PHYSICAL AND HYDRAULIC PROPERTIES OF CHANCHAGA RIVER BED SOIL AND SOIL DEPOSITED BY EROSION AS THEY AFFECT FARM STRUCTURES

BY

ODION, FINIAN ERHAGBE

MATRIC NO. 2004/18398EA

BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2010

DECLARATION

I hereby declare that this project work is an original work carried out and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

.... 17-02-10 ....

Odion, Finian Erhagbe — Date

CERTIFICATION

This project entitled "Physical and Hydraulic Properties of Chanchaga River Bed Soil and Soil Deposited by Erosion as they affect Farm Structures" by Odion, Finian Erhagbe, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

Engr. Mrs. H. I. Mustapha
Supervisor

16.02.10
Date

Engr. Dr. A.A. Balami
H.O.D, Agricultural and Bio resources Engineering

16.02.10
Date

Engr. Prof. G.O. Chukwuma
External Examiner

10-02-10
Date

DEDICATION

This project is dedicated to the glory of God Almighty for his blessing and protection throughout my years of studies. I also wish to dedicate this research work to my late father Mr. J. I. Odion and my mum Mrs. M. E. Odion.

ACKNOWLEDGEMENTS

I wish to use this medium to express my profound gratitude to God Almighty for His guidance and mercies. My thanks and appreciation goes to my project supervisor, Engr. Mrs. H. I. Mustapha for her indefatigable efforts in scrutinizing the manuscripts, assistance in areas of materials and her motherly care and advice to me. Ma, I say a big thank you, may God continue to bless you and your family. My appreciation goes to my Head of Department, Engr. Dr. A.A. Balami.

I want to also use this medium to thank all my lecturers in the department of Agric. and Bioresources Engineering especially Engr. Solomon, Engr. P. Adeoye, Mr. Sadeeq and others for their support and care throughout mu study in FUT, Minna.

I owe my endless gratitude next to my parents late Mr. J. I. Odion (who left like a candle in the wind but his flame still burns in my heart) and my mum Mrs. M. E. Odion (the best mum in the world). My heartfelt thanks to my elder brothers Mr. Cletus, Mr. Hillary and Mr. Eustace Odion, they are the stream of my inspiration from which I drank to survive. I must also thank my elder sisters Mrs. Juliana, Ursla and Edna; they are the knight in shining armor that can do no wrong in the sight of young innocent eyes. To them I say God bless you all.

I am sincerely thankful to Barrister P. C. Duru for his fatherly love and financial support, God will always bless and reward you Sir. I must also say a big thank you to Mr. & Mrs. Nicholas Odion, Mrs. Cynthia Odion, Aunty Jacinta Ifeoma, Carol Egwue, Mr. & Mrs. Remi Akinloye for their assistance. May God reward you all (Amen).

Lastly to all my friends and benefactors like Humphery (U know the story), Joe, Chijioke, Abdul (Pidoo), McVincent, Floxxy (U know it), Ololo, Solomon, Soloso, Agaba, Dayo, Victor, Fidelix, Saint, Judith, Mary, Nick, Mike, Oche. I love you all.

ABSTRACT

Soil has been a major bane to the effective delivery of engineering activities in Nigeria; agriculture, building and road constructions etc. The physical and hydraulic properties of the soils were investigated by excavating five trial pits for the river bed soil and five for the soil deposited by erosion. The soil is heterogeneous and two types were identified; brown, clayey, silty, gravely sand and brown, gravely, clayey, silty sand but the whole soil samples have the ratio of sand > gravel > silt + clay. The average optimum moisture content and average dry density of the river bed soil are 6.4% and 1794kg/m^3 respectively while that for the erosion soil deposited are 8.3% and 1774kh/m^3. The hydraulic conductivity for the river soil is 14.90cm/hr while that for the erosion soil is 16.75cm/hr and the apparent specific gravity ranges between 2.46 to 2.70 for the soil deposited by erosion and 2.46 to 2.64 for the river soil. The liquid limit, plastic limit and plasticity index is at 48.5%, 20.2% and 28.6% respectively for the river soil while for the soil deposited by erosion, the liquid limit is 40.55, and plastic limit 18.7% and plasticity index 21.8%. The bulk densities are higher in the river bed soil due to the high clay content of the soil than those of the soil deposited by erosion due to the high sand content. But the hydraulic conductivity is higher in the soil deposited by erosion as a result of its high sand and low clay. The high clay content of the river soil makes it more suitable for farm structures than the erosion soil deposited due to its high sand content. The finer particles in the soil deposited by erosion are due to the lower value of the specific gravity of the erosion soil. This also makes the erosion soil deposited not suitable for farm structures. The shrinkage potential ranges from low to high for the river bed soil and low to medium in the soil deposited by erosion.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND SYMBOLS

Trial Pit1 = River Sand.

Trial Pit2 = River Sand (5m North from trial pit1).

Trial Pit3 = River Sand (5m South from trial pit1).

Trial Pit4 = River Sand (5m West from trial pit1).

Trial Pit5 = River Sand (5m East from trial pit1).

Trial Pit6 = Sand deposited by Erosion.

Trial Pit7 = Sand deposited by Erosion (5m North from trial pit1).

Trial Pit8 = Sand deposited by Erosion (5m South from trial pit1).

Trial Pit9 = Sand deposited by Erosion (5m West from trial pit1).

Trial Pit10 = Sand deposited by Erosion (5m East from trial pit1).

Cc = Compressive Index; OMC = Optimum Moisture Content; MDD = Maximum Dry Density;

LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index = LL – PL.

SC = Clayey Sand; SN = Silty Sand; ML = Silt; MH = Plastic Silt.

CL = Clay of Low Plasticity.

CH = Clay of High Plasticity.

FG = Gravelly Silt or Gravelly Clay.

CLG = Gravelly Clay of Low Plasticity.

CIG = Gravelly Clay of Intermediate Plasticity.

CHG = Gravelly Clay of High Plasticity.

LISTS OF APPENDICES

CHAPTER ONE

1.0. INTRODUCTION

1.1. General Overview

Soil is one of our most important natural resources and an understanding of the soil system is key to the success and environment harmony of human use of land. Soils are grouped into coarse-grained soil (more than 50% retained on a 0.075mm sieve) and fine-grained soils (at least half smaller than 0.075mm sieve) (Brady and Weil, 2002). This classification seems to be so generalized that mention is not being made as to whether the origin, location or site of soils have any influence on the engineering behavior of the soil.

