Analysis of Patna Collapsible Soil for Hydraulic Construction Purposes

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Submitted by

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<u>CERTIFICATE</u>

This is to certify that the project report entitled, "**Analysis of Patna Collapsible Soil for Hydraulic Construction Purposes**", is being carried out by **ANURAG JHA(2K15/GTE/04)** in partial fulfillment for the award of degree of Masters of Technology in Geotechnical Engineering (Department of Civil Engineering), Delhi technological University under my supervision.

Under the guidance of

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Chapter 1

INTRODUCTION

1.1 General

The first and foremost requirement for a successful irrigated agriculture is the development and maintenance of soil root region in which the water – air –salt ratio is favorable for plant growth. When a water table rises or water gets deteriorated or stagnated in the fields and remains in the root zone for longer period, the yield of the crop gets seriously affected due to the air deficiency in the root zone. This air deficiency requires drainage facilities in the cropped area. A simple but comprehensible definition of drainage is the removal of excess water from root zone which permits some air for normal plant growth. If the prime objective is to lower the ground water table below a certain level below root zone of the crops, then subsurface drainage system is necessary.

There are different factors on which the selection of optimum drainage plan and the design and construction of adequate and successful drainage depends, those are reliability and adequacy of the basic drainage data. The basic data must provide the knowledge of soil texture, porosity, saturated hydraulic conductivity of the soil and the topography of the area under consideration

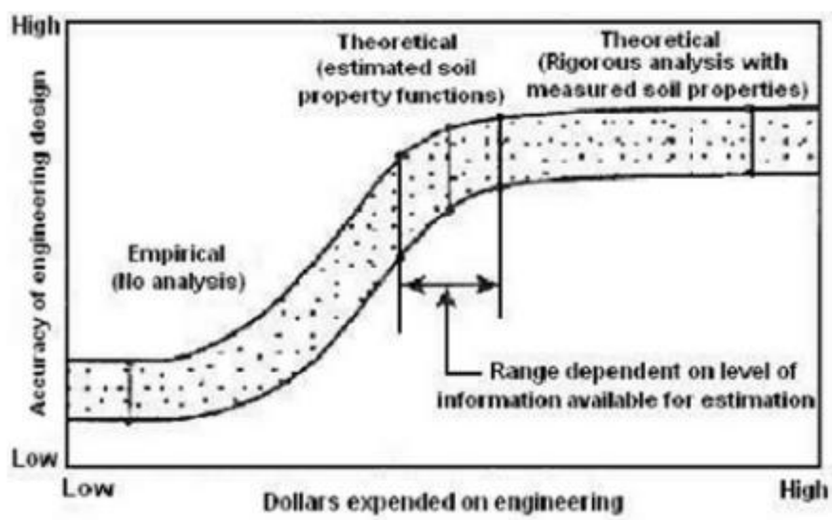
There won't be any infiltration if the soil is completely saturated. It will lead to overland flow and if there is flash flood with very high intensity than infiltration rate, no or very less water will go inside the soil profile and will flow over surface resulting into flood. Due to the urbanization the land cover and the land use increases, due to the increase in the soil very less soil interface for the infiltration process and all the rain water will accumulate on the surface and will flow as runoff after certain period. It’s only because of urbanization, very little amount of soil is uncovered, those soil gets saturated as the rain start falling and increases the moisture retention time of the soil resulting into more surface and is also called Urban flooding.

It is quite difficult to do direct prediction of unsaturated hydraulic conductivity, rather it can be indirectly evaluated through the soil moisture characteristics curve. It is the functional relationship amidst the hydraulic conductivity, the moisture content and suction (pressure) head. Characteristics equations is useful in the studies related to ground water modeling and particularly in subsurface flow modeling in unsaturated zone. The main difficulty in the Richards equations to actual field situations is the estimations of the parameters of the soil characteristics curves. Physical properties of soil constitute the basic data to carry out the studies related to the above problems. For example, Runoff and infiltration prediction following precipitation, the following distribution of infiltrated water through drainage design the textural analysis of the soil is an important parameter which governs the movement of the water in subsurface soil. soil texture is a characteristic, which has a general relationship with hydraulic conductivity and water retention. For the management of water in irrigation command area the wilting point, field capacity and available moisture are very important parameters, which can be determined from the characteristics curve. To understand the amount of water that is available to plants soil moisture characteristics curve is useful, the water that can be taken up by the soil before percolation starts, and the amount of water that must be used for immigration (Micheak, 1986). Therefore, the basic data must provide the knowledge of soil texture, saturated hydraulic conductivity and the soil characteristics of the area under consideration. Easy and reliable techniques for estimating these properties are necessary. hence, suitable techniques for the estimation of unsaturated hydraulic conductivity are required based on national are regional data base. for the purpose, the characteristics equations have been derived to estimate the unsaturated hydraulic conductivity.

The measurement of soil parameters for the unsaturated soil constitutive models needs extensive laboratory tests. For most practical problems, it has been found that approximate soil properties are adequate for analysis. Thus, empirical procedures to evaluate unsaturated soil parameters would be valuable. The soil–water characteristic curve (SWCC) can be used to estimate various parameters used to describe unsaturated soil behavior. The SWCC is a relationship between soil suction and some measure of the water content. It can be measured or predicted based on soil index properties. Estimation based on index properties is highly desirable due to its simplicity and low cost.

A theoretical basis for unsaturated soil mechanics has been established over the past three decades. The constitutive equations for volume change, shear strength, and flow through unsaturated soil have become generally accepted in geotechnical engineering (Fredlund and Raharjo 1993). The fundamental accepted principal in this theory is that the unsaturated soil behavior could not be described just by making use of one stress state variable; in other words, both the net normal stress, $(\sigma - u_a)$, where σ is the total stress and u_a is the pore-air pressure, and the matric suction, $(u_a - u_w)$, where u_w is the pore-water pressure, are generally required for the constitutive models.

As a result, evaluation of suction is most essential to assess the unsaturated soil behavior. Suction evaluating in direct measure needs to time consuming and costly laboratory tests, so estimation of suction with indirect methods based on other parameters such as water content would be considered. Consequently, the soil–water characteristic curve (SWCC) that defines degree of saturation corresponding to particular suction in a soil is widely used to estimate unsaturated soil properties. Through the practical applications of the soil–water characteristic curve, prediction of shear strength, water storage, and permeability coefficient may be pointed out. Figure 1 provides a qualitative illustration of the benefits derived from using estimated unsaturated soil property functions (Fredlund 2000). Estimates of the unsaturated soil property function are shown to provide a significant increase in the accuracy of the engineered designs, for a nominal increase at the soil investigation and testing stage. The accuracy of the output from an analysis depends strongly upon the independent variable being computed. There are different methods to evaluate the soil–water characteristic curve. However, these methods are divided to two general branches: laboratory and estimating methods. The researchers, with taking account of the general form of SWCC, have suggested some equations to approximate these curves. Such equations basically consist of two or three constant evaluated by making use of either suction laboratory results in various water contents or statistical relations based on other soil properties. According to existing difficulties in evaluation of these curves experimentally and noticeable variability, the estimation of such parameters has widely been used by many of researchers.



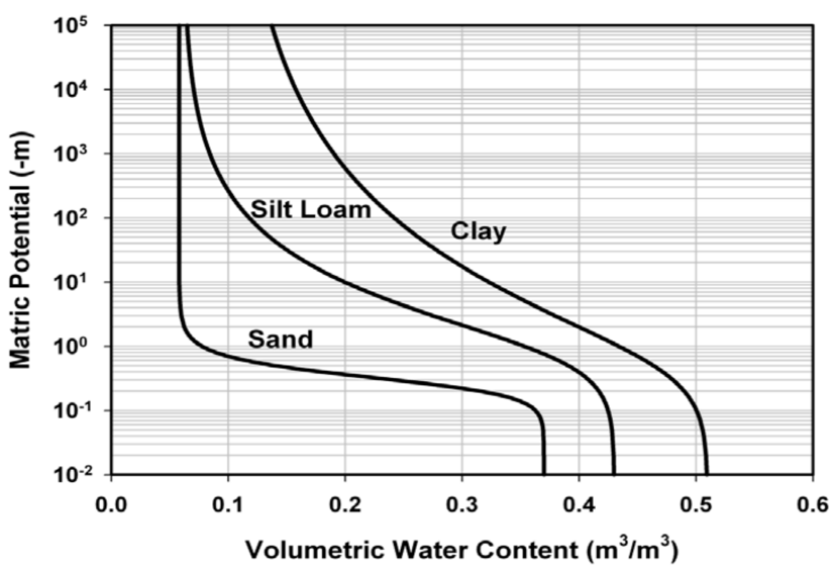


Figure 1: Typical soil water characteristic curves for soils of different texture.

1.2 OBJECTIVES OF THE STUDY

The objectives of the following paper are

a) To estimate the soil Properties such as Particle size distribution, Specific gravity, natural moisture content, Density, water retained within soil mass at different Pressures.
b) To estimate the soil moisture characteristic curve.

Chapter 2

LITERATURE REVIEW

The following studied have been carried out in previous years using different methodology and different parameter methodology and parameter estimation. The main purpose of this literature review is to take guidance from earlier studies

Rathft et al (1983) The available water for plants in various types of soils under discussion and mentioned here will depends upon the texture of the soil texture, also the clayey solid has the higher availability of water than that of sandy soils.

Fredlund et al (1998) SWCC represents the pore size distribution, water content in these pores of the soil and the stressed condition of soil and water content of these pores. Hence it has been concluded that SWCC is a very important soil function which relates water suction and content of the soil.

Kumar et al. (2001) An empirical formula has been proposed which enable us to derive the approximate soil moisture retention curve from its collected saturated hydraulic conductivity data.

Kumar et.al. (2002) Various results indicated that use of land (i.e. cultivation or farming), physical and chemical property such as organic carbon, clay, mean weight diameter (MWD) and water stable aggregate (WSA) plays significant and major role in water retention and erodibility indices in a positive way. Unused soils like Forest soils has higher retention of water, higher infiltration rate, and lower erosion and depression ratio than that of the soils of cultivated and orchard land. Water availability to the plants through irrigation or rainfall is one of the most important parameters which influence the crop production. The description of the moisture/water content of the soil shall be considered along with the behavior of soil water and plant system. As, there is a possibility that the total soil water content in the root zone of a plant appears to be sufficient for adequate plant growth but the overall water distribution in different layers of the soil is not optimum.

Thakur et al. (2005) Experiments were conducted to measure the suction of a locally available silty soil and commercially available white clay, using a Dew Point Potential Meter (WP4). The results were used to develop soil-water characteristic curves, SWCCs, for these soils and for checking the efficiency of different fitting functions, in high suction ranges. Efforts have also been made to demonstrate the influence of the soil type and dry unit weight on the soil suction. The study brings out the observation that dry unit weight has negligible influence on the soil suction and parameters effecting SWCC.

Zhou et al. (2005) The soil-water characteristic curve (SWCC) is the primary partially saturated soil information as its behavior and properties can be derived from it. Although there have been many studies of unsaturated soils and the SWCC, there is still no combined constitutive model that can simulate soil characteristics accurately. In cases when hydraulic hysteresis is dominant (e.g. under cyclic loading) it is particularly important to use the SWCC. In the past decades, several mathematical expressions have been proposed to model the curve. There are various influences on the SWCC as a source of information, so the curves obtained from conventional tests often cannot be directly applied; and the mathematical expressions from one scenario cannot be used to simulate another situation. The effects of void ratio, initial water content, stress state and high suction were studied in this work revealing that water content and stress state are more important than the other effects; but that the influences tend to decrease when suction increases. The van Genuchten model was modified to simulate better the changes in the degree of saturation at low values of suction. Predictions were compared with experimental results to determine the simulation capability of the model.

C. P. Kumar and Sanjay Mittal (2008) Knowledge obtained with the relationships between moisture content of soil (θ), unsaturated hydraulic conductivity (K) and water pressure in the soil (h) helps in building mathematical model of agricultural systems and it's hydrologic. Pressure plate apparatus can be used to obtain moisture retention of the soil, with these data retention curve can be drawn. These retention curve can be further used to derive the approximate soil moisture retention curve by developing an empirical relationship at those places where only saturated hydraulic conductivity data is available.

D.G. Fredlund And Anqing Xing (2009) Various parameters needed to describe unsaturated soil behavior can be estimated using the soil-water characteristic curve which can be obtained through proposed general equation of soil-water characteristic curve. With the help of a computer program which is nonlinear and least-squares in nature one can determine the relevant parameters needed for experimental data as mentioned in its literature. If the soil-water characteristic curve depends on the size of the pores distributed in the soil (i.e., the desaturation of soil is a function of the pore-size distribution) this equation is formed. The equation has the function of an integrated frequency distribution curve. The equation is well applicable for sandy, silt and clayey soils over the whole suction range i.e. from 0 to 10"Pa.

Lins et al. (2009) To understand the unsaturated soil mechanics the determination of soil-water characteristic curve (SWCC) is a major concern. The major objective of our study is with a small suction range of just few kPa an extensive experimental database for sand is to be generated. This database enables to understand how different experimental procedures indicates the sensitivity of hydraulic properties. Comparison of data and results obtained from steady state and transient state tests of SWCC is also considered to be one of the objective. Experimental results can be obtained from an initial boundary value experiment (column testing device) and so called homogenous element test (modified pressure plate apparatus) by considering different hydraulic loading path and its directions. Different experiments are done and analyzed for sand with difference in its initial states. Finally, all the results are assembled and presented for SWCC including its initial curves, main curves, and scanning paths.

Anderson M. Ferreira1, Francisco José C. P. Soeiro (2010) As a result, these propositions are based on physical indexes, soil characterization, and current laboratory tests or simply curve fitting. The relationship of the volume of water in the soil pores and soil suction, conventionally referred to as the soil-water characteristic curve (SWCC) is a useful tool in the prediction of the engineering behavior of unsaturated soils.

Apiniti Jotisankasa and HansaVathananukij (2011)

A study has been carried out to investigate soil-water characteristics curves of undisturbed soils from slopes which experienced large scale debris flow as well as localized slope failure in Thailand. New miniature tensiometers developed at Kasetsart University were employed to monitor the suction changes in these tests and in the field. The basic properties of the soils indicate that most soils from debris flow areas in Thailand are silty and of low plasticity (ML, SM, CL). The mechanism of slope failure is also demonstrated using simple infiltration model and slope stability equation. The wetting front traveling, soil characteristics and drainage condition at the bottom of the slope appear to be important factors. Application of these test results for early warning system for flashflood and landslide disaster is finally demonstrated based on some simplifying assumptions.

R. G. Fawcea't and N. Colh-George (2012) estimate of the bar percentage of soil is a useful soil description in field investigations where a measure is required of the water "available" for plant growth. However, knowledge of the moisture characteristic would be of greater value, particularly in seasonal studies of soil-water-plant relations. Where suitable physical equipment is not available, estimates of the I 5-bar percentage may be made using a filter paper method (Williams and Sedgley 1965). This method is based on one previously described by Gardner (1937) who proposed that moisture potentials from about -0.3 to -1000 bars (pF 2.5 to 6) could be estimated by this means. The method presented here and tested is simpler than those proposed by either Gardner (1937) or Williams and Sedgley (I965).

Aldaood et al. (2014) The determination of water holding capacity variations with environmental conditions, relative humidity (suction), is essential in the assessment of the behavior of gypseous soil. The relationship between suction and moisture content is expressed by the soil-water retention curve (SWRC) or soil-water characteristic curve (SWCC). This relationship was determined for the first time for lime treated gypseous soil, using tensiometric plate, osmotic membrane and vapor equilibrium techniques, in the suction pressure range of (10–1,000,000 kPa). Soil samples containing (0, 5, 15 and 25%) gypsum was treated with 3% lime and cured for 28, 90 and 180 days at 20 °C and 40 °C. Results showed that the water holding capacity of the soil samples increased with increasing gypsum content, curing period and curing temperature. The effect of gypsum content on SWCC was greater than the effect of curing conditions, although microstructural properties of the treated soil samples showed that curing conditions also had a significant effect on the SWCC. All the experimental data fitted well to the Fredlund and Xing (1994) and Van Genuchten (1980) models for SWCC.

