.48	40.49	13.88

Table 4.1 Summary of various GSD indices for all soils

SUMMARY AND CONCLUSIONS.

6.1 Summary

The results of this study can be summed up as follows :

- Based on the univariate regression analysis D10 (effective particle size) %F that is percentage of medium sized fraction by weight and density showed highest correlation with permeability explaining most of the variation in permeability of soil samples.
- The plots between density and permeability showed that sandy soils show minimum permeability on slightly dry side of optimum.
- Based on the Bi-variate regression analysis two predictive models were prepared which can be used for better estimation of permeability.

6.2 Future Scope.

- The results of this study can be validated for sandy soils from other locations.
- The model prepared can be verified and modified for other soils

REFERENCES

- Alyamani, M. S. and Sen, Z., 1993, Determination of hydraulic conductivity from grain size distribution curves: Ground Water, Vol. 31, pp. 551-555.
- Carmen, P.C., 1937, Fluid flow through a granular bed: Transaction of the Institution of Chemical Engineers, Vol. 15, pp. 150-156.
- Carrier, W.D., 2003, Goodbye, Hazen; hello, Kozeny-Carman: Journal of Geotechnical and Geo environmental Engineering.
- Cheng, C. and Chen, X., 2007, Evaluation of methods for determination of hydraulic properties in an aquifer-aquitard system hydrologically connected to river: Hydrogeology Journal, Vol. 15, pp. 669678.
- Das, B.M., 2008, Advanced soil mechanics: Taylor & Francis, New York, NY, 567 p. DeGroot, D.J., Ostendorf, D.W., and Judge, A.I., 2012, In situ measurement of hydraulic conductivity of saturated soils: Geotechnical Engineering Journal of the SEAGS & AGSSEA, Vol. 43, No. 4, pp. 63-72.
- Hazen, A., 1892, Some physical properties of sands and gravels: Mass. State Board of Health, Ann.