Soil consists of grain usually rock fragments or clay particles, with water and gas, usually air or water vapour, in the void spaces between the grains. If there is no gas present the soil is saturated and if there is no water it is dry, while if there is both water and gas in the voids the soil is unsaturated. The mechanical properties / behaviour of the soil (strength and stiffness) depend principally on the nature of the grains (what you see) and the current state of the soil (how the grains are arranged), but these are governed, to some extent, by the manner of formation which may be deposited, residual or compacted.

It is important to note the difference between soil description and soil classification. Soil description is simply what you see and how the soil responds to simple test while soil classification is a scheme for separating soils into broad groups, each with broadly similar behaviour.

The use of soil or sand cuts across all spheres of engineering works: agriculture, aggregate for road works, concrete, mortar, construction of filter, stabilization of soils etc. The importance attached to river sand as to warrant its haulage through ten of hundreds of kilometres when its use is desired in various engineering works, calls for a case study. This is more so because erosion sand deposited is readily available and in fact abundant in almost all places. Finding out by analysis of results based on experiment on river and erosion sands, that both possess the same engineering characteristics and that one can be substituted for the other, it will then be natural at least from economic point of view and labor saving, to adopt the use of erosion soil where necessary.

In the process of achieving these objectives, the classification test (particle size distribution), and permeability test usually come to mind. In order to arrive at a good degree of precision, it is necessary to include infiltration capacity of the soil, specific gravity, porosity, particle density and void ratio. The object of soil classification is to divide soils into groups such that all the soils in a particular group have similar characteristics, by which they may be identified and exhibit similar behavior in given engineering situations. A classification system also provides a common language for the exchange of information and experience regarding soils.

1.1.1. The Nature of Soils

Success or failure of both agricultural and engineering projects often hinges on the physical characteristics of the soil used. The hydraulic characteristics of soils influence how soils function in an ecosystem and how they can be managed. The occurrence and growth of many plants species and the movement of water and solutes over and through the soil are closely related to soil physical characteristics. Together, soil texture and structure help determine the nutrient supplying ability of soil solids, as well as the ability of the soil to hold and conduct water and air, and for understanding soil behaviour and management (Atkinson, 1993).

Brady and Weil (2002) emphasized that the behaviour of a soil in the field depends not only on the significant properties of the individual constituents of the soil mass, but also on those properties which are due to the arrangement of the particle within the mass. The principal soil grain properties are the size and shape of the grain and, in clay soils, the mineralogical character of the smallest grain. The action of hydraulics characteristics of soil determine how soils behave when used for highways, building constructions and foundation or when manipulated by tillage. In fact, through their influence on water movement through and off soils, soil physical properties exert considerable control over the destruction of the soil itself by erosion.

Soil which is at the heart terrestrial ecology is the product of both destructive and creative (synthesis) process. Weathering of rock and microbial decay of organic residues are example of destructive process, whereas the formation of new minerals, such as certain clays, and new stable organic compounds are examples of synthesis (Brady and Weil, 2002).

1.1.2. **Sand as a Type of Soil**

The original rocks and minerals are destroyed by both physical disintegration and chemical decomposition. Without appreciably affecting their composition, physical disintegration breaks down parent rock into smaller rocks and eventually into sand and silt particles that are commonly made up of individual minerals. Simultaneously, the minerals decompose chemically, releasing soluble materials and synthesizing new minerals, some of which are resistant end products. During the chemical changes, particle size continues to decrease, and constituents continue to dissolve in the aqueous destructive solution (Brady and Weil, 2002).

During transportation, the size and shape of particles can undergo change and the particle can be sorted into size ranges. The different sizes and shapes of the weathered soil constitute sand which is cohesionless aggregates of rounded subangular or angular fragments of more or less unaltered rocks or minerals. Sand is used to classify a particular grain size and to describe a soil that is loose when dry, not sticky at all when wet, and when rubbed it leaves no film on the finger (easy to handle). Individual sand particles are normally visible to the naked eyes and their sizes range between 0.06m, 0.2m, 0.6m and 2.0m depending on their fineness, medium or coarse (Atkinson, 1993).

Sand particles are probably most familiar to us. The coarsest sand particles may be rock fragments containing several minerals, but most sand grains consist of a single mineral, usually quartz (SiO_2) or other primary silicate. The dominance of quartz means that the sand separate generally has a far smaller total content of plant nutrients than do the finer separates. As sand particles are relatively, so, too, the voids between them are relatively large and promote free drainage of water and entry of air into the soil. Because of their large size, particles of sand have relatively low surface area (Brady and Weil, 2002).

Brady and Weil (1999) maintain that sandy soils generally have higher conductivities than finer-textured soils. In sandy soils, preferential flow (movement of pesticides and other toxic chemicals through the soil) occur as "fingers" of rapidly wetted soil, much the way raindrops falling on a window glass will coalesce and flow down the window in tiny streams.

In sandy soils, organic matter contents generally are low, the solid particles are less likely to be aggregated together, and the bulk densities are commonly higher than that of other soils. This is due to the uniformity of their grain sizes and the type of packing arrangement which significantly affect the bulk density. Sandy soils are usually freely drained and in dry season may suffer from drought, which make the soils prone to erosion. These are due to the soils having large amount of large pores and less total porosity (Brady and Weil, 1999). The large pores present little frictional resistance to rapid capillary water movement (the upward movement of water) which is responsible by two forces. The forces are:

(i) The attraction of water for the soil (adhesion and adsorption).

(ii) The surface tension of water, which is due largely to the attraction of water molecules for each other (cohesion).

Because of the relatively low porosity, and equidimensional shape of the individual mineral grains, very sandy soils resist compression once the particles have settled into a tight packing arrangement. Changeable soil properties can indicate the status of a soil's quality relative to its potential, much the way water turbidity or oxygen content indicate the water quality status of a river (Atkinson, 1993).

