1.0 INTRODUCTION

1.1 BACKGROUND

The deposition in the Kathmandu Valley is lacustrine and fluvial in origin. The deposited sediments are made up of clay, silt, sand and gravel. The property of sediments varies from place to place and also properties vary as depth in same location.

The property of soil which permits flow of water or any liquid through it is called permeability. In other words, the permeability is the ease with which water can flow through it. A soil is highly pervious when water can flow through it easily. An impervious soil doesn't permit the water to flow through it. However, such completely impervious soils don't exist in nature. All the soil is pervious to some extent. A soil is termed impervious when the permeability is extremely low.

The permeability characteristic of soil is one of the important engineering properties of soil. Knowledge of which is very useful in number of engineering problems, such as settlement of buildings, yield of wells, seepage through and below the earth structures. It controls the hydraulic stability of soil masses. The permeability of soils is required in the design of filters used to prevent piping in hydraulic structures and also very useful in agriculture field.

This study focuses on the permeability characteristics of soils of Kathmandu. And comparison is made with the permeability test result that is obtained from different literature.

In this study the soil sample were collected from different location of Kathmandu valley and their respective coefficient of permeability was determined using the appropriate method of determination of coefficient of permeability. Falling head method and constant head method were used in lab for determination of coefficient of permeability.

1.2 OBJECTIVES OF STUDY

The main objective of this study is:

i) Determination of the permeability characteristic of some selected soils from Kathmandu valley.

ii) To compare the permeability characteristics of tested soil from Kathmandu valley with the permeability test result obtained from different literatures.

1.2 LIMITATION

In my research work the following limitations were found out

- The de-aired water couldn't be used; water from the lab tap was directly used.
- The undisturbed soil sample permeability characteristics couldn't be determined as the sample collected were disturbed.
- Only nine soil sample from the Kathmandu valley were tested.

2.0 LITERATURE REVIEW

2.1 BACKGROUND

Soil permeability can be measured in either the laboratory or the field. Laboratory determinations are much easier to conduct than the field methods. Because permeability depends much more on soil fabric i.e. microstructure (the arrangement of individual particles) and macro structure (such as stratification) and because of getting representative soil sample. But also the field methods are often required to get a good indication of the average permeability. Laboratory tests however permit the relationship of permeability to void ratio to be studied and are thus usually conducted whether or not field test are done.

The coefficient of permeability can be determined by using following methods.

a) Laboratory methods
   i. Constant head method
   ii. Falling (variable) head method
   iii. From consolidation test
b) Field methods
   i. Pumping out test
   ii. Pumping in test
c) Indirect methods
   i. Computation from the particle size or specific surface
   ii. Computation from the consolidation test data
d) Capillarity permeability test

The various types of apparatus which are used in soil laboratories for determining the permeability of soils are called permeameters. The apparatus used for the constant head permeability test is called a constant head permeameter and the one used for the falling head test is a falling head permeameter. The soil samples used in laboratory methods are either undisturbed or disturbed. Since it is not possible to obtain undisturbed samples of cohesionless soils, laboratory tests on cohesionless materials are always conducted on samples which are reconstructed to the same density as they exist in nature. The results of tests on such reconstructed soils are often misleading since it is impracticable to obtain representative samples and place them in the test apparatus to give exactly the same density and structural arrangement of particles. Direct testing of soils in place is generally preferred in cases where it is not possible to procure undisturbed samples. Since this method is quite costly, it is generally carried out in connection with major projects such as foundation investigation for dams and large bridges or building foundation jobs where lowering of the water table is involved. In place of pumping tests, bore hole tests as proposed by the U.S. Bureau of Reclamation are quite inexpensive as these tests eliminate the use of observation wells. Empirical correlations have been developed relating grain size and void ratio to hydraulic conductivity and will be discussed later on.

2.2 CONSTANT HEAD PERMEABILITY TEST

Figure 2.1(a) shows a constant head permeameter which consists of a vertical tube of Lucite (or any other material) containing a soil sample which is reconstructed or undisturbed as the case may be. The diameter and height of the tube can be of any convenient dimensions. The head and tail water levels are kept constant by overflows. The sample of length L and cross-sectional area A is subjected to a head h which is constant during the progress of a test. A test is performed by allowing water to flow through the sample and measuring the quantity of discharge Q in time t.

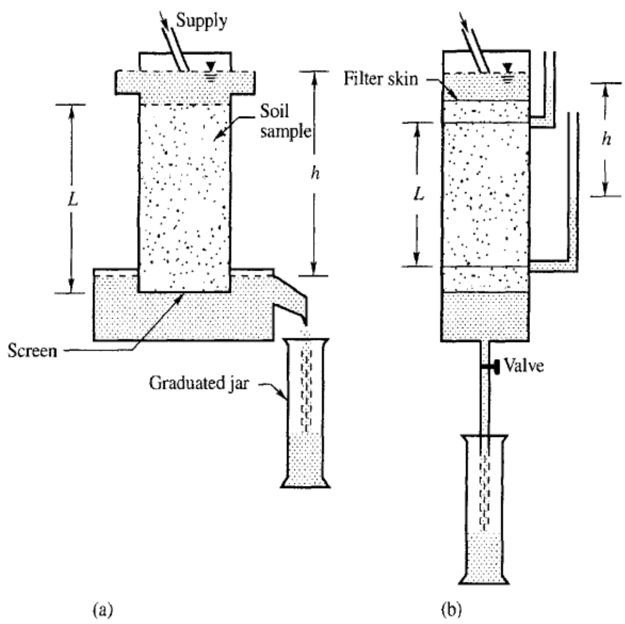

Fig 2.1: Constant head Permeability Method

The value of k can be computed directly from Darcy's law expressed as follows

Soil Permeability and Seepage discharge

$$Q = k\frac{h}{L}At \text{ ....} \quad 2.1$$

$$\text{Or, } k = \frac{QL}{hAt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.2$$

The constant head permeameter test is more suited for coarse grained soils such as gravelly sand and coarse and medium sand. Permeability tests in the laboratory are generally subjected to various types of experimental errors. One of the most important of these arises from the formation of a filter skin of fine materials on the surface of the sample. The constant head permeameter of the type shown in Fig. 2.1(b) can eliminate the effect of the surface skin. In this apparatus the loss of head is measured through a distance in the interior of the sample, and the drop in head across the filter skin has no effect on the results.

2.3 FALLING HEAD PERMEABILITY TEST

A falling head permeameter is shown in Fig. 2.2(a). The soil sample is kept in a vertical cylinder of cross-sectional area A. A transparent stand pipe of cross sectional area, a, is attached to the test cylinder. The test cylinder is kept in a container filled with water, the level of which is kept constant by overflows. Before the commencement of the test the soil sample is saturated by allowing the water to flow continuously through the sample from the stand pipe. After saturation is complete, the stand pipe is filled with water up to a height of h_0 and a stop watch is started. Let the initial time be t_0. The time t_1 when the water level drops from h_0 to h_1 is noted. The hydraulic conductivity k can be determined on the basis of the drop in head (h_0 - h_1) and the elapsed time (t_1 - t_0) required for the drop as explained below.

Let h be the head of water at any time t. Let the head drop by an amount dh in time dt. The quantity of water flowing through the sample in time dt from Darcy's law is

$$dQ = kiA\,dt = k\frac{h}{L}A\,dt \ldots\ldots\ldots\ldots\ldots\ldots. \quad 2.3$$

Where, i = h/L the hydraulic gradient.

The quantity of discharge dQ can be expressed as

$dQ = -a\,dh$............................. 2.4

Since the head decreases as time increases, dh is a negative quantity

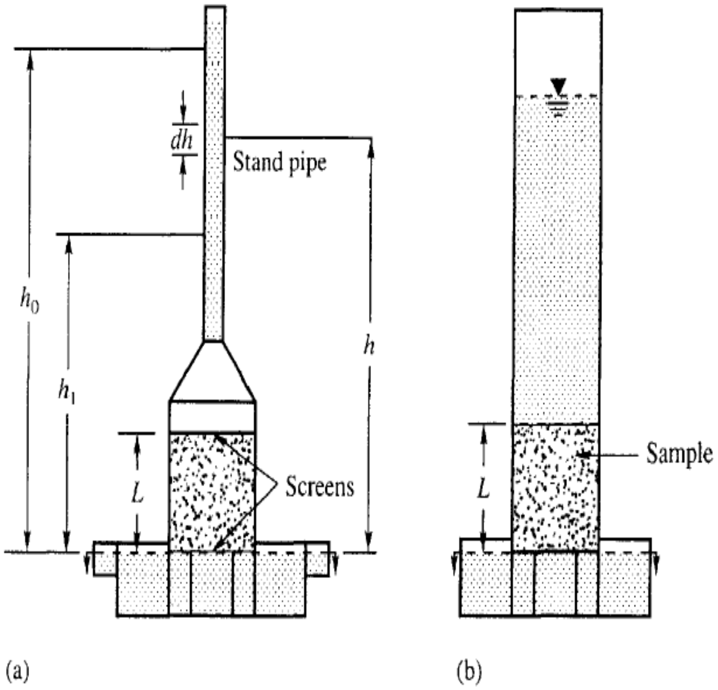

Fig 2.2: Falling head Permeability Test

It can be equated to

$$-a\,dh = k\frac{h}{L}A\,dt \text{ ... ...} \qquad 2.5$$

The discharge Q in time (t_1 - t_0) can be obtained by integrating Eq.

Therefore, Eq can be rearranged and integrated as follows

$$-a\int_{h_0}^{h_1}\frac{dh}{h} = \int_{t_0}^{t_1} dt \text{ ... ...} \qquad 2.6$$

$$a\log_e\frac{h_0}{h_1} = \frac{kA}{L}(t_1 - t_0) \text{ ... ...} \qquad 2.7$$

The general expression for k is given by

$$k = \frac{aL}{A(t_1 - t_0)}\log_e\frac{h_0}{h_1} \text{ ....} \qquad 2.8$$

Or

$$k = \frac{2.3aL}{A(t_1 - t_0)}\log_{10}\frac{h_0}{h_1} \text{ ... ...} \qquad 2.9$$

The setup shown in Fig. 2.2(a) is generally used for comparatively fine materials such as fine sand and silt where the time required for the drop in head from h_0 to h_1 is neither unduly too long nor too short for accurate recordings. If the time is too long evaporation of water from the surface of the water might take place and also temperature variations might affect the volume of the sample. These would introduce serious errors in the results. The setup is suitable for soils having permeabilities ranging from 10^{-3} to 10^{-6} cm per sec. Sometimes, falling head permeameters are used for coarse grained soils also. For such soils, the cross sectional area of the stand pipe is made the same as the test cylinder so that the drop in head can conveniently be measured. Fig. 2.2(b) shows the test set up for coarse grained soils. When a = A, Eq. is reduced to

$$k = \frac{L}{(t_1 - t_0)} \log_e \frac{h_0}{h_1} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad 2.10$$

2.4 FACTORS AFFECTING PERMEABILITY

The coefficient of permeability of soil can be defined as the approach velocity of permeant for flow through soil of unit area under a unit gradient. The permeability value thus depends on the characteristics of permeant and soil.

An equation reflecting the influence of the permeant and the soil was developed by Taylor (1948) using Poiseille's law for laminar flow. The equation is given as

$$k = Ds^2 \frac{\gamma}{\mu} \frac{e^3}{(1+e)} C \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad 2.11$$

The following is an expression for the permeability of porous media, known as the Kozeny- Carman equation since it was proposed by Kozney and improved by Carman:

$$k = \frac{1}{k_{\circ} S^2} \frac{\gamma}{\mu} \frac{e^3}{(1+e)} \dots\dots\dots\dots\dots\dots\dots\dots\dots \quad 2.12$$

$k_{\circ}$ = factors depending on pore size and ratio of length of actual flow path to soil bed thickness

S = specific surface area

Since D_S is defined as the diameter of particle having a specific surface S eqn. 2.12 can be considered as the simplification of Kozney- Carman equation.

2.4.1 Permeant Characteristics:

The equation 2.11 shows that both the viscosity and the unit weight of the Permeant influence the values of permeability. While viscosity and unit weight are only variable that influence the permeability of pervious soil, other permeant characteristics can have major influence on the permeability of relatively impervious soil.

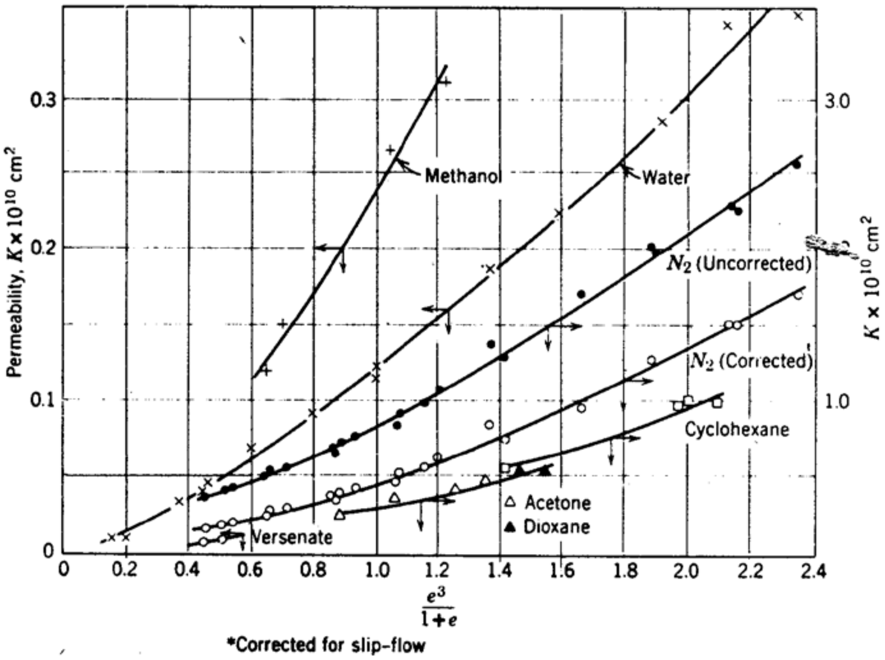

Fig 2.3 Permeability of Kaolinite to various fluids as a function as a function of $e^3/(1+e)$. (From Michaels and Lin, 1954.)

From Michaels and Lin, 1954 that viscosity and unit weight are not only permeant characteristics, as suggested by theoretical equations, that influence the permeability of fine grained soils. Since the electro-osmotic back flow and the mobility of the fluid immediately adjacent to the soil particle depends on the polarity of the pore fluid. Some measure of polarity should be included in the equation.

The unit weight of water does not vary much over the range of temperature. However, there is large variation in the value of the coefficient of viscosity. The coefficient of permeability increases with increase with an increase in temperature due to reduction in the viscosity.

It is conventional to report the coefficient of permeability at 20° C. following relation can be used for conversion of coefficient of permeability to 20° C.

$k_{20} = (\eta_{T^\circ C}/\eta_{20^\circ C}) * k_T$ ………………..2.13

The variation of ($\eta_{T°C}/\eta_{20°C}$) with the test temperature T varying from 15 to 30^{o}C is given in table no 2.1

Table no 2.1 Variation of ($\eta_{T°C}/\eta_{20°C}$)

Temperature, T^{o}C	**($\eta_{T°C}/\eta_{20°C}$)**	**Temperature, T^{o}C**	**($\eta_{T°C}/\eta_{20°C}$)**
15	1.135	23	0.931
16	1.106	24	0.910
17	1.077	25	0.889
18	1.051	26	0.869
19	1.025	27	0.850
20	1.000	28	0.832
21	0.976	29	0.814
22	0.953	30	0.797

2.4.2 Soil properties

The following five soil characteristics influence the permeability

- Particle size
- Void ratio
- Composition
- Structure of soil mass/ fabric
- Shape of particles
- Degree of saturation

The above equation considers directly on the particle size and void ratio, while the other three characteristics are treated indirectly or ignored. It is hard to isolate effect of one of these characteristics since these characteristics are closely interrelated.

2.4.2.1 Particle Size

The above eqn. 2.11 suggests that the permeability varies with the square of some particle diameter. The permeability of coarse grained soil is very large as compared to that of fine grained soil. The permeability of coarse sand may be more than one million times as much that of clay. It is well known that smaller the soil particles the smaller void, and lower the permeability. A relationship between permeability and particle size is much more reasonable in silts and sands than clay, since in silts and sands the particle are more nearly equdimensional and the extremes in fabric are closer together.

From experiments on sand, Hazen proposed

$$k=100D_{10}^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.14$$

Where k is in cm/sec and D is in cm.

2.4.2.2 Void Ratio

The equation 2.11 indicates that the plot of k versus $e^3/(1+e)$ should be straight line. Other theoretical equations have suggested that k versus $e^2/(1+e)$ or k versus e^2 should be straight line. There are considerable experimental data which shows that e versus log k is frequently a straight line.

If the permeability of soil at void ratio 0.85 is known, then its value for another void ratio can be determined using the following equation given by Casagrande

$k = 1.4\ k_{0.85}\ e^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.15$

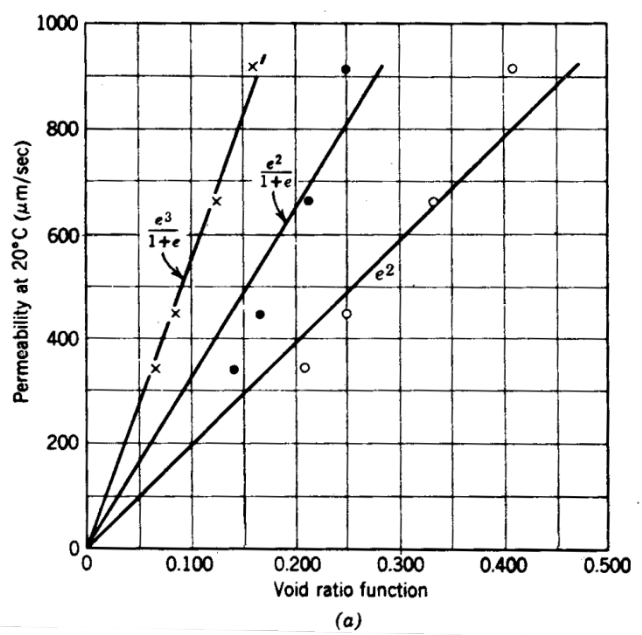

Fig 2.4 Relation between void e and k for variable head test (Soil Mechanics T.William Lambe Robert V. Whitman)

2.4.2.3 Composition

The influence of composition is less importance for the silts, sand and gravel (mica and organic matter are two exception) but have major influence on the clayey soil. The influence of composition in soil can be illustrated in figure below.

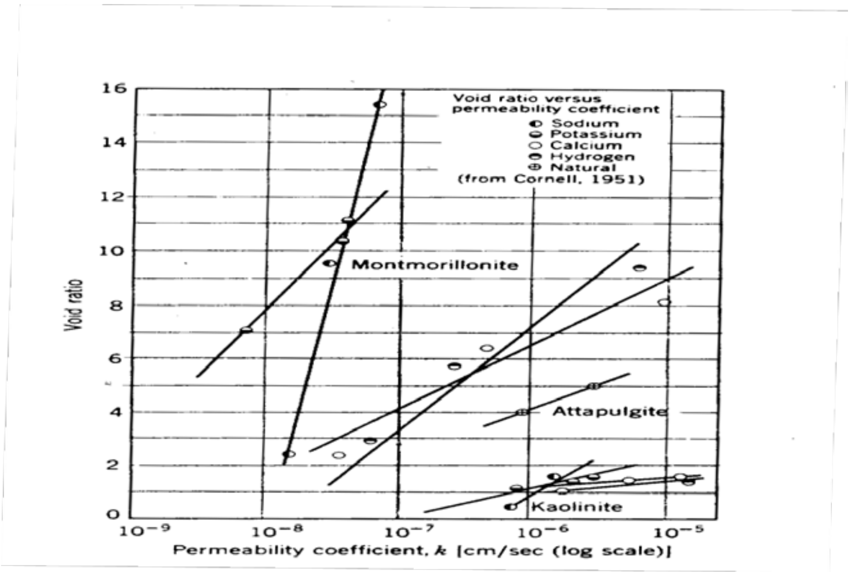

Fig 2.5 Coefficient of permeability versus void ratio (Soil MechanicsT.William Lambe Robert V. Whitman)

2.4.2.4 Structure of Soil/ Fabric

Comparing the soil components with same void ratio the soil with flocculated structure have more permeability than the soil with dispersed structure. The more dispersed structure more parallel they are, the more tortuous is the flow path if the flow is normal to the particles. In flocculated soil there are some large flow channels.

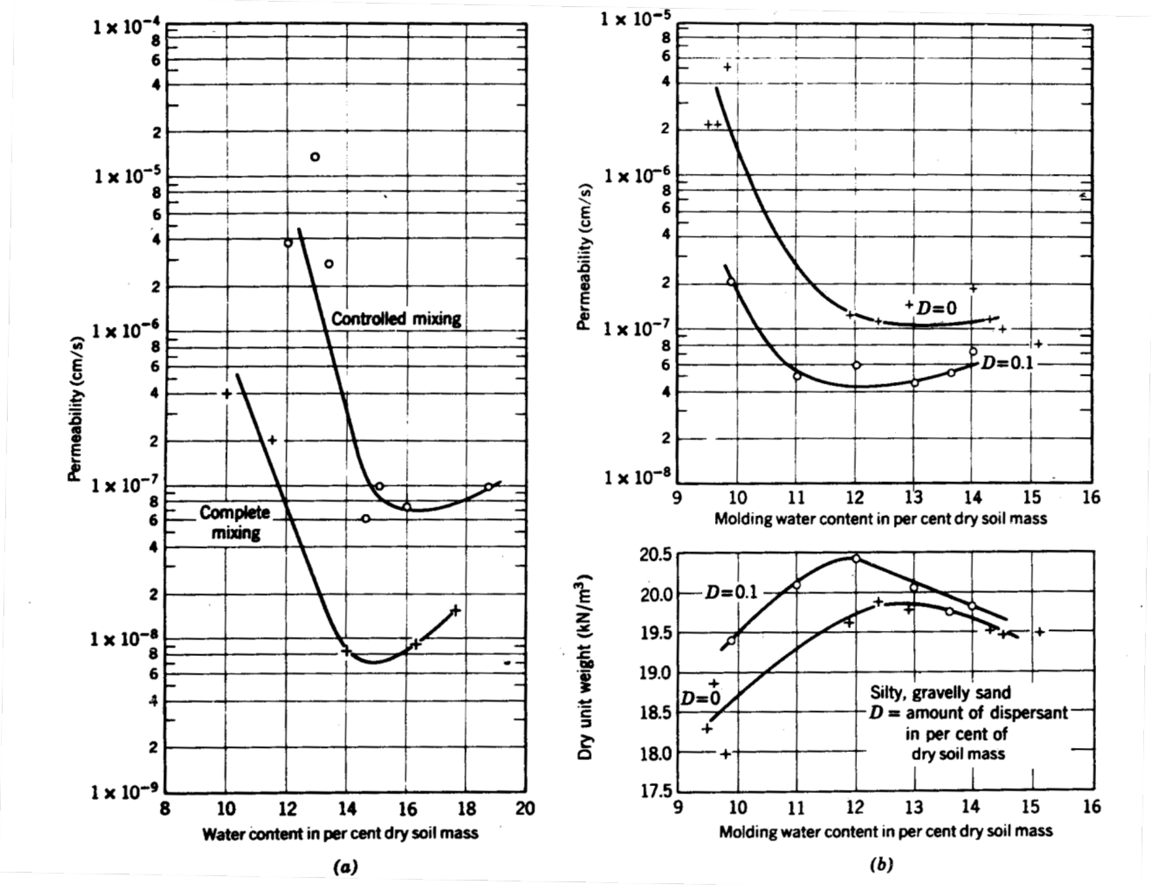

Fig 2.6 Effect of structure on permeability a) effect of mixing in permeability b) effect of dispersion of permeability (Soil Mechanics T.William Lambe Robert V. Whitman)

2.4.2.5 Shape of Particle

The permeability of a soil depends upon the shape of particles. Angular particles have greater surface area than rounded. For same void ratio soils with rounded particle are more permeable than soils with angular particle, as the permeability is inversely proportional to the surface area.