Wang et al. (2015) It is well known that soil water characteristic curve (SWCC) plays an important role in unsaturated soil mechanics, but the measurement of SWCC is inconvenient. In laboratory, it requires days of testing time. For fine-grained clays, it may last for a couple of months using pressure plate tests. In this study, the effects of sample dimensions and shapes on the balance time of measuring SWCCs using pressure plate tests and the shape of SWCCs are investigated. It can be found that the sample dimensions and shapes have apparent influence on the balance time. The testing durations for circular samples with smaller diameters and annular samples with larger contact area are significantly shortened. However, there is little effect of sample dimensions and shapes on the shape of SWCCs. Its mechanism is explored and discussed in detail through analyzing the principle of pressure plate tests and microstructure of the sample. Based on the above findings, it is found that the circular samples with smaller dimensions can accelerate the testing duration of SWCC using the pressure plate. The annular samples with large contact area and circular samples with small dimensions require short testing duration in pressure plate tests, and the effect of the latter is more apparent

Chapter 3

STUDY AREA

3.1 Study Area

Location

1.	State	Bihar
2.	District	Patna
3.	Latitude	25º 13‘and 25º 45
4.	Longitudes	84º 43' and 86º 44'
5.	River	ganga

Patna district is situated in the South Bihar alluvial plains. The district is situated between North latitudes 25º 13‘and 25º 45 ‘and East longitudes 84º 43' and 86º 44’. The district is bounded in the north by river Ganga, in the south by Jahanabad and Nalanda districts, in the east by Lakhisarai district and in the west by Bhojpur district. The total geographical area of the district is 3172 sq.km.

3.2 Geomorphology& Soils

Geomorphology

The district forms a part of the Ganga basin and is characterized by a monotonously flat relief with elevation in general, the western part of the district is sloping due north and north-east, with elevation of the land surface varying from 68 m in the south to 48 m in the north, and from 67 m in the west to 45 m in the east. A notable geomorphic feature is the strong natural levee formation or upland all of them are along the southern bank of the Ganga which acts as a natural barrier thereby causing many of the streams flowing from south torun parallel to the course of Ganga before finally joining it further east of the district boundary.

Soils

Soils are predominantly sandy loam with clay loam at places. The places are with low to medium nutrient status. The pH value lies between 6.3 to 8.2 and so is generally alkaline in nature. Traditionally soils in an area are classified based on mode of deposition. Soils are divided into three groups such as. (i) Recent alluvium (ii) Tal and (iii) Older alluvium. The soils have developed on alluvial deposits which is transported from younger geological formation where physical weathering is predominant. Generally, soils which get developed in them are coarser in texture.

Agriculture and Irrigation practices

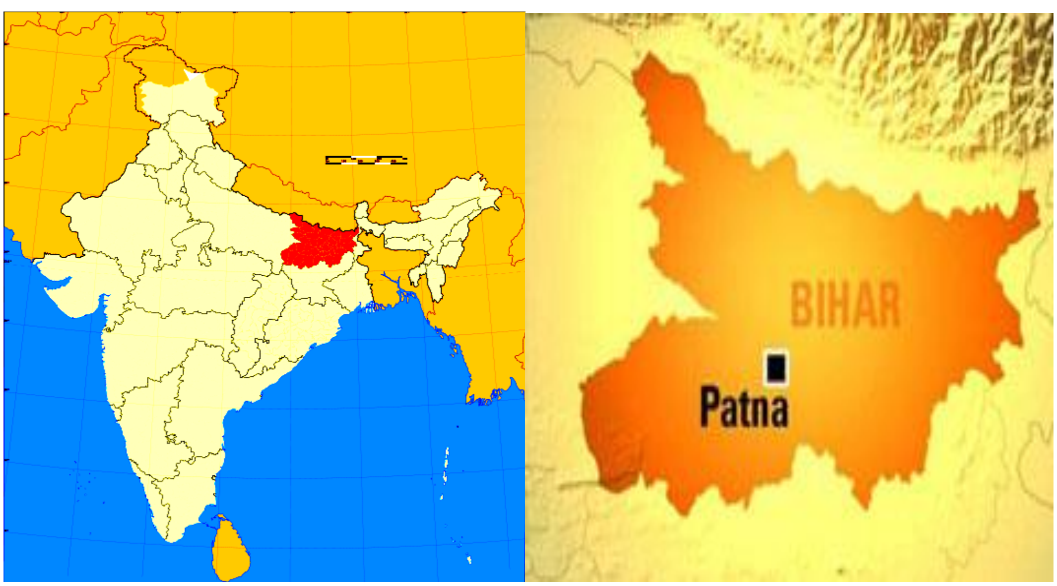
The principal crops grown in the district are Agahani rice, Bhadai Maize, Wheat, Gram, Sugarcane and Jute. Kharif crops are grown from the end of June to the end of October and Rabi from the end of October to the end of March. The Summer crops are grown from April to June, where sufficient irrigation facilities exist. The gross cropped area is 256694.99 ha. and net area sown is 201103.63 ha. indicating cropping intensity of 127.64 % in the district, which is slightly lower than the State average for the two Tal and Diara areas are mostly mono cropped. Total area under net irrigation in the district is 1,09, 000 ha (Govt. of Bihar,) of which groundwater irrigation alone is approximately 80%.

Climate and Rainfall

The climate of the district is not moderate but can be said extreme as the temperature goes up to 47'c i.e. too hot in summer and around 1'c during winter. January is the coldest month. The temperature starts rising from March and reaches its peak in May. Rain starts sometime in mid-June and lasts till mid-September. Maximum rains occur during the monsoon months of July and August. Sometimes winter rains occur in Jan-February. The normal annual rainfall in the district is around 1076 mm.

3.3 SAMPLING SITE IN PATNA TOWN

1. NIT PATNA (P1)
2. B.I.T PATNA (P2)
3. GANDHI MAIDAN (P3)
4. NIH PATNA WALMI COMPLEX (P4)
5. AKU CAMPUS (P5)
6. PATNA CITY (SAHEB) (P6)



Source (world resources institute)

Fig 3.1: MAP OF INDIA AND BIHAR

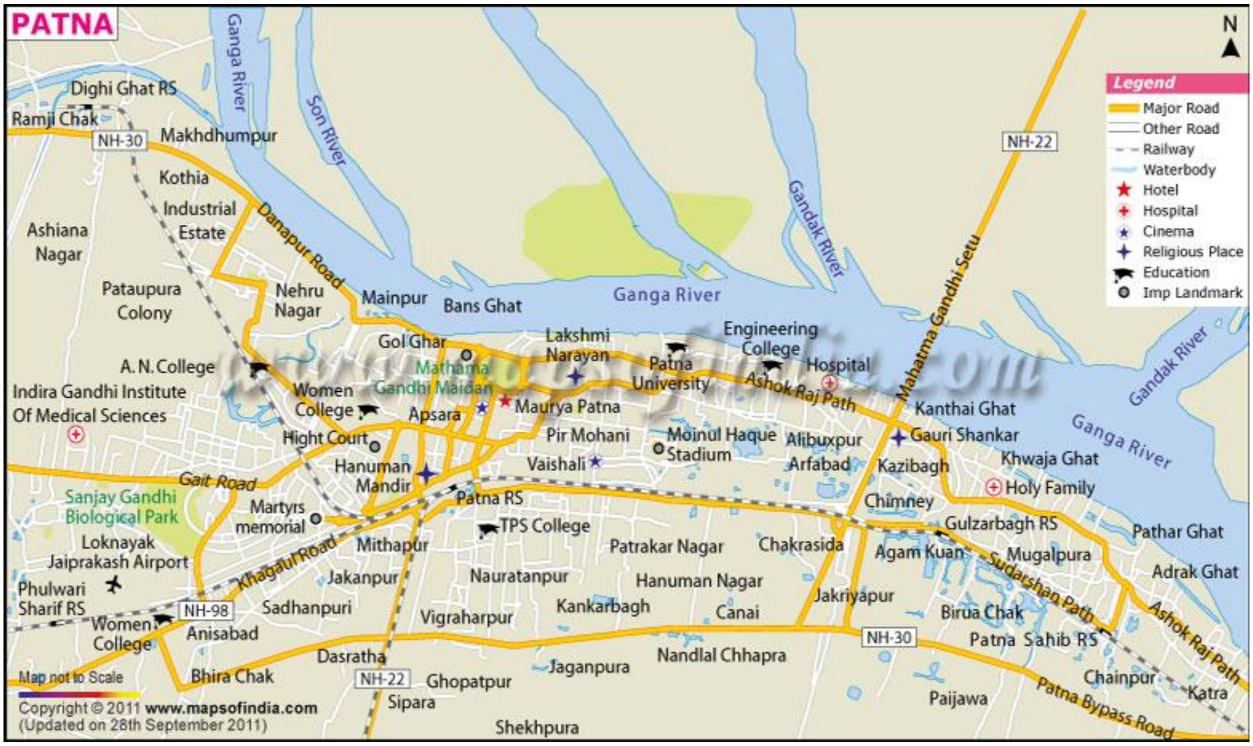


Fig 3.2: Map of Study Area Showing All the Locations

Chapter 4

METHODOLOGY

4.1 Particle Size Distribution

Particle size distribution is an attempt to determine the relative proportion of the different grain size that makes a given soil mass. The relative proportion of sand, silt and clay determines the soil texture. The diameter of the Particles present in the soil Sample makes the soil to be course medium and fine. Table 1 gives the textural class names of soils as per particle diameter. the soil texture is determined by separating sand, silt, and clay fractions and measuring their proportion which is called the mechanical analysis. The soil texture triangle is then used to convert quantitative data from detailed gradation analysis of separates less than 2 mm in diameter to textural class name of soil.

Table 4.1: Textural Classification as Per Particle Diameter

Material	Diameter
Stones	>250 mm
Cobbles	250-75 mm
Coarse gravel	75-12.7 mm
Fine gravel	12.7-2 mm
Very coarse sand	2-1 mm
Coarse sand	1-0.5 mm
Medium sand	0.5-0.25 mm
Fine sand	0.25-0.1 mm
Very fine sand	0.1-0.05 mm
Silt	0.05-0.002 mm
Clay	<0.002 mm

To carry out the particle size distribution, first the stove dried up soil sample weighing 500g is wash during the sieve of no 200. the portion of the soil particles retained on sieve is subjected to sieve study and the particles ephemeral through the sieve is subjected to master sizer analysis.

In sieve analysis, the portion retained on every sieve is collected and weighted. The % of soil sample retained on every sieve based on total mass of soil sample and the % of mass passing through each sieve is calculated.

The Indian standard (is “460,1962), in the sieve are designated by size of aperture in mm there as in bs (410,1962 and astm) (E11, 1961) standard, a sieve sizes are given in the term of the number of openings per inch. These are described in report TR-82 by doc seth, 1990.

The sieving process doesn’t provide information on the shape of soil grains .it only yields information on grains that can pass through rectangular sieve opening of a certain size. Information obtained form the grain size analysis is presented in the form of a curve. In such a curve, the y –axis or the ordinate in the graph indicates the percentage of soil particles having diameter finer than indicated on x-axis.

The capacity of soil to hold water is related to surface area as well as pore space volume hence, water holding capacity is related to both structure and texture of the soil. in general, fine texture soils have the maximum total water holding capacity, but maximum available water is held in medium texture soils. Soil texture is especially important in sub surface drainage as it has a direct relationship which hydraulic conductivity and water retention (David 1982).

4.2 Porosity

To calculate the porosity of the soils, the particle density and the bulk density must be known. Particle density (specific gravity) is the mass per unit volume of the soil particle. Particle density is sometimes referred to as true density. The bulk density is the dry weight per unit volume of the soil in its field condition. The porosity is the volume percentage of the soil of the unit bulk volume not occupied by the solid particle.

n = (1- bulk density /particle density) *100

Particle density has been calculated using multi volume pycnometer. Multi volume pycnometer work on the principle of measurement of skeletal volumes by observing the reduction of gas capacity in the sample chamber caused by the presence of the sample since helium or most other suitable gasses penetrate even the smallest pores and surface irregularities, the volume obtained permits computation of the ultimate theoretical density of the solid comprising the sample if there are no closed pores.

Bulk density has been calculated using geo1360. It calculates the bulk volume and calculate the bulk density of the coarse and crushed sample under a wide range of compaction state.

4.3 Specific Gravity

The specific gravity of any substance is defined as the ratio of unit weight of the material and the unit weight of the distilled water at 4° C. the specific gravity of a material can be computed using any ratio of weight of substance to a weight of water if equal volumes are involved.

$$G_s = W_s / W_w$$

Where, W_s the weight of the soil of known volume, $W_w$is the weight of equal volume of distilled water at 4°C.the volume of a known weight of soil grains can be obtained by using a container of known volume and the

Archimedes principle that a body submerged in a volume of water will displace a volume of water equal to the volume of the submerged body.

4.4 Permeability

The permeability is defined as the property of a material, which permits the passage or seepage of water through its interconnected voids. Gravels are high permeable while stiff clay is list permeable. The various factors affecting permeability includes grain size, property of pore fluids, void ratio of the soil, structural arrangements of the soil, in trapped air and absorbed water in clayey soils.

Two general laboratory methods are available for the determination of coefficient of permeability, these methods are constant head and falling head permeameter. Both methods used basic Darcy's law. These are explained in all the standard classical text book. ICW permeameter has been used for the purpose with constant head and falling head methods.

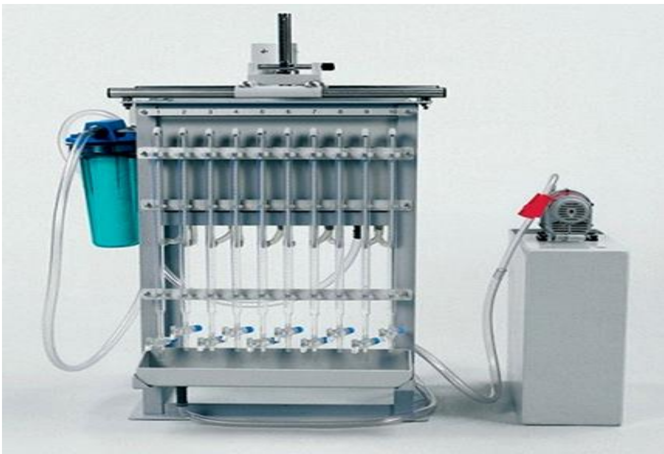


Fig 4.1: Ksat for determination of saturated hydraulic conductivity on 250 cm^3 soil samples by constant-head and falling-head experiments.

4.5 Soil Moisture Characteristic

4.5.1 Soil Moisture Tension and Pf Values

The moisture contained in the pore space of a soil mass is subjected to the capillary force. This capillary force causes a negative soil moisture tension, which is also called suction. The suction is expressed as the height of water column (h) that will rise from the water table against the force of gravity. This height is inversely proportional to the diameter of pores. Therefore, h= 0.3/d. where d is the equivalent pore diameter of a cylindrical pore with the same capillary. The negative logarithm of soil moisture tension in centimeters of water is used to indicate the soil moisture tension. This negative log of soil moisture is referred to as pF.

The tension phenomenon described herein occurs in a wide variety of porous materials, including sands, clays, agricultural soils and porous rocks. When some of the water is removed from a water-saturated porous system, the residual water evidently remains physically interconnected, judging from the fact that water can be transmitted through the system at reduced water content by suction. The removal of water may result in contraction of the system, as in the case of clay, or in the entry of air, as in the case of sand. The liquid phase and the solid phase in contact with it comprise a closely linked force system. Equilibrium can be established between the system at reduced water content and a separate mass of water at reduced pressure through a porous membrane in contact with both. The equilibrium tension required in the external water phase is considered an attribute of the moist, porous, system itself. From this point of view, the tension originates through the combined action of the internal forces of the system in a virtual displacement of water. It follows from this and from the principle of virtual work that the tension is numerically equal to the differential work done by the internal forces per unit volume of water absorbed. The movement of water, under tension, through porous systems represents a special class of flow phenomena in which tensiometers or equivalent devices are required for measuring the hydraulic potential. Flow patterns can be determined in much the same way as in systems characterized by positive hydrostatic pressures, but special attention must be paid to the Darcy coefficient (the capillary conductivity) which varies with the tension. The theoretical conditions for the equilibrium of water in the soil and for emergence from the soil have been developed in terms of the tension and certain applications have been indicated. The phenomenon referred to in the soil science literature as moisture tension has been recognized for almost forty years and has been used as a means of explaining the absorption and movement of water in the soil. It is closely related to osmotic pressure but its mechanism cannot in general be identified with the traditional mechanisms of osmotic pressure. Moisture tension has been observed in wet clay soils and in other finely divided porous systems contai,fing interstitial water, but the phenomenon is not confined to colloidal systems, since moist sand and moist porous rock, such as pumice, show similar effects.