1.1.3. Erosion

Soil particles washed or blown from the eroding areas are subsequently deposited elsewhere- in nearby low-lying landscapes sites, in streams and rivers etc. The environmental and economic damages suffered by sites on which the eroded soil materials are deposited may be as great as or greater than that incurred on the sites from which the soil material was removed. Erosion is a process that transforms soil into sediment. The displaced soil material (sediment and dust) lead to major water and air pollution problems, bringing enormous economic and social costs to society. Erosion selectively removes organic matter and fine minerals particles, while leaving behind mainly relatively less active, coarser fractions. The soil left behind usually has lower water-holding and cation-exchange capacities, less biological activity, and a reduced capacity to supply nutrients for plant (Brady and Weil, 2002).

Soil erosion that takes place naturally, without the influence of human activities, is termed geological erosion while accelerated erosion occurs when people disturb the soil or the natural vegetation by grazing livestock, cutting forests, tearing up land for construction of roads and buildings (Brady and Weil, 1999). In discussing erosion, soil description normally essential are the nature of the grains, current state of soil and formation of the soil. Soils completely washed away by erosion are lost for all practical purpose. More often, soils are degraded in quality rather than totally destroyed. Erosion causes contamination of a soil with toxic substances from industrial processes or chemical spills can degrade the soil capacity to provide habitat for soil organisms, to grow plants that are safe to eat, or safely recharge ground and surface waters (Brady and Weil, 2002).

1.1.3.1 Erosion by Water

Water supplied to soils by rain, snowfall, and irrigation moves by a number of pathways. Some of the precipitation is interrupted by plants and returned to the atmosphere by evaporation without ever reaching the soil and some returned by vaporization after plants uptake and use which results to transpiration. Most of the water that does reach the soil penetrates downward by the process of infiltration especially if the soil surface structure is loose and open. If the rate of rainfall exceeds the infiltration capacity of the soils, the excess water unable to penetrate will begin to ponds on the soil surface.

About two-thirds of the total soil moved annually by soil erosion in Nigeria is by water and one-third by wind. The soil materials eroded by water may be deposited at some point in the landscape where the energy of flow is reduced or may be carried into major river systems. Sediments that washes into streams or river (less than 20%) makes the water cloudy or turbid. It is important to note that high turbidity prevents sunlight from penetrating the water and thus reduces photosynthesis and survival of the submerged aquatic vegetation (SAV). The demise of the SAV, in turn, degrades the fish habitat and the aquatic food chain (Brady and Weil, 1999).

Sediments deposited on the river bottom can have a disastrous effect on many fresh water fish by burying the pebbles and rocks among which they normally spawn. The buildup of bottom sediments can actually raise the level of the river, so that flooding becomes more frequent and more severe. Soil erosion by water is fundamentally a three-step process (Brady and Weil, 1999)

(a) Detachment of soil particles from the soil mass.

(b) Transportation of the detached particles downhill by floating, rolling, dragging and splashing.

(c) Deposition of the transported particles at some place lower in elevation.

1.1.3.2 Factors Affecting Erosion

Erosion damages the site on which it occurs and also has undesirable effect in the larger environment. The cost associated with the damages may not be immediately apparent; they are real and grow with time. The most obviously damaging aspect of erosion is the lost of soil itself (Brady and Weil, 2002).

Soil science society of America (1996) made it cleared that it is impossible to play-down the importance of preventing soil erosion but like many problems before you can address it you first have to understand it. Soil erosion is a very complicated problem to solve, because there are so many factors, which affect the rate of erosion. These factors include:

(i) Rainfall;

(ii) Soil type;

(iii) Landscape or topography;

(iv) Farm management;

(v) Infiltration capacity of the soil; and

(vi) Permeability of the profile.

Soil erosion includes the process of detachment of soil particles from the soil mass and the subsequent transport and deposition of those sediment particles. This sediment has a tremendous societal cost in terms of stream degradation, disturbance to wildlife habitat, and direct cost for dredging, as well as losing productive soil for agricultural land. The deterioration of soil structure often leaves a dense crust on the soil surface, which, in turn, greatly reduces water infiltration and increases water runoff (Soil Science Society of America, 1996).

Considerable progress in reducing soil erosion was made during the 1940s and 1950s, when such physical practices as contour strips, terraces, and wind breaks were installed with much persuasion and assistance from government agencies. Also, rather remarkable progress is made in reducing soil erosion, largely as a result of two factors (Nwafor, 2006):

(i) The spread of conservation tillage; and

(ii) The implementation of land-use changes as part of the conservation reserve program.

1.2 Statement of the Study

To study river Chanchaga in respect to the physical and hydraulic properties of the river bed soil and soil deposited by erosion around its banks as they affect farm structures.

1.3 Objectives

(1) To evaluate the physical and hydraulic properties of the river soil and soil deposited by erosion.

(2) To determine the effect of river soil and soil deposited by erosion on the environment (Chanchaga).

(3) To show the significance level of river soil and soil deposited by erosion.

1.4 Justification

The need for this study arisen from the fact that sand is a vital requirement for construction of buildings, drainage etc which lead to any meaningful development of a nation.

Also, to look into the problems caused by soil erosion with a view to preferring solutions through hydraulic properties.

This dissertation is, therefore, to identify the difference between river soil and erosion soil deposited in terms of their hydraulic properties and making useful recommendations.

The need for this study will help to check if the river soil and erosion soil in river Chanchaga can as a medium to promote the growth of plants and animals (including humans), while regulating the flow of water in the ecosystem.

1.5 Scope and Limitation

The study is limited to the role of hydraulic conductivity, bulk density, permeability, porosity, particle density, Atterberg limit, compaction, void ratio and aggregate stability on river Chanchaga's soil and the erosion soil deposited.

This dissertation confined to river Chanchaga in Minna, Niger state. It equally restricted to the physical and hydraulic characteristics of the river sand and sand deposited by erosion as they affect farm structures.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Methods of Soil Analysis and their Influencing Factors

Since the total amount of an element in a soil tells us very little about the ability of that soil to supply that element to plants, more meaningful partial soil analyses have been developed. Soil testing is the routine partial analysis of soil for the purpose of guiding nutrient management. The soil testing process consists of three critical phases (Brady and Weil, 2006):

(i) Sampling the soil;

(ii) Chemically analysis the sample; and

(iii) Interpreting the analytical result to make a recommendation on the kind and amount of nutrient to supply.

The three general procedures of analyzing soil are:

(i) Sieve analysis;

(ii) Hydrometer method; and

(iii) Combined analyses.