2.4.2.6 Degree of Saturation

The degree of saturation of soil has an important influence on its permeability. Higher the degree of saturation, the higher is the permeability. If the soil is not fully saturated it contains air pockets formed due to entrapped air or due to air liberated from percolating water. The influence on permeability due to degree of saturation for various sand is shown in figure below.

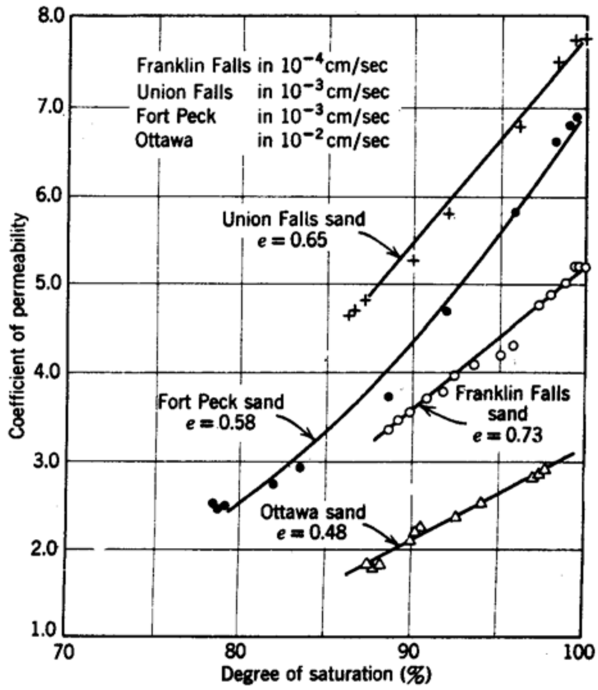

Fig 2.7: Permeability versus degree of saturation for various sand. (From Wallace, 1948)

Terzaghi and Peck in 1967 classified the soil permeability according to the coefficient of permeability which is given in table no 2.2

Table no 2.2 Classification of soil permeability

Degree of permeability	**values of k (cm/sec)**
High	over 10^{-1}
Medium	10^{-1} to 10^{-3}
Low	10^{-3} to 10^{-5}
Very low	10^{-5} to 10^{-7}
Practically impermeable	less than 10^{-7}

The permeability test data result obtained from Lambe and Whitman literature is shown in figure 2.8

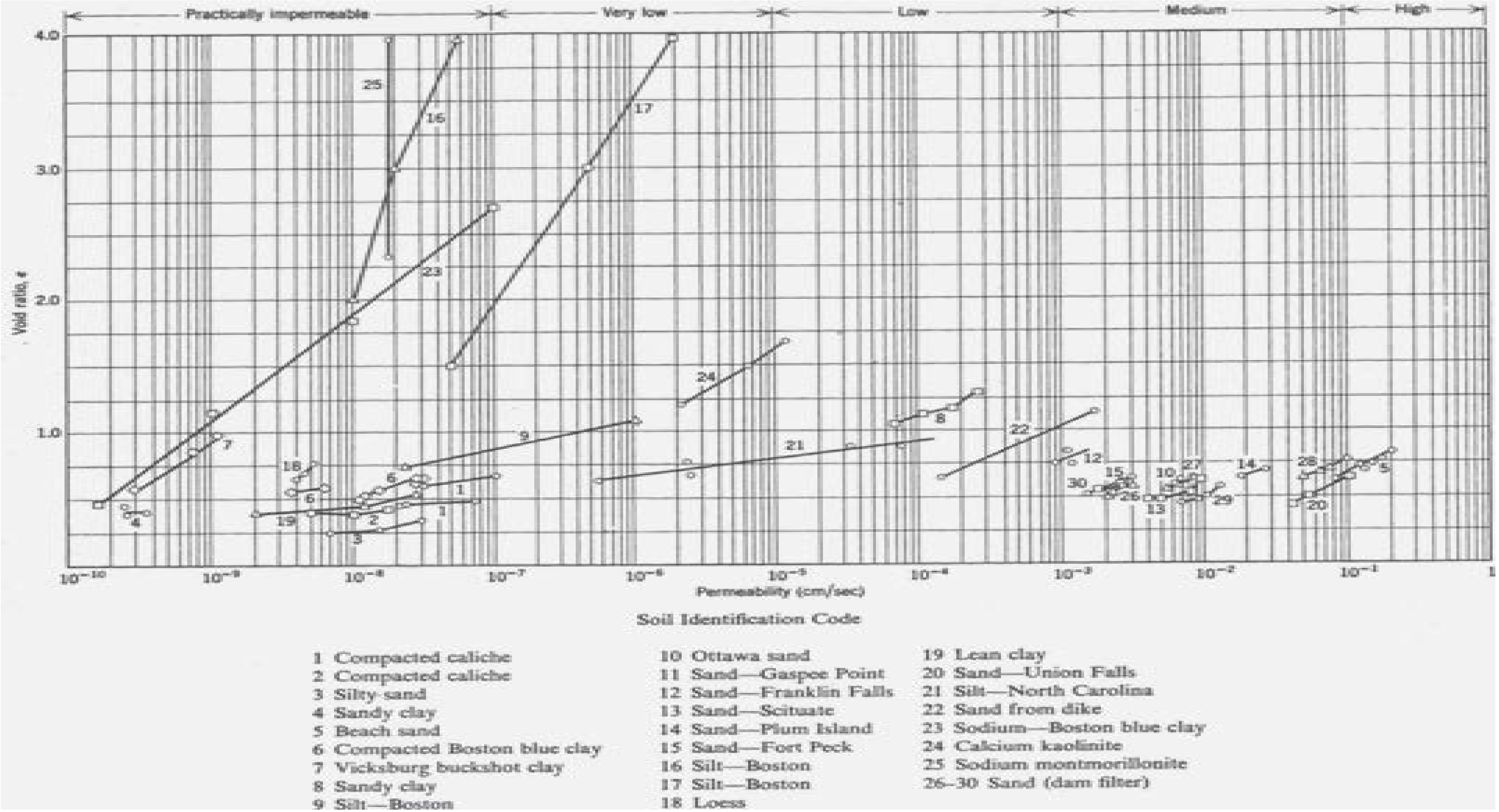

Fig 2.8 Permeability test data

2.5 PLOT DIGITIZER

Plot Digitizer is a Java program used to digitize scanned plots of functional data. Often data is found presented in reports and references as functional X-Y type scatter or line plots. In order to use this data, it must somehow be digitized. This program will allow you to take a scanned image of a plot (in GIF, JPEG, or PNG format) and quickly digitize values off the plot just by clicking the mouse on each data point. The numbers can then be saved to a text file and used where ever you need them. Plot Digitizer works with both linear and logarithmic axis scales. Besides digitizing points off of data plots, this program can be used to digitize other types of scanned data (such as scaled drawings or orthographic photos).

To make the digitizing task easier, this program includes many handy features. For example: You can recalibrate the Y axis without having to recalibrate the X axis (multiple sets of data are commonly plotted with the same X axis). You can insert points between two already digitized points by right clicking and choosing "Insert" from the pop-up menu. You can delete points by right-clicking on the points and choosing "Delete". You can move points by clicking and dragging them. You can compute the length of a digitized curve and you can compute the area of a digitized polygon. You can zoom images in and out. You can save calibrations for an image for later use, and finally, there is unlimited undo/redo.

A special feature of this program is the ability to semi-automatically digitize lines off a plot. The user simply indicates where the line is on the plot with a thick paint brush and the program attempts to automatically sort out the data from grid lines, etc. This auto-digitizing feature depends on an image vectorization program called "autotrace". In order to use the auto-digitizing feature, you must have the open source autotrace image vectorization program installed. Unfortunately, autotrace does ***not*** currently seem to work on the Windows platform.

3.0 MATERIALS AND METHOD

3.1 MATERIALS USED AND SAMPLE PREPARATION

3.1.1 Collection of Soil Sample

Soil sample were collected from different location of Kathmandu valley i.e. from Thimi, Champi, Matatirtha, Kalanki, Manohara River, Bagmati River at Jorpati and Bungmati, Kamerotar soil and Luvu soil. Only the disturbed samples were taken.

3.1.2 Sample Preparations

3.1.2.1 Soil Characterization Test Samples

For soil characterization (property test), sample were firstly air dried in room temperature and then oven dried and broken to small particles with wooden pallet to conduct tests.

3.1.2.2 Permeability Test Samples

Sample collected from bags when air dried and oven dried are pulverized as necessary and collected in a big tray. For test each soil sample were prepared with varying density by varying water content and compacting effort. 3 to 4 test sample were prepared for each soil with varying density on the permeability test mould.

3.1.3 Soil Characterization and Permeability Test

3.1.3.1 Moisture Content:

Oven-drying method is used to determine the moisture contents of the samples. For the oven-drying method, small, representative specimens obtained from large bulk samples were weighed as received, then oven-dried at 105°C for 24 hours. The sample was then reweighed, and the difference in weight was assumed to be the weight of the water driven off during drying. The difference in weight was divided by the weight of the dry soil, giving the water content on a dry weight basis.

3.1.3.2 Particle Size Distribution:

More than 500gm of Soil from Bagmati River, Manohara River and Bagmati River soil at Bungmati were oven dried and were sieved through various sieve number and % passing were determined. Grain size distribution curve were plotted for those soils. For soils from Kalanki, Champi, Luvu, Matatirtha, Thimi and Kamerotar above 500gm of sample was collected and washes from 0.75mm sieve and kept in oven. Then retain material were sieve in 4.75mm, 2mm, 0.85mm, 0.425mm, 0.297mm, 0.15mm, and 0.075mm sieves. For particle size less than 75 micron hydrometer analyses were performed for these soil. For hydrometer analyses approximately 50 grams of dry soil passing 75 micron was treated with a dispersing agent for 72 hours. Then hydrometer analyses were performed to measure the amount of silt and clay size particles. After that combine grain size distribution curve were plotted for these soils.

3.1.3.3 Atterberg Limits:

Representative samples of each soil were subjected to Atterberg limits testing to determine the plasticity of the soils. An Atterberg limits device (Casagrande apparatus) was used to determine the liquid limit of each soil samples using the material passing through a 425 µm (No. 40) sieve. The plastic limit of each soil was determined by using soil passing through a 425 µm sieve and rolling 3-mm diameter threads of soil until they began to crack. The plasticity index was then computed for each soil based on the liquid and plastic limit obtained. The liquid limit and plasticity index were then used to classify each soil. Atterberg limits were computed for soil samples from Luvu, Kalanki, Matatirtha, Champi, Thimi and Kamerotar.

3.1.3.4 Specific Gravity:

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature of 25^{o}C. Kathmandu valley soil samples specific gravity were determined using ASTM D 854-00. For the test water density bottle method was used.

3.1.3.5 Soil Classification:

Soil samples were classified using the Unified Soil Classification System (USCS). Using the particle size distribution and the Atterberg limits, the USCS designates a two letter symbol and a group name for each soil. A visual-manual procedure can also be used to identify soils easily in the field; however, all classifications provided in this research are based on the laboratory testing-based procedure.

3.1.3.6 Permeability Test:

Oven dried soil samples were taken and test samples were prepared with varying water content and compacting effort, i.e. with varying densities (for varying void ratio). The test specimens were prepared in permeater and were first saturated by process of back flow of water through permeater. After the soil samples were fully saturated (removal of all entrapped air inside permeater), the test specimen were arranged in such a manner for test as per the test were falling head or constant head. The permeability tests were conducted as per IS 2720-Part XVII. The falling head test was conducted for Bungmati sand, Thimi soil, Kalanki soil, Champi soil, Kamerotar soil, Matatirtha soil and Luvu soil, while constant head was conducted for the sand of Bagmati River, Manohara River sand and sand from Bungmati.

3.1.4 Digitization of Test Result from Literature

The permeability test result from the literature of the Lambe and Whitman was digitize through plot digitizer software

4.0 RESULTS AND DISCUSSION

4.1 GEOTECHNICAL PROPERTIES OF COLLECTED SOIL SAMPLES

Soil sample collected from different parts of Kathmandu valley were tested in lab to find out their geotechnical properties. Some of the geotechnical properties that were found out during the research work are presented in table no 4.1.

Table 4.1: Geotechnical properties of Soil from Kathmandu valley

Soil source	Color	Sp. Gr	LL	PL	PI	C_u	C_c
Bagmati sand	White	2.63	-	-	-	3.64	0.82
Manohara sand	White	2.65	-	-	-	2.93	0.86
Bungmati sand	grey white	2.67	-	-	-	2.15	1.04
Kalanki soil	Black	2.60	28.80	16.94	11.86	-	-
Champi soil	light yellow	2.70	16.10	-	NP	-	-
Thimi soil	Grey	2.63	42.80	31.41	11.39	-	-
Matatirtha soil	Yellow	2.60	28.00	21.55	6.45	-	-
Kamerotar soil	Grey	2.65	21.90	-	NP	-	-
Luvu soil	Grey	2.55	36.20	21.75	14.45	-	-

4.2 GRADATION OF SOIL SAMPLES

On sieve analysis the sand from Manohara River, Bagmati River and Bungmati were sieved through the number of sieve. The silt and clay content on these sands were 0.91%, 1.54% and 3.05% respectively. The sand from Bungmati was found to be finer than sand from Manohara and Bagmati. All other soil samples after doing sieve analysis it was found that all soils have clay and silt content more than 50%. Silt and clay content of Kalanki soil was found to be 91.85%, 73.79% for Champi soil, 85.08% for Thimi soil, 61.66% for Kamerotar soil, 76.19% for Matatirtha soil and 96.10% for Luvu soil. Hydrometer analyses were conducted along with sieving through different sieve for soils other than soil from Bagmati River, Manohara River and Bungmati Sand. Grain size distribution curve for these soil samples after the lab tests are shown in figure 4.1 to 4.10.