4.5.2 Field Capacity

The moisture or water present in a saturated soil can drain out, the water quickly leaves the soil via largest pores and air is pulled into the soil. This movement of water is mainly due to the gravitational potential difference. When the rapidly running water in the unsaturated soil ceases to move then the soil is called at field capacity. Field capacity occurs when soil retains the maximum amount of water with little or no further loss of water by drainage or loss of gravitational water. A soil water matrix potential of about -1/3 bars has been found to correspond to the field capacity. A bar is equal to 1020 cm of water column or 1020 gm/cm^2.

4.5.3Wilting Point

As soil becomes drier, the conductivity rapidly decreases and movement and uptake of water becomes slower. Therefore, if no added water is added to the soil, the plant will absorb water slower than water is lost by transpiration. Thus, water deficit develops in the plant. This point is called wilting point.

4.5.4 Available Water

The water present in the soils between field capacity and wilting point is known as available water. It is generally considered to be matrix potential in the range of -0.33 to -15.0 bars.

4.5.5 Effect of Texture on Available Water

The capacity of soil to hold water is related to surface area as well as pore space volume. Hence, water holding capacity is related to both structure and texture of the soil. in general, fine textured soils have the maximum total water holding capacity. several researchers have indicated that available water in many soils is closely correlated with content to soil and very fine sand. It is well known that sandy soils are droughty than clayey soils, because fine –textured soils can retain more available water. also, there is a difference in the soil of soil-moisture characteristics curves of sand and clay. the flatness of the curve for fine sandy loam at water matrix potential is less than -4.0 bars which means that most of the available water in the sandy soils have a high potential. therefore, plants can readily use this water in sandy soils. Since in clay or clay loam soils the water is available at lower potential therefore it can be rapidly used by the plants.

Soil moisture characteristics, also called soil moisture retention curves, are the plots of moisture content versus head. It shows the amount of moisture in each soil held at various tensions. the moisture characteristics curve of a soil sample can generally be determined by equilibrating a soil sample at a succession of known tension value and each time determining the amount moisture. the graph is plotted between the tension and corresponding soil moisture value to obtain the soil moisture characteristics curve. different soil type gives different characteristics curves.

Pressure plate apparatus is a standard method for obtaining the soil moisture characteristics curve .it consists of a pressure chamber in which a saturated soil sample (either disturb or undisturbed) is placed on a porous ceramic plate through which the soil solution passes but no soil particle or air can pass easily. the soil solution, which passes through the membranes in contact with atmospheric pressure. as soon as the air pressure inside the chambers are raised above the atmospheric it takes excess water from the soil and flow out of the chamber through the membrane outlet. Soil water will flow out from the soil sample until the metric potential of the unsaturated flow is same as the applied air pressure. the air pressure is then, released and the moisture content of the soil is gravimetrically determined for that tension. when air pressure in the chamber is increased flow of water from the samples starts again and continue until a new equilibrium is reached. the same procedure is repeated at various pressures, the pair of pressure and moisture content data so obtained is used to construct the soil moisture characteristics curves. soil moisture characteristics curves are helpful to know the amount of water that is available to plants, the water which is to be taken up by the soil before percolation starts, and the quantity of water that should be used for irrigation.

A soil water matrix potential of about -1/3 bars has been found correspond to the field capacity, where as a soil water matrix potential of about -15 bars has been found to correspond to wilt point (Henry, 1984). The water present in the soil between field capacity and wilting point is known as available water .it is generally considered to be matrix potential in the range of -0.3 to -15.0 bars.

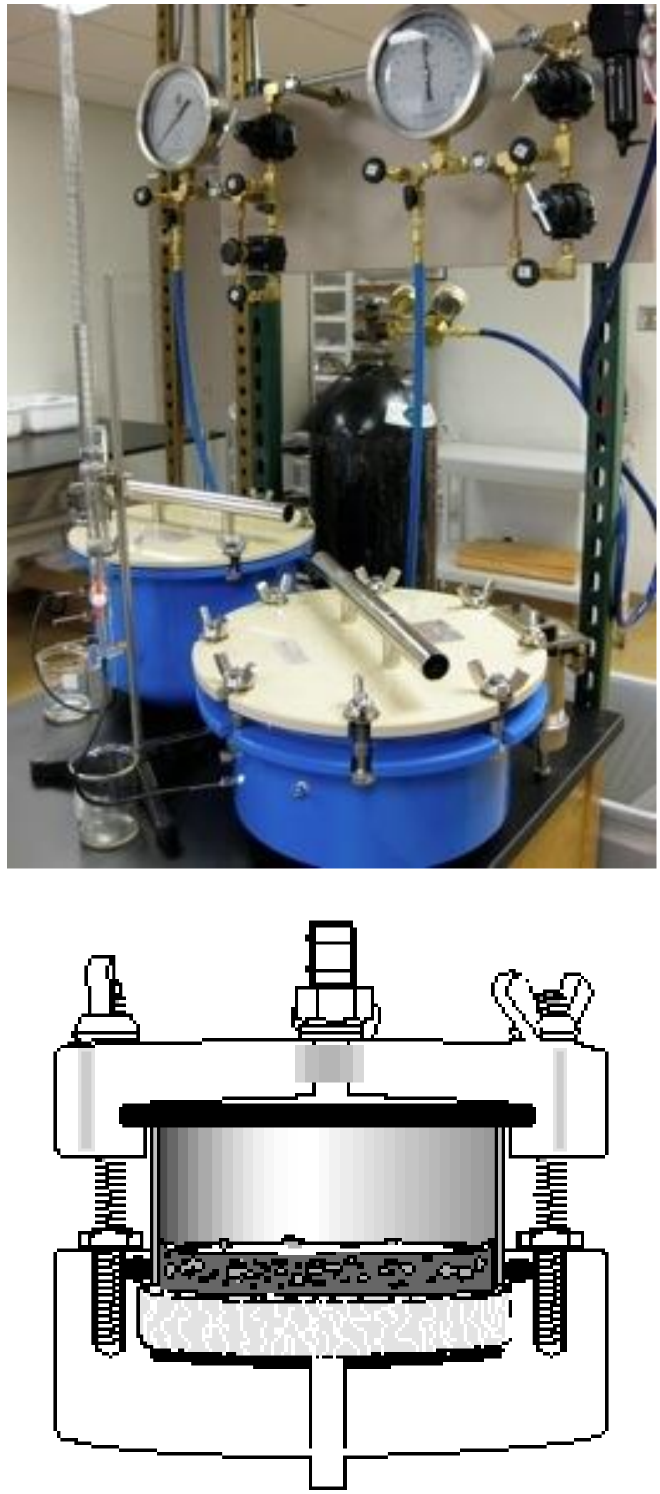


Fig 4.2: Pressure Plate Apparatus

Chapter 5

Procedure and Data collection

5.1 Soil Sampling

The study area fig.1, was selected for the determination of hydrological soil property of the study region. this figure shows the road network, villages, and canals network of the area. figure 2 presents the locations of the soil sampling sites. these sites were tentatively chosen in such a way that different types of soils found in the area are covered and the sites are easily approachable and are well disturbed all over the study area. total six sites selected are P1, P2, P3, P4, P5, P6 as located on the map and it can be seen in Fig 2. Disturbed and undisturbed soil sample were collected from these sites and along different depths. disturbed soil sample were collected from particle size analysis, n, Gs and soil water characteristics. the undisturbed soil sample were collected to measure the Ksat in the laboratory through ICW permeameter. figure 3 and figure 4 presents the photographs as the time of collecting disturbed and undisturbed soil sample respectively from the study area.

Soil Sampling:

six locations were selected within the Patna town for the soil sampling and laboratory tests were conduct on these soil samples to find out their properties. The locations are:

1) NIT, Patna(P1)
2) BIT, Patna (P2)
3) Gandhi Maidan, Patna (P3)

4) NIH Patna walmi complex (P4)
5) Aku campus (P5)
6) Patna city (Saheb) (P6)

5.2 Soil Moisture

It is defined as the ratio of weight of water to the weight of solids in each mass of soil. Soil moisture is also sometimes called as Water content.

$$w= (W_w/W_d) \times 100$$

It is usually expressed in % form. The water content may be either by volume or by mass. Many different methods are adopted for determining water content within the soil which include laboratory methods or field methods. These methods include Sand bath method, Oven Drying method, Alcohol method, co2 method, Pycnometer method, Radiation method, TDR etc. among these the oldest and most accurate methods are Oven dry method which is being used in this paper.

Steps involved in Oven dry method for determining soil water content: -

1) A container is taken and the mass with the lid is noted down, note down that it should be clean and non-corrodible.
2) 20-30 g of the soil sample is kept inside the container and the mass is taken using a balance which is accurate to 0.01 g.
3) Now this sample is kept in thermostatically controlled oven and 105^0c-110^0c temperature is maintained for 24 hours.
4) After 24 hours sample is taken out from the oven and again it is weighed.
5) Now the ratio of mass of water to the mass of dry soil is found out. And expressed as % to get the water content of soil.

WATER CONTENT, w= $\{(A_2-A_1)/(A_3-A_1)\} \times 100$

Here

A_1= mass of container with lid in g

A_2= mass of container with lid and wet soil in g

A_3= mass of container with lid and dry soil in g

Location: NIT PATNA

Table 5.1: WATER CONTENT

Mass of wet soil+container (gm)	14
Mass of dry soil+container (gm)	12.5
Mass of container(gm)	6.5
Mass of water (gm)	1.5
Mass of dry soil (gm)	6
water content (%)	25

Location: BIT PATNA

Table 5.2: WATER CONTENT

mass of wet soil+container (gm)	25
mass of dry soil+container (gm)	23
mass of container(gm)	8
mass of water (gm)	2
mass of dry soil (gm)	15
water content (%)	13.33

Location: GHANDI MAIDAN PATNA

Table 5.3: WATER CONTENT

mass of wet soil+container (gm)	16
mass of dry soil+container (gm)	14
mass of container(gm)	8
mass of water (gm)	2
mass of dry soil (gm)	6
water content (%)	33.33

Location: NIH PATNA (WALMI COMPLEX)

Table 5.4: WATER CONTENT

mass of wet soil+container (gm)	16
mass of dry soil+container (gm)	14
mass of container(gm)	8
mass of water (gm)	2
mass of dry soil (gm)	6
water content (%)	33.33

Location: AKU CAMPUS

Table 5.5: WATER CONTENT

mass of wet soil+container (gm)	25
mass of dry soil+container (gm)	23
mass of container(gm)	8
mass of water (gm)	2
mass of dry soil (gm)	15
water content (%)	13.33

Location: PATNA SAHEB

Table 5.6: WATER CONTENT

mass of wet soil+container (gm)	27
mass of dry soil+container (gm)	25
mass of container(gm)	10
mass of water (gm)	2
mass of dry soil (gm)	15
water content (%)	13.33

d5.3. Grain Size Analysis

1. Oven dried soil sample weighing 500gm was taken and soaked with water for 24 hours.

2. This soil sample was washed through sieve no 200(75 – micron sieve). Washing was carried out carefully.

3. To groups of soil, one passing through the sieve no. 200 i.e., -75 microns (called as fine particles) and another retained on the sieve no 200 i.e., +75 microns (called coarse particles) were collected separately.

4. Both the fractions of soil were than oven dried. The group retained on sieve i.e., +75 microns were subjected to sieve analysis and the group passing through the sieve i.e., -75microns was subjected to master sizer analysis.

5.3.1 Mechanical Sieve Analysis

1 oven dried soil sample retained on sieve no. 200 were taken for the sieve analysis.

2. The soil sample was sieved through a set of sieves i.e. 4, 10, 14, 20, 40, 60, 70, 700 sieves no. The sieving was performed with mechanical sieve shaker for 10 to 15 minutes.

3. The stack of sieve was removed from sieve shaker and weight of material retained on each sieve was calculated. The percentage of total soil sample retained on each sieve was also calculated.

4. The percentage of weight passing through each sieve was calculated. The calculation was with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure as given by

Percentage passing = percentage arriving – percentage retained

5. A plot of grain size versus percent passing was plotted on semi logarithmic scale.

5.4 grain size analysis

1. Oven dried soil sample weighing 500gm was taken and socked with water for 24 hours.

2. The soil sample was washed through sieve no 200 (75-micron sieve). Washing was carried out carefully.

3. Two groups of soil, one passing through the sieve no, 200 i.e. -75 microns (called as fine particles) and another retained on the sieve no. 200 i.e. +75 microns (called coarse particles) were collected separately.

4.both the fractions of soil were than oven dried. The group retained on sieve i.e. +75 microns was subjected to sieve analysis and the group passing through the sieve i.e. -75 microns was subjected master sizer analysis.

5.4.1 mechanical sieve analysis

1. Oven dried soil sample retained on sieve were taken for the sieve analysis

2. The soil sample were sieved through a set of sieves. The sieving was performed with mechanical sieve shaker for 10 to 15 minutes.

3. The stack of sieve was removed from sieve shaker and weight of material retained on each sieve was calculated. The percentage of total soil sample retained on each sieve was also calculated.

4. The % of weight passing through each sieve was calculated. The calculation was started with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure as given by

5. % passing= %arriving -%retained

6. A plot of grain size versus percent passing was plotted on semi log scale

Location: NIT PATNA

Table 5.7: Mechanical Sieve analysis for sand i.e. particle size greater than 75 microns

sieve size	mass. of sieve+soil (gm)	mass of sieve (gm)	Amount of soil retained in gram	% retained	cumulative % retention	% Passing
4.75 mm	402	392	10	4	4	96
2.36 mm	402	396	6	3	7	93
1.18 mm	408	402	6	3	10	90
600 µ	343	342	1	0.5	10.5	90.5
300 µ	222.5	214	8.5	4.25	14.75	85.25
150 µ	488	480	8	4	18.57	81.25
75 µ	255	254.5	0.5	0.25	19	81
pan			160	80	100	0

Location: BIT PATNA

Table 5.8: Mechanical Sieve analysis for sand i.e. particle size greater than 75 microns

sieve size	mass. of sieve+soil (gm)	mass of sieve (gm)	Amount of soil retained in gm	% retained	cumulative % retention	% Passing
4.75 mm	458.5	457.5	1	0.5	2.5	97.5
2.36 mm	414	412.5	1.5	0.75	3.25	96.75
1.18 mm	403	402	1	0.5	4.75	95.25
600 µ	343	340	3	1.5	625	94.75
300 µ	350	338	12	6	11.25	88.75
150 µ	392	376	16	8	19.25	80.75
75 µ	305	298	7	3.5	21.75	77.25
pan			158.5	79.25	100	0

Location: GHANDHI MAIDAN PATNA

Table 5.9: Mechanical Sieve analysis for sand i.e. particle size greater than 75 microns

sieve size	mass. of sieve+soil (gm)	Mass of sieve (gm)	Amount of soil retained in gm	% retained	cumulative % retention	% Passing
4.75 mm	458	457.5	0.5	0.25	3.25	96.75
2.36 mm	413	412.5	0.5	0.25	3.5	96.5
1.18 mm	403	402	1	0.5	4	96
600 µ	341	340	1	0.5	4.5	95.5
300 µ	340	338	2	1	5.5	94.5
150 µ	381	376	5	2.5	9	91
75 µ	302	298	4	2	11	89
pan			186	93	100	0

Location: NIH PATNA (WALMI COMPLEX)

Table 5.10: Mechanical Sieve analysis for sand i.e. particle size greater than 75 microns

sieve size	mass. of sieve+soil (gm)	mass of sieve (gm)	Amount of soil retained in gm	% retained	cumulative % retention	% Passing
4.75 mm	458	457.5	0.5	0.25	0.25	94.75
2.36 mm	413	412.5	0.5	0.25	0.5	94.5
1.18 mm	403	402	1	0.5	1	94
600 µ	341	340	1	0.5	1.5	93.5
300 µ	340	338	2	1	2.5	97.5
150 µ	381	376	5	2.5	5	90
75 µ	302	298	4	2	7	88
pan			186	93	100	0

Location: AKU CAMPUS

Table 5.11: Mechanical Sieve analysis for sand i.e. particle size greater than 75 microns

sieve size	mass. of sieve+soil (gm)	mass of sieve (gm)	Amount of soil retained in gm	% retained	cumulative % retention	% Passing
4.75 mm	458.5	457.5	1	0.5	0.5	97.5
2.36 mm	414	412.5	1.5	0.75	1.25	96.75
1.18 mm	403	402	1	0.5	1.75	96.25
600 µ	343	340	3	1.5	3.25	94.75
300 µ	350	338	12	6	9.25	88.75
150 µ	392	376	16	8	17.25	80.75
75 µ	305	298	7	3.5	20.75	77.25
pan			158.5	79.25	100	0

Location: PATNA SAHEB

Table 5.12: Mechanical Sieve analysis for sand i.e. particle size greater than 75 microns

sieve size	mass. of sieve+soil (gm)	Mass of sieve (gm)	Amount of soil retained in gm	% retained	cumulative % retention	% Passing
4.75 mm	392	392	0	0	0.5	99.5
2.36 mm	396	396	0	0	1.5	98.5
1.18 mm	403	402	1	0.5	2.5	97.5
600 μ	344	342	2	1	5	95
300 μ	216	214	2	1	11.25	88.75
150 μ	485	480	5	2.5		70.63
75 μ	267	254.5	12.5	6.25	11.25	68.98
pan			177.5	88.75	100	0

5.5 Specific Gravity

The S.G of soil sample can be calculated by obtaining the value of the known mass of soil grains and dividing this by the mass of the same value of distilled water. the value of a known mass of soil grains can be obtained by using a container of known volume. procedure is as follows:

1. mass of oven dry soil sample has been taken;

2. oven dry soil of known mass has been kept in known volume of container;

3. known volume of distilled water has been added in the container, such that soil is completely saturated and water level should reach up to level marked for the known volume;

4. volume of soil grain has been calculated by subtracting the volume of added distilled water from the volume of the container;

5. mass of same volume of distilled water has been taken;

6. the specific gravity has been calculated by dividing mass of the soil grains by the mass of the same volume of distilled water at 4º C.