2.1.1 Sieve Analysis

Sieve analysis consists of shaking the soil through a stack of wire screens with openings of know sizes; the definition of particle diameter for a sieve test is, therefore, the size dimension of a square hole (Dane and Topp, 2004).

The sieve analysis will help to know the particle diameter of the river bed soil and erosion soil deposited around the river banks in relation to the void between them which promotes the free drainage of water and entry of air into the soil.

2.1.2 Hydrometer Method

According to Dane and Topp (2004), the hydrometer is based on stakes' equation for the velocity of a freely falling sphere; the definition of particle diameter for a hydrometer test is, therefore, the diameter of a sphere of the same density which falls at the same as the particle in question. This is calculated using this equation:

$$D = \frac{\mu}{s-w} \times \frac{Z_r}{t} \tag{2.1}$$

Where,

μ = viscosity of water at test temperature (gcm^{-1}s^{-1})

S = unit weight of soil grain (g)

W = unit weight of water at test temperature (g)

Z_r = distance from surface of suspension to the centre of volume of hydrometer (cm)

T = total elapsed time (s).

This method will help in determining the relatively low surface area of the sand particles which greatly affect the soil movement that causes erosion and may leads to undercut of pavement and building foundations. The gullies that may carve up cause unsafe condition of land and expensive repairs.

2.1.3 Combined Analyses

This employs both sieve and the hydrometer tests, thus the definition of particle size of a square opening for the larger grains and the diameter of the equivalent sphere for the smaller soil particles. The test procedure which should be followed depends on the soil in question. If nearly all its grains are so large that they cannot pass through square opening of 0.075mm (No.200 screen), the sieve analysis is preferable. For those soils which are nearly all finer than a No.200

screen, the hydrometer test is recommended. For silt, silty clays, etc, which has a measurable portion of their grains both coarser and finer than a No.200 sieve, the combined analysis is needed (Dane and Topp, 2002).

The combined analyses deal mainly with soils that have both coarse and fine materials. This method will help to detect the deterioration of the soil structure and quality as it affects its ecosystem.

2.2 Particle Size Distribution of Soil (Classification Test)

People classify things in order to make sense of their world. From the time crops were first cultivated, humans noticed differences in soils and classified them, grouping them according to their suitability for different uses by giving them descriptive names such as black cotton soils, rice soils or olive soils. Other soil names still in common use today have geological connotations, suggesting the parent materials from which the soil is formed. The natural body concept of soils recognizes the existence of individual entities, each of which we call a soil. In turn, we may aggregate these groups into categories of soil, each having some characteristics that set them apart from others. There are no sharp demarcations between one soil individual and another. Rather, there is a gradation in properties as one move from one soil individual to an adjacent one (Brady and Weil, 2002).

In distinguishing the important soil and rock layers, engineering classifications based on the nature and state of the soils should be used rather than the geological classifications which are based on age. The nature of a soil is described principally by the grading (the distribution of particle sizes) and the mineralogy, while the state is described by the current water content and unit weight (together with the current stresses), (Atkinson, 1993).

2.2.1 Measurement of Grading

The distribution of particle size is found by sieving and sedimentation. Soil is first passed through a set of sieves with decreasing aperture size and the weight retained on each sieve is recorded. The smallest practical sieve has an aperture size of about 0.075mm, corresponding roughly to the division between silt and sand (Atkinson, 1993).

Atkinson (1993) also shown that a rapid estimate of grading can be made by sedimentation in a jam or milk bottle. Take a sample about one-third or the height of the container, fill the container with water and shake it up. You can see and estimate the grading of gravel, sand and silt; clay will remain in suspension for a long time and any material floating on the surface is likely to be organic (i.e. peat).

2.2.2 Measurement of Water Content and Unit Weight

Water content or moisture content is the quantity of water contained in a mineral, such as soil (called soil moisture) or rocks on a volumetric or gravimetric basis (Soil Science of America, 1996). The water content of a soil is mathematically defined (Atkinson, 1993):

$$W = \frac{W_w}{W_s} \qquad (2.2)$$

And the unit weight γ is defined as the weight of a sample divided by the volume of the same sample in a cylinder. It is mathematically represented as (Atkinson, 1993):

$$\gamma = \frac{W}{V} \qquad (2.3)$$

Where,

γ = unit weight of water (gcm^{-3}).

W_w = weight of water evaporated by heating soil to 105°C (g).

W_s = weight of a dry soil (g).

W = weight of a sample ($W_w + W_s$) (g).

V = volume (cm^3).

These weights can be measured by simple weighing and the volume of a cylindrical or cubic sample determined by direct measurement (Atkinson, 1993).

2.3 Permeability of Soil

Water from rain is a primary requisite for parent material weathering and soil development. To fully promote soil development, water must not only enter the profile and participate in the weathering reactions; it must also percolate through the profile and translocate soluble weathering products. More rain water infiltrate and leach through a coarse, sandy profile than tight, clayey one, therefore the sandy profile can be said to experience a greater effective permeability and more rapid soil development may be expected (Brady and Weil, 2002).

Darcy's law showed experimentally that the rate of water (Q), flowing through soil of cross-sectional area (A), was proportional to the imposed gradient (i) (Brady and Weil, 2002)

$$\frac{Q}{A} \alpha i \qquad (2.4)$$

And $$Q = K\, i\, A$$

Where,

Q = volume quantity of water (cm^2).

K = coefficient of permeability.

A = cross-sectional area (cm^2).

The coefficient of proportionality (K) has been called Darcy's coefficient of permeability or coefficient of permeability. Thus permeability is a property which indicates the ease with which water will flow through the soil. Permeability enters all problems involving the flow of water through soils, such as seepage under dams, the squeezing out of water from a soil by application of a load, and drainage of sub grade, dams, and backfills.

Permeability depends on a number of factors, the main ones are:

(i) The size of soil grain;

(ii) The properties of the fluid which is viscosity, which in turn is sensitive to changes in temperature;

(iii) The void ratio of the soil which is a factor of density hence the greater the void ratio the lower the density and the higher the permeability;

(iv) Shapes and arrangement of pores which permeability depends on but this dependency is difficult to express mathematically;

(v) Degree of saturation which either causes an increase in permeability or a decrease in permeability.