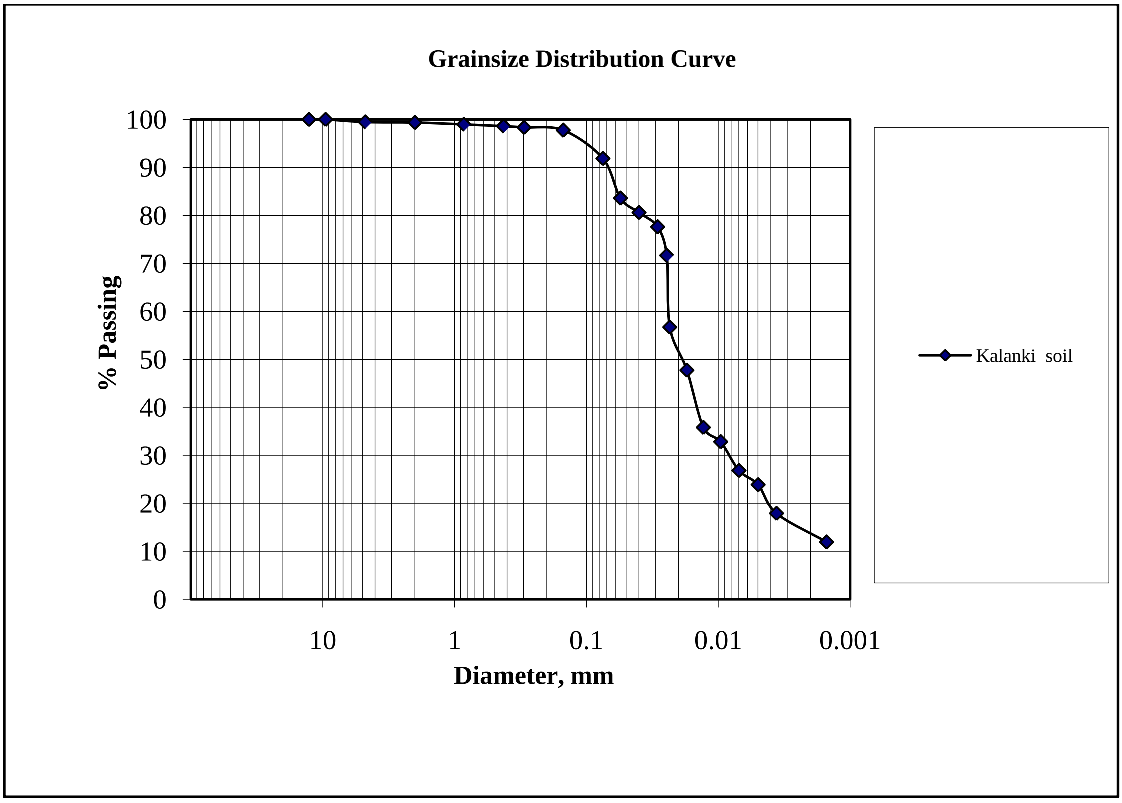

Fig 4.1 Particle size distribution of soil from Kalanki

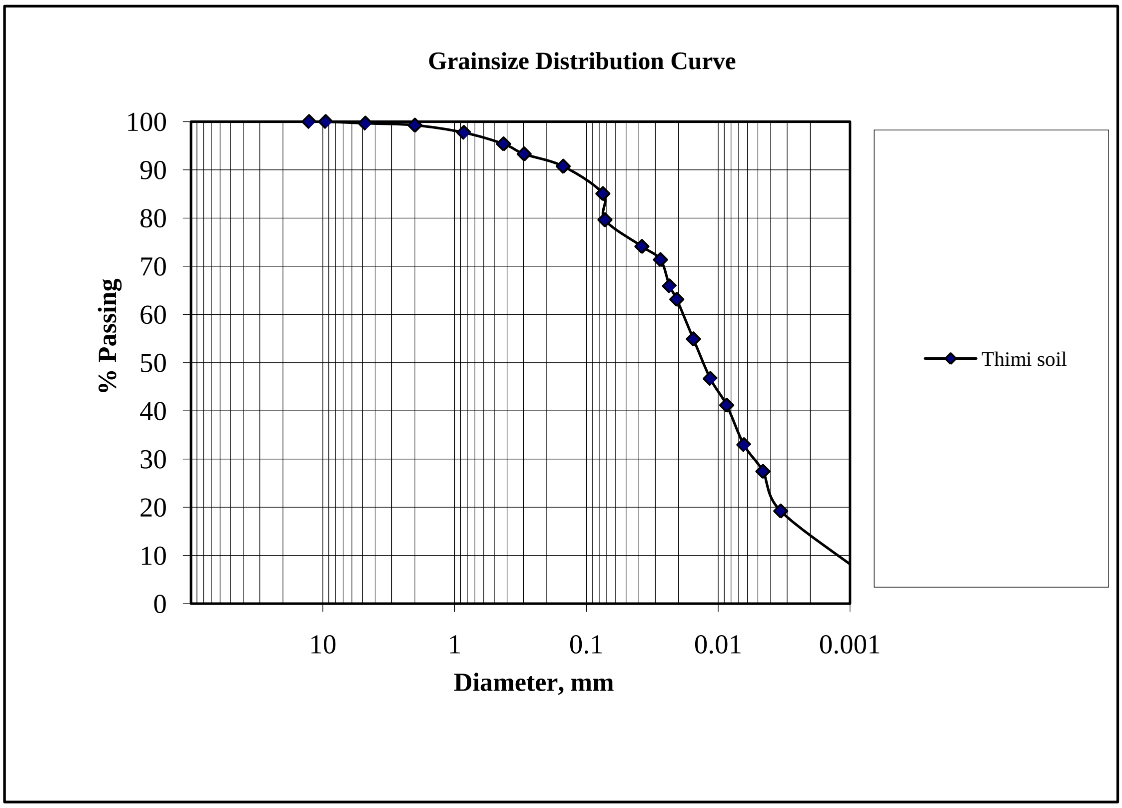

Fig 4.2 Particle size distribution of Thimi soil

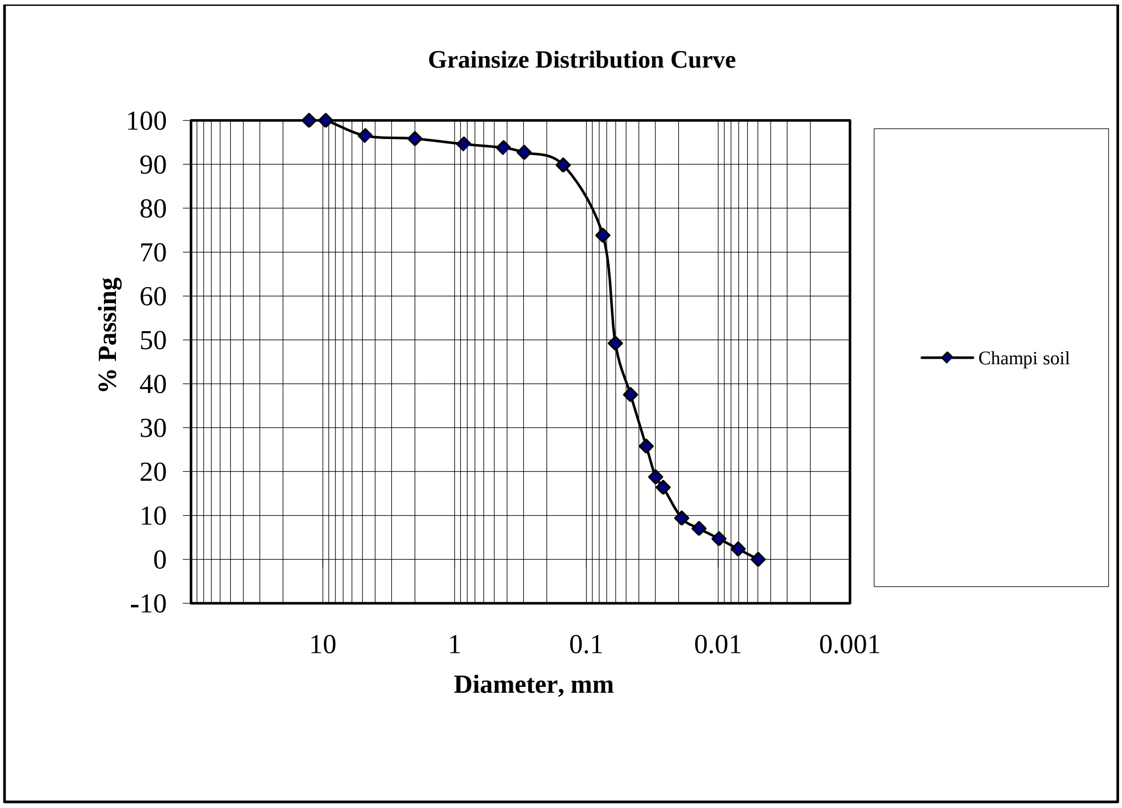

Fig 4.3 Particle size distribution of Champi soil

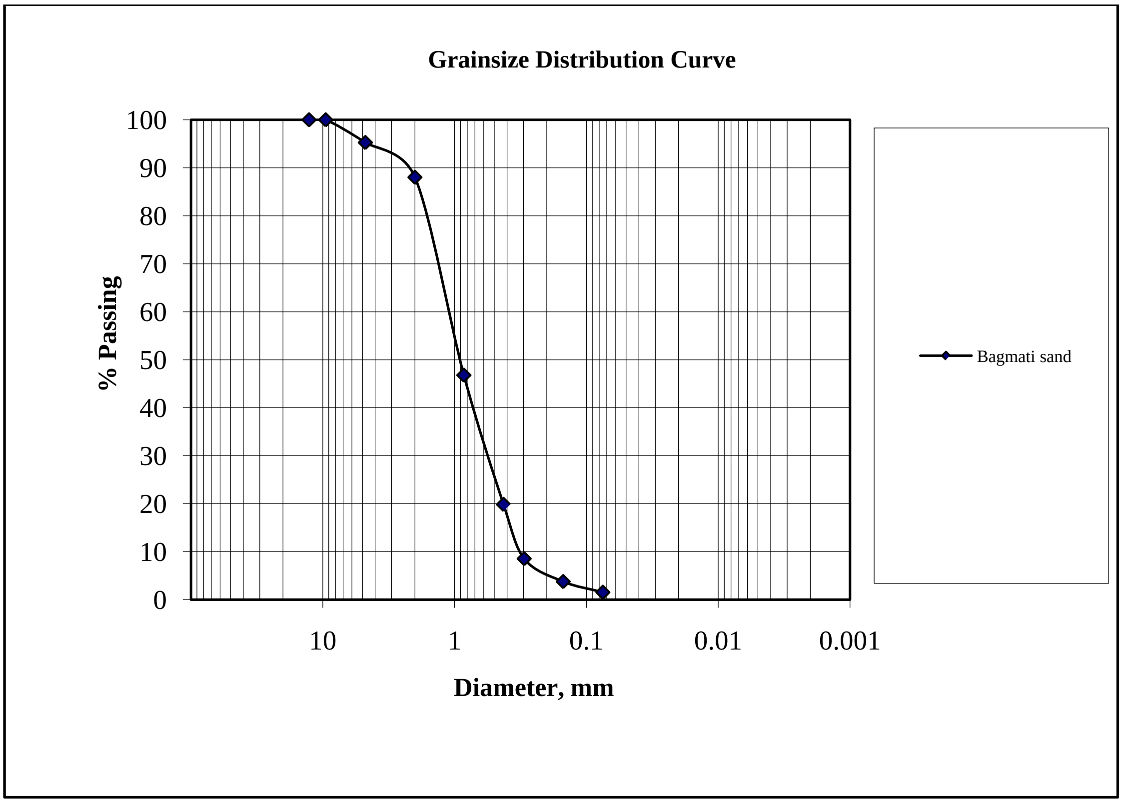

Fig 4.4 Particle size distribution of Bagmati sand

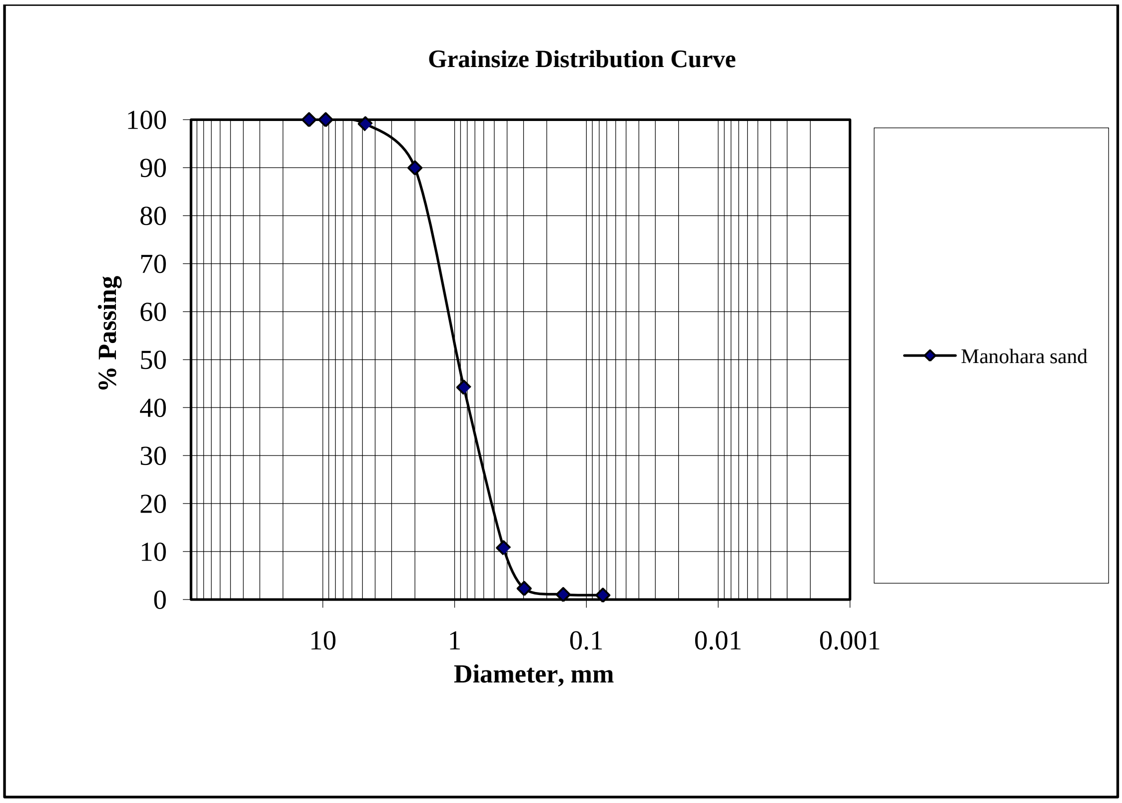

Fig 4.5 Particle size distribution of Manohara sand

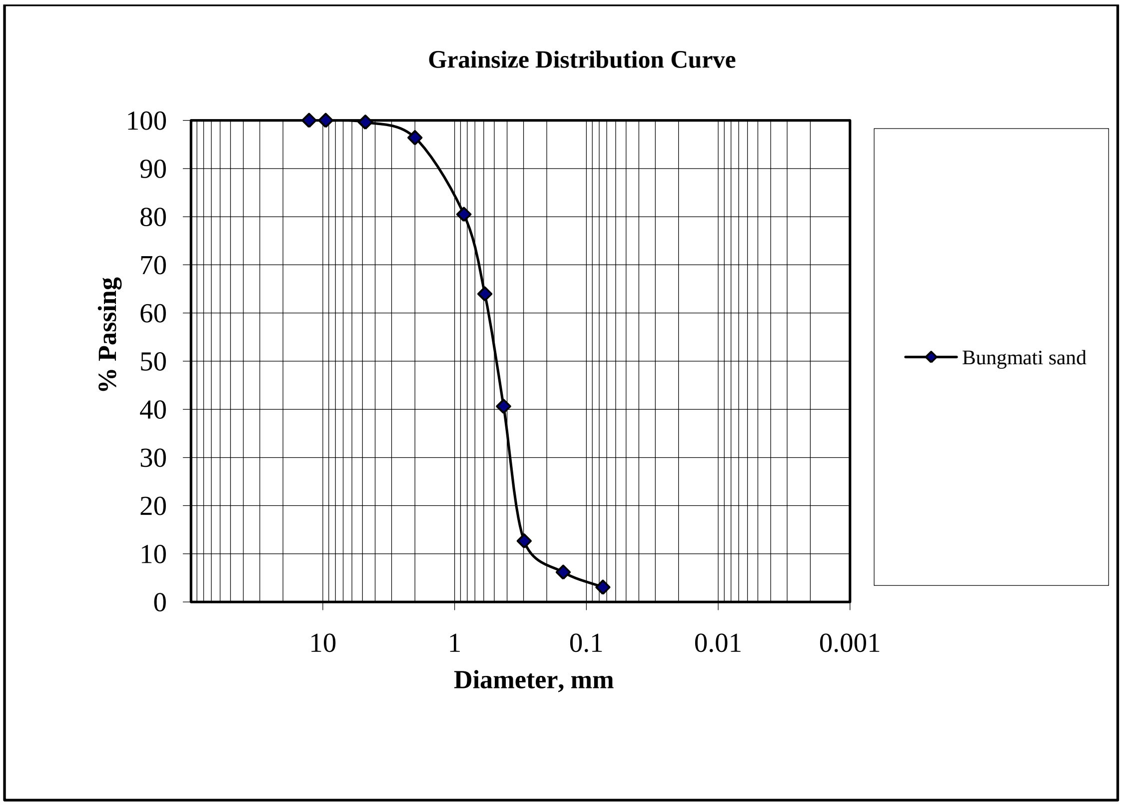

Fig 4.6 Particle size distribution of Bungmati sand

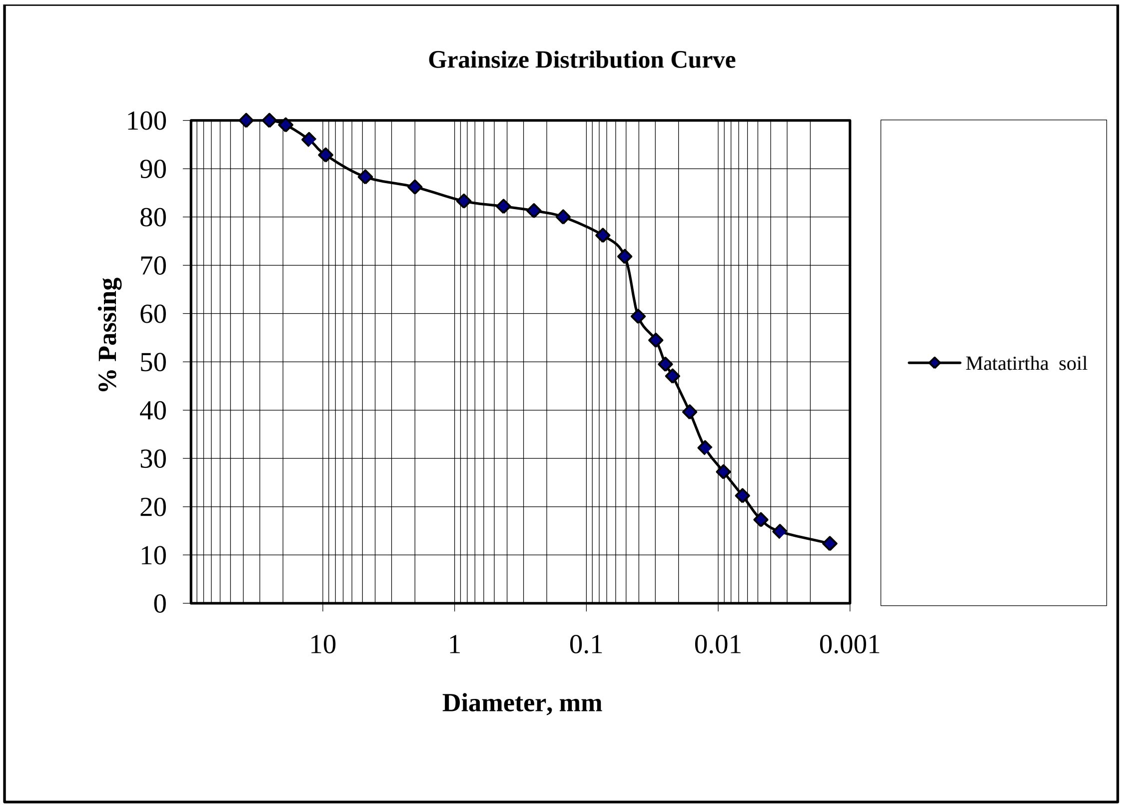

Fig 4.7 Particle size distribution of Matatirtha soil

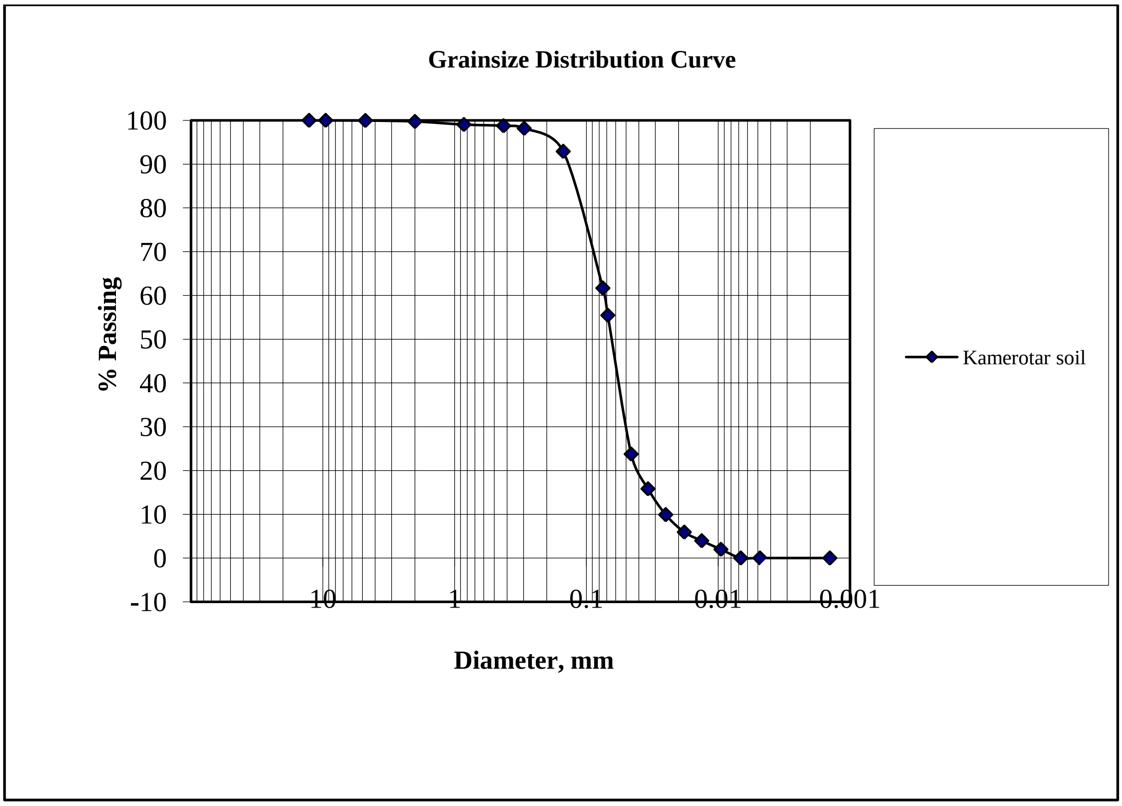

Fig 4.8 Particle size distribution of Kamerotar soil

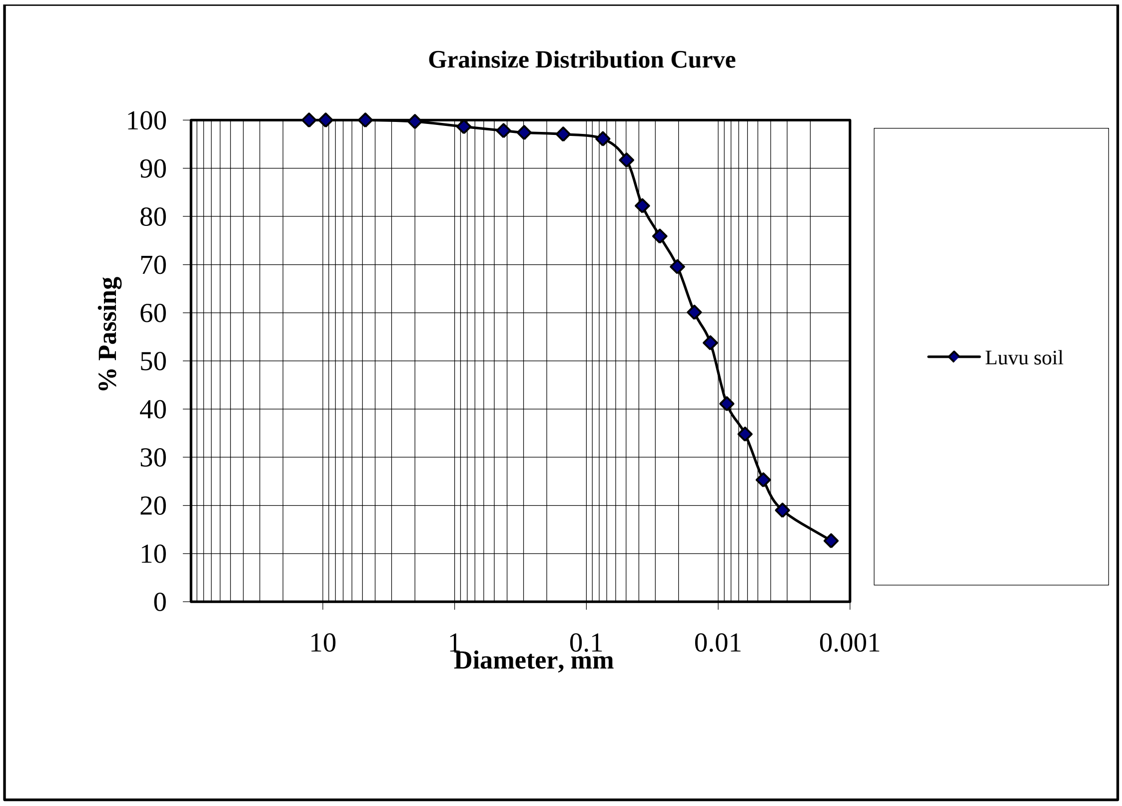

Fig 4.9 Particle size distribution of Luvu soil

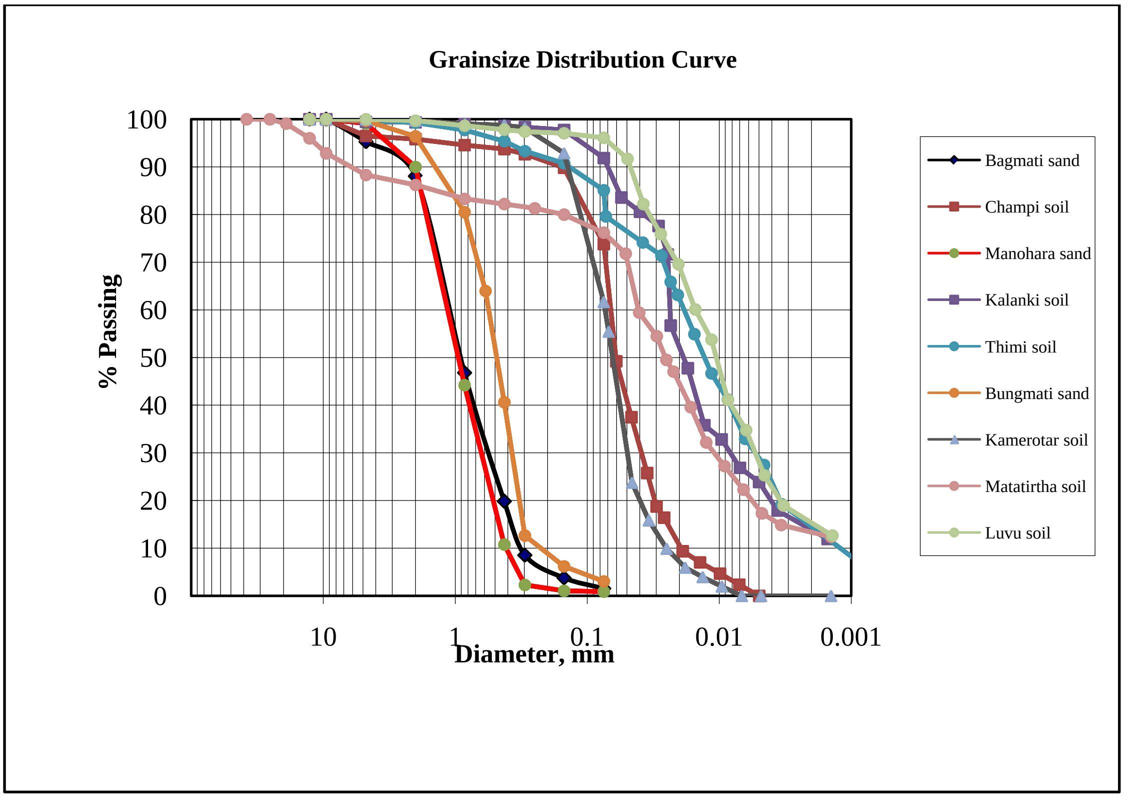

Fig 4.10 Gradation curve for Kathmandu valley soils

The D_{10}, D_{30}, D_{60}, C_u & C_c of Bagmati, Manohara and Bungmati sand of test samples are given in table no 4.2

Table no 4.2 Cu & C_c of soil samples

Sources	Bagmati	Manohara	Bungmati
D_{10}	0.33	0.41	0.26
D_{30}	0.57	0.65	0.39
D_{60}	1.20	1.20	0.56
C_u	3.64	2.93	2.15
C_c	0.82	0.86	1.04

4.3 ATTERBERG LIMITS

Atterberg limits of the test soil sample were determined from Casagrande apparatus. From the test it was found that soil from Kamerotar and Champi was found to be non plastic. The liquid limit, plastic limit and plasticity index of test soil samples are given in table no 4.1. The plasticity chart of soils from the Kalanki, Luvu, Matatirtha and Thimi are shown in annex Figure no A1 to A4.