Location: NIT PATNA

Table 5.13: Specific gravity using density bottle method

mass of density bottle (gram) A1	12.5
mass of density bottle with dry soil (gram) A2	28
mass of density bottle with dry soil and water (gram) A3	73.5
mass of bottle with only water A4	65
mass of dry soil (A2- A1)	15
mass of an equal volume of water {(A2-A1) -(A3-A4)}	7
specific gravity [{(A2-A1) -(A3-A4)}/ (A2- A1)]	2.21428

Location: BIT PATNA

Table 5.14: Specific gravity using density bottle method

mass of density bottle (gram) A1	12.5
mass of density bottle with dry soil (gram) A2	28.5
mass of density bottle with dry soil and water (gram) A3	68
mass of bottle with only water A4	63
mass of dry soil (A2- A1)	16
mass of an equal volume of water {(A2-A1) -(A3-A4)}	6
specific gravity [(A2- A1)/ {(A2-A1) -(A3-A4)}]	2.666666667

Location: GHANDHI MAIDAN PATNA

Table 5.15: Specific gravity using density bottle method

mass of density bottle with dry soil (gram) A2	25
mass of density bottle with dry soil and water (gram) A3	69.5
mass of bottle with only water A4	63
mass of dry soil (A2- A1)	12.5
mass of an equal volume of water {(A2-A1) -(A3-A4)}	6
specific gravity [(A2- A1)/ {(A2-A1) -(A3-A4)}]	2.083333333

Location: NIH PATNA (WALMI COMPLEX)

Table 5.16: Specific gravity using density bottle method

mass of density bottle with dry soil (gram) A2	25
mass of density bottle with dry soil and water (gram) A3	69.5
mass of bottle with only water A4	63
mass of dry soil (A2- A1)	12.5
mass of an equal volume of water {(A2-A1) -(A3-A4)}	6
specific gravity [(A2- A1)/ {(A2-A1) -(A3-A4)}]	2.083333333

Location: AKU CAMPUS

Table 5.17: Specific gravity using density bottle method

mass of density bottle (gram) A1	12.5
mass of density bottle with dry soil (gram) A2	28.5
mass of density bottle with dry soil and water (gram) A3	68
mass of bottle with only water A4	63
mass of dry soil (A2- A1)	16
mass of an equal volume of water {(A2-A1) -(A3-A4)}	6
specific gravity [(A2- A1)/ {(A2-A1) -(A3-A4)}]	2.666666667

Location: PATNA SAHEB

Table 5.18: Specific gravity using density bottle method

mass of density bottle (gram) A1	12.5
mass of density bottle with dry soil (gram) A2	30
mass of density bottle with dry soil and water (gram) A3	76
mass of bottle with only water A4	65
mass of dry soil (A2- A1)	17.5
mass of an equal volume of water {(A2-A1) -(A3-A4)}	6.5
specific gravity [(A2- A1)/ {(A2-A1) -(A3-A4)}]	2.692307692

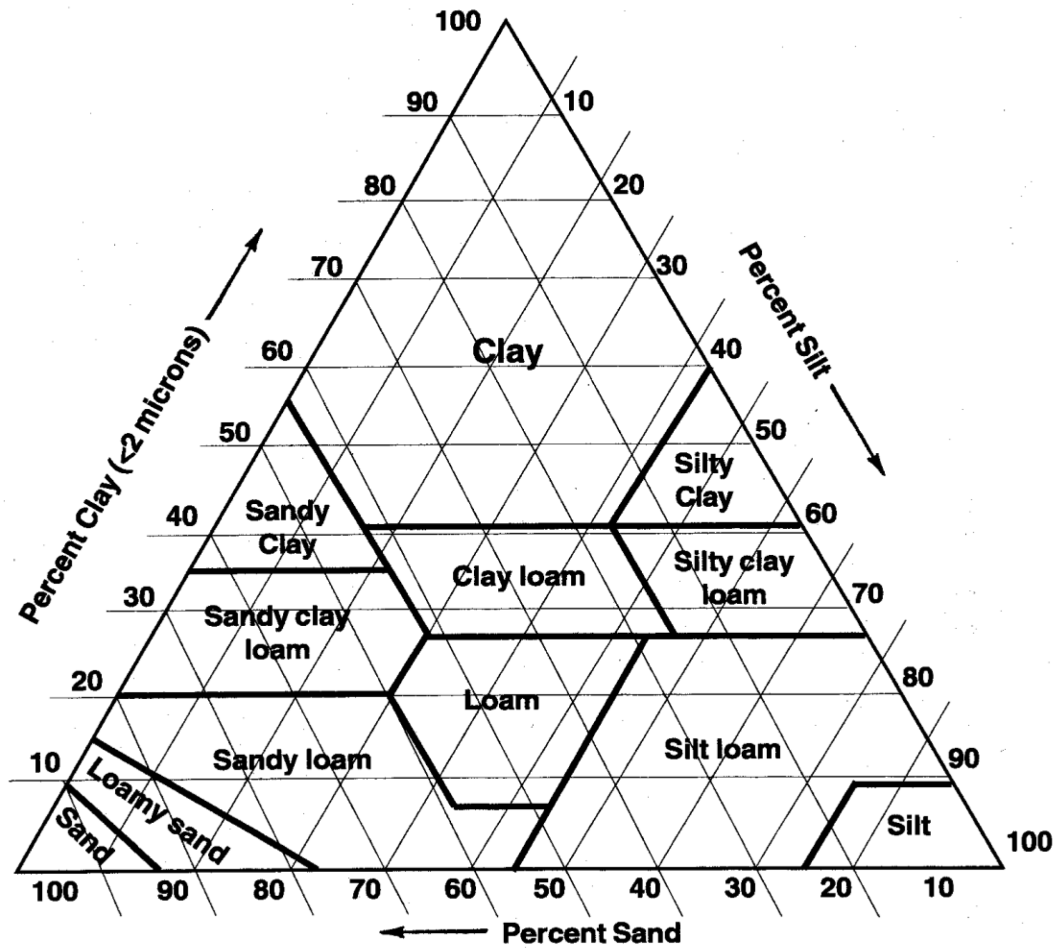


Fig 5.1: Textural classification of soil based on % of sand, silt and clay

5.6 Hydrometer analysis: -

The distribution of particle sizes expressed as a percent of the total dry mass is called Soil gradation or sieve analysis. In this procedure the % of sand, silt and clay in the inorganic fraction of soil is measured. This method is based on Stoke's law governing the rate of sedimentation of particles suspended in water.

Wet Sieving: A wet sieve analysis is required If the soil contains a substantial quantity (more than 12%) of fine particles. All lumps are broken into individual particles.

1. A 75-micron sieve is used through which the soil is passed. The soil passed is collected after wet sieving and dried in oven at 105-110^{0}c.
2. After removing soluble salts and organic matter if any, about 50 g of the oven dry soil sample is taken.
3. The soil is then mixed with prepared solution, the solution acts as the dispersing medium, the solution is of sodium hex metaphosphate(33g) and sodium carbonate(7g) in 1000ml distilled water
4. The solution is stirred well using mechanical spoon or using any mechanical process stirring.
5. The readings are recorded from the hydrometer at regular intervals as indicated in the data sheet. From the data obtained the particle size distribution curve is plotted in the semi-logarithmic graph sheet along with the dry sieve analysis results.

Correction applied to hydrometer reading

Meniscus Correction (Cm): The suspension is opaque, so the readings will be taken at the top of the meniscus, but it should be from the bottom of the meniscus. It is constant for a hydrometer (Always positive).

Temperature Correction (Ct): The correction is negative If the temperature is less than 27^{0}c, Temperature should be measured from starting till end of the tests at regular intervals and are averaged. Then it is compared with the standard temperature (27^{0}c).

Dispersion Agent Correction (Cd): Addition of dispersing agent which is sodium hex metaphosphate(33g) + sodium carbonate(7g) always increases the specific gravity of the specimen. Hence, this correction is always negative.

5.7 Porosity

Porosity has been calculated using the Multi volume Pycnometer and GeoPyc 1360. This is advanced equipment, which calculate the particle density and bulk density respectively and finally % porosity

5.8 Permeability

The permeability is determined in the laboratory using ICW Permeameter with both the method constant head and falling head. Procedures are as follows:

1. Undisturbed soil samples have been collected from the field using core cutter (sampling set).

2. Collected soil sample of permemetermould have been saturated completely for 24 hours.

3. Permemametermould have been kept in the bottom tank and filled the bottom tank with water up to its outlet.

4. Water inlet nozzle of the mould has been connected to the stand pipe filled with water has been permitted to flow for some time till steady state of the flow is reached.

5. The required time interval for the water level in the stand pipe to fall from some convenient initial value to some final value has been noted with the help of the stop watch.

6. Steps 1to5 have been repeated and the time for the water level in the stand pipe to drop from the same initial head to the same final value has been determined.

7. By using the formula given in all classical text book, the coefficient of permeability has been calculated.

The study area as shown in fig was selected for the estimation of characteristics equations. there are 6 locations from where 24 soil samples at different depths have been collected (3 samples from each locations). Fig 2 shows the locations of the soil sampling site. these sites were tentatively chosen in such a way that different types of soils found in the area were covered and the sites were easily approachable and where well distributed all over the study area. collected soil samples have been used for the analysis of grain size distribution and soil characteristic curve. measurement of field saturated hydraulic conductivity was also carried out at all sites by Guelph permeameter.

5.9 Soil Moisture Characteristics

Just after dying the soil samples were prepared, light hammering is done and is passed through 2.0 mm sieve. The passing soils from 2.0 mm sieve were used for determining soil moisture characteristics by applying 0.10, 1.00, 3.3., 5.00, 10.00, 15.00 bars pressure respectively.

Pressure plate apparatus i.e. soil moisture corporation co. USA was used to test the soil moisture retention behavior of the soil samples. Each of these samples, were tested against 0.10, 0.33, 0.50, and 1.0 bars, by one bar pressure plate. Whereas 3 bars, by 3 bar plates and 5 bars, by 4 bar plates as well as 10 bars and 15 bars with 15 bar pressure plate following procedure were followed in the experiment.

1. Firstly all the pressure plates are saturated and then prepared soil sample placed on plate in three separate rings and soaked with water for complete saturation.

2. Saturated plates containing soil sample were kept in pressure chambers and applied desired pressure till it reached equilibrium.

3. All the Sample were taken out from the pressure chambers. It is then weighted on the high precision microbalance to record the moist mass of the samples.

4. The weighed samples placed in the oven at 105C -110C till mass become constant on drying. The dry mass is recorded by weighing and soil moisture and soil moisture by mass was determined from the moist and dry mass of the sample.

Soil moisture measurement for all soil samples of 6 site at different depth were carried out and results are given in the table 5. Soil moisture retention curves are also plotted and are shown in fig 26 to 29 respectively.

The study area as shown in fig was selected for the estimation of characteristics equations. there are 6 locations from where 24 soil samples at different depths have been collected (3 samples from each locations). Fig 2 shows the locations of the soil sampling site. these sites were tentatively chosen in such a way that different types of soils found in the area were covered and the sites were easily approachable and where well distributed all over the study area. Collected soil samples have been used for the analysis of grain size distribution and soil characteristics curve. Measurement of field saturated hydraulic conductivity were also carried out at all sites by Guelph permeameter.

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Location: NIT Patna

Table 5.19: Moisture content of soil at different pressures at site P1

Pressure (in Bar)	mass of soil+ Water (in gm)	Dry mass (in gm)	mass of Container (in gm)	mass of Water (in gm)	mass of Dry soil (in gm)	water Content (in %)	Volumetric water content (in %)
0	45.479	37.859	7.135	7.6199	30.724	24.8013	31.00142
0.33	76.55	73.55	44.85	3	28.7	10.4526	13.0662
1	68.412	64.789	43.55	3.623	21.239	17.0584	21.3228
5	81.656	78.985	51.489	2.6701	27.495	9.71037	12.13792
10	77.88	75.889	54.33	1.991	21.559	9.23512	11.5439
15	93.456	91.589	53.112	1.867	38.477	4.85229	6.065312

Location: BIT Patna

Table 5.20: Moisture content of soil at different pressures at site P2

Pressure (in Bar)	mass of soil+ Water (in gm)	Dry mass (in gm)	mass of Container (in gm)	mass of Water (in gm)	mass of Dry soil (in gm)	water Content (in %)	Volumetric water content (in %)
0	49.365	37.847	6.8975	11.5153	30.952	37.2039	50.22472
0.33	76.749	73.843	45.741	2.906	28.102	10.3409	13.96022
1	68.459	65.894	45.8971	2.5615	20.003	12.8071	17.28987
5	81.986	78.985	51.518	2.9991	27.465	10.9182	14.73974
10	78.487	76.897	50.147	1.59	26.75	5.94395	8.024299
15	93.874	92.164	50.796	1.7086	41.364	4.13016	5.575643

Location: GHANDHI MAIDAN Patna

Table 5.21: Moisture content of soil at different pressures at site P3

Pressure (in Bar)	mass of soil+ Water (in gm)	Dry mass (in gm)	mass of Container (in gm)	mass of Water (in gm)	mass of Dry soil (in gm)	water Content (in %)	Volumetric water content (in %)
0	59.478	47.897	9.847	11.581	38.05	30.4367	38.95842
0.33	88.417	86.123	53.0456	2.294	33.074	6.93529	8.877119
1	83.19	78.987	53.0547	4.203	25.933	16.2079	20.74571
5	85.743	84.531	51.4811	1.2152	33.05	3.67685	4.706372
10	77.857	76.412	50.164	1.445	26.248	5.50511	7.046632
15	83.124	80.748	50.4811	2.376	30.269	7.85016	10.0482