In general, the ability of water to flow through a soil is referred to as the soil's permeability. As you can probably guess, the permeability of sand is higher than that of clay due to the increasing size of voids, which in turn increases the soil's grain size. It is important to note that permeability affects how quickly water can flow through the soil, just as the porosity of a soil affects how much water it can hold (Soil Science Journal, 2004).

2.3.1 Permeability Test

Permeability test on soil samples is usually made with falling-head permeability or constant-head permeability. This gives reliable for highly permeable materials such as clean sands and gravels. In the constant head test, water from a constant head tank flows through the sample in a cylinder and is collected in measuring jar. Two stand pipes and the flow is in steady state. This is mathematically represented as (Atkinson, 1993);

$$V = \frac{\Delta Q}{A\Delta_t} \quad (2.5)$$

From Darcy's law (1956):

$$V = Ki \text{ And } Ki = \frac{\Delta Q}{A\Delta_t} \quad (2.6)$$

Where,

K = coefficient of permeability.

A = cross-sectional area (cm^2).

Q = quantity of flow (cm^2).

t = time taken (s).

2.4 Infiltration Capacity of Soil

The term infiltration refers specifically to entry of water into the soil surface. Infiltration rate has the dimensions of volume per unit of time per unit of area. Infiltration should not be confused with hydraulic conductivity or with soil capillary conductivity. Infiltration is the sole source of soil water to sustain the growth of vegetation and of the ground water supply of wells, springs, and streams (Schwab et al, 1993).

Brady and Weil (2002) defined infiltration as the process by which water enters the soil pore spaces to becomes soil water and the rate at which water can enter the soil is termed the infiltrability (*i*). It is mathematically represented as;

$$i = \frac{Q}{At} \tag{2.7}$$

Where,

Q = volume quantity of water (cm^2).

A = area of soil surface (cm^2).

t = time (s).

The movement of water into the soil by infiltration may be limited by any restriction to the flow of water through the soil profile. The most important items influencing the rate of infiltration have to do with the physical characteristics of the soil and the cover on the soil surface, but such other factors as soil water, temperature, and rainfall intensity are also involved (Schwab et al, 1993).

Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeter per hour. The rate decreases as the soil becomes saturated. If the precipitation rate or rainfall intensity at the soil exceeds the infiltration rate, ponding begins and this is followed by runoff unless there are some physical barriers. Infiltration is governed by two forces; gravity and capillary action. While similar pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even the force of gravity (Soil Science Journal, 2004).

The Soil Science Journal (2004) also maintained that the process of infiltration can continue if there is room available for additional water at the soil surface. The available volume for additional water in the soil depends on the porosity of the soil and the rate at which previously infiltrated water can move away from the surface through the soil. The maximum rate that water can enter a soil in a govern condition is the infiltration capacity.

The infiltration capacity of a soil may be easily measured using a simple device known as double ring infiltrometer. Two heavy metal cylinders one smaller in diameter than the other, are pressed partially into the soil so that the smaller is inside the larger. A layer of cheesecloth is placed inside the rings to protect the soil surface from disturbance, and water is poured into both cylinders. The depth of water in the central cylinder is then recorded periodically as the water infiltrates the soil (Brady and Weil, 2002).

The entire hydrologic system of a soil is sometimes analyzed using hydrology transport models, mathematical models that consider infiltration runoff and channel flow to predict river flow rates and stream water quality (Soil Science Journal, 2004).

2.5 Hydraulic Conductivity of Soil

Soil contains a large distribution of pore sizes and channels through which water may flow. The exact geometry of these openings is unknown instead; averages are taken over many pores to define microscopic flow equations to describe movement of water through porous media. Any factor affecting the size and configuration of soil pores will influence hydraulic conductivity. The quality of water per unit of time that flows through a column of saturated soil can be expressed by Darcy's law as follows (Brady and Weil, 2002);

$$Q = AKsat\frac{\Delta\varphi}{L} \text{ And } K_{sat} = \frac{QL}{A(\varphi 1 - \varphi 2)} \qquad (2.8)$$

Where,

Q = quantity of water per unit time (cm^3hr^{-1}).

K_{sat} = saturated hydraulic conductivity ($cmhr^{-1}$).

A = cross-sectional area (cm^{-2}).

$\Delta\varphi$ = change in water potential between ends of the column (cm).

L = length of the column (cm).

Three types of water movement within the soil are recognized:

(i) Saturated flow;

(ii) Unsaturated flow; and

(iii) Vapour flow.

In all cases water flows in response to energy gradient, with water moving from a zone of higher potential to one of lower potential. Saturated flow takes place when the soil pores are completely filled with water. Unsaturated flow occurs when the larger pores in the soil are filled with air, leaving only the smaller pores to hold and transmit water. Vapour movement occurs as vapour pressure difference develop in relatively dry soils.

Brady and Weil (2002) tested and showed that sandy soils generally have higher saturated conductivities than finer-textured soils because they usually have more macro space. Likewise, soils with stable granular structure conduct water more rapidly than those with unstable structure units, which break down upon being wetted.

2.6 Structural Stability of Soil

Aggregate size and stability are interrelated concepts in the description of soil structure using fragmentation procedures and associated indices for assessing soil aggregation, based on the size distribution and stability of fragments after mechanical disruption. Soil aggregation can be viewed as the arrangement of primary soil particles into hierarchical structural units, identified on the basis of varying failure zone strengths reflecting the characteristics of both void and solid phases (Dekker, 2002).

Dekker (2002) also confirmed that direct characteristics of soil aggregation can be performed by describing morphological features in the field using image analysis techniques or by measuring the size distribution and connectivity of pores. Other procedures are based on the partial breakdown of structural units by dispersion or fragmentation, and evaluation of the resulting fragment size distribution. With application of high-energy stress, the resulting fragment size distribution will be independent of further increments in stress and more closely related to the sizes of primary soil particles (e.g. sand, silt, clay) than aggregates. Soil fragmentation rarely implies complete disruption of aggregates and be performed under dry, moist, or saturated conditions.

Soil quality considers the soil fitness for any given function, such as those concerned with biological production, buildings foundation or disposal waste. Soil quality is the capacity of a soil to function within (and sometimes outside) its ecosystem boundaries to sustain biological productivity and diversity, maintain environmental quality; and promote plant and animal health. The soil's ability to perform a desired function is often dependent on one or more dynamic physical, chemical or biological processes that occur in soil ecosystem (Brady and Weil, 2002).