4.4 SPECIFIC GRAVITY

The specific gravities of the test soil samples were determined through density bottle and it was found that the specific gravity of all soil samples lies between 2.55 to 2.70. The specific gravities of all soil are given in table no 4.1.

4.5 SOIL CLASSIFICATION

Soil samples were classified using the Unified Soil Classification System (USCS). Sand from Bagmati, Manohara and Bungmati sand have $C_u < 6$ and C_c for Bagmati and Manohara sand < 1 and for Bungmati sand > 1 so these sand are classified as SP as per USCS. As per USCS plasticity chart from annex Figure A1 to A4, Kalanki soil was classified as CL, Thimi soil as ML and OL, Luvu soil as CL, Matatirtha soil as

CL-ML. Kamerotar soil and Champi soil are non plastic in nature and more than 50% passes through 75 micron so they are classified as silts.

4.6 PERMEABILITY TEST

The permeability tests were conducted for nine soil sample from various location of Kathmandu valley, it was found that as the void ratio decrease coefficient of permeability also decreases and vice versa. Constant head test was done for soil from Manohara and Bagmati whereas falling head test was done for rest of all soil. The test results are shown in figure 4.8 to 4.13. From the test it was found that with variation of void ratio from 0.57 to 1.43 the coefficient of permeability of Kalanki soil varies from 4.19E-07 cm/sec to 1.02E-04 cm/sec. For Bagmati sand with variation of e from 0.61 to 0.87 k varies from 1.08-02 cm/sec to 1.12E-02 cm/sec. For Bungmati sand with variation of e from 0.62 to 1.04 k varies from 2.46E-04 cm/sec to 7.42E-03 cm/sec. For soil from Champi it was found that with variation of e from 0.76 to 1.19 k varies from 4.07E-06 cm/sec to 9.11E-05 cm/sec. For soil from Kamerotar with variation of e from 0.76 to 1.01 k varies from 8.94E-06 cm/sec to 3.22E-04 cm/sec. For Matatirtha soil it was found that with variation of e from 0.51 to 0.99 k varies from 1.27E-06 cm/sec to 5.67E-04 cm/sec. Similarly for Manohara sand it was found that with variation of e from 0.63 to 0.93 k varies from 7.96E-03 cm/sec to 1.50E-02 cm/sec. For Thimi soil with variation of e from 0.81 to 1.42 it was found k varies from 1.71E-07 cm/sec to 4.38E-05 cm/sec. Similarly for Luvu soil with variation of e from 0.18 to 1.18 k varies from 1.16E-07 cm/sec to 7.15E-05 cm/sec. The test results of the tested nine soil sample of Kathmandu valley are presented in table no 4.3.

Table no 4.3 Test result data of Kathmandu valley soils

Soil source	k_t (cm/sec)	void ratio (e)	temperature T^0C	k_{20}(cm/sec)
Bagmati Sand	1.18E-02	0.87	22	1.12E-02
	1.15E-02	0.66	22	1.09E-02
	1.13E-02	0.61	22	1.08E-02
Bungmati sand	8.92E-03	1.04	28	7.42E-03
	8.82E-03	0.89	27	7.50E-03
	7.38E-03	0.83	24	6.72E-03
	8.55E-04	0.76	20	8.55E-04
	4.56E-04	0.71	20	4.56E-04
	2.58E-04	0.62	22	2.46E-04
Champi soil	9.11E-05	1.19	20	9.11E-05
	1.56E-05	1.00	20	1.56E-05
	6.43E-06	0.88	20	6.43E-06
	4.07E-06	0.76	20	4.07E-06
Kalanki soil	8.95E-05	1.43	15	1.02E-04
	2.90E-05	1.17	17	3.12E-05
	4.78E-06	0.82	18	5.03E-06
	3.98E-07	0.57	18	4.19E-07
Kamerotar soil	3.63E-04	1.01	25	3.22E-04
	1.03E-04	0.91	30	8.20E-05
	1.59E-05	0.77	24	1.44E-05
	9.83E-06	0.76	24	8.94E-06
Matatirtha soil	6.67E-04	0.99	27	5.67E-04
	4.84E-04	0.96	27	4.12E-04
	2.05E-05	0.69	23	1.91E-05
	1.27E-06	0.51	20	1.27E-06
Manohara sand	1.17E-02	0.93	10.50	1.50E-02
	1.09E-02	0.83	10.50	1.40E-02
	8.44E-03	0.81	21.00	8.24E-03
	9.00E-03	0.76	22.00	8.58E-03
	1.08E-02	0.71	22.00	1.03E-02
	1.03E-02	0.69	10.50	1.33E-02
	8.55E-03	0.63	23.00	7.96E-03
Thimi soil	4.38E-05	1.42	20	4.38E-05
	6.23E-06	1.07	20	6.23E-06
	1.71E-07	0.81	20	1.71E-07
Luvu soil	8.22E-05	1.18	26	7.15E-05
	6.36E-05	0.98	24	5.79E-05
	1.27E-07	0.18	24	1.16E-07