Location: NIH Patna

Table 5.22: Moisture content of soil at different pressures at site P4

Pressure (in Bar)	mass of soil+ Water (in gm)	Dry mass (in gm)	mass of Container (in gm)	mass of Water (in gm)	mass of Dry soil (in gm)	water Content (in %)	Volumetric water content (in %)
0	54.623	42.981	7.1089	11.642	35.871	32.4549	38.94503
0.33	82.568	80.413	56.487	2.1575	23.923	9.01761	10.82118
1	95.148	89.853	56.8563	5.295	32.997	16.0476	19.25647
5	87.772	84.009	44.8888	3.7713	39.111	9.64225	11.57074
10	88.123	83.982	44.8888	4.1378	39.094	10.5838	12.7003
15	79.436	78.98	44.9587	0.456	34.023	1.34037	1.608404

Location: AKU Patna

Table 5.23: Moisture content of soil at different pressures at site P5

Pressure (in Bar)	mass of soil+ Water (in gm)	Dry mass (in gm)	mass of Container (in gm)	mass of Water (in gm)	mass of Dry soil (in gm)	water Content (in %)	Volumetric water content (in %)
0	55.632	44.54	8.8974	11.092	35.646	31.1206	37.03288
0.33	82.1	76.523	47.897	5.577	28.626	19.4829	23.18392
1	81.859	75.469	46.8745	6.3901	28.594	22.3478	26.59339
5	78.974	75.004	44.3798	3.967	30.626	12.9532	15.41433
10	70.564	68.564	44.1456	2.0006	24.418	8.19323	9.749912
15	75.897	72.456	44.721	3.441	27.735	12.4061	14.76398

Location: PATNA SAHEB

Table 5.24: Moisture content of soil at different pressures at site P6

Pressure (in Bar)	mass of soil+ Water (in gm)	Dry mass (in gm)	mass of Container (in gm)	mass of Water (in gm)	mass of Dry soil (in gm)	water Content (in %)	Volumetric water content (in %)
0	60.856	48.413	10.897	12.4437	37.513	33.1697	43.12057
3.3	89.697	86.235	52.45	3.4605	33.785	10.2426	13.31493
1	84.458	80.018	52.98	4.44	27.038	16.4213	21.34773
5	86.96	84.542	51.98	2.418	32.562	7.42584	9.653584
10	80.635	78.879	51.125	1.7535	27.754	6.31808	8.213411
15	82.524	80.963	51.368	1.561	29.595	5.27454	6.856902

Chapter 6

RESULTS AND DISCUSSION

Soil characteristics curve may be represented by means of reasonably easy parametric expression. the difficulty in characterize the soil hydraulic properties then reduce to estimating parameters of the appropriate constitutive model. the results of moisture content and suction head (θ-Ψ) can be fitted to the desired soil moisture characteristics model. Once the soil moisture characteristics function is estimated the unsaturated hydraulic conductivity relationship K(θ)- θ can be evaluated if the saturated hydraulic conductivity, Ks is known. Many different functional relationships have been used to describe the relationship between K, θ and Ψ. the most common relationship are Brooks – Corey model has been used for its simplicity (Rawls and Brakensick 1988).

The disturbed and undisturbed soil sample collected from 6 different locations along different depth in the study area were analyzed in the soil and groundwater laboratory of the institute to determine the grain size distribution , porosity , saturated hydraulic conductivity and soil characteristics curve , using the analyzed data , the particle size distribution curves were plotted putting grain size (mm) on log scale and the percentage passing of the soil through sieves on normal scale for all the soil sample . figure 6 to 23 show variation of the particle size distribution along depth at site. It is clearly evident from these figures that there are no much variations in the grain size along the depth except few locations which implies that soils in vertical directions are nearly homogeneous. the spatial variations of grain size distributions vary spatially.

Making use of these particle size distribution curves (figs. 6 through 26) the grain size distribution of the soil was assessed to determine the textural classifications of the soils using textural classifications graph of soil, fig.5. the textural formations of soil including effective and mean size are presented in table 2. The grain size distributions of soil sample show the presence of gravel content, which varies from 0% to 20% except few samples. it goes up to 30 percent also. the variations of sand content in the soil sample ranges from 40 % to 70%, except few samples. The silt content varies by and large, from 20 to 45%. the variation of clay content is found varying from 1 to 8 %. based on the textural classification of soil sample, the soil of the study area could be classified into two major groups: sandy loan and loamy sand, except few locations, which are sand and loam. table 3 presents the soil type along the vertical direction at surface, 30, 60, and 100cm below the ground surface. table 3 also depicts that there are mainly two types of soil on the surface i.e., sandy loam and loamy sand, which extended up to 30cm below the ground surface except P6 (Patna), where it is loam. figure 27 presents the extent of the soil types present in the study area based on textural analysis.

The undisturbed soil sample have been collected for the determination of the permeability in the laboratory using ICW Permeameter. Table 4 presents the values of permeability, specific gravity, particle density and porosity of soil samples. the value of permeability varies from 0.022 to 1.009 m/day except at site NP2. IT HAS 15.3 m/day. The specific gravity of the soil samples varies from 2.5 to 2.89.

The soil moisture measurement for different disturbed soil sample were determined using different pressure (0.1, 0.33, 1.0, 3.0, 5.0, 10.0, 15.0 bar). The results are presented in table 5. using the data of soil moisture for different pressure the soil moisture characteristics curves prepared and are prepared and are presented in fig 31, for different locations. the moisture content at field capacity and wilting point were obtained. the range of field capacity and wilting point vary from6.93 to 19.48 % and 1.34 to 12.40671 %. respectively. the available moisture that is useful to plant can be calculated based on these values. it is varying from 4.52 % to 10.02 %. it means the minimum water availability capacity of soil is 4.52 and maximum is 10.02 %. the locations wise value of the saturated hydraulic conductivity, saturated moisture content, field capacity and wilting points are summarized in table.

Table 6.1: Textural Classification of Soil

Sl. No.	depth	sand%	silt%	clay %	mean size	effective size	soil texture
1	0	20	68	12	0.473	0.007	silty loam
2	15	20.5	70	9.5	0.534	0.005	silty loam
3	30	23.8	62.4	13.8	0.495	0.006	silty loam
4	45	20	67.5	12.5	0.827	0.02	silty loam
5	15	22.75	63.26	13.29	0.222	0.004	silty loam
6	35	26.5	57	16.5	0.785	0.004	silty clay
7	50	25.54	55.95	18.5	0.463	0.003	silty clay
8	65	24.76	59.7	15.54	0.171	0.004	silty clay
9	10	11	72	17	0.052	0.003	silty loam
10	40	13.34	69.96	16.7	0.049	0.002	silty loam
11	50	12.5	68.53	18.97	0.218	0.003	silty loam
12	65	11.98	68.52	19.5	0.122	0.003	silty loam
13	10	12	72.656	15.34	0.079	0.003	silty loam

14	35	14.44	69.26	16.3	0.07	0.003	silty loam
15	65	13.55	70	16.8	0.013	0.002	silty loam
16	85	12.54	70.35	17.11	0.017	0.002	sandy loam
17	15	22.78	64.02	13.2	0.338	0.004	silty loam
18	40	20.4	65.3	14.3	0.354	0.004	silty loam
19	55	22.1	53.9	17.4	0.248	0.004	silty clay
20	75	19.5	64.1	16.4	0.225	0.004	Silty clay loam
21	15	31.02	52.53	16.43	0.218	0.004	Silty clay loam
22	30	28.54	52.92	18.54	0.201	0.004	Silty clay loam
23	60	26.54	56.13	17.33	0.078	0.005	silty loam
24	75	20.7	61.4	17.9	0.12	0.012	silty loam

Table 6.2: Values of Permeability, Specific Gravity, Particle Density, Bulk Density and Porosity

S.N	Site	Depth	Permeability (M/D)	Specific Gravity	Particle Density	Bulk Density	Porosity
1	P1	0-20	0.4	2.68	2.366	1.3316	0.437
2	P2	0-20	0.4	2.75	2.556	1.2171	0.524
3	P3	35-45	0.0535	2.7	2.8579	1.409	0.507
4	P4	0-20	0.4	2.85	3.0697	1.501	0.511
5	P5	0-20	0.4	2.89	2.829	1.363	0.518
6	P6	30-40	0.0305	2.87	2.639	1.25	0.526

Table 6.3: Soil Moisture Characteristics Data at The Ground Surface

s. no	LOCATIONS	Pressure 1st Row Is In Bar And 2nd Row Is In CM					
		0.1	1	0.33	5	10	15
		101.98	1019.8	3059	5099	10198	15297
1	P1	24.8	17.1	10.5	9.71	9.24	4.85
2	P2	37.20349	12.80731	10.3409	10.91832	5.943925	4.130106
3	P3	30.43627	16.20759	6.935249	3.676853	5.505181	7.85016
4	P4	32.45419	16.04706	9.017651	9.642285	10.58358	1.340337
5	P5	31.12006	22.34738	19.48229	12.95322	8.193203	12.40671
6	P6	30.43627	16.20759	6.935249	3.676853	5.505151	7.85016

Table 6.4: Values of Permeability, Bulk Density, Porosity, Wilting Point, And Field Capacity

Site	Soil Type	Ks(M/D)	Ks(Cm/H)	Bulk Density	Porosity	Wilting Point	Field Capacity
P1	silty loam	0.4	0	1.332	0.437	4.852249	10.45296
P2	silty loam	0.4	0	1.217	0.524	4.130106	10.3409
P3	silty loam	0.054	0.223	1.409	0.507	7.85016	6.935249
P4	silty loam	0.4	0	1.501	0.511	1.340337	9.017659
P5	silty loam	0.4	0	1.363	0.518	12.40671	19.48229
P6	silty loam	0.031	0.127	1.25	0.526	7.85016	6.935249

6.1 GRAIN SIZE DISTRIBUTION ANALYSIS

6.1.1 LOCATION: - NIT PATNA (P1)

Table 6:5

Particle size	Passing %
4.75	95
2.36	92
1.18	89
0.6	88.5
0.3	84.25
0.15	80.25
0.075	80
0.0673	61.28
0.04916	53.98
0.03547	48.14
0.02589	40.856
0.01893	33.522
0.01387	29.182
0.00998	26.26
0.00716	23.53
0.00511	20.43
0.00368	16.05
0.00299	14.59
0.00262	13.732
0.0015	11.672

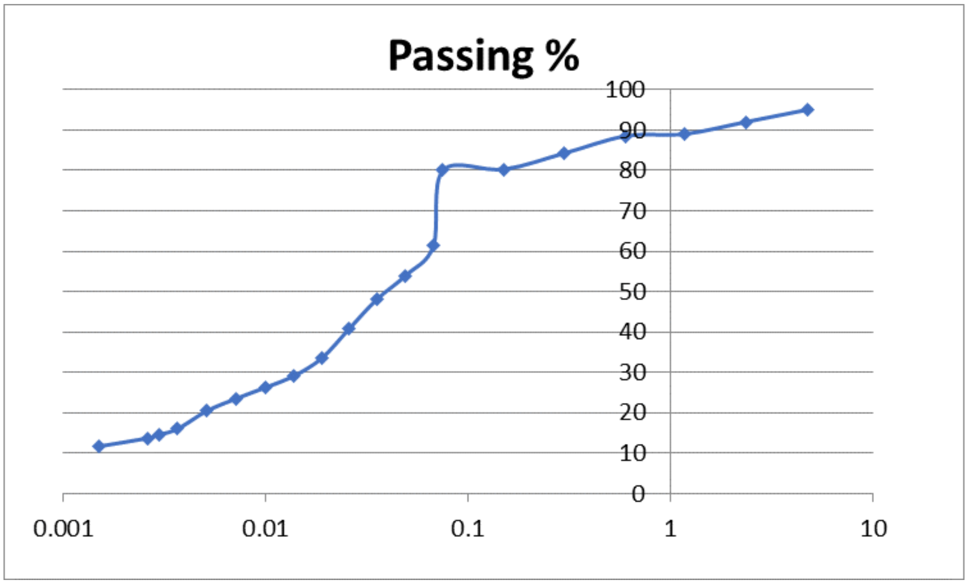

Fig 6.0: Grain Size Distribution at Site P1

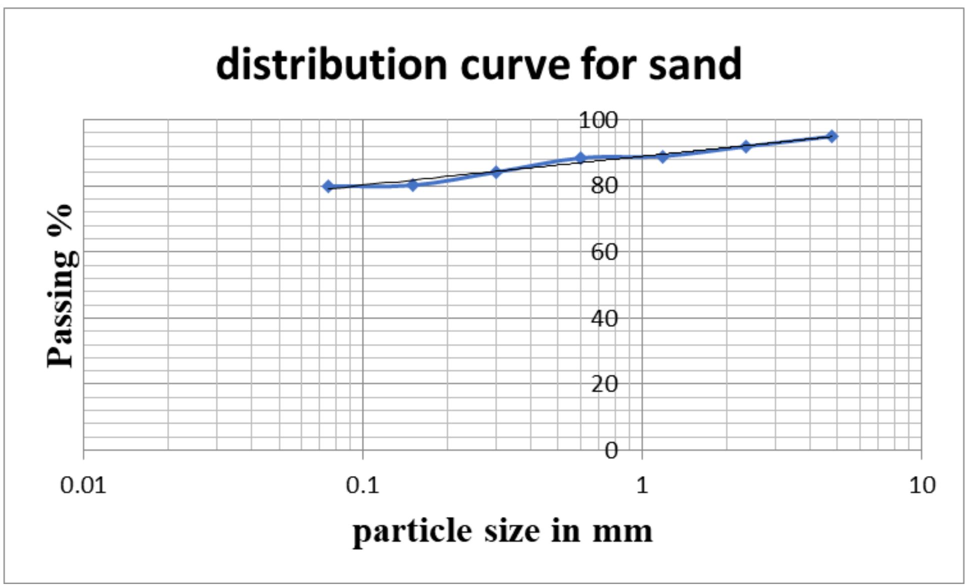

Fig 6.1: Distribution Curve for Sand

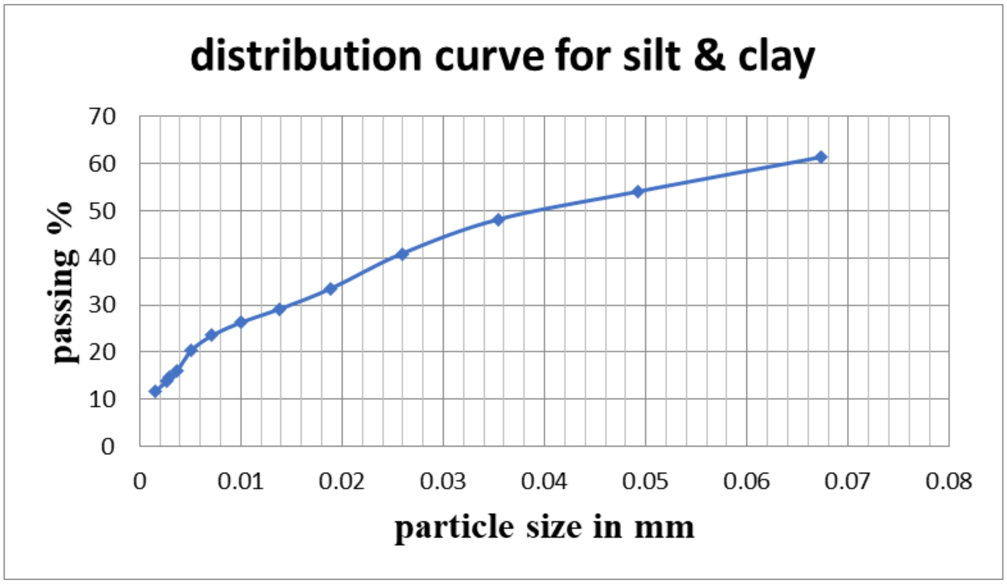

Fig 6.2: Distribution Curve for Silt & Clay

6.1.2 LOCATION: - BIT PATNA (P2)

Table 6.6

Particle size (in mm)	Passing %
4.75	97.5
2.36	96.75
1.18	95.25
0.6	94.75
0.3	88.75
0.15	80.75
0.075	77.25
0.0608	41.176
0.0433	37.765
0.03146	32.345
0.0223	30.015
0.0159	29.547
0.0118	27.198
0.0083	25.358
0.006	18.286
0.0043	17.918
0.003	15.95
0.0025	14.476
0.0021	13.294
0.0012	11.446