2.7 Porosity of Soil

Porosity consists of a portion occupied by soil air and another occupied by soil water. The fraction of the bulk volume of soil that is occupied by water and air ranges from about 0.3 to 0.6.

It is high in a soil composed of particles of a range of sizes that are loosely packed together. The pore spaces exists because of inevitable gaps in the parking of particles and because of disturbances including those due to roots, soil animals, swelling, cracking or shrinking. Pore space allows soil to act as a medium for the movement of water and air (Jury et al, 1991.

Jury et al (1991) showed that porosity is equal to one minus the solid volume fraction. It is mathematically represented as:

$$\emptyset = 1 - \frac{Vs}{V} \tag{2.9}$$

2.8 Compaction of Soil

Compaction is a process whereby the constituent of soil are rearranged as a result of additional load which also can cause reduction in the inter-granular spaces in the soil sample stabilized. It is the most popular means of stabilizing soils and it is achieved by applying load on a soil sample and resulting in more compact (denser) soil sample and this is accompanied by expulsion of air from the soil sample thereby decreasing the void ratio.

Compaction can also be defined as a process by which soil particles are constrained to pack more closely through the expulsion of air voids as a result of additional load. This is the mechanical way of stabilizing soils, which is characterized by reduction in permeability of the soil while the shear strength and unit weight are increased. As compaction process increases, the soil becomes more compressed depending on the grain size of the soil.

However, compaction differs from consolidation; consolidation of soil expels water as compactive energy which is a measure of mechanical energy applied to the soil mass. The grain size of a soil sample determines the compactive energy applied, therefore, the coarser the sample, the higher the energy the energy level of compaction applied and the reverse is the case for fine-grained soil sample. As compaction increases, dry density increases and moisture content decreases. There are three (3) levels of compaction;

(i) Standard America Association of State Highway Transportation Official (AASHTO) level;

(ii) Modified AASHTO level;

(iii) West Africa level.

CHAPTER THREE

3.0 METHODS AND MATERIALS

3.1 Description of the Study Area

Structural feature and weathering pattern in the area were carefully studied. The study area (i.e. River Chanchaga) is located along Minna-Chanchaga -Suleja road and lies between latitude $9^0 30'$N and $9^0 33'$N of the equator and longitude $6^0 34'$E and $6^0 37'$E of Greenwich meridian. It is low lying terrain and is easily accessible. The erosion soil deposited is drained by the seasonal River Chanchaga system and associated tributaries (Oke et al.2009).

The climate condition of the area is generally classified as part of the tropical climate with alternating wet and dry seasons with heavy rainfall in the wet season (from April to October) and little or no rainfall in the dry season (October to March). The study area has a mean annual rainfall of about 1100mm to 1332mm. The highest mean monthly rainfall is in September with about 240mm to 300mm, and the monthly temperature is highest in March at about 32°C and lowest in August at about 26°C. It is important to note that Minna lies within the middle belt of Nigeria in a transitional zone between the humid belt and the dry Sudan-shade (Federal Meteorology Minna Airport, Minna, Niger State).

The soil is heterogeneous and two types were identified: brown, clayey, silty, and gravely sand; and brown, gravely, clayey and silty sand. The soil cohesion ranges from $9KN/m^2$ to $27.50KN/m^2$ while the angle of internal friction (Ø) range from 15^0 to 35^0. The comprehension index is of the order 0.11 to 0.74.

3.2 Experimental Procedure

3.2.1 Methods/Samplings

Preliminary study where carried out by examining existing literature about the study area. This was followed by a reconnaissance survey to examine all available soil and rock unit in the River Chanchaga area. Field work commenced from July 10th 2009 and lasted through 12th July 2009. A total of ten trial pits, five from the river bed soil and the other five from the erosion soil deposited were dug using a cylindrical hand Angler. Undistributed soil samples were collected at a depth of between 31cm-38cm for the river soil and 50cm for the soil deposited by erosion below the natural ground level. Ten soil samples were obtained for laboratory analysis. An ester GPS was used to the location and elevation of the trial pits area.

The soil samples were taken down the profile from two different locations within the River Chanchaga and its bank. In each of the two locations, five samples from different horizon (each 5m from the location of the first sample) down the profile were used for the physical investigation. The samples obtained within the river bed were spread out on trays and left to dry in the laboratory for four days; while those of the erosion were left to dry for only two days. This was done because the water content of the samples obtained from the river bed contained more water compare to those of the erosion soil.

3.2.2 Laboratory Test

Soil samples were collected from the ten trial pits and analyzed at the Dantata and Sawoe soil laboratory in Abuja; and soil science laboratory, Federal University of Technology (FUT) Minna for relevant geotechnical parameters.

The test were sieve analysis, compaction test, specific gravity, absorption test which were carried out at Dantata and Sawoe laboratory; and hydraulic conductivity test at FUT, Minna.

Laboratory investigation can be divided into two which are:

i. Pre-test preparation

ii. Engineering test

3.2.2.1 Pre-Test Preparation

This is air-drying sample for a period of about 2-3 weeks due to the degree of wetness of the sand. This is important because air dried sample are ideal for geotechnical investigation. It is a step necessary so as to obtain a dependable result.

3.2.2.2 Engineering Test

This test are carried out to know the suitability of the sand as compacted materials, road performance characteristics etc. The laboratory investigation involved in the engineering test is classification test which include grain, size distribution and specific determination and geotechnical test.

3.3 Methods Used for the Tests

Sieve analysis was carried out by sieving some quantity of soil through a set sieve using the British Standard (BS) sieve test. The various apparatus used were British standard sieve set with aperture ascription; electronic scale, mechanical sieve shaker, panpand brush. The various procedure or step taken during the test is attached as Appendix A and results were obtained.

Compaction test was done to know the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) using the modifier proctor test due to the soil days on water. The material need to carry out the test were measuring scale and cylinder; modified proctor mould; 4.5kg and 2.5kg hammers; straight edges knife; filter paper; head pan; sieve (19.0mm); scop;

dice; mallet; tray pan. The procedures taken in carrying out this test are attached as appendix B and results were recorded.