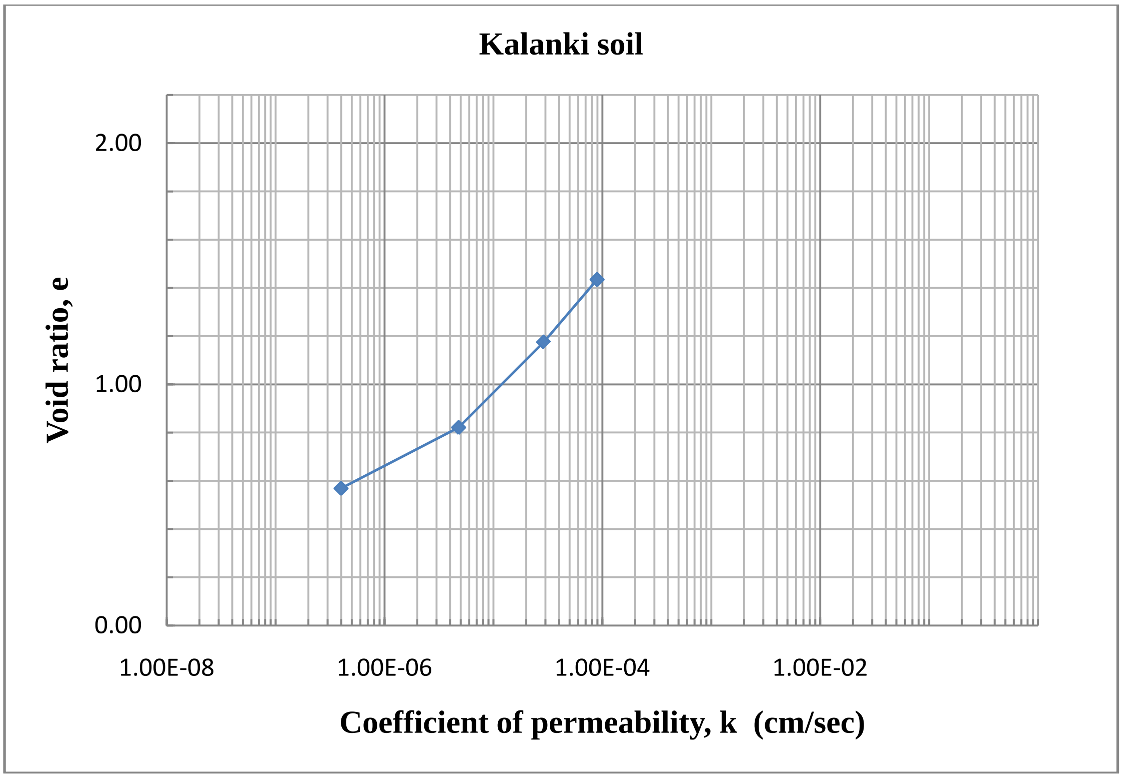

Fig 4.11 e versus k for Kalanki soil

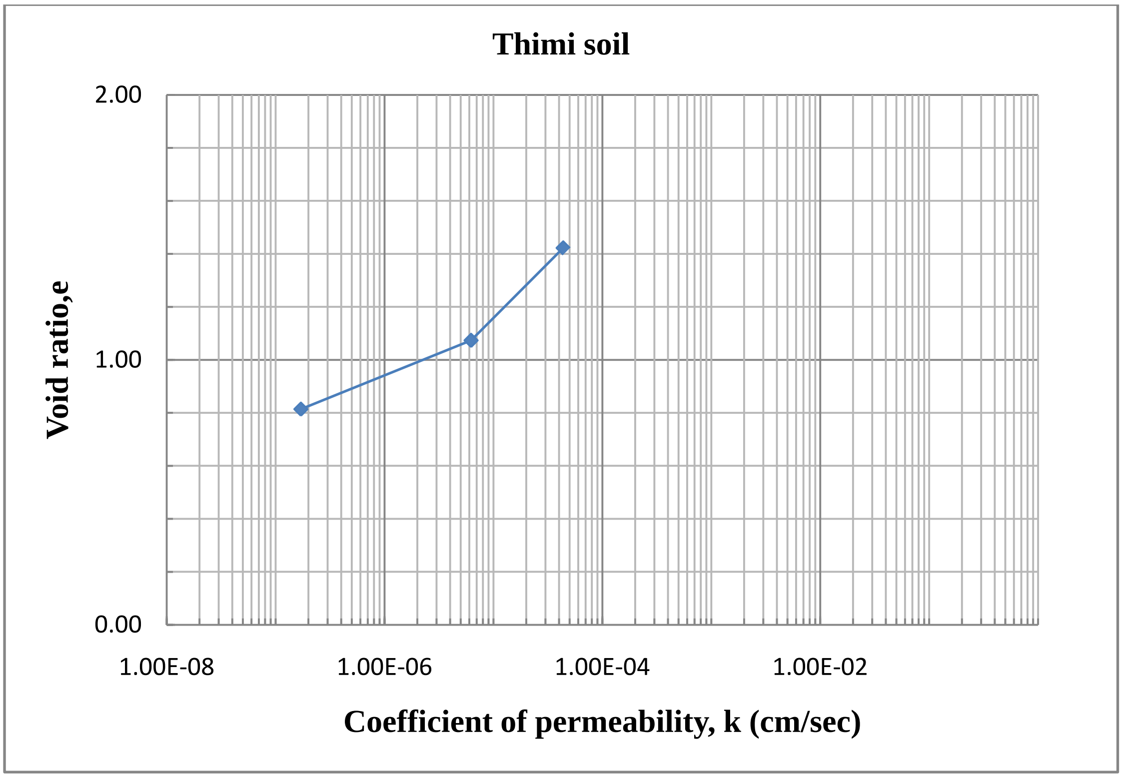

Fig 4.12 e versus k for Thimi soil

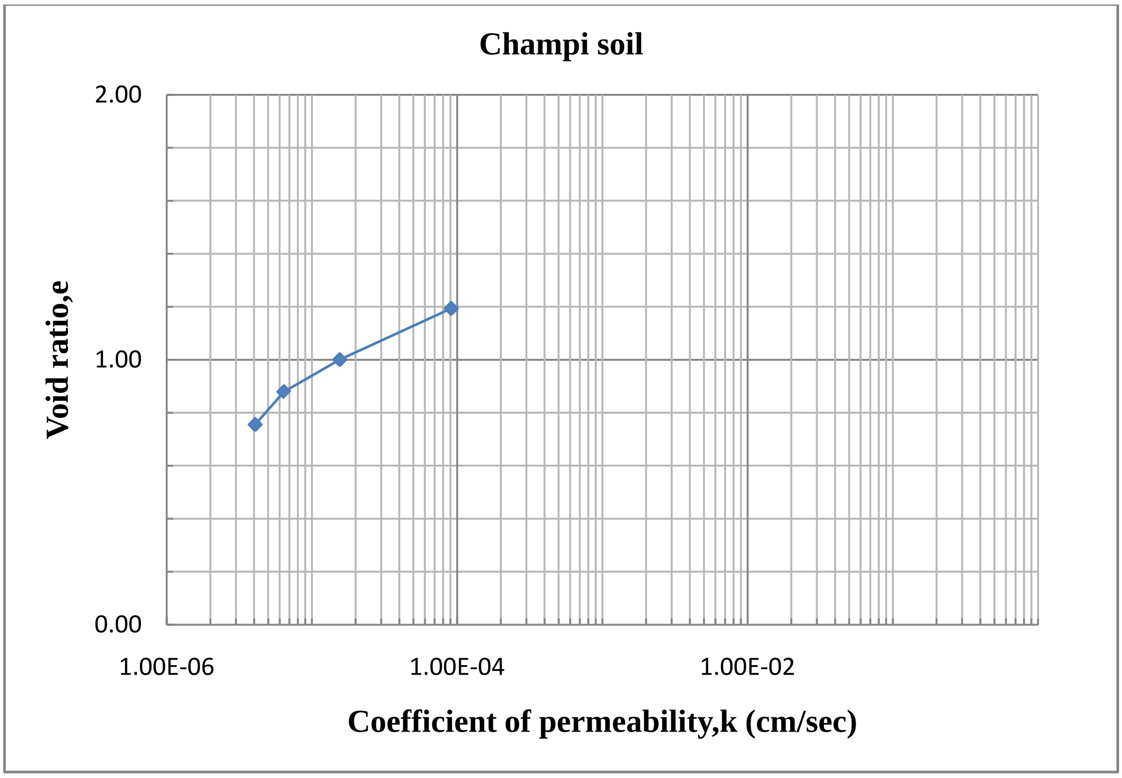

Fig 4.13 e versus k for Champi soil

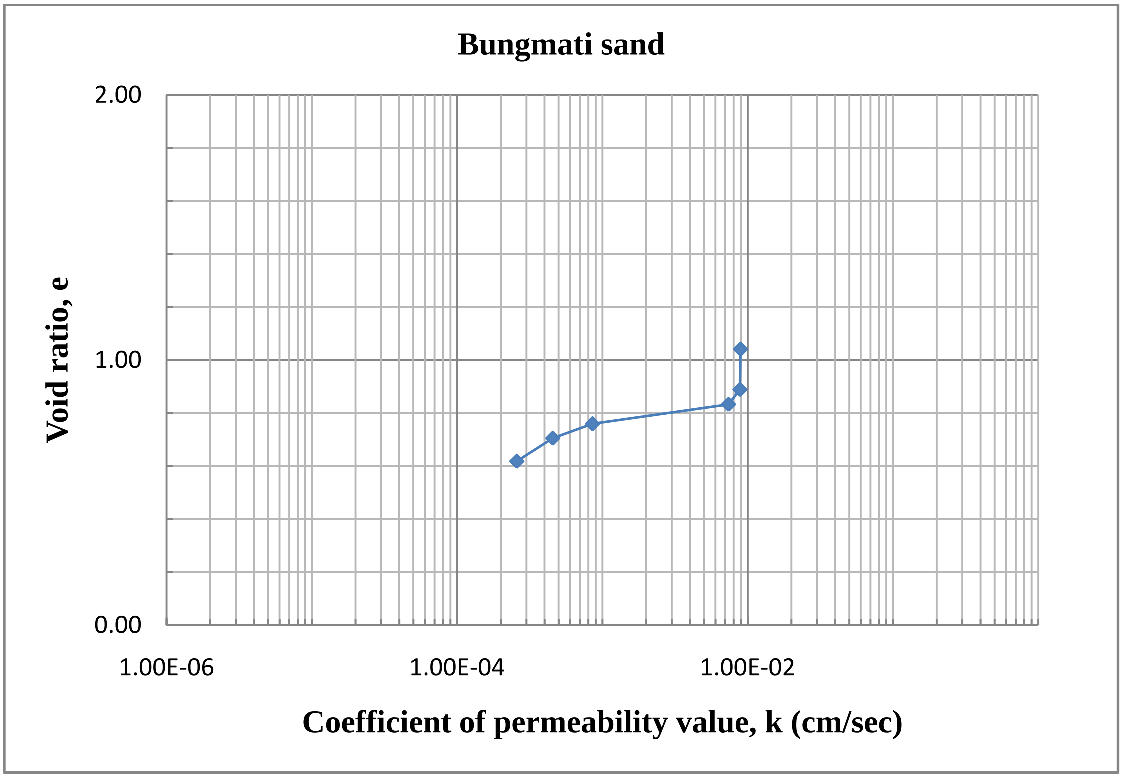

Fig 4.14 e versus k for Bungmati sand

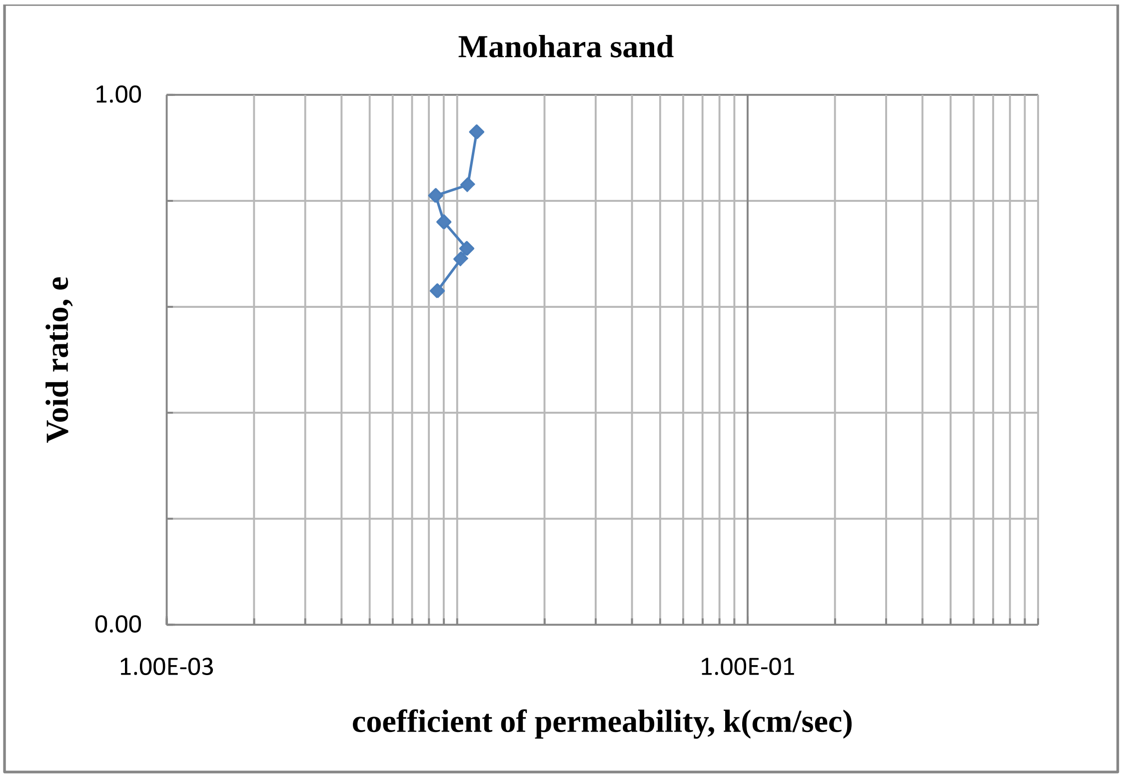

Fig 4.15 e versus k for Manohara sand

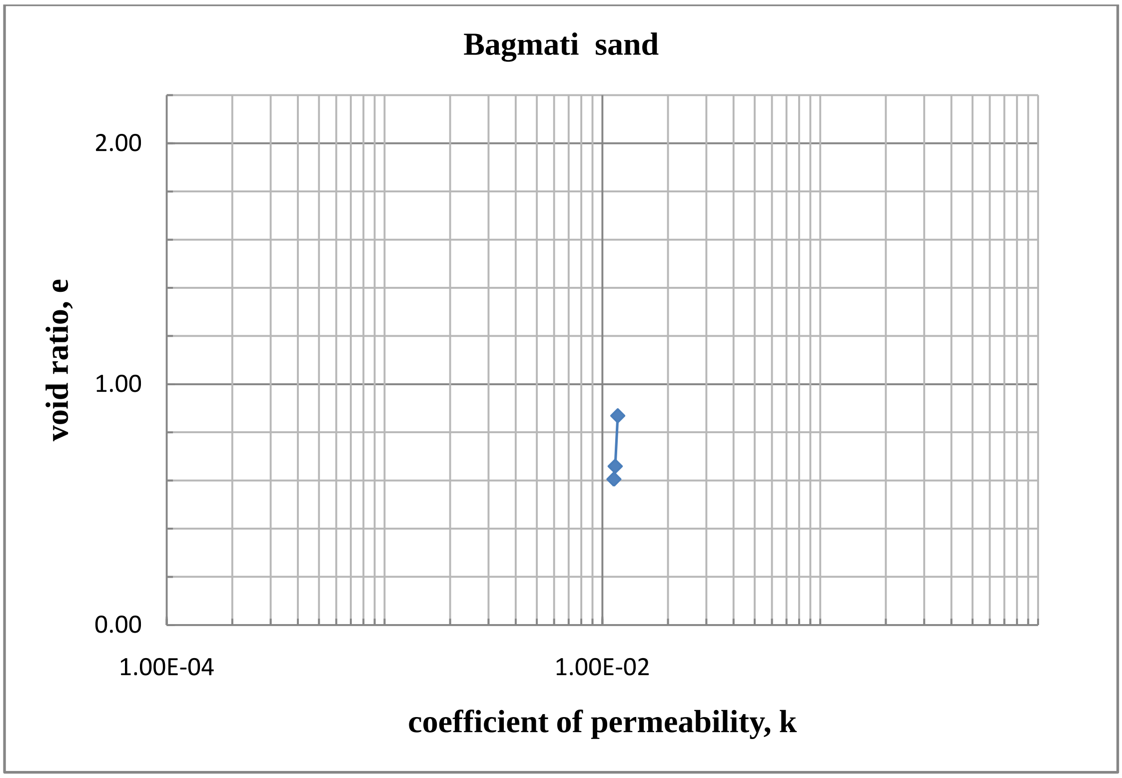

Fig 4.16e versus k for Bagmati sand

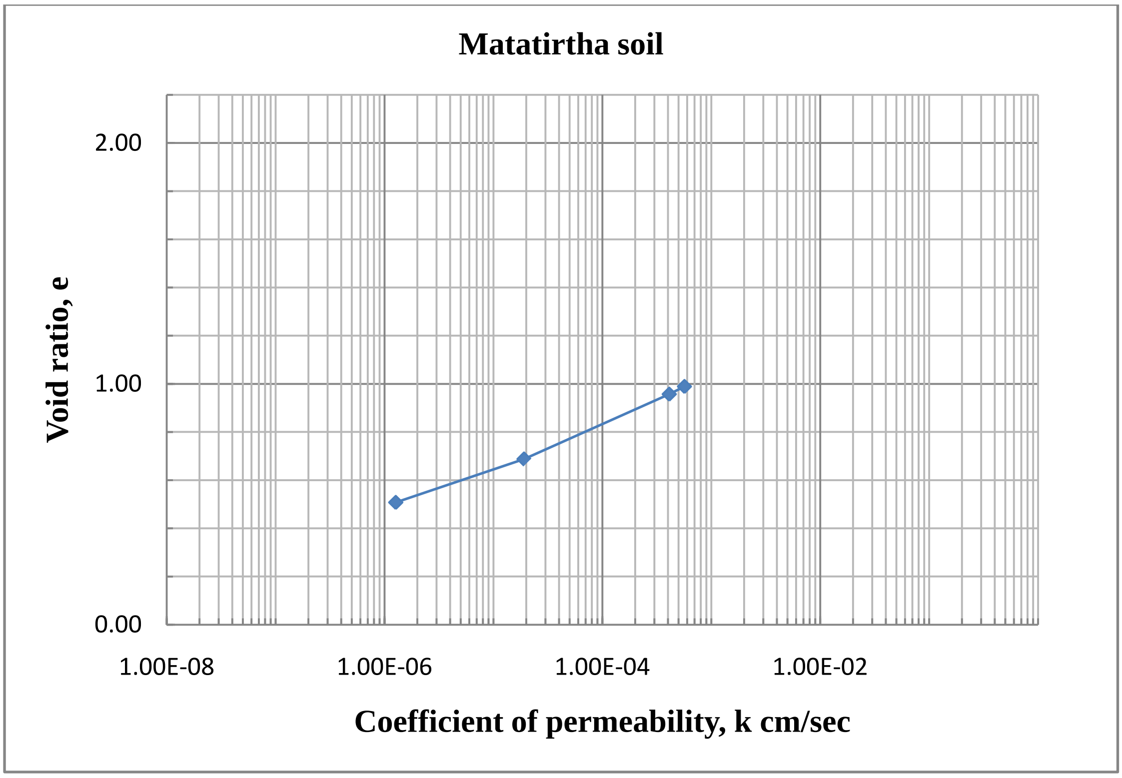

Fig 4.17 e versus k for Matatirtha soil

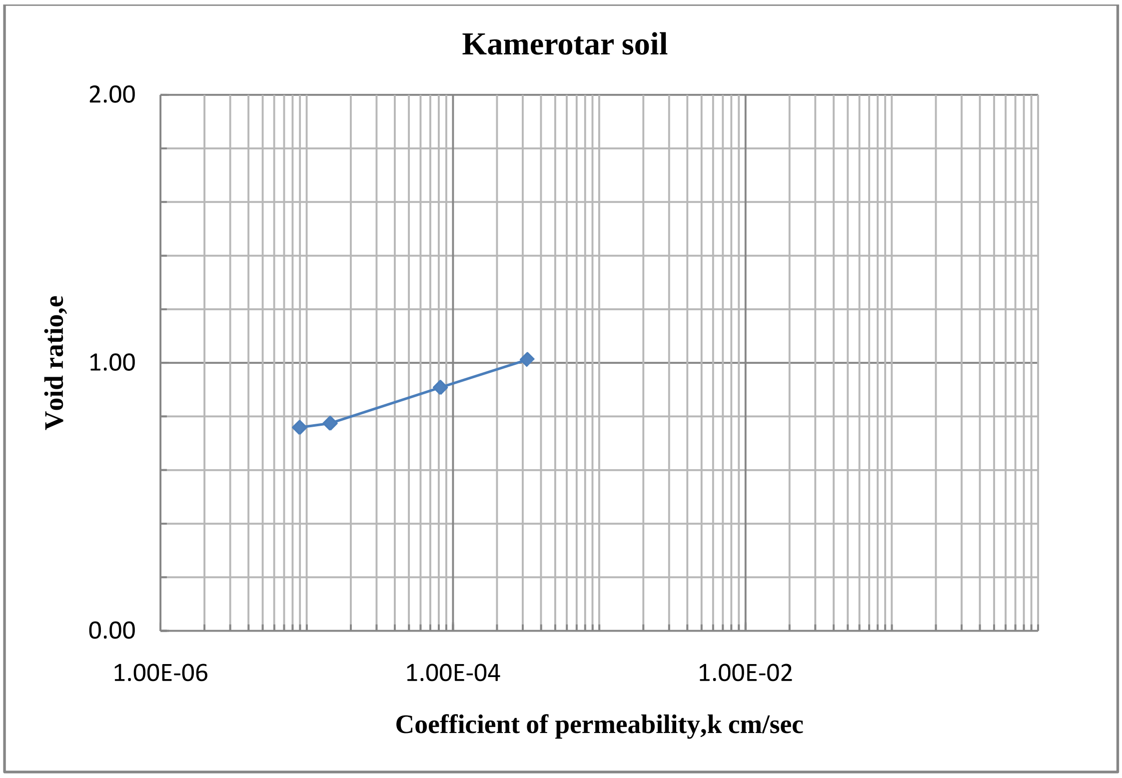

Fig 4.18 e versus k for Kamerotar soil

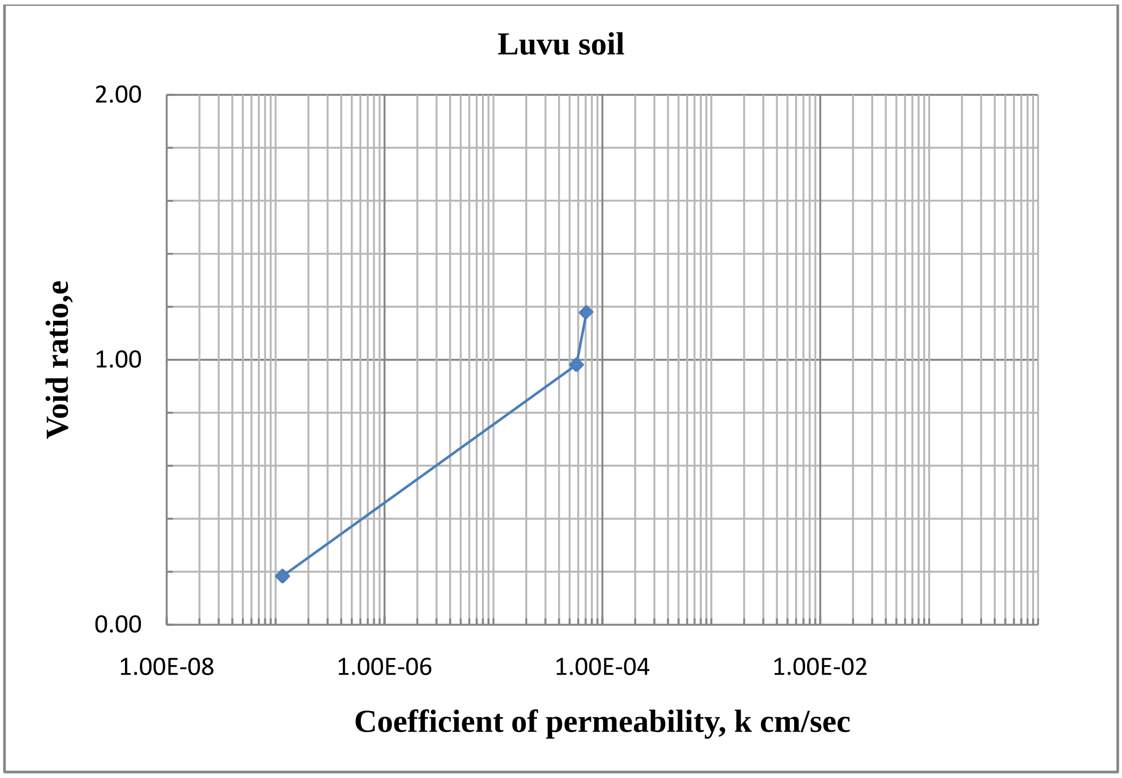

Fig 4.19 e versus k for Luvu soil

4.7 DIGITIZATION OF TEST RESULT FROM LITERATURE

The test result obtained from the literature of the Lambe and Whitman was first scanned and then the plot digitizer software was used to digitize the result. The output of the digitize test result is shown in Figure no 4.21. Comparision with my test result with the digitize lab test results are shown in Figure no 4.22.

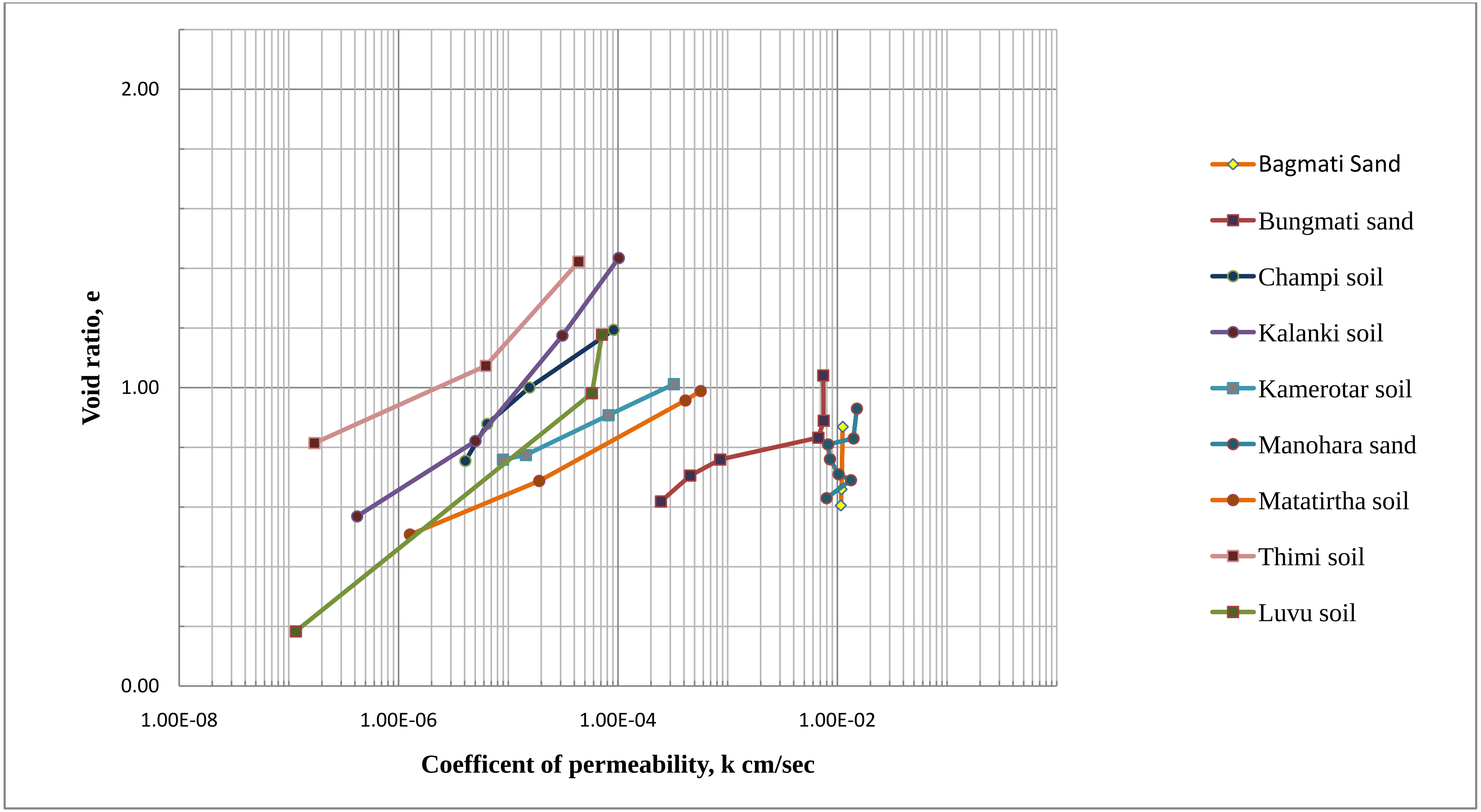

Fig 4.20 e versus k for Kathmandu valley soils

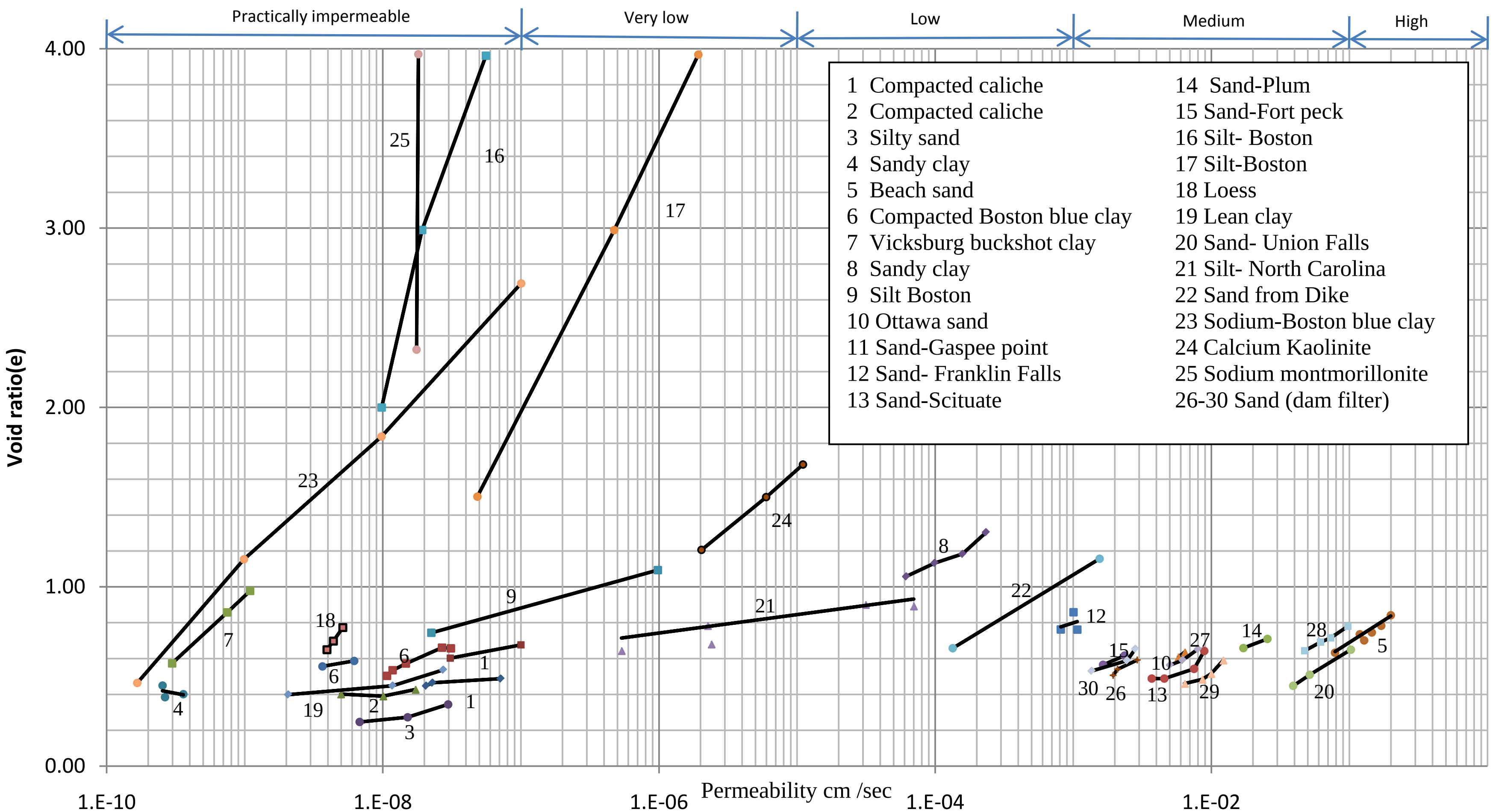

Fig no 4.21 Digitize Permeability Test data from literature of lambe and whitman

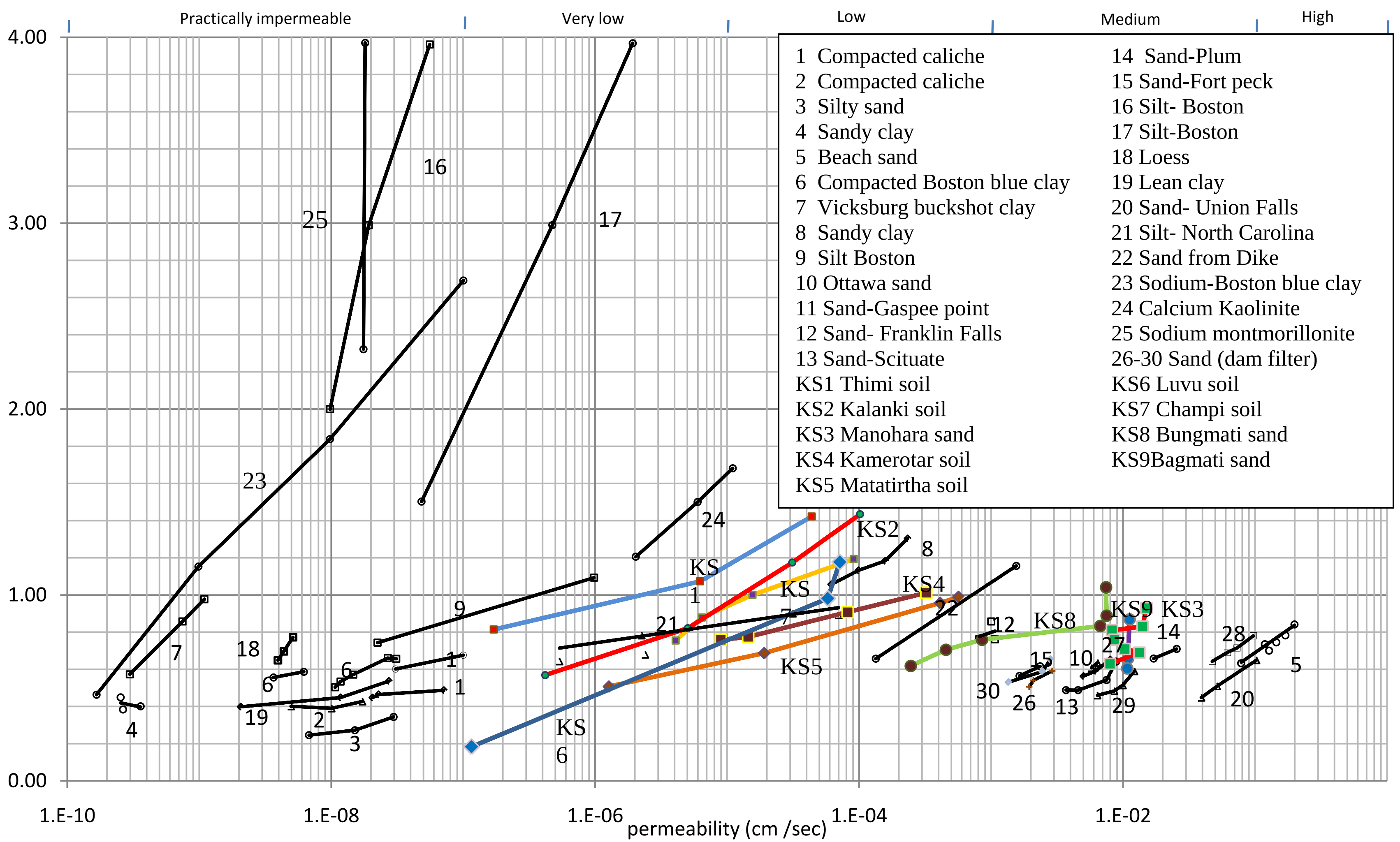

Fig 4.22 Comparison of e vs k of Kathmandu soils with test result from literature of lambe and Whitman

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the lab test on nine soils from Kathmandu valley it was found that sand from Bagmati, Bungmati and Manohara were classified as SP, Kalanki and Luvu soils were classified as CL, Thimi soil as ML and OL, Matatirtha soil as CL-ML and Kamerotar and Champi soil as ML. From permeability test conducted on the nine soils from Kathmandu valley and comparison with test result from literature of Lambe and Whitman some major conclusion driven are as follows;

- Coefficients of permeability of the Katmandu valley soil tested in this research were found to vary within the range of 10^{-2}cm/sec to 10^{-7}cm/sec.
- Coefficient of permeability of Kalanki soil was found to vary within the range of 10^{-6}cm/sec to 10^{-4} cm/sec.
- Coefficient of permeability of Thimi soil was found to vary within range of 10^{-6}cm/sec to 10^{-4}cm/sec.
- Coefficient of permeability of Champi soil was found to vary within the range of 10^{-5}cm/sec to 10^{-4}cm/sec.
- Coefficient of permeability of Matatirtha soil was found to vary within the range of 10^{-3}cm/sec to 10^{-6}cm/sec.
- Coefficient of permeability of Kamerotar soil was found to vary within the range of (10^{-4} cm/sec to 10^{-6}cm/sec.
- Coefficient of permeability of Luvu soil was found to vary within the range of 10^{-4}cm/sec to 10^{-7}cm/sec.
- Sand of Manohara and sand of Bagmati have similar gradation curve and the coefficient of permeability of these two sands was of similar nature within range of 10^{-2} cm/sec. Whereas sand of Bungmati was finer than these two sand which coefficient of permeability varies from 10^{-2} cm/sec to 10^{-4} cm/sec.
- The tested nine soil samples from Kathmandu valley as per classification from Terzaghi and Peck (1967) were classified as soil having very low permeability to medium permeability.
- Permeability Characteristics of Champi soil was found similar to that of Silt – North Carolina.

- Permeability characteristics of soil from Thimi, Champi, Matatirtha, Kalanki, Kamerotar and Luvu lies between the permeability characteristics of silt Boston to Sand from Dike.
- Sand from Bungmati has permeability characteristics similar to that of sand from Dike.
- Permeability characteristics of Sand from Manohara and Bagmati are similar to that of sand (dam filter). Both of these sand permeability characteristics lies close near to that of sand from Ottawa, Sand-Plum and Sand-Scituate.

5.2 RECOMMENDATION

This study can be further elaborate in respect to the following future research:

- Comparative study of Kathmandu valley soils with more no of soil and variety of soil.
- Study of other geotechnical properties of Kathmandu valleys soils and comparison with each other and other standard soil.
- Comparison of the permeability characteristics of sand from Katmandu valley with Ottawa sand.
- Variation of permeability characteristics of soil with molding water, degree of saturation.
- Effect of mixing in permeability characteristics of some selected soil from Kathmandu valley.
- Effect of dispersant in the permeability of Kathmandu valley soil.