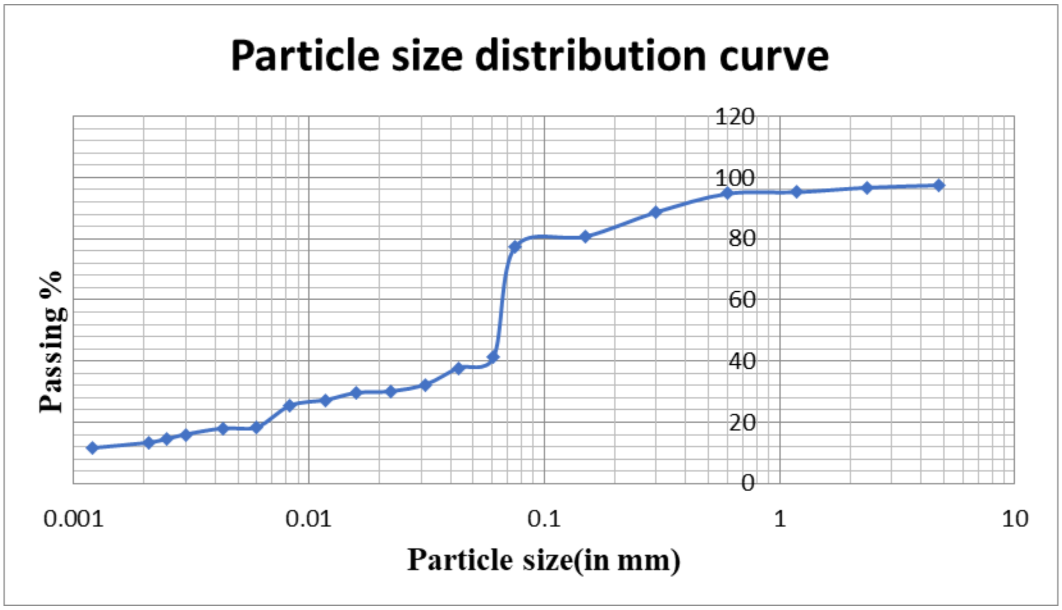

Fig 6.3: Grain Size Distribution at Site P2

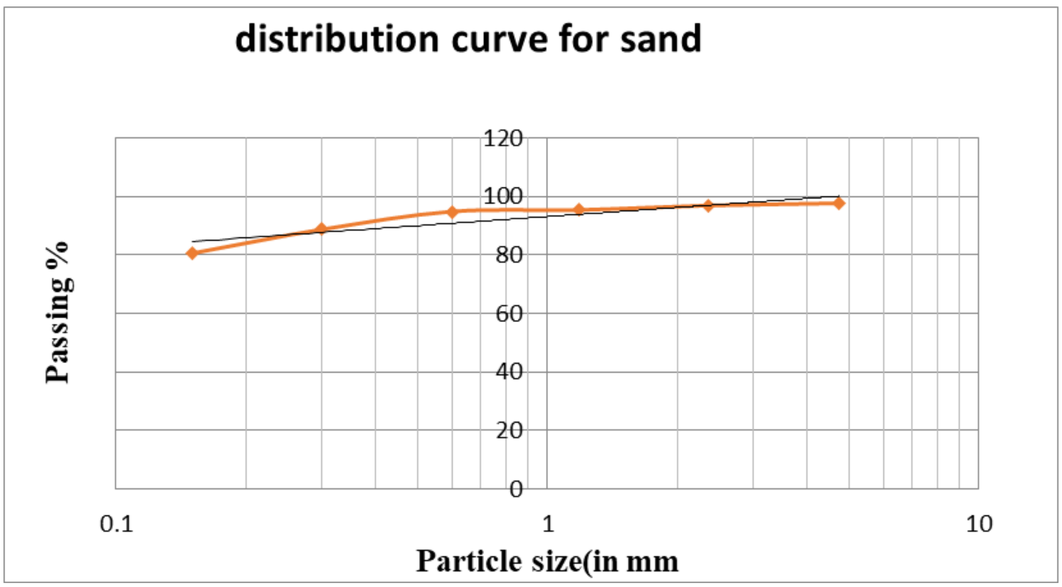

Fig 6.4: Distribution Curve for Sand

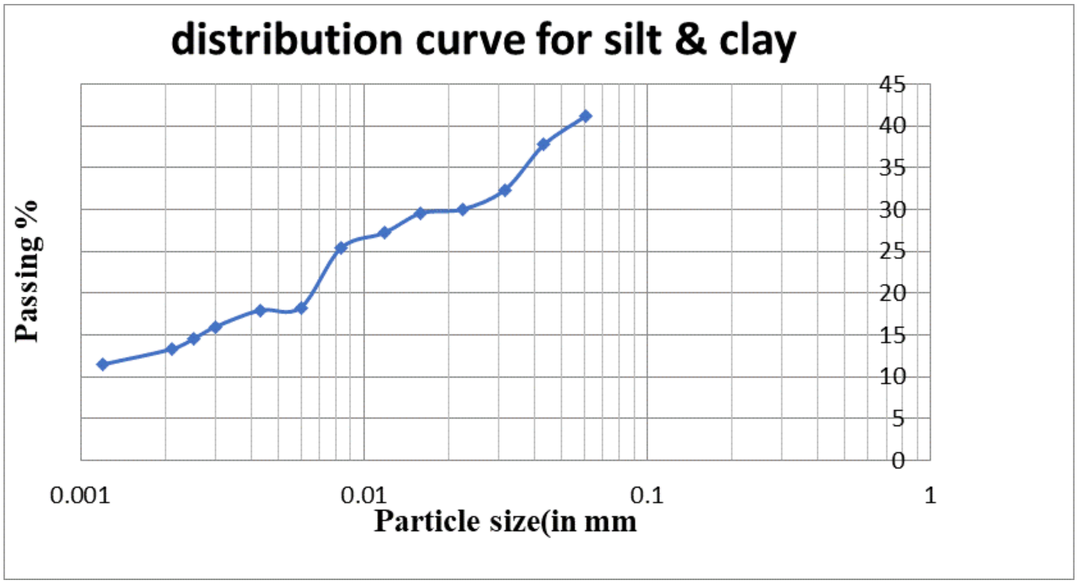

Fig 6.5: Distribution Curve for Silt & Clay

6.1.3 LOCATION: - GANDHI MAIDAN PATNA (P3)

Table 6.7:

Particle size (in mm)	Passing %
4.75	96.75
2.36	96.5
1.18	96
0.6	95.5
0.3	94.5
0.15	91
0.075	89
0.07	85.46
0.05042	73.58
0.03724	62.64
0.02589	60.82
0.01915	51.867
0.01442	40.76
0.01035	37.11
0.00755	28
0.00536	26.876
0.0038	24.667
0.00313	20.543
0.00275	17.098
0.00161	11.322

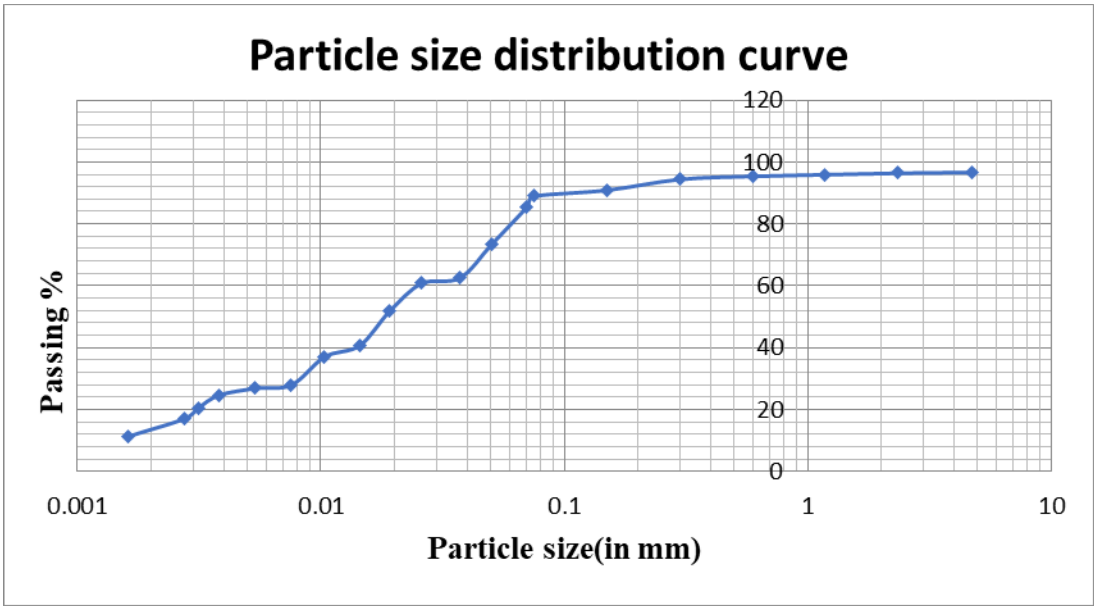

Fig 6.6: Grain Size Distribution at Site P3

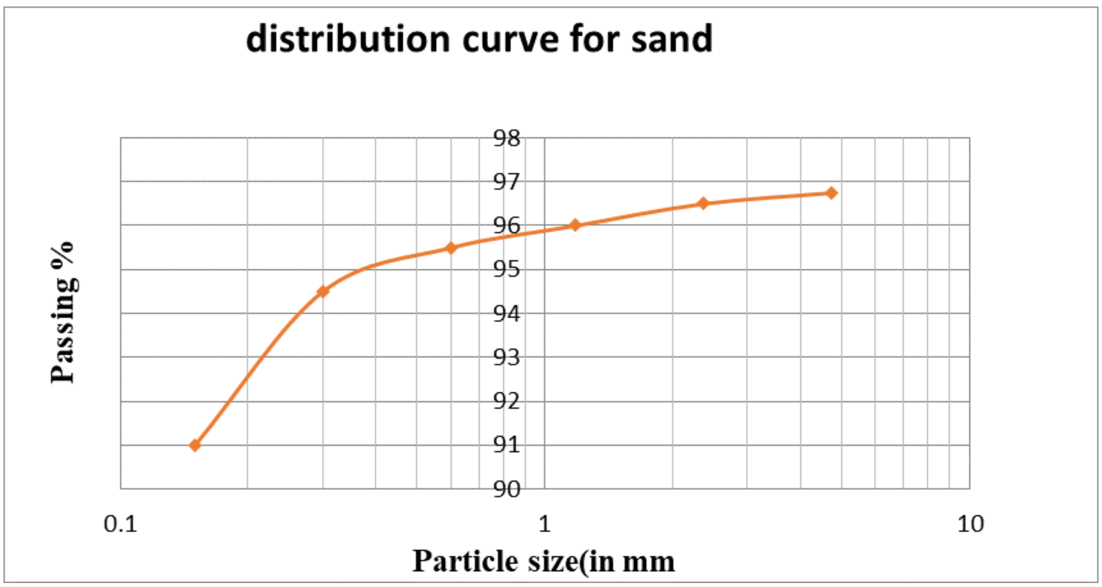

Fig 6.7: Distribution Curve for Sand

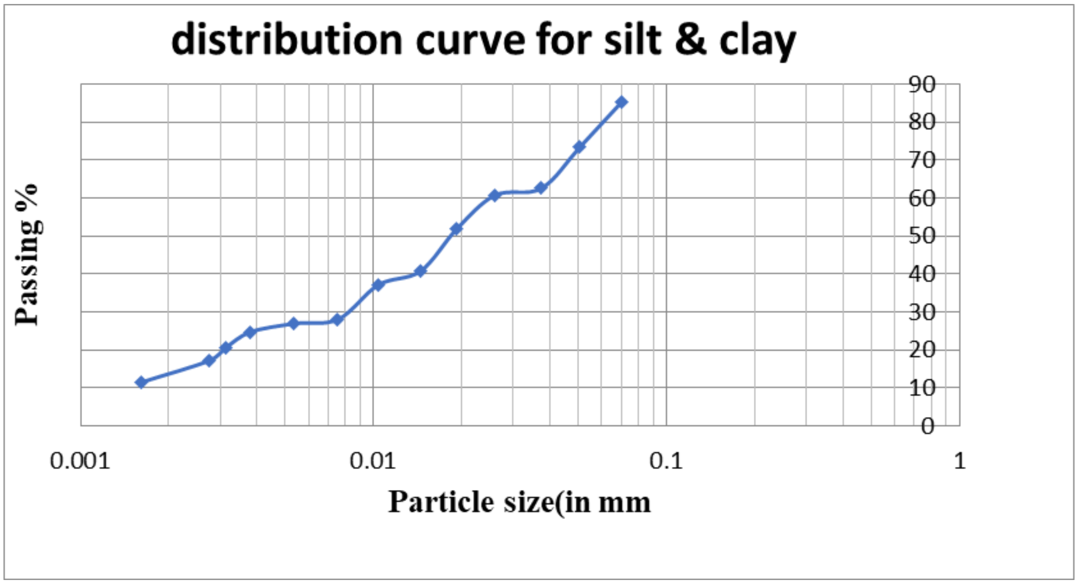

Fig 6.8: Distribution Curve for Silt & Clay

6.1.4 LOCATION: - NIH PATNA (P4)

Table 6.8:

Particle size (in mm)	Passing %
4.75	94.75
2.36	94.5
1.18	94
0.6	93.5
0.3	97.5
0.15	90
0.075	88
0.07	83.46
0.05042	71.58
0.03724	60.64
0.02589	58.82
0.01915	49.7
0.01442	38.76
0.01035	35.11
0.00755	26
0.00536	24.17
0.0038	22.499
0.00313	18.909
0.00275	15.344
0.00161	9.743