The specific gravity which may be expressed as bulk specific gravity is the characteristics generally used for the calculation of the volume occupied by the sand or aggregate in various mixtures and also in the compaction of voids in particle. To determine specific gravity, a sample is immersed in water for 24 hours in order for the water to fill the pores. Water will then be removed from the sand and kept to dry out from the surface of the particles. The water removed and the oven dried particles are weighed on a balance. The apparatus used during the course of this test are balanced; sample container, water tank, sieve, pycometer bottle. The procedures followed in getting the results are attached as Appendix C.

The absorption test is used to calculate the changes in weight of either the river soil or erosion soil deposited, to the water absorbed in the pores space within the constituent particles. The Laboratory standard for absorption is that obtained after submerging dry material for more or less than 24 hours in water and then dried. The steps taken to obtain the results are more or less the same with that of the specific gravity and are attached as appendix D. The various apparatus used during the test are oven, moisture container, electronics scale, and glass plate.

For the saturated hydraulic conductivity measurement, soil samples are collected for both the river and erosion soil in an undisturbed form using core samplers which served as retainer for the soil and taken to the laboratory. The bottom end of the core samplers are sealed with a muslin sheet and completely saturated for a day by placing them in a basin filled with water to about 4cm. The experiment will then be set up by attaching another empty core sampler to the top of the filled core sampler with the aid of a cellotape. They are then placed on a permeameter rack clamped to a retort stand vertically. The materials used are retort-stand; funnel; core rings or cylinder; clock; permeameter rack; graduated beaker. The procedures for the test are attached as Appendix E and results were recorded.

The atterberg limit test is designed to determine the engineering properties of fine grained soil particles. Atterberg limits are define as the water content at which the consistency of a soil changes from one state to another (Bell, 1999). They are called the shrinkage, plastic and liquid limit. This test is also aimed at classifing fine grained soil.

The atterberg limit test is divided into two; which are:

Liquid Limit Test: The liquid limit of a soil is the emperically established moisture content at which a soil changes from the liquid state to the plastic state (Jones et al,1992) The casagrande method of liquid limit test was adopted in testing they soil samples from the study area. The following apparatus were utilized in carring out the liquid limit test;Casagreande's liquid limit device, three sample cans, grooving tools, mixing treys, spatula, oven, and 425µm sieve. The procedures adopted in carring out this test are attached as Appendix F.

Plastic Limit Test: plastic limit is the emperically established moisture content at which a soil becomes too try to be plastic (Jones et al, 1992). The apparatus for this test include; a flat glass plate, spatula, plastic limit device, a rod with a diameter of 3mm and length of about 100mm. The procedures taken for this test are attached as Appendix G.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation or Results

The overburden unit in the area comprises of a suit of brown lateritic soil. The soils in the study area were found to contain a higher percentage of sand, silt, clay sized particles mixed with a low percentage of gravel. During the time of the field observation, the natural moisture content of the soils was relatively high. The reason is that the soils were collected from River Chacnhaga and its bank. At the maximum trial pit depth of the soil deposited by erosion (i.e. 50cm), no crystalline rock was encountered in the pit.

4.1.1 Sieve Analysis

The results of the sieve or mechanical analysis are generally presented by semi-log known as particle size distribution. The particle diameters are plotted on the log scale and the corresponding percentage timer are plotted on the arithmetic scale. The general slope has the shape of the distribution and it is described by means of soma constant such as effective size, uniformity coefficient and coefficient of gradation. These terms are denoted as Dio, Cu and Cc respectively.

It is important to note that particle size distribution curve shows both the range of particle size present in the soil as well as the manner in which variation occurs. The summary of the sieve analysis results containing the percentage passing for the river bed soil and soil deposited by erosion are shown in Tables 4.1 and 4.2 respectively while the summary of the percentage quantity of particle size results for the river soil and erosion soil are shown in Tables 4.3 and 4.4 respectively.

Table 4.1: Summary of the Sieve Analysis Result for the River Soil.

Sieve Set (mm)	38.1	25.4	19.04	12.70	9.52	4.76	2.36	1.18	600μm	300μm	150μm	75μm
Trial Pit No.						Percent Passing						
1				100	99.6	94.6	84.0	63.5	38.2	16.9	3.6	0.8
2					100	94.6	70.9	43.0	23.5	9.8	1.7	0.7
3				100	98.7	93.1	79.6	57.1	32.3	13.5	3.4	1.0
4					100	96.4	85.2	63.8	37.3	13.4	2.5	0.4
5				100	98.8	92.0	78.2	56.0	32.1	12.4	3.3	0.6
Average				100	99.4	94.1	79.6	56.7	32.7	13.2	2.9	0.7

Table 4.2: Summary of the Sieve Analysis Result for the Soil deposited by Erosion.

Sieve Set (mm)	38.1	25.4	19.04	12.70	9.52	4.76	2.36	1.18	600μm	300μm	150μm	75μm
Trial Pit No.					Percent Passing							
6					100	97.6	76.2	54.2	31.2	15.1	3.0	0.7
7					100	97.3	76.2	53.2	31.2	13.7	2.9	0.8
8				100	99.7	94.5	83.7	62.9	37.8	16.6	3.3	0.5
9					100	98.8	95.2	88.7	75.9	42.8	9.3	0.5
10					100	94.2	67.5	42.3	21.4	8.0	1.7	0.6
Average				100	99.9	96.5	79.8	60.3	39.5	19.2	4.0	0.6

Table4.3: Sieve Analysis Result Indicating Percentage (%) Quantity of Particle Sizes of the River Soil.

Trial Pit No.	Depth(m)	% of Gravel	% of Sand	% of Silt + Clay	Coefficient of Uniformity(Cu)	Coefficient of Curvature(Cc)
1	0.28	18.0	81.50	0.50	5.57	0.36
2	0.31	35.0	64.70	0.30	6.33	0.44
3	0.33	34.0	65.10	0.90	3.00	0.75
4	0.35	20.0	79.77	0.23	4.72	2.36
5	0.38	27.0	75.58	0.42	4.72	0.85
Average		26.8	73.33	0.47	4.87	0.95

Table4.4: Sieve Analysis Result Indicating Percentage (%) Quantity of Particle Sizes of the Soil deposited by Erosion.