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Annex

Table no A1a Gradation table Data of Kathmandu valley soil

Bagmati sand		Champi soil		Manohara sand		Kalanki soil		Thimi soil		Bungmati sand	
Dia mm	%passing	Dia mm	%passing	Dia mm	%passing	Dia mm	%passing	Dia mm	%passing	Dia mm	%passing
12.700	100.00	12.7000	100.00	12.700	100.00	12.7000	100.00	12.7000	100.00	12.700	100.00
9.500	100.00	9.5000	100.00	9.500	100.00	9.5000	100.00	9.5000	100.00	9.500	100.00
4.750	95.27	4.7500	96.49	4.750	99.11	4.7500	99.45	4.7500	99.67	4.750	99.64
2.000	88.04	2.0000	95.84	2.000	89.97	2.0000	99.35	2.0000	99.28	2.000	96.40
0.850	46.80	0.8500	94.58	0.850	44.21	0.8500	98.95	0.8500	97.75	0.850	80.49
0.425	19.84	0.4250	93.74	0.425	10.78	0.4250	98.59	0.4250	95.40	0.590	63.97
0.297	8.55	0.2970	92.69	0.297	2.30	0.2970	98.34	0.2970	93.30	0.425	40.63
0.150	3.78	0.1500	89.81	0.150	1.06	0.1500	97.75	0.1500	90.74	0.297	12.66
0.075	1.54	0.0750	73.79	0.075	0.91	0.0750	91.85	0.0750	85.08	0.150	6.20
		0.0603	49.22			0.0552	83.59	0.0724	79.62	0.075	3.05
		0.0463	37.50			0.0399	80.60	0.0380	74.13		
		0.0352	25.78			0.0289	77.62	0.0275	71.39		
		0.0299	18.75			0.0246	71.65	0.0234	65.90		
		0.0262	16.41			0.0233	56.72	0.0207	63.15		
		0.0189	9.38			0.0173	47.76	0.0154	54.91		
		0.0140	7.03			0.0130	35.82	0.0115	46.68		
		0.0099	4.69			0.0096	32.84	0.0086	41.19		
		0.0071	2.34			0.0070	26.87	0.0064	32.95		
		0.0050	0.00			0.0050	23.88	0.0046	27.46		
						0.0036	17.91	0.0034	19.22		
						0.0015	11.94	0.0007	5.49		

Table A1b Gradation Table of Different Soil of Kathmandu valley

Kamerotar soil		Matatirtha soil		Luvu soil	
Dia mm	%passing	Dia mm	%passing	Dia mm	%passing
12.7000	100.00	38.1000	100.00	12.7000	100.00
9.5000	100.00	25.4000	100.00	9.5000	100.00
4.7500	99.95	19.1000	99.08	4.7500	100.00
2.0000	99.75	12.7000	96.01	2.0000	99.71
0.8500	99.04	9.5000	92.85	0.8500	98.64
0.4250	98.74	4.7500	88.29	0.4250	97.81
0.2970	98.16	2.0000	86.22	0.2970	97.41
0.1500	92.89	0.8500	83.29	0.1500	97.06
0.0750	61.66	0.4250	82.20	0.0750	96.10
0.0689	55.46	0.2500	81.31	0.0496	91.70
0.0458	23.77	0.1500	79.99	0.0376	82.21
0.0341	15.85	0.0750	76.19	0.0277	75.89
0.0250	9.90	0.0512	71.81	0.0204	69.56
0.0181	5.94	0.0405	59.43	0.0152	60.08
0.0134	3.96	0.0298	54.48	0.0115	53.75
0.0095	1.98	0.0252	49.52	0.0086	41.11
0.0067	0.00	0.0222	47.05	0.0063	34.78
0.0048	0.00	0.0165	39.62	0.0045	25.30
0.0014	0.00	0.0126	32.19	0.0033	18.97
		0.0091	27.24	0.0014	12.65
		0.0066	22.29		
		0.0048	17.33		
		0.0034	14.86		
		0.0014	12.38		

Table A2a Specific Gravity Determination

soil source :	Champi soil		Kalanki soil		Manohara sand		Bagmati sand		Bungmati sand	
pycnometer no	3	10	12	13	3	10	14	12	12	13
wt of Pyc.+water +sample (W1)	167.63	171.39	174.16	172.05	174.03	165.30	175.85	174.33	174.10	172.11
Temprature	21.00	21.00	14.00	14.00	20.00	20.00	20.00	20.00	21.00	21.00
Wt of Pyc.+water (W2)	155.00	152.53	161.70	153.80	155.32	152.82	157.36	161.85	161.55	153.38
Net Dry Wt. of sample (Ws)	20.00	30.00	20.00	30.00	30.00	20.00	30.00	20.00	20.00	30.00
Specific gravity of water at T°C (Gt)	0.99802	0.99802	0.9993	0.9993	0.99823	0.99823	0.99823	0.99823	0.99802	0.99802
Specific gravity of solids (Gs)	2.71	2.69	2.65	2.55	2.65	2.65	2.60	2.65	2.68	2.66
average of two	**2.70**		**2.6**		**2.65**		**2.63**		**2.67**	

Table A2b Specific Gravity Determination

soil source :	Kamerotar soil		Luvu soil		Matatirtha soil			Thimi soil		
pycnometer no	7	8	14	12	8	6	7	10	13	14
wt of Pyc.+water +sample (W1)	183.43	173.70	169.39	180.12	179.46	174.73	195.65	171.44	172.16	169.63
Temprature	25	25	24	24	27	27	27	20	20	20
Wt of Pyc.+water (W2)	164.79	161.16	157.28	161.80	161.08	162.28	164.62	152.81	153.59	157.22
Net Dry Wt. of sample (Ws)	30.00	20.00	20.00	30.00	30.00	20.00	50.00	30.00	30.00	20
Specific gravity of water at T°C (Gt)	0.99708	0.99708	0.99733	0.99733	0.99655	0.99655	0.99655	0.99823	0.99823	0.99823
Specific gravity of solids (Gs)	2.63	2.67	2.54	2.56	2.57	2.62	2.62	2.63	2.62	2.63
average	**2.65**		**2.55**		**2.60**			**2.63**		