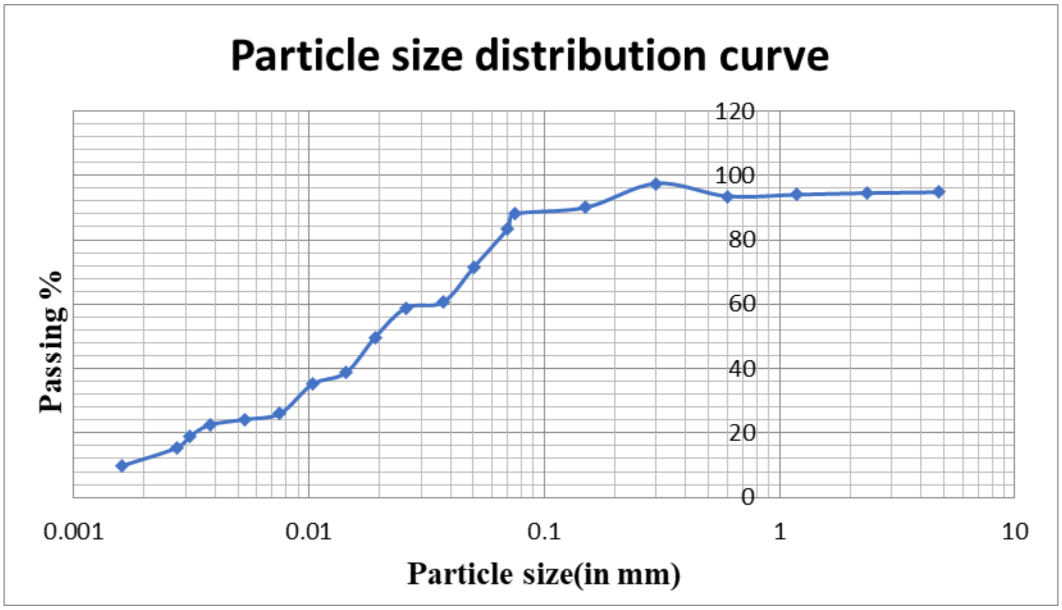

Fig 6.9: Grain Size Distribution at Site P4

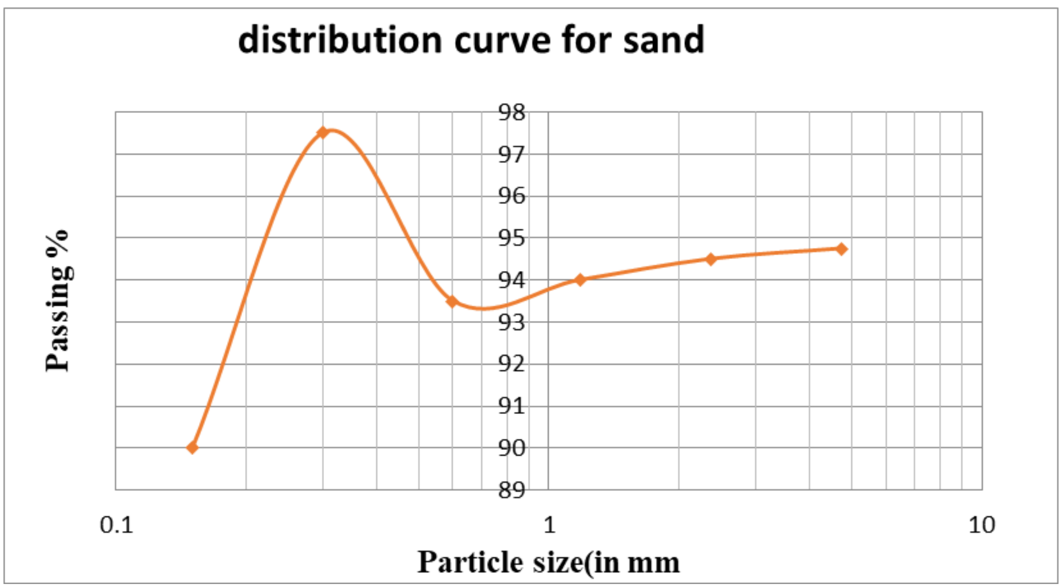

Fig 6.10: Distribution Curve for Sand

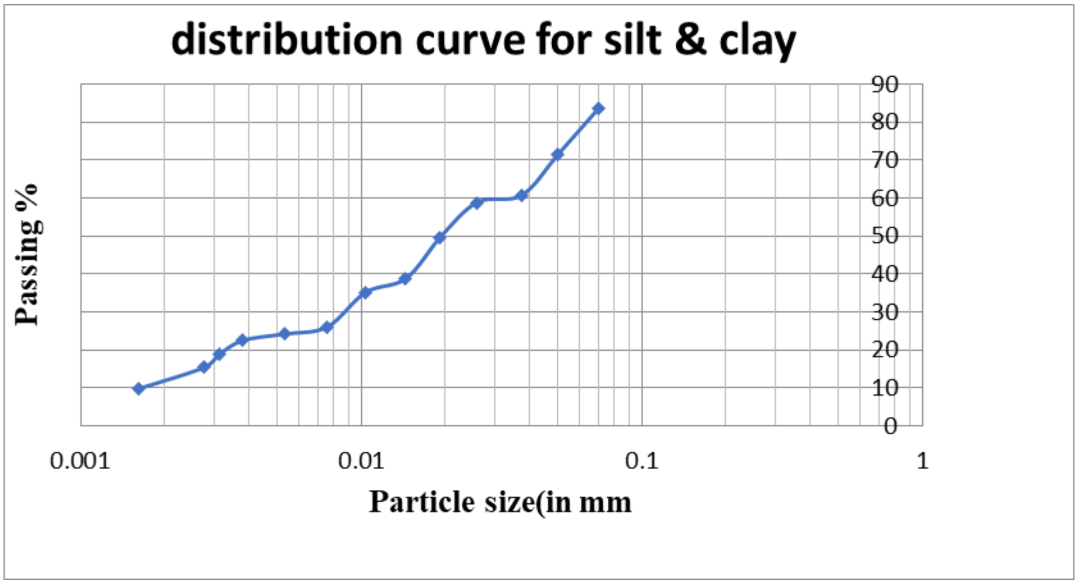

Fig 6.11: Distribution Curve for Silt & Clay

6.1.5 LOCATION: - AKU CAMPUS PATNA (P5)

Table 6.9:

Particle size (in mm)	Passing %
4.75	97.5
2.36	96.75
1.18	96.25
0.6	94.75
0.3	88.75
0.15	80.75
0.075	77.25
0.0608	41.108
0.0433	37.905
0.03146	32.133
0.0223	30.932
0.0159	29.597
0.0118	27.121
0.0083	23.988
0.006	18.436
0.0043	16.0338
0.003	15.75
0.0025	14.481
0.0021	13.204
0.0012	11.926

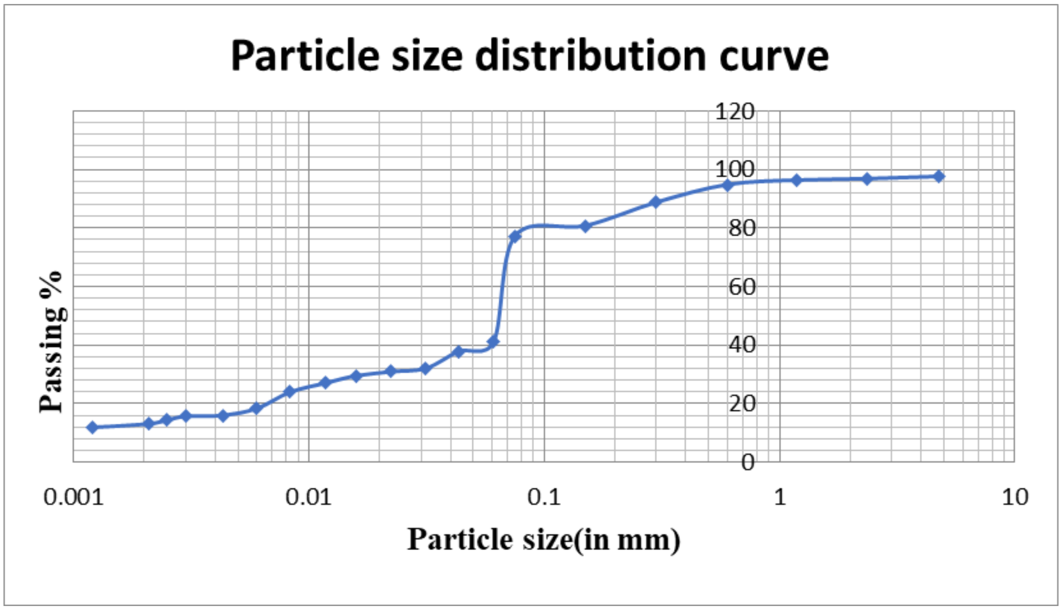

Fig 6.12: Grain Size Distribution at Site P5

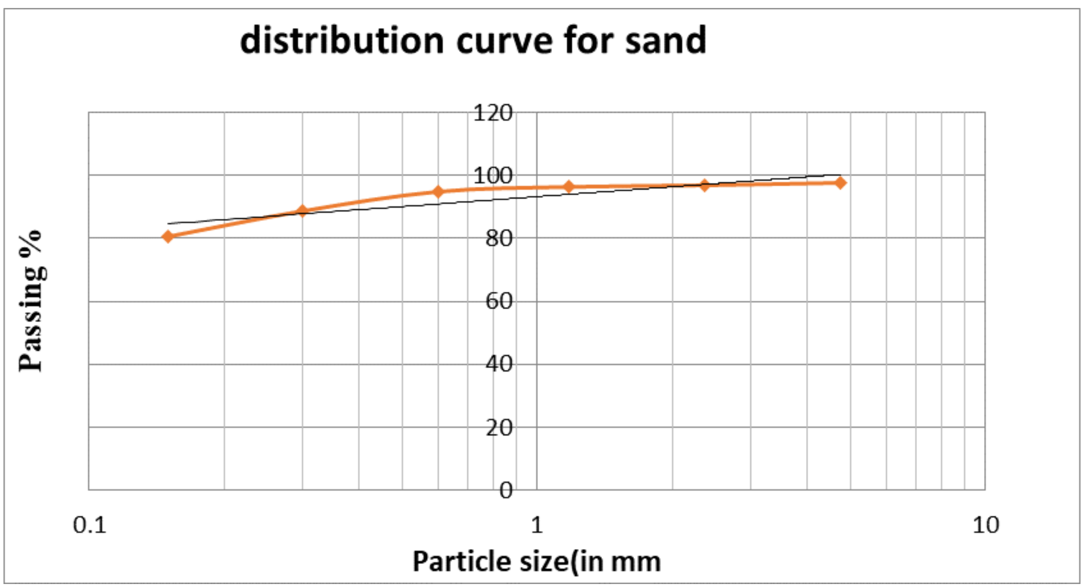

Fig 6.13: Distribution Curve for Sand

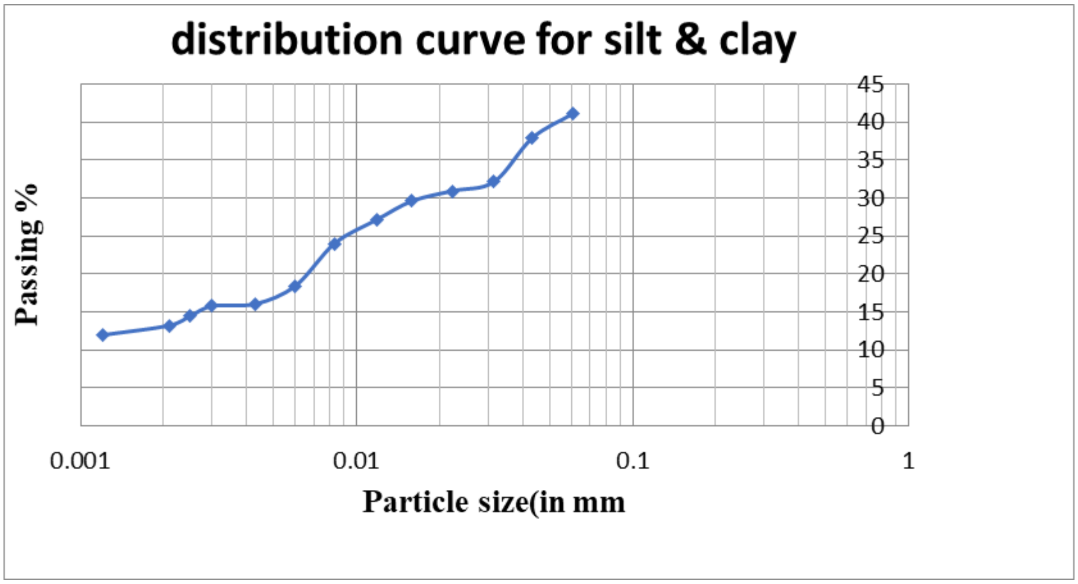

Fig 6.14: Distribution Curve for Silt & Clay

6.1.6 LOCATION: - PATNA CITY SHAEB PATNA (P6)

Table 6.10:

Particle size (in mm)	Passing %
4.75	99.5
2.36	98.5
1.18	97.5
0.6	95
0.3	88.75
0.15	70.63
0.075	68.98
0.054	60.9
0.0394	57.52
0.0285	53.354
0.0204	52.765
0.0147	49.24
0.0108	45.204
0.0077	40.906
0.0055	35.1116
0.003981	29.615
0.00289	25.432
0.002414	18.364
0.002124	16.433
0.00126	13.33