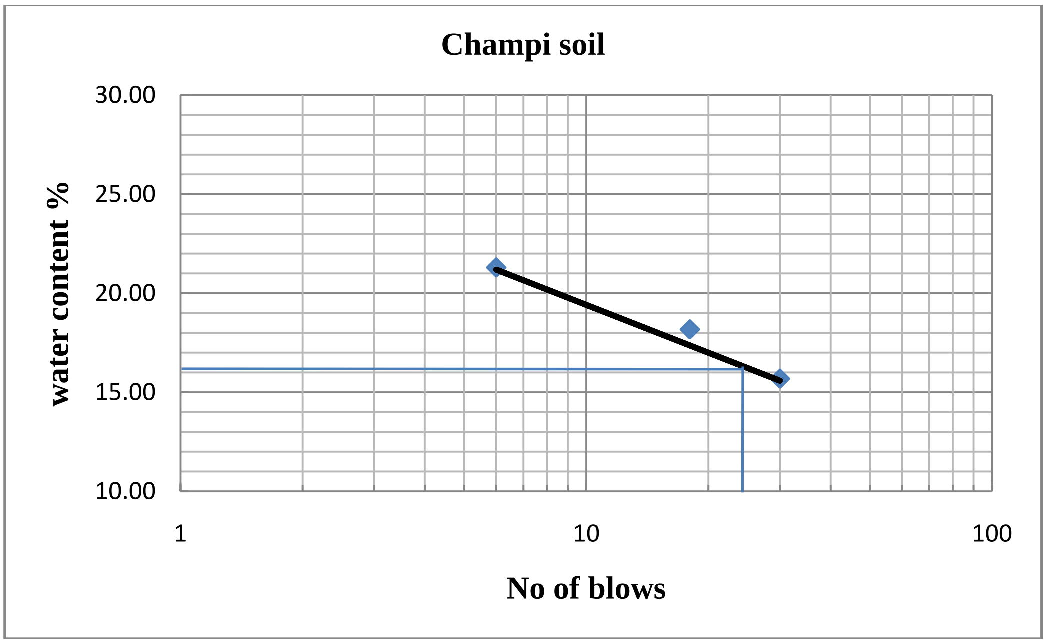

Figure A1: Determination of liquid limit of Champi soil

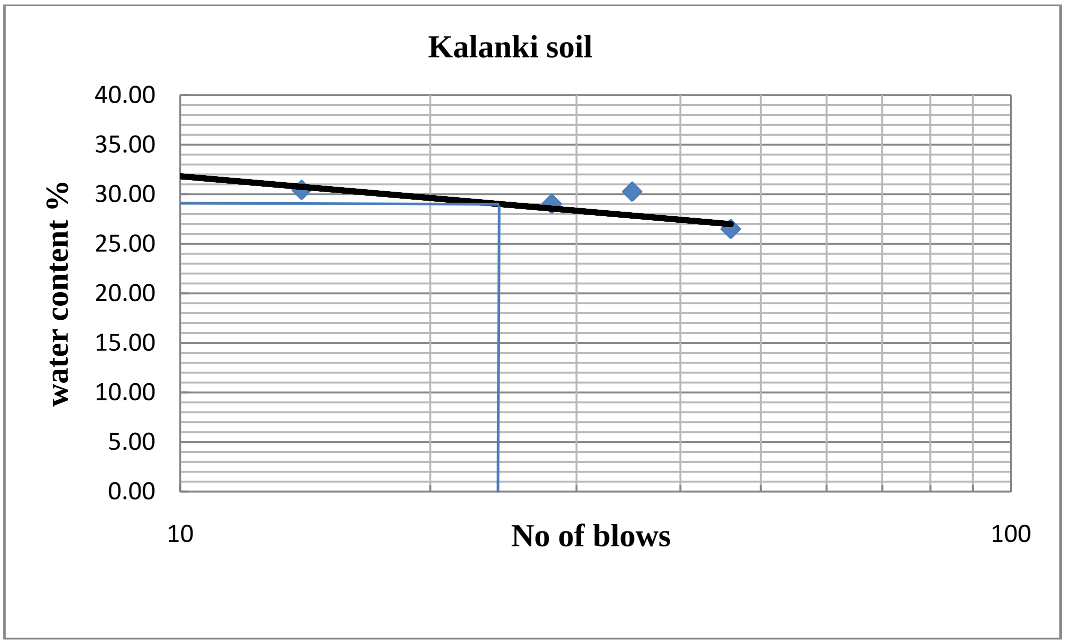

Figure A2: Determination of liquid limit of Kalanki soil

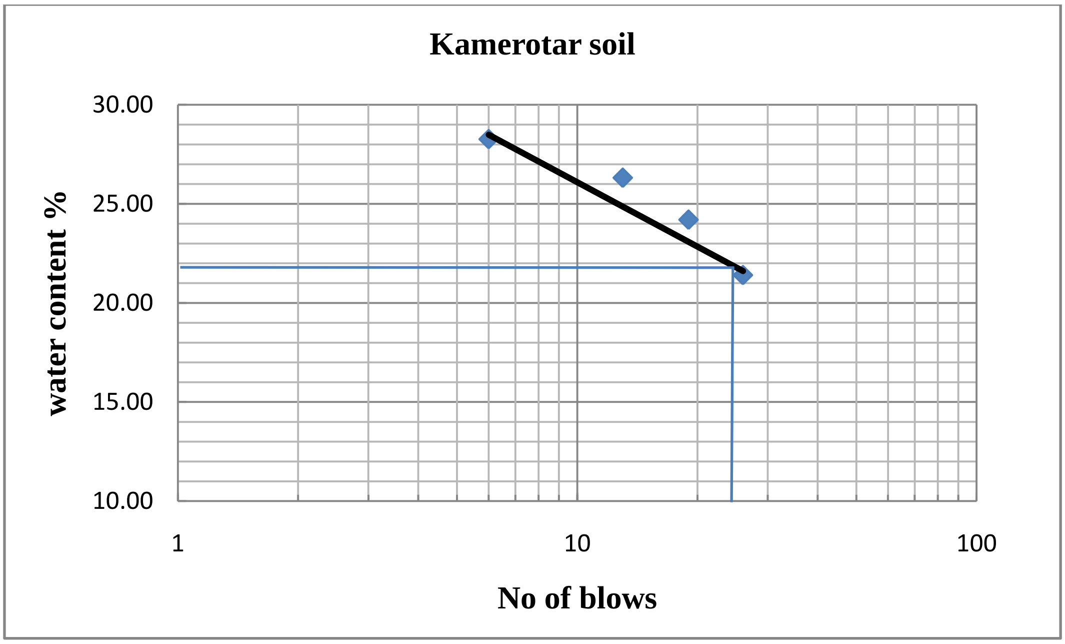

Figure A3: Determination of liquid limit of Kamerotar soil

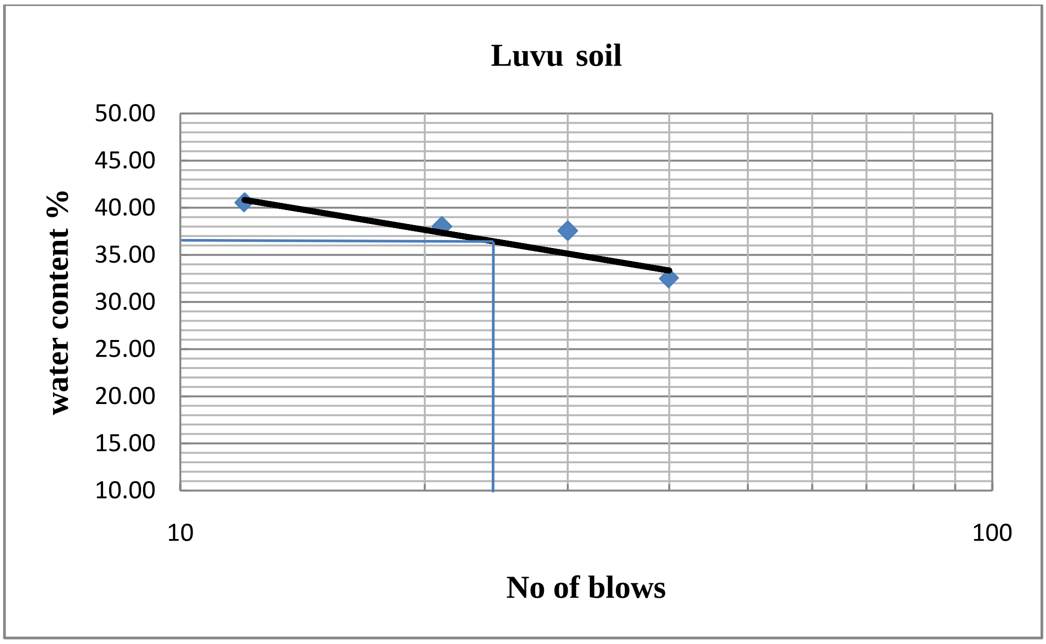

Figure A4: Determination of liquid limit of Luvu soil

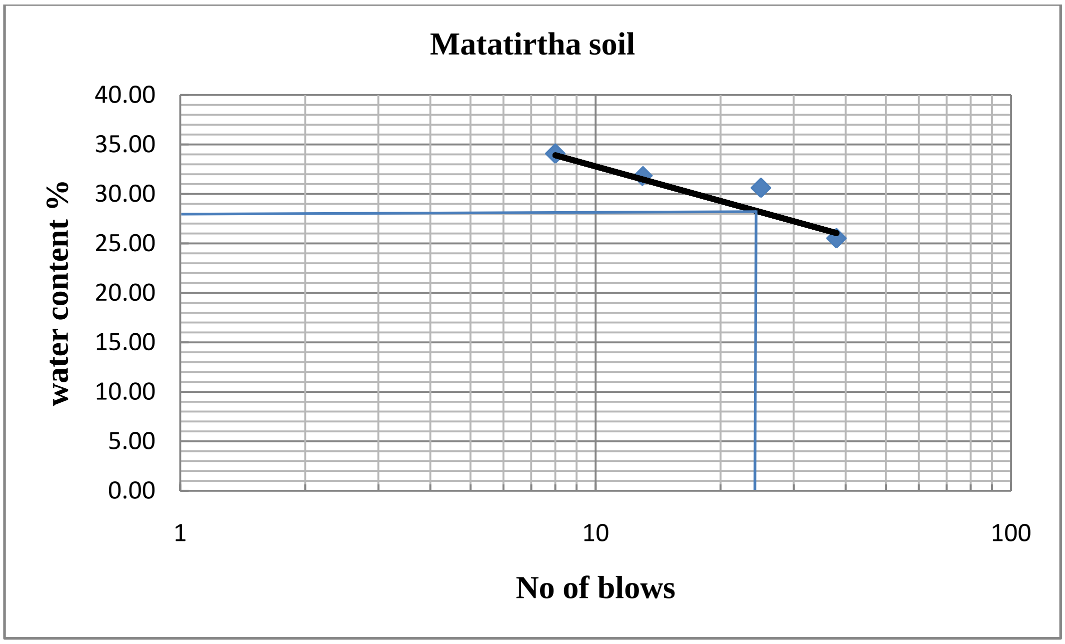

Figure A5: Determination of liquid limit of Matatirtha soil

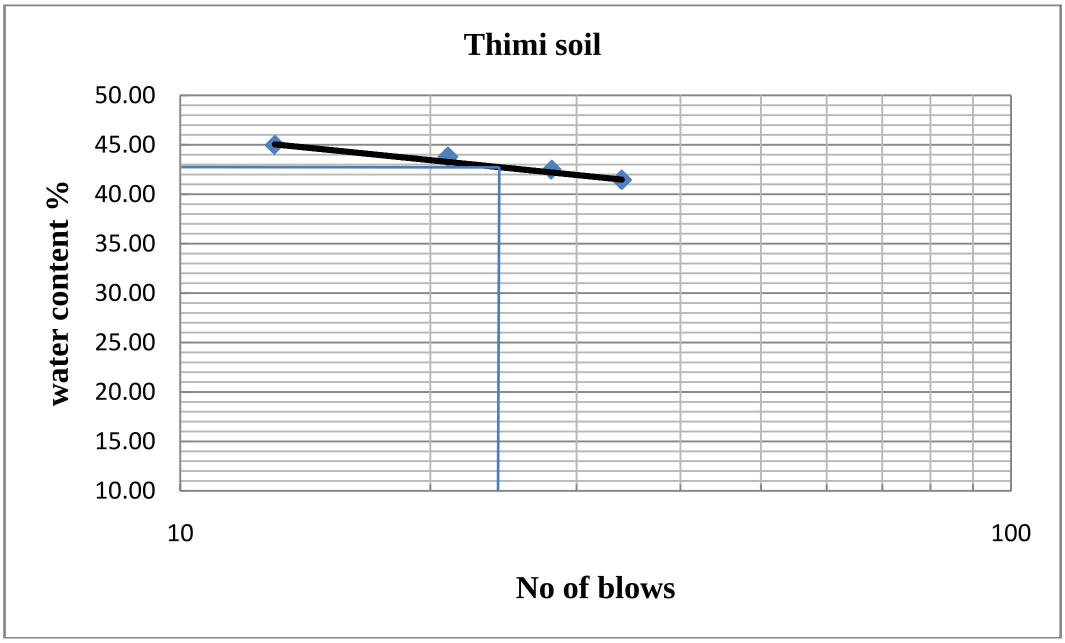

Figure A6: Determination of liquid limit of Thimi soil

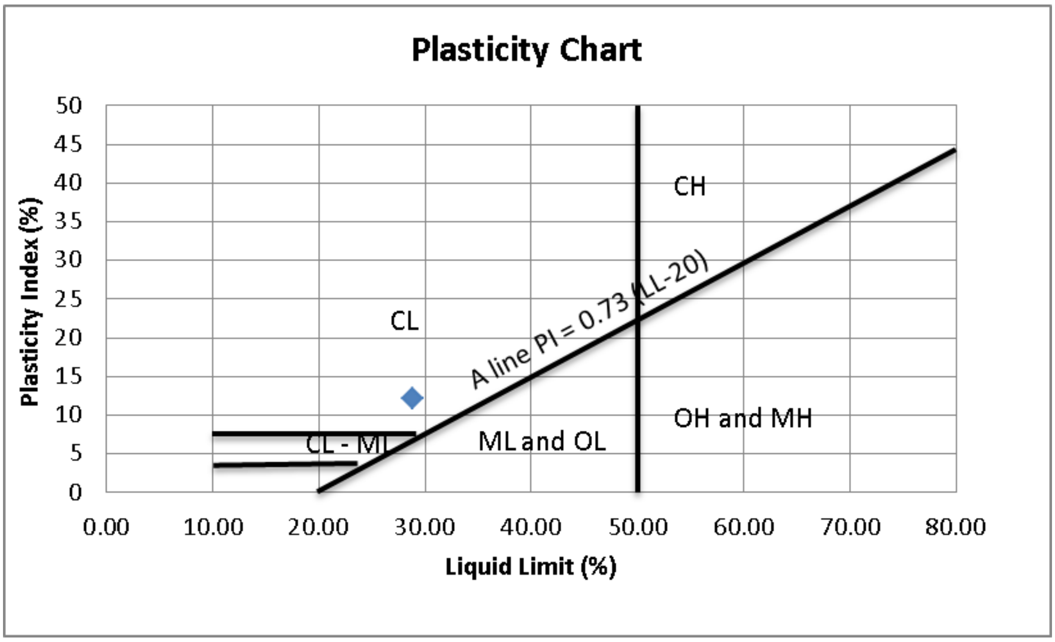

Fig A7: plasticity chart of Kalanki soil

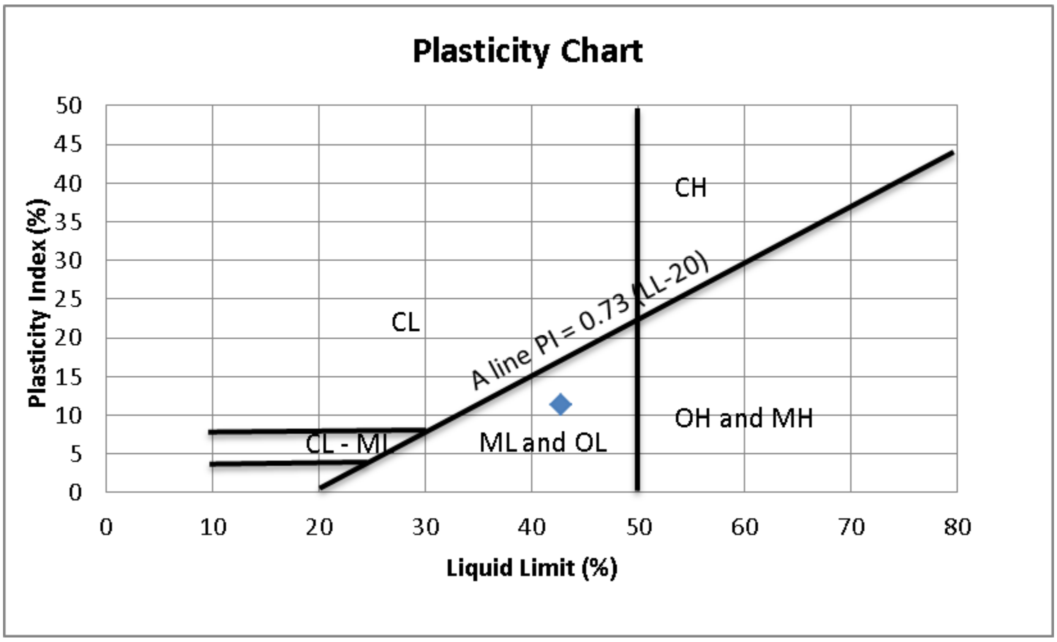

Fig A8: Plasticity chart of Thimi soil

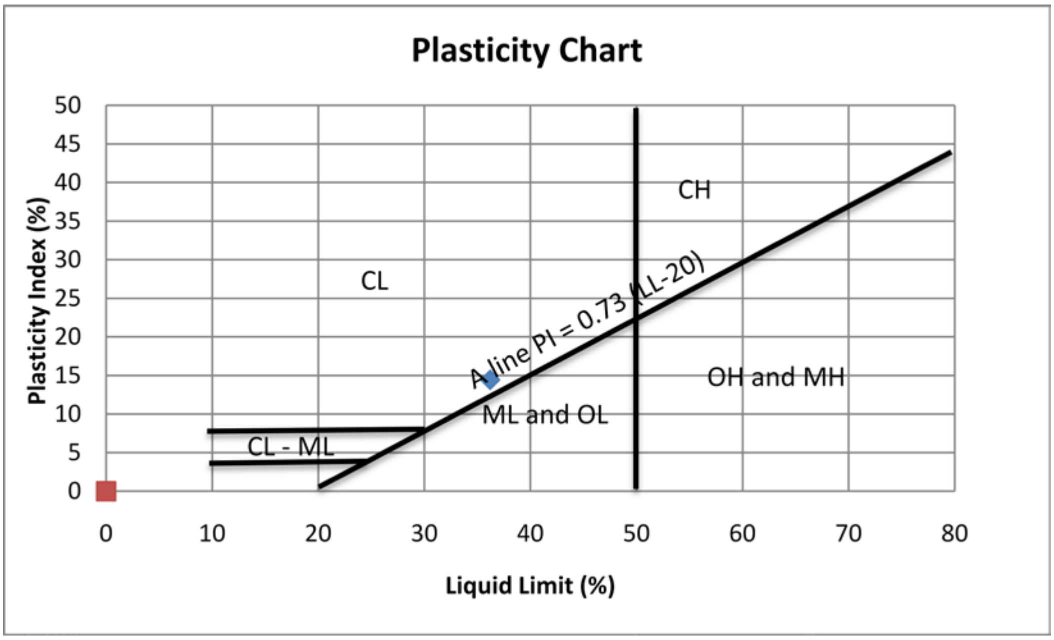

Fig A9: Plasticity chart of Luvu soil

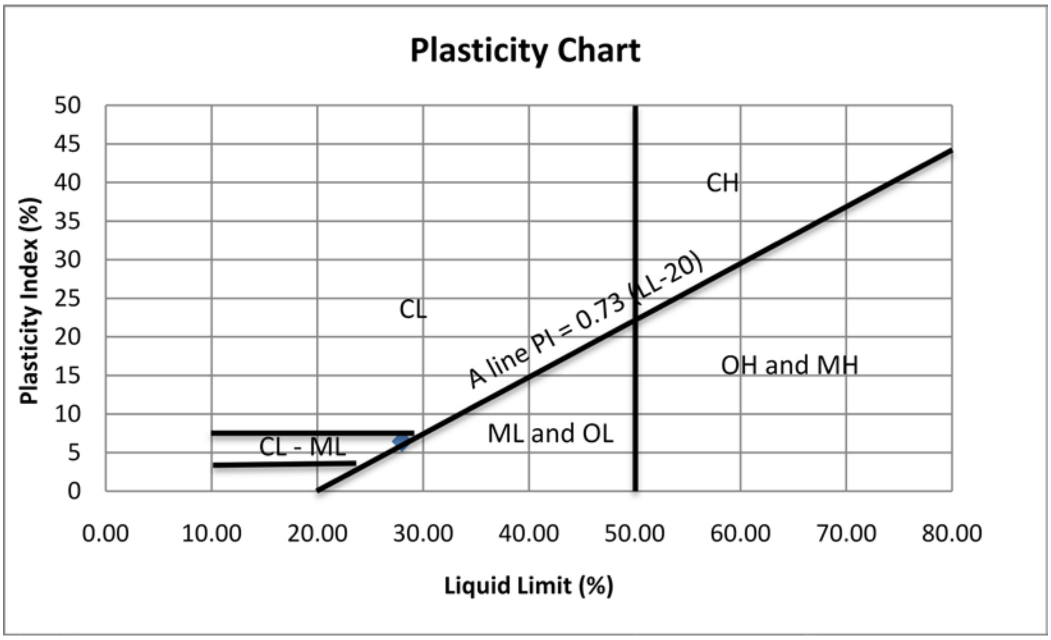

Fig A10: Plasticity chart of Matatirtha soil

Permeability test data of different Kathmandu valley soil

Soil source: Kalanki soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		15.00	15.00	15.00	
water content (%)					
	can no	37.00	182.00	216.00	
	wt of can (gm)	33.00	10.83	26.63	
	wt of can +wet soil (gm)	72.55	16.87	71.79	
	wt of can + dry soil (gm)	66.92	15.96	65.30	
	wt of dry soil(gm)	33.92	5.13	38.67	
	wt of water (gm)	5.63	0.91	6.49	avg
	water content (%)	0.17	0.18	0.17	**0.17**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8080.00	8080.00	8080.00
2	mass of mould +base plate+ soil	9905.00	9905.00	9905.00
3	initial head, h1(cm)	124.00	121.00	103.00
4	final head, h2 (cm)	86.80	84.80	73.10
5	head sqrt(h1*h2) (cm)	103.75	101.30	86.77
6	timeinterval			
	h1 to sqrt(h1*h2)			
	sqrt(h1*h2) to h2			
	h1 to h2 (sec)	90070.00	80280.00	84060.00
7	mass of soil(gm)	1825.00	1825.00	1825.00
8	bulk density, ρ=mass/volume	1.96	1.96	1.96
9	dry density ,ρd=ρ/(1+w) gm/cc	1.68	1.68	1.68
10	void ratio,e=G ρw/ρd -1	0.57	0.57	0.57
11	k=2.3al/Atlog10(h1/h2)	3.80E-07	4.25E-07	3.91E-07
		avg k	3.98E-07	cm/sec

Soil source : Kalanki soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		17.00	17.00	17.00	
water content (%)					
	can no	1.00	RKc2	15.00	
	wt of can (gm)	15.00	17.70	18.16	
	wt of can +wet soil (gm)	36.05	72.25	84.29	
	wt of can + dry soil (gm)	33.25	63.08	73.28	
	wt of dry soil(gm)	18.25	45.38	55.12	
	wt of water (gm)	2.80	9.17	11.01	avg
	water content (%)	0.15	0.20	0.20	**0.19**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8080.00	8080.00	
2	mass of mould +base plate+ soil	9672.00	9672.00	
3	initial head, h1(cm)	123.00	98.00	
4	final head, h2 (cm)	98.00	78.00	
5	head sqrt(h1*h2) (cm)	109.79	87.43	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	1806.00	2460.00	
	sqrt(h1*h2) to h2 (sec)	2404.00	2520.00	
	h1 to h2 (sec)	4210.00	4980.00	
7	mass of soil(gm)	1592.00	1592.00	
8	bulk density, ρ=mass/volume	1.71	1.71	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.44	1.44	
10	void ratio,e=G ρw/ρd -1	0.82	0.82	
11	k=2.3al/Atlog10(h1/h2)	5.17E-06	4.39E-06	
		avg k	**4.78E-06**	cm/sec

Soil source : Kalanki soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		18.00	18.00	18.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8925.00	8925.00	8925.00
2	mass of mould +base plate+ soil	10050.00	10050.00	10050.00
3	initial head, h1(cm)	108.00	108.00	108.00
4	final head, h2 (cm)	78.00	78.00	78.00
5	head sqrt(h1*h2) (cm)	91.78	91.78	91.78
6	timeinterval			
	h1 to sqrt(h1*h2)	523.00	510.00	535.00
	sqrt(h1*h2) to h2	544.00	553.00	568.00
	h1 to h2 (sec)	1067.00	1063.00	1103.00
7	mass of soil(gm)	1125.00	1125.00	1125.00
8	bulk density, ρ=mass/volume	1.21	1.21	1.21
9	dry density ,ρd=ρ/(1+w) gm/cc	1.21	1.21	1.21
10	void ratio,e=G ρw/ρd -1	1.17	1.17	1.17
11	k=2.3al/Atlog10(h1/h2)	2.92E-05	2.94E-05	2.83E-05
		avg k	**2.90E-05**	cm/sec

Soil source: Kalanki soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		18.00	18.00	18.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8925.00	8925.00	8925.00
2	mass of mould +base plate+ soil	9930.00	9930.00	9930.00
3	initial head, h1(cm)	108.00	108.00	108.00
4	final head, h2 (cm)	78.00	78.00	78.00
5	head sqrt(h1*h2) (cm)	91.78	91.78	91.78
6	timeinterval			
	h1 to sqrt(h1*h2)	169.00	167.00	174.00
	sqrt(h1*h2) to h2	172.00	180.00	184.00
	h1 to h2 (sec)	341.00	347.00	358.00
7	mass of soil(gm)	1005.00	1005.00	1005.00
8	bulk density, ρ=mass/volume	1.08	1.08	1.08
9	dry density ,ρd=ρ/(1+w) gm/cc	1.08	1.08	1.08
10	void ratio,e=G ρw/ρd -1	1.43	1.43	1.43
11	k=2.3al/Atlog10(h1/h2)	9.15E-05	8.99E-05	8.72E-05
		avg k	**8.95E-05**	cm/sec

Soil source: Matatirtha soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		27.00	27.00	27.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8910.00	8910.00	8910.00
2	mass of mould +base plate+ soil	10140.00	10140.00	10140.00
3	initial head, h1(cm)	103.00		
4	final head, h2 (cm)	73.00		
5	head sqrt(h1*h2) (cm)	86.71	0.00	0.00
6	timeinterval			
	h1 to sqrt(h1*h2)	24.52		
	sqrt(h1*h2) to h2	24.98		
	h1 to h2 (sec)	49.50		
7	mass of soil(gm)	1230.00	1230.00	1230.00
8	$bulk\ density, \rho = mass/volume$	1.32	1.32	1.32
9	dry density ,$\rho d = \rho/(1+w)$ gm/cc	1.32	1.32	1.32
10	void ratio,e=$G\ \rho w/\rho d\ -1$	0.99	0.99	0.99
11	$k=2.3al/At\log10(h1/h2)$	6.67E-04		
		avg k	6.67E-04	cm/sec

Soil source: Matatirtha soil

length of specimen(cm)		10.95	10.95	10.95	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		859.58	859.58	859.58	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		27.00	27.00	27.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8910.00	8910.00	8910.00
2	mass of mould +base plate+ soil	10065.00	10065.00	10065.00
3	initial head, h1(cm)	103.00		
4	final head, h2 (cm)	73.00		
5	head sqrt(h1*h2) (cm)	86.71	0.00	0.00
6	timeinterval			
	h1 to sqrt(h1*h2)	31.00		
	sqrt(h1*h2) to h2	32.00		
	h1 to h2 (sec)	63.00		
7	mass of soil(gm)	1155.00	1155.00	1155.00
8	*bulk density*, ρ=*mass*/*volume*	1.34	1.34	1.34
9	dry density ,$\rho d=\rho/(1+w)$ gm/cc	1.34	1.34	1.34
10	void ratio,$e=G\ \rho w/\rho d\ -1$	0.96	0.96	0.96
11	$k=2.3al/At\log 10(h1/h2)$	4.84E-04		
		avg k	4.84E-04	cm/sec

Soil source : Matatirtha soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		23.00	23.00	23.00	
water content (%)					
	can no	Rit	5A		
	wt of can (gm)	17.90	17.65		
	wt of can +wet soil (gm)	68.16	90.67		
	wt of can + dry soil (gm)	62.75	83.20		
	wt of dry soil(gm)	44.85	65.55		
	wt of water (gm)	5.41	7.47		avg
	water content (%)	0.12	0.11		**0.12**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8700.00	8700.00	
2	mass of mould +base plate+ soil	10320.00	10320.00	
3	initial head, h1(cm)	123.00	123.00	
4	final head, h2 (cm)	54.20	98.00	
5	head sqrt(h1*h2) (cm)	81.65	109.79	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)			
	sqrt(h1*h2) to h2 (sec)			
	h1 to h2 (sec)	4200.00	975.00	
7	mass of soil(gm)	1620.00	1620.00	
8	*bulk density*, $\rho = mass/volume$	1.74	1.74	
9	dry density , $\rho d = \rho/(1+w)$ gm/cc	1.56	1.56	
10	void ratio, $e = G\ \rho w/\rho d\ -1$	0.69	0.69	
11	$k = 2.3al/At \log10(h1/h2)$	1.87E-05	2.23E-05	
		avg k	**2.05E-05**	cm/sec

Soil source : Matatirtha soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	84.00	266.00		
	wt of can (gm)	16.79	34.01		
	wt of can +wet soil (gm)	64.46	95.75		
	wt of can + dry soil (gm)	57.72	87.25		
	wt of dry soil(gm)	40.93	53.24		
	wt of water (gm)	6.74	8.50		avg
	water content (%)	0.16	0.16		**0.16**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8700.00	8700.00	
2	mass of mould +base plate+ soil	10590.00	10590.00	
3	initial head, h1(cm)	132.00	111.90	
4	final head, h2 (cm)	108.00	95.70	
5	head sqrt(h1*h2) (cm)	119.40	103.48	
6	timeinterval			
	h1 to sqrt(h1*h2)			
	sqrt(h1*h2) to h2			
	h1 to h2 (sec)	12420.00	15120.00	
7	mass of soil(gm)	1890.00	1890.00	
8	$bulk\ density$, $\rho = mass/volume$	2.03	2.03	
9	dry density ,$\rho d = \rho/(1+w)$ gm/cc	1.74	1.74	
10	void ratio,$e = G\ \rho w/\rho d\ -1$	0.51	0.51	
11	$k = 2.3al/At \log10(h1/h2)$	1.55E-06	9.92E-07	
		avg k	**1.27E-06**	cm/sec

Soil source: Thimi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8910.00	8910.00	8910.00
2	mass of mould +base plate+ soil	9920.00	9920.00	9920.00
3	initial head, h1(cm)	93.00	93.00	93.00
4	final head, h2 (cm)	63.00	63.00	63.00
5	head sqrt(h1*h2) (cm)	76.54	76.54	76.54
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	391.00	404.00	419.00
	sqrt(h1*h2) to h2 (sec)	436.00	451.00	579.00
	h1 to h2 (sec)	827.00	855.00	880.00
7	mass of soil(gm)	1010.00	1010.00	1010.00
8	*bulk density*, $\rho = mass/volume$	1.09	1.09	1.09
9	dry density , $\rho d = \rho/(1+w)$ gm/cc	1.09	1.09	1.09
10	void ratio,e= $G\ \rho w/\rho d\ -1$	1.42	1.42	1.42
11	$k = 2.3al/At \log 10(h1/h2)$	4.52E-05	4.37E-05	4.24E-05
		avg k	**4.38E-05**	cm/sec

Soil source : Kalanki soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		17.00	17.00	17.00	
water content (%)					
	can no	1.00	RKc2	15.00	
	wt of can (gm)	15.00	17.70	18.16	
	wt of can +wet soil (gm)	36.05	72.25	84.29	
	wt of can + dry soil (gm)	33.25	63.08	73.28	
	wt of dry soil(gm)	18.25	45.38	55.12	
	wt of water (gm)	2.80	9.17	11.01	avg
	water content (%)	0.15	0.20	0.20	**0.19**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8080.00	8080.00	
2	mass of mould +base plate+ soil	9672.00	9672.00	
3	initial head, h1(cm)	123.00	98.00	
4	final head, h2 (cm)	98.00	78.00	
5	head sqrt(h1*h2) (cm)	109.79	87.43	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	1806.00	2460.00	
	sqrt(h1*h2) to h2 (sec)	2404.00	2520.00	
	h1 to h2 (sec)	4210.00	4980.00	
7	mass of soil(gm)	1592.00	1592.00	
8	bulk density, ρ=mass/volume	1.71	1.71	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.44	1.44	
10	void ratio,e=G ρw/ρd -1	0.82	0.82	
11	k=2.3al/Atlog10(h1/h2)	5.17E-06	4.39E-06	
		avg k	**4.78E-06**	cm/sec

soil source: Thimi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8910.00	8910.00	
2	mass of mould +base plate+ soil	10090.00	10090.00	
3	initial head, h1(cm)	108.00	108.00	
4	final head, h2 (cm)	78.00	78.00	
5	head sqrt(h1*h2) (cm)	91.78	91.78	
6	timeinterval			
	h1 to sqrt(h1*h2)	2450.00		
	sqrt(h1*h2) to h2	2546.00		
	h1 to h2 (sec)	4996.00	5014.00	
7	mass of soil(gm)	1180.00	1180.00	
8	*bulk density*, ρ=*mass*/*volume*	1.27	1.27	
9	dry density ,ρ*d*=ρ/(1+*w*) gm/cc	1.27	1.27	
10	void ratio,e=*G* ρ*w*/ρ*d* −1	1.07	1.07	
11	*k*=2.3*al*/*At*log10(h1/h2)	6.25E-06	6.22E-06	
		avg k	**6.23E-06**	cm/sec

soil source: Thimi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.63	2.63	2.63	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	RKC9	10.00		
	wt of can (gm)	17.49	16.36		
	wt of can +wet soil (gm)	47.95	37.13		
	wt of can + dry soil (gm)	42.60	33.93		
	wt of dry soil(gm)	25.11	17.57		
	wt of water (gm)	5.35	3.20		avg
	water content (%)	0.21	0.18		**0.20**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8095.00	8095.00	
2	mass of mould +base plate+ soil	9710.00	9710.00	
3	initial head, h1(cm)	107.50	109.00	
4	final head, h2 (cm)	90.30	85.00	
5	head sqrt(h1*h2) (cm)			
6	timeinterval			
	h1 to sqrt(h1*h2)			
	sqrt(h1*h2) to h2			
	h1 to h2 (sec)	81540.00	174960.00	
7	mass of soil(gm)	1615.00	1615.00	
8	$bulk\ density, \rho=mass/volume$	1.74	1.74	
9	dry density ,$\rho d=\rho/(1+w)$ gm/cc	1.45	1.45	
10	void ratio,$e=G\ \rho w/\rho d\ -1$	0.81	0.81	
11	$k=2.3al/At\log10(h1/h2)$	2.05E-07	1.36E-07	
		avg k	**1.71E-07**	cm/sec

Soil source: Luvu soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.54	2.54	2.54	
tempreature °C		26.00	26.00	26.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	
1	mass of mould +base plate(gm)	8910.00	8910.00	
2	mass of mould +base plate+ soil	9995.00	9995.00	
3	initial head, h1(cm)	103.00	93.00	
4	final head, h2 (cm)	73.00	63.00	
5	head sqrt(h1*h2) (cm)	86.71	76.54	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	196.00	217.00	
	sqrt(h1*h2) to h2 (sec)	211.00	231.00	
	h1 to h2 (sec)	407.00	448.00	
7	mass of soil(gm)	1085.00	1085.00	
8	$bulk\ density, \rho = mass/volume$	1.17	1.17	
9	dry density ,$\rho d = \rho/(1+w)$ gm/cc	1.17	1.17	
10	void ratio,e=$G\ \rho w/\rho d\ -1$	1.18	1.18	
11	$k=2.3al/At\log10(h1/h2)$	8.11E-05	8.34E-05	
		avg k	**8.22E-05**	cm/sec

soil source: luvu soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.54	2.54	2.54	
tempreature °C		24.00	24.00	24.00	
water content (%)					
	can no	266.00	RB10		
	wt of can (gm)	17.49	16.13		
	wt of can +wet soil (gm)	98.50	130.40		
	wt of can + dry soil (gm)	90.66	116.34		
	wt of dry soil(gm)	73.17	100.21		
	wt of water (gm)	7.84	14.06		avg
	water content (%)	0.11	0.14		**0.12**

sn no	**observation and calculation**	**test set**			
		1.00	**2.00**	**3.00**	
1	mass of mould +base plate(gm)	8910.00	8910.00		
2	mass of mould +base plate+ soil	10250.00	10250.00		
3	initial head, h1(cm)	107.50	109.00		
4	final head, h2 (cm)	90.30	85.00		
5	head sqrt(h1*h2) (cm)				
6	timeinterval				
	h1 to sqrt(h1*h2)				
	sqrt(h1*h2) to h2				
	h1 to h2 (sec)	398.00	280.00		
7	mass of soil(gm)	1340.00	1340.00		
8	$bulk\ density, \rho = mass/volume$	1.44	1.44		
9	dry density ,$\rho d = \rho/(1+w)$ gm/cc	1.28	1.28		
10	void ratio,$e = G\ \rho w/\rho d\ -1$	0.98	0.98		
11	$k = 2.3al/At \log 10(h1/h2)$	4.20E-05	8.52E-05		
		avg k	**6.36E-05**	cm/sec	

soil source: Luvu soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.54	2.54	2.54	
tempreature °C		24.00	24.00	24.00	
water content (%)					
	can no	RB10	P8	13.00	
	wt of can (gm)	16.13	18.27	15.53	
	wt of can +wet soil (gm)	93.72	106.60	92.60	
	wt of can + dry soil (gm)	83.66	94.90	82.72	
	wt of dry soil(gm)	67.53	76.63	67.19	
	wt of water (gm)	10.06	11.70	9.88	avg
	water content (%)	0.15	0.15	0.15	**0.15**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8095.00	8095.00	
2	mass of mould +base plate+ soil	10390.00	10390.00	
3	initial head, h1(cm)	131.00	131.00	
4	final head, h2 (cm)	116.70	116.70	
5	head sqrt(h1*h2) (cm)			
6	timeinterval			
	h1 to sqrt(h1*h2)			
	sqrt(h1*h2) to h2			
	h1 to h2 (sec)	87120.00	87120.00	
7	mass of soil(gm)	2295.00	2295.00	
8	$bulk\ density, \rho=mass/volume$	2.47	2.47	
9	dry density ,$\rho d=\rho/(1+w)$ gm/cc	2.15	2.15	
10	void ratio,$e=G\ \rho w/\rho d\ -1$	0.18	0.18	
11	$k=2.3al/At\log10(h1/h2)$	1.27E-07	1.27E-07	
		avg k	**1.27E-07**	cm/sec

soil source: Luvu soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.54	2.54	2.54	
tempreature °C		24.00	24.00	24.00	
water content (%)					
	can no	RB10	P8	13.00	
	wt of can (gm)	16.13	18.27	15.50	
	wt of can +wet soil (gm)	72.22	105.43	82.56	
	wt of can + dry soil (gm)	61.89	89.16	70.55	
	wt of dry soil(gm)	45.76	70.89	55.05	
	wt of water (gm)	10.33	16.27	12.01	avg
	water content (%)	0.23	0.23	0.22	**0.22**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8095.00	8095.00	
2	mass of mould +base plate+ soil	10555.00	10555.00	
3	initial head, h1(cm)	119.50	119.50	
4	final head, h2 (cm)	115.90	115.90	
5	head sqrt(h1*h2) (cm)			
6	timeinterval			
	h1 to sqrt(h1*h2)			
	sqrt(h1*h2) to h2			
	h1 to h2 (sec)	173820.00	173820.00	
7	mass of soil(gm)	2460.00	2460.00	
8	*bulk density*, ρ=*mass*/*volume*	2.64	2.64	
9	dry density ,$\rho d=\rho/(1+w)$ gm/cc	2.16	2.16	
10	void ratio,$e=G\ \rho w/\rho d\ -1$	0.18	0.18	
11	$k=2.3al/At\log10(h1/h2)$	1.69E-08	1.69E-08	
		avg k	**1.69E-08**	cm/sec

soil source: Kamerotar soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		25.00	25.00	25.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8910.00	8910.00	8910.00
2	mass of mould +base plate+ soil	10140.00	10140.00	10140.00
3	initial head, h1(cm)	103.00	103.00	103.00
4	final head, h2 (cm)	73.00	73.00	73.00
5	head sqrt(h1*h2) (cm)	86.71	86.71	86.71
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	45.00		
	sqrt(h1*h2) to h2 (sec)	46.00		
	h1 to h2 (sec)	91.00		
7	mass of soil(gm)	1230.00		
8	bulk density, ρ=mass/volume	1.32	0.00	0.00
9	dry density ,ρd=ρ/(1+w) gm/cc	1.32	0.00	0.00
10	void ratio,e=G ρw/ρd -1	1.01		
11	k=2.3al/Atlog10(h1/h2)	3.63E-04		
		avg k	**3.63E-04**	cm/sec

Soil source: Kamerotar soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		30.00	30.00	30.00	
water content (%)					
	can no	13.00	RB10	266.00	
	wt of can (gm)	15.48	16.12	34.03	
	wt of can +wet soil (gm)	61.03	59.88	83.49	
	wt of can + dry soil (gm)	57.08	56.04	79.25	
	wt of dry soil(gm)	41.60	39.92	45.22	
	wt of water (gm)	3.95	3.84	4.24	avg
	water content (%)	0.09	0.10	0.09	**0.09**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	
2	mass of mould +base plate+ soil	10340.00	10340.00	
3	initial head, h1(cm)	103.00	103.00	
4	final head, h2 (cm)	73.00	73.00	
5	head sqrt(h1*h2) (cm)			
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	155.00		
	sqrt(h1*h2) to h2 (sec)	166.00		
	h1 to h2 (sec)	321.00		
7	mass of soil(gm)	1420.00	1420.00	
8	bulk density, ρ=mass/volume	1.53	1.53	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.39	1.39	
10	void ratio,e=G ρw/ρd -1	0.91	0.91	
11	k=2.3al/Atlog10(h1/h2)	1.03E-04		
		avg k	**1.03E-04**	cm/sec

Soil source: Kamerotar soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		24.00	24.00	24.00	
water content (%)					
	can no	13.00	RB10	266.00	
	wt of can (gm)	15.48	16.12	34.03	
	wt of can +wet soil (gm)	75.54	68.25	107.47	
	wt of can + dry soil (gm)	67.69	61.38	97.23	
	wt of dry soil(gm)	52.21	45.26	63.20	
	wt of water (gm)	7.85	6.87	10.24	avg
	water content (%)	0.15	0.15	0.16	**0.15**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	
2	mass of mould +base plate+ soil	10530.00	10530.00	
3	initial head, h1(cm)	123.00	123.00	
4	final head, h2 (cm)	93.00	93	
5	head sqrt(h1*h2) (cm)	106.95	106.95	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	495		
	sqrt(h1*h2) to h2 (sec)	513.00		
	h1 to h2 (sec)	1008.00	5198.00	
7	mass of soil(gm)	1610.00	1610.00	
8	bulk density, ρ=mass/volume	1.73	1.73	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.50	1.50	
10	void ratio,e=G ρw/ρd -1	0.77	0.77	
11	k=2.3al/Atlog10(h1/h2)	2.66E-05	5.16E-06	
		avg k	**1.59E-05**	cm/sec

soil source: Kamerotar soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		24.00	24.00	24.00	
water content (%)					
	can no	13.00	RB10	266.00	
	wt of can (gm)	15.48	16.12	34.03	
	wt of can +wet soil (gm)	73.01	70.77	100.79	
	wt of can + dry soil (gm)	63.73	62.45	90.09	
	wt of dry soil(gm)	48.25	46.33	56.06	
	wt of water (gm)	9.28	8.32	10.70	avg
	water content (%)	0.19	0.18	0.19	**0.18**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	
2	mass of mould +base plate+ soil	10580.00	10580.00	
3	initial head, h1(cm)	123.00	123.00	
4	final head, h2 (cm)	103.00	103.00	
5	head sqrt(h1*h2) (cm)	112.56	112.56	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)			
	sqrt(h1*h2) to h2 (sec)			
	h1 to h2 (sec)	1731.00		
7	mass of soil(gm)	1660.00	1660.00	
8	bulk density, ρ=mass/volume	1.78	1.78	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.51	1.51	
10	void ratio,e=G ρw/ρd -1	0.76	0.76	
11	k=2.3al/Atlog10(h1/h2)	9.83E-06		
		avg k	**9.83E-06**	cm/sec

soil source: Champi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.70	2.70	2.70	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no				
	wt of can (gm)				
	wt of can +wet soil (gm)				
	wt of can + dry soil (gm)				
	wt of dry soil(gm)				
	wt of water (gm)				avg
	water content (%)				**0.00**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8910.00	8910.00	8910.00
2	mass of mould +base plate+ soil	10055.00	10055.00	10055.00
3	initial head, h1(cm)	108.00	108.00	108.00
4	final head, h2 (cm)	78.00	78.00	78.00
5	head sqrt(h1*h2) (cm)	91.78	91.78	91.78
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	162.00	172.00	175.00
	sqrt(h1*h2) to h2 (sec)	168.00	172.00	179.00
	h1 to h2 (sec)	330.00	344.00	354.00
7	mass of soil(gm)	1145.00	1145.00	1145.00
8	*bulk density*, ρ=*mass*/*volume*	1.23	1.23	1.23
9	dry density ,ρ*d*=ρ/(1+*w*) gm/cc	1.23	1.23	1.23
10	void ratio,e=G ρw/ρd -1	1.19	1.19	1.19
11	k=2.3al/Atlog10(h1/h2)	9.45E-05	9.07E-05	8.81E-05
		avg k	**9.11E-05**	cm/sec

Soil source: Champi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.70	2.70	2.70	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	10.00	15.00	P8	
	wt of can (gm)	16.38	18.15	18.22	
	wt of can +wet soil (gm)	80.47	86.25	110.25	
	wt of can + dry soil (gm)	66.19	71.18	89.66	
	wt of dry soil(gm)	49.81	53.03	71.44	
	wt of water (gm)	14.28	15.07	20.59	avg
	water content (%)	0.29	0.28	0.29	**0.29**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8095.00	8095.00	
2	mass of mould +base plate+ soil	9710.00	9710.00	
3	initial head, h1(cm)	108.00	108.00	
4	final head, h2 (cm)	78.00	78.00	
5	head sqrt(h1*h2) (cm)			
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	980.00	990.00	
	sqrt(h1*h2) to h2 (sec)	995.00	1046.00	
	h1 to h2 (sec)	1975.00	2036.00	
7	mass of soil(gm)	1615.00	1615.00	
8	bulk density, ρ=mass/volume	1.74	1.74	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.35	1.35	
10	void ratio,e=G ρw/ρd -1	1.00	1.00	
11	k=2.3al/Atlog10(h1/h2)	1.58E-05	1.53E-05	
		avg k	**1.56E-05**	cm/sec

Soil source: Champi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.70	2.70	2.70	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	H7	P5	33.00	
	wt of can (gm)	15.06	15.79	17.09	
	wt of can +wet soil (gm)	68.01	67.31	65.92	
	wt of can + dry soil (gm)	57.68	57.09	56.60	
	wt of dry soil(gm)	42.62	41.30	39.51	
	wt of water (gm)	10.33	10.22	9.32	avg
	water content (%)	0.24	0.25	0.24	**0.24**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	
2	mass of mould +base plate+ soil	10580.00	10580.00	
3	initial head, h1(cm)	120.00	87.60	
4	final head, h2 (cm)	87.60	62.6	
5	head sqrt(h1*h2) (cm)	102.53	74.05	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)			
	sqrt(h1*h2) to h2 (sec)			
	h1 to h2 (sec)	4530.00	5198.00	
7	mass of soil(gm)	1660.00	1660.00	
8	bulk density, ρ=mass/volume	1.78	1.78	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.44	1.44	
10	void ratio,e=G ρw/ρd -1	0.88	0.88	
11	k=2.3al/Atlog10(h1/h2)	6.66E-06	6.20E-06	
		avg k	**6.43E-06**	cm/sec

soil source: Champi soil

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.70	2.70	2.70	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	P8	10.00	15.00	
	wt of can (gm)	18.59	16.76	18.58	
	wt of can +wet soil (gm)	70.46	74.39	62.68	
	wt of can + dry soil (gm)	61.90	64.70	55.46	
	wt of dry soil(gm)	43.31	47.94	36.88	
	wt of water (gm)	8.56	9.69	7.22	avg
	water content (%)	0.20	0.20	0.20	**0.20**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	
2	mass of mould +base plate+ soil	10635.00	10635.00	
3	initial head, h1(cm)	119.00	108.00	
4	final head, h2 (cm)	94.00	78.00	
5	head sqrt(h1*h2) (cm)	105.76	91.78	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)		3750.00	
	sqrt(h1*h2) to h2 (sec)		3778.00	
	h1 to h2 (sec)	5659.00	7528.00	
7	mass of soil(gm)	1715.00	1715.00	
8	bulk density, ρ=mass/volume	1.84	1.84	
9	dry density ,ρd=ρ/(1+w) gm/cc	1.54	1.54	
10	void ratio,e=G ρw/ρd -1	0.76	0.76	
11	k=2.3al/Atlog10(h1/h2)	4.00E-06	4.14E-06	
		avg k	**4.07E-06**	cm/sec

soil source: Bugmati sand

	test	I	II	III
length of specimen (cm)		10.85	11.85	11.85
dia of permeater (cm)		10.00	10	10
area of specimen (cm^{2})		78.50	78.5	78.5
volume of specimen(cm^{3})		851.73	930.225	930.225
specific gravity of solids		2.66	2.64	2.64
tempreature ºC		28.00	27	24
water content (%)		0.00	0	0
sn no	**observation and calculation**			
1	mass of mould +base plate (gm)	8910.00	8920.00	8920.00
2	mass of mould +base plate+ soil	10022.00	10220.00	10260.00
3	hydraulic head (cm)	183.00	182.50	184.10
4	time interval (sec)	30.00	30.00	30.00
5	quantity of flow (ml)			
	first in time period t	358.00	320.00	270.00
	second in time period t	350.00	320.00	270.00
	third in time period t	355.00		270.00
	avg Q	354.33	320.00	270.00
7	mass of soil (gm)	1112.00	1300.00	1340.00
8	bulk density, ρ=mass/volume	1.31	1.40	1.44
9	dry density ,$\rho d=\rho/(1+w)$ gm/cc	1.31	1.40	1.44
10	void ratio,e=G ρw/ρd -1	1.04	0.89	0.83
11	$k=Ql/Aht$ cm/sec	8.92E-03	8.82E-03	7.38E-03

soil source : Bugmati sand

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	H7	10	P8	
	wt of can (gm)	15.00	16.42	18.26	
	wt of can +wet soil (gm)	47.29	39.93	49.63	
	wt of can + dry soil (gm)	43.76	37.38	46.25	
	wt of dry soil(gm)	28.76	20.96	27.99	
	wt of water (gm)	3.53	2.55	3.38	avg
	water content (%)	0.12	0.12	0.12	**0.12**

sn no	**observation and calculation**	**test set**		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	8920.00
2	mass of mould +base plate+ soil	10500.00	10500.00	10500.00
3	initial head, h1(cm)	108.00	108.00	108.00
4	final head, h2 (cm)	78.00	78.00	78.00
5	head sqrt(h1*h2) (cm)	91.78	91.78	91.78
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	18.00	18.00	18.50
	sqrt(h1*h2) to h2 (sec)	18.00	18.00	19.00
	h1 to h2 (sec)	36.00	36.00	37.50
7	mass of soil(gm)	1580.00	1580.00	1580.00
8	*bulk density*, $\rho = mass/volume$	1.70	1.70	1.70
9	dry density ,$\rho d = \rho/(1+w)$ gm/cc	1.51	1.51	1.51
10	void ratio,$e = G\ \rho w/\rho d\ -1$	0.76	0.76	0.76
11	$k = 2.3al/At \log 10(h1/h2)$	8.67E-04	8.67E-04	8.32E-04
		avg k	**8.55E-04**	cm/sec

Soil source: Bugmati sand

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		20.00	20.00	20.00	
water content (%)					
	can no	H7	10	P8	
	wt of can (gm)	15.00	16.42	18.26	
	wt of can +wet soil (gm)	47.29	39.93	49.63	
	wt of can + dry soil (gm)	43.76	37.38	46.25	
	wt of dry soil(gm)	28.76	20.96	27.99	
	wt of water (gm)	3.53	2.55	3.38	avg
	water content (%)	0.12	0.12	0.12	**0.12**

sn no	observation and calculation	test set		
		1.00	**2.00**	
1	mass of mould +base plate(gm)	8920.00	8920.00	
2	mass of mould +base plate+ soil	10550.00	10550.00	
3	initial head, h1(cm)	108.00	108.00	
4	final head, h2 (cm)	78.00	78.00	
5	head sqrt(h1*h2) (cm)	91.78	91.78	
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	34.00	35.00	
	sqrt(h1*h2) to h2 (sec)	33.00	35.00	
	h1 to h2 (sec)	67.00	70.00	
7	mass of soil(gm)	1630.00	1630.00	
8	$bulk\ density,\ \rho = mass/volume$	1.75	1.75	
9	dry density ,$\rho d=\rho/(1+w)$gm/cc	1.56	1.56	
10	void ratio,e=$G\ \rho w/\rho d\ -1$	0.70	0.70	
11	$k=2.3al/At \log10(h1/h2)$	4.66E-04	4.46E-04	
		avg k	**4.56E-04**	cm/sec

soil source : Bugmati sand

length of specimen(cm)		11.85	11.85	11.85	
dia of permeater(cm)		10.00	10.00	10.00	
area of specimen(cm^2)		78.50	78.50	78.50	
volume of specimen(cm^3)		930.23	930.23	930.23	
dia of stand pipe(cm)		0.90	0.90	0.90	
area of stand pipe($cm^{2)}$		0.64	0.64	0.64	
specific gravity of solids		2.66	2.66	2.66	
tempreature °C		22.00	22.00	22.00	
water content (%)					
	can no	H7	P8	10	
	wt of can (gm)	15.12	18.30	16.49	
	wt of can +wet soil (gm)	64.00	41.98	79.16	
	wt of can + dry soil (gm)	57.48	38.14	70.55	
	wt of dry soil(gm)	42.36	19.84	54.06	
	wt of water (gm)	6.52	3.84	8.61	avg
	water content (%)	0.15	0.19	0.16	**0.17**

sn no	observation and calculation	test set		
		1.00	**2.00**	**3.00**
1	mass of mould +base plate(gm)	8920.00	8920.00	8920.00
2	mass of mould +base plate+ soil	10710.00	10710.00	10710.00
3	initial head, h1(cm)	108.00	108.00	108.00
4	final head, h2 (cm)	78.00	78.00	78.00
5	head sqrt(h1*h2) (cm)	91.78	91.78	91.78
6	timeinterval			
	h1 to sqrt(h1*h2) (sec)	58.00	60.00	61.00
	sqrt(h1*h2) to h2 (sec)	60.00	63.00	61.00
	h1 to h2 (sec)	118.00	123.00	122.00
7	mass of soil(gm)	1790.00	1790.00	1790.00
8	bulk density, ρ=mass/volume	1.92	1.92	1.92
9	dry density ,ρd=ρ/(1+w) gm/cc	1.65	1.65	1.65
10	void ratio,e=G ρw/ρd -1	0.62	0.62	0.62
11	k=2.3al/Atlog10(h1/h2)	2.64E-04	2.54E-04	2.56E-04
		avg k	**2.58E-04**	cm/sec

soil source: Manohara sand

	Test	I	II	III	IV
length of specimen (cm)		11.85	11.85	11.85	11.85
dia of permeater (cm)		10.00	10.00	10.00	10.00
area of specimen (cm^{2})		78.50	78.50	78.50	78.50
volume of specimen(cm^{3})		930.23	930.23	930.23	930.23
specific gravity of solids		2.66	2.66	2.66	2.66
tempreature ºC		10.5 c	22.00	10.5 c	10.5 c
water content (%)		0.00	0.00	0.00	0.00
sn no	**observation and calculation**				
1	mass of mould +base plate (gm)	8920.00	8920.00	8920.00	8920.00
2	mass of mould +base plate+ soil	10205.00	10370.00	10380.00	10270.00
3	hydraulic head (cm)	181.50	180.70	182.70	181.60
4	time interval (sec)	60.00	60.00	60.00	60.00
5	quantity of flow (ml)				
	first in time period t	855.00	775.00	750.00	785.00
	second in time period t	838.00	775.00	748.00	788.00
	third in time period t	835.00			
	avg Q	842.67	775.00	749.00	786.50
7	mass of soil (gm)	1285.00	1450.00	1460.00	1350.00
8	bulk density, ρ=mass/volume	1.38	1.56	1.57	1.45
9	dry density ,ρd=ρ/(1+w)	1.38	1.56	1.57	1.45
10	void ratio,e=G ρw/ρd -1	0.93	0.71	0.69	0.83
11	$k=Ql/Aht$ cm/sec	1.17E-02	1.08E-02	1.03E-02	1.09E-02

soil source: Manohara sand				
length of specimen(cm)		11.85		
dia of permeater(cm)		10.00		
area of specimen(cm^2		78.50		
volume of specimen(cm^3)		930.23		
specific gravity of solids		2.66		
tempreature ºC		23 C		
water content %				
	can no	RC30	RK C5	
	wt of can (gm)	18.10	17.50	
	wt of can + wet soil (gm)	67.77	80.02	
	wt of can + dry soil (gm)	64.60	76.13	
	wt of soil (gm)	46.50	58.63	
	wt of water (gm)	3.17	3.89	
	water content (%)	0.07	0.07	
	avg water content (%)	0.07		
sn no	**observation and calculation**			
1	mass of mould +base plate (gm)	8920.00		
2	mass of mould +base plate+ soil	10540.00		
3	hydraulic head (cm)	181.50		
4	time interval (sec)	30.00		
5	quantity of flow (ml)			
	first in time period t	310.00		
	second in time period t	310.00		
	third in time period t	305.00		
	avg Q	308.33		
7	mass of soil	1620.00		
8	$bulk\ density$, $\rho = mass/volume$	1.74		
9	dry density ,$\rho d = \rho/(1+w)$ gm/cc	1.63		
10	void ratio,e=$G\ \rho w/\rho d\ -1$	0.63		
11	$k = Ql/Aht$ cm/sec	8.55E-03		

soil source: Manohara sand

length of specimen(cm)		11.85		
dia of permeater(cm)		10.00		
area of specimen(cm^2		78.50		
volume of specimen(cm^3)		930.23		
specific gravity of solids		2.66		
tempreature ºC		22 C		
water content %				
	can no	P6	RC-22	
	wt of can (gm)	16.03	11.25	
	wt of can + wet soil (gm)	109.35	61.02	
	wt of can + dry soil (gm)	92.48	52.18	
	wt of soil (gm)	76.45	40.93	
	wt of water (gm)	16.87	8.84	
	water content (%)	0.22	0.22	
	avg water content (%)	**0.22**		
sn no	**observation and calculation**			
1	mass of mould +base plate (gm)	8920.00		
2	mass of mould +base plate+ soil	10590.00		
3	hydraulic head (cm)	178.90		
4	time interval (sec)	30.00		
5	quantity of flow (ml)			
	first in time period t	300.00		
	second in time period t	300.00		
	third in time period t	300.00		
	avg Q	300.00		
7	mass of soil	1670.00		
8	$bulk\ density$, $\rho = mass/volume$	1.80		
9	dry density ,$\rho d = \rho/(1+w)$gm/cc	1.47		
10	void ratio,e=$G\ \rho w/\rho d\ -1$	0.81		
11	$k = Ql/Aht$ cm/sec	8.44E-03		

soil source: Bagmati Sand

	Test	I	II	III
length of specimen (cm)		11.85	11.85	11.85
dia of permeater (cm)		10.00	10	10
area of specimen ($cm^{2)}$		78.50	78.5	78.5
volume of specimen($cm^{3)}$		930.23	930.225	930.225
specific gravity of solids		2.64	2.64	2.64
tempreature ºC		22.00	22	22
water content (%)		0.00	0	0
sn no	**observation and calculation**			
1	mass of mould +base plate (gm)	8900.00	8920.00	8920.00
2	mass of mould +base plate+ soil	10214.00	10400.00	10450.00
3	hydraulic head (cm)	184.00	181.50	183.40
4	time interval (sec)	60.00	60.00	60.00
5	quantity of flow (ml)			
	first in time period t	870.00	825.00	829.00
	second in time period t	855.00	828.00	821.00
	third in time period t	855.00		820.00
	avg Q	860.00	826.50	823.33
7	mass of soil (gm)	1314.00	1480.00	1530.00
8	bulk density, ρ=mass/volume	1.41	1.59	1.64
9	dry density ,ρd=ρ/(1+w)	1.41	1.59	1.64
10	void ratio,e=G ρw/ρd -1	0.87	0.66	0.61
11	$k=Ql/Aht$ cm/sec	1.18E-02	1.15E-02	1.13E-02