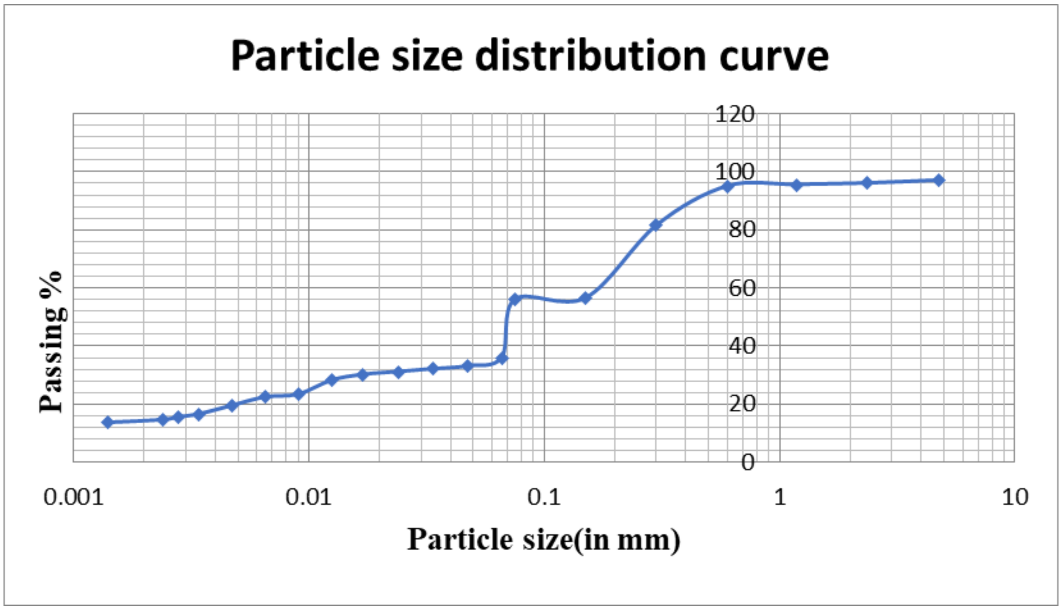

Fig 6.15: Grain Size Distribution at Site P5

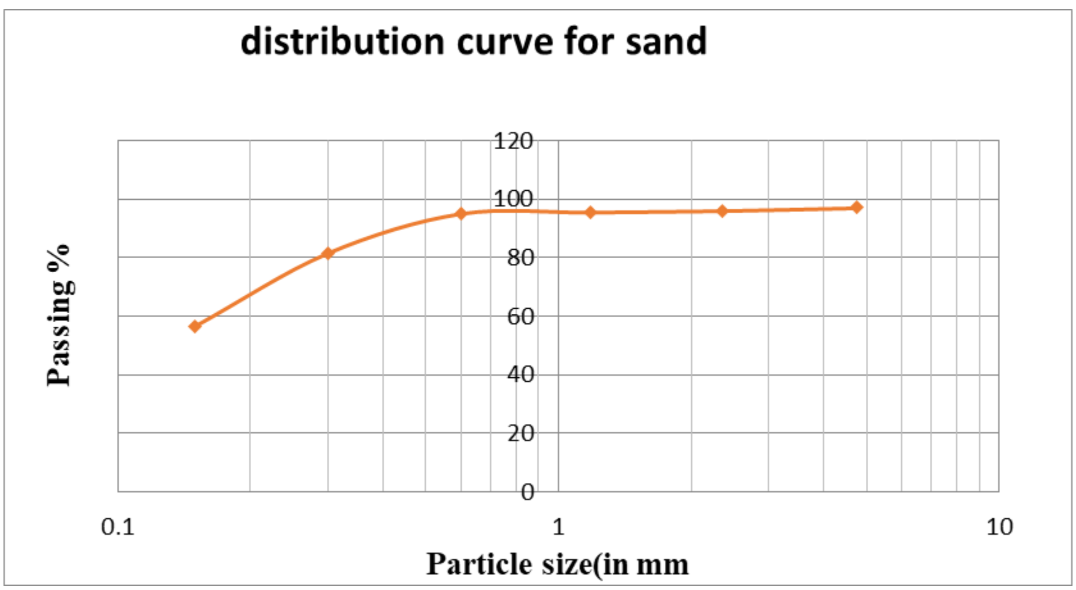

Fig 6.16: Distribution Curve for Sand

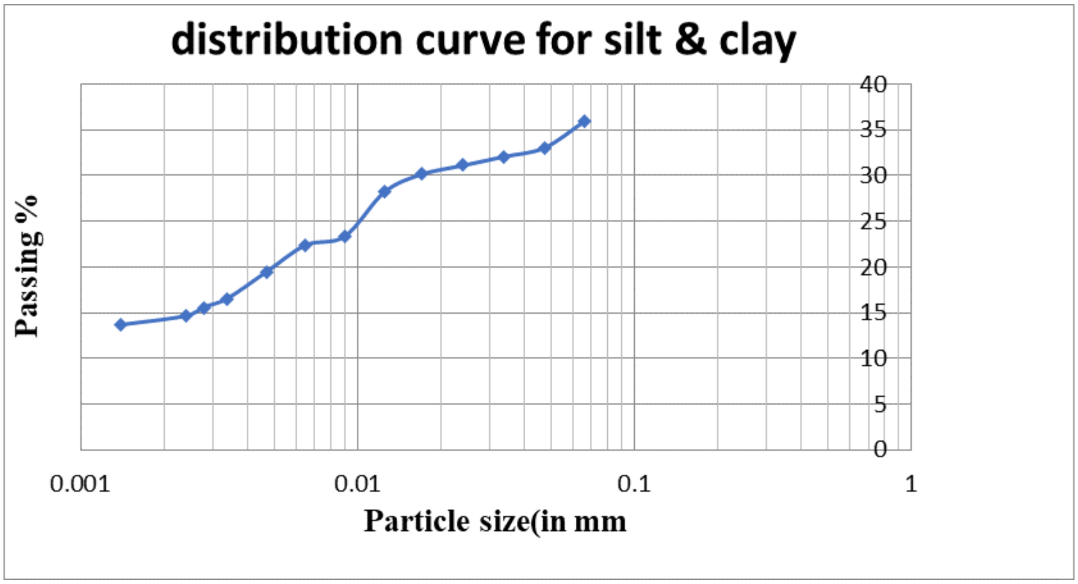

Fig 6.17: Distribution Curve for Silt & Clay

6.2 SOIL MOISTURE CHARACTERISTIC CURVE FOR SITE P1, P2, P3, P4, P5 AND P6

Table 6.11: Soil Moisture Reading at P1

	BARS	PRESSURE
P1	0.1	24.80113
	1	17.05824
	3.3	10.45296
	5	9.710337
	10	9.235122
	15	4.852249

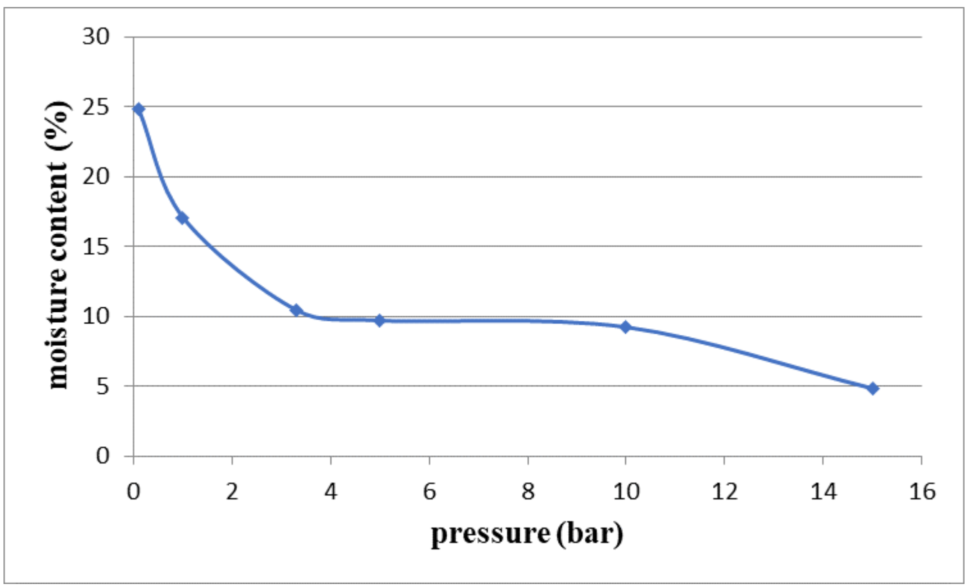

Fig 6.18: Soil Moisture Characteristic Curve for Site: P1

Table 6.12: Soil Moisture Reading at P2

P2	BARS	PRESSURE
	0.1	37.20349
	1	12.80731
	3.3	10.3409
	5	10.91832
	10	5.943925
	15	4.130106

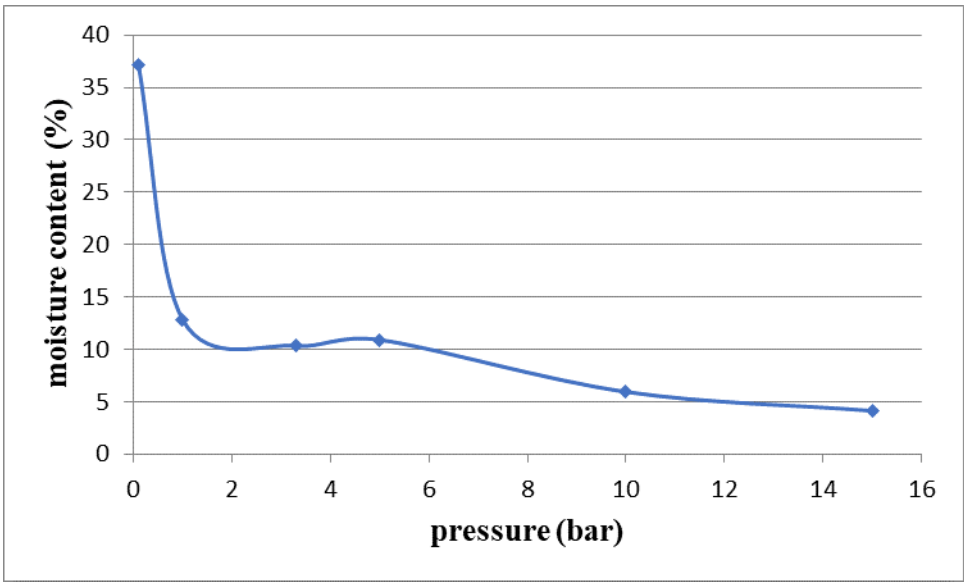

Fig 6.19: Soil Moisture Characteristic Curve for Site: P2

Table 6.13: Soil Moisture Reading at P3

P3	BARS	PRESSURE
	0.1	30.43627
	1	16.20759
	3.3	6.935249
	5	3.676853
	10	5.505181
	15	7.85016

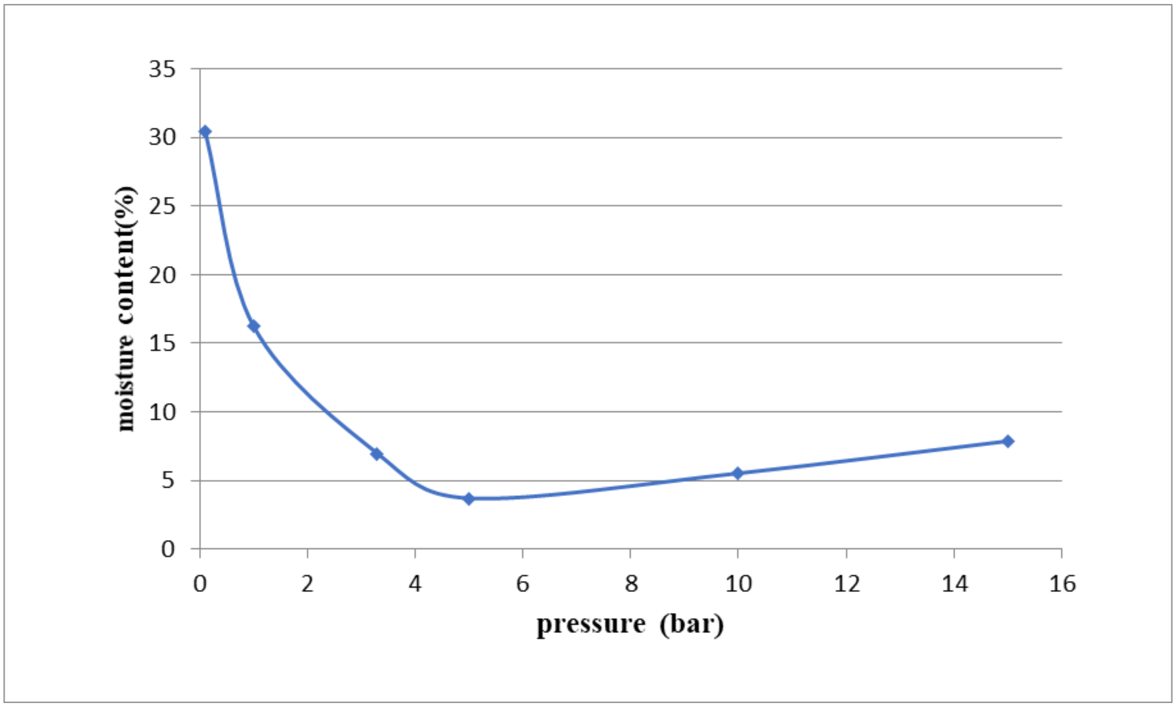

Fig 6.20: Soil Moisture Characteristic Curve for Site: P3

Table 6.14: Soil Moisture Reading at P4

P4	BARS	PRESSURE
	0.1	32.45419
	1	16.04706
	3.3	9.017651
	5	9.642285
	10	10.58358
	15	1.340337

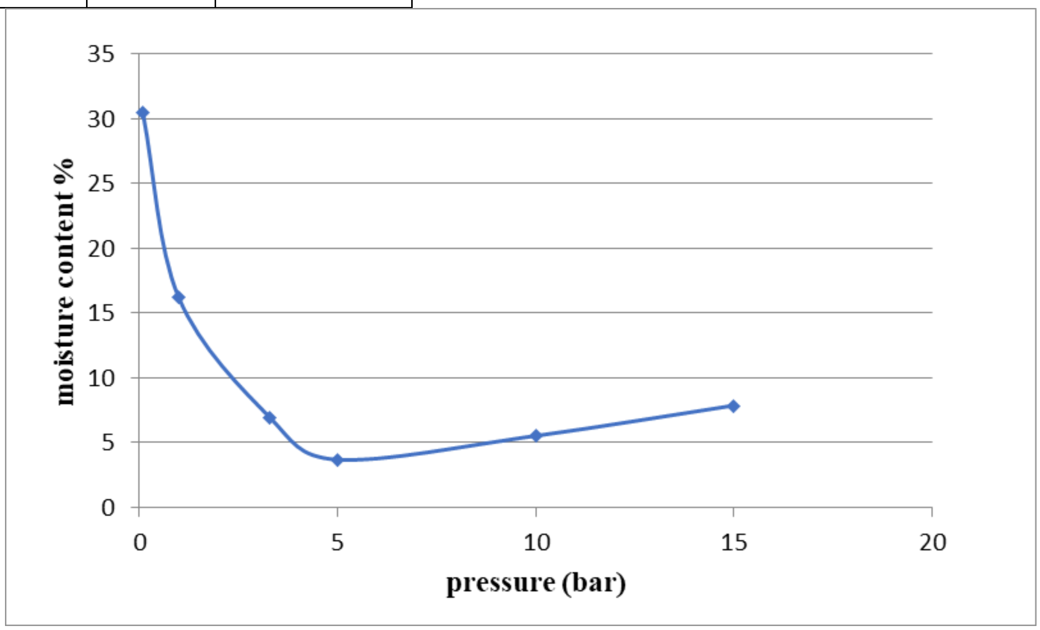

Fig 6.21 Soil Moisture Characteristic Curve for Site: P4

Table 6.15: Soil Moisture Reading at P5

P5	BARS	PRESSURE
	0.1	31.12006
	1	22.34738
	3.3	19.48229
	5	12.95322
	10	8.193203
	15	12.40671

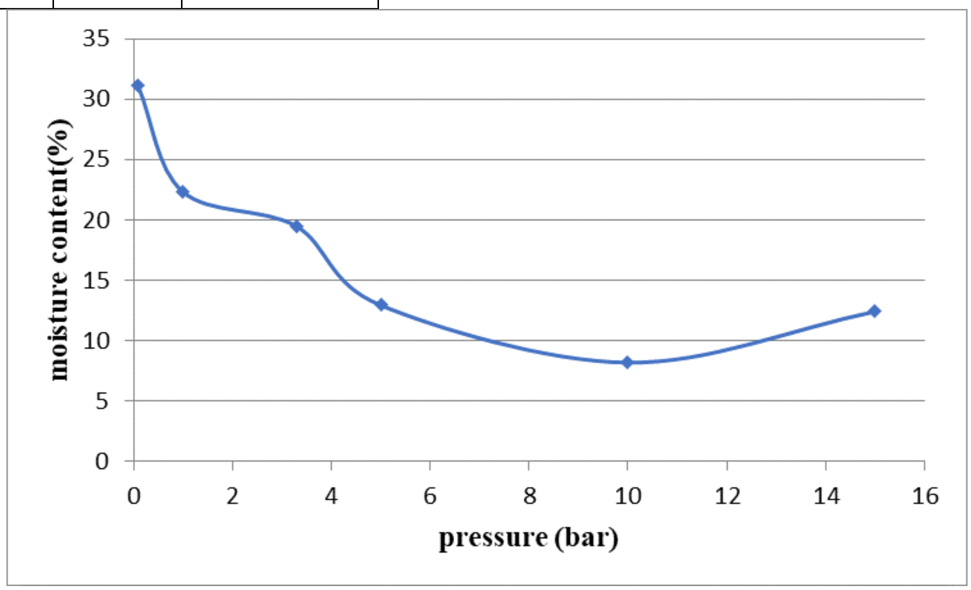

Fig 6.22: Soil Moisture Characteristic Curve for Site: P5

Table 6.16: Soil Moisture Reading at P6

P6	BARS	PRESSURE
	0.1	30.43627
	1	16.20759
	3.3	6.935249
	5	3.676853
	10	5.505151
	15	7.85016

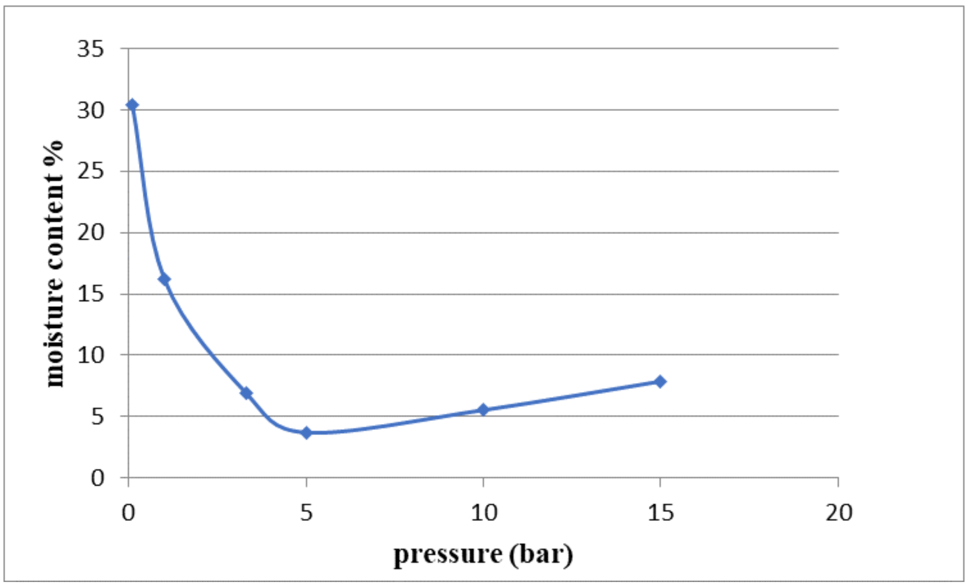

Fig 6.23: Soil Moisture Characteristic Curve for Site: P6

Chapter 7

CONCLUSIONS

The unconcerned and uninterrupted soil sample from six locations along different depths were collected and analyzed in the soil sample & Groundwater Laboratory of the Institute. unconcerned soil samples were asked to determine the grain size distribution, n, Gs and soil water characteristics curves. uninterrupted soil samples were asked with ICW Permameter to conclude Ksat.

Based on the laboratory analysis carried out in the NIT PATNA Laboratory, the following conclusions can be made: there are mainly 2 types of soil on the surface i.e., silty clay, silty loam, silty clay loam which extended up to thirty cm under the ground plane. The values of Ksat in the study region varies since 0.02294 m/d to 1.0094 m/d. Field capacity varies from 6.93 to 19.48 %. wilting points are lying between 1.34 to 12.40671 %. The specific gravity of the soils is from 2.5 to 2.89. The porosity values are from 0.4372 to 0.6381.

For silty clay soil values of hydrological properties are as follow: Ksat, 0.25 (cm/hr.); n, 0.56; filed capacity, 19.48229% and wilting point, 12.40671% whereas for silty loam these are Ksat, 0.748 (cm/hr.); porosity, 0.466; field capacity, 10.45296 % and wilting point 4.852249%.

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