Trial Pit No.	Depth(m)	%of Gravel	% of Sand	% of Silt + Clay	Coefficient of Uniformity(Cu)	Coefficient of Curvature(Cc)
6	0.5	28.0	71.69	0.31	6.67	3.47
7	0.5	28.0	71.55	0.45	5.32	0.18
8	0.5	29.0	70.80	0.20	7.41	0.83
9	0.5	6.0	93.80	0.20	3.28	0.77
10	0.5	35.0	64.78	0.22	3.08	0.45
Average		25.2	74.52	0.28	5.15	1.14

4.1.2 Compaction Test

The water content is from the top and base of the compacted soil forming appropriate method of the moisture content determination. With the values of moisture content and the wet bulk density, dry density is calculated as follows:

$$\text{Moisture Content} = \frac{\text{Weight of water x 100}}{\text{Weight of dry soil}}$$

$$\text{Wet density (kg/m}^3\text{)} = \frac{\text{Weight of compacted soil x 100}}{\text{volume of mould}}$$

$$\text{Dry density (kg/m}^3\text{)} = \frac{\text{Wet density x 100}}{\text{100+moisture content}}$$

Tables 4.5 and 4.6 show the wet and dry densities, and the moisture content results for the river soil while tables 4.7 and 4.8 show that for the soil deposited by erosion.

Table 4.5: Results of Wet and Dry Densities of the River Soil.

	Trial Pit 1			Trial Pit 2			Trial Pit 3			Trial Pit 4			Trial Pit 5		
Sample No.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Water Added (%)	2	4	6	4	6	8	4	6	8	4	6	8	2	4	6
weight of Mould(g)	2361	2361	2361	2361	2361	2361	2330	2330	2330	2361	2361	2361	2361	2361	2361
Weight of Mould + Wet Soil (g)	4000	4066	4084	4010	4076	4094	4096	4190	4213	4077	4160	4129	4220	4283	4269
Weight of Wet Soil (g)	1639	1705	1723	1649	1715	1733	1766	1860	1883	1716	1799	1768	1858	1922	1909
Volume of Mould (cm^3)	942	942	942	942	942	942	942	942	942	942	942	942	942	942	942
Wet Density (kgm^{-3})	1739.9	1809.9	1829.1	1750.5	1820.6	1839.7	1874.7	1974.5	1998.9	1821.7	1809.8	1876.9	1973.5	2040.3	2025.5
Dry Density (kg/m^3)	1704.1	1738.6	1712.6	1683.2	1695.2	1683.2	1782	1843.6	1838.9	1733.3	1791.6	1717.2	1865.3	1889.2	1848.1
Average Wet Density (kg/m^3)		1792.9			1803.6			1949.4			1869.5			2013.1	
Average Dry Density (kg/m^3)		1718.4			1687.2			1821.5			1747.4			1867.5	

Table 4.6: Moisture Content Results for the River Soil.

	Trial Pit 1						Trial Pit 2						Trial Pit 3						Trial Pit 4						Trial Pit 5					
Sample No.	1		2		3		1		2		3		1		2		3		1		2		3		1		2		3	
Container No.	401	402	407	408	409	500	101	102	103	104	105	106	11	12	13	14	15	16	221	223	224	225	222	226	111	112	113	114	115	116
Weight of Water(g)	1.8	1.9	2.5	2.5	4.2	4.2	2.4	2.4	4.1	4.0	5.0	5.2	3.7	3.4	4.6	3.7	6.1	5.4	5.1	3.3	4.0	4.1	5.3	5.2	3.3	3.3	5.0	4.7	5.6	5.5
Weight of Container + Wet Soil(g)	113.0	117.4	93.5	89.6	93.9	93.9	92.5	91.5	91.5	88.6	91.4	92.2	100.9	98.7	92.7	88.2	100.0	98.4	93.1	94.9	93.2	93.2	89.5	89.5	86.8	88.9	93.4	93.5	90.7	91.7
Weight of Container + Dry Soil(g)	111.2	115.5	91.0	87.1	89.7	89.7	88.6	87.5	84.2	81.2	82.2	82.8	97.2	95.3	88.1	84.5	93.9	93.0	90.1	91.6	89.2	89.1	84.6	27.7	83.5	85.6	88.4	88.8	85.1	86.2
Weight of Dry Soil(g)	85.8	90.2	63.2	59.9	62.1	62.2	60.9	59.9	56.5	53.7	54.5	55.2	69.6	67.5	60.3	56.8	66.3	65.5	62.4	64.4	61.2	61.4	56.6	56.6	56.1	58.2	61.0	61.1	57.8	58.4
Weight of Container(g)	25.4	25.3	27.8	27.2	27.6	27.5	27.7	27.6	27.7	27.5	27.7	27.6	27.6	27.8	27.8	27.8	27.6	27.5	27.6	27.2	28.0	27.7	27.6	27.7	27.4	27.4	27.4	27.7	27.6	27.8
Moisture Content (%)	2.1	2.1	4.0	4.2	6.8	6.8	3.9	4.0	7.3	7.4	9.2	9.4	5.3	5.0	7.6	6.5	9.2	8.2	5.0	5.1	6.5	6.7	9.4	9.2	5.9	5.7	8.2	7.7	9.7	9.4
Average Moisture Content (%)	2.1		4.1		6.8		4.0		7.4		9.3		5.2		7.1		8.7		5.1		6.6		9.3		5.8		8.0		9.6	

Table 4.7: Results of Wet and Dry Densities of the Soil deposited by Erosion.

	Trial Pit 6			Trial Pit 7			Trial Pit 8			Trial Pit 9			Trial Pit 10		
Sample No.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Water Added (%)	2	4	6	5	7	9	4	6	8	4	6	8	4	6	8
weight of Mould(g)	2330	2330	2330	2330	2330	2330	2361	2361	2361	2341	2341	2341	2361	2361	2361
Weight of Mould + Wet Soil (g)	4013	4110	4160	4035	4129	4206	4110	4190	4200	4044	4102	4090	4076	4213	4272
Weight of Wet Soil (g)	1683	1780	1830	1705	1799	1876	1749	1829	1839	1703	1761	1749	1715	1852	1911
Volume of Mould (cm^3)	942	942	942	942	942	942	942	942	942	940	940	940	942	942	942
Wet Density (kgm^{-3})	1786.6	1889.6	1942.7	1809.8	1909.9	1991.5	1856.7	1941.6	1952.2	1811.7	1873.4	1860.6	1820.6	1966.0	2028.7
Dry Density (kg/m^3)	1708.0	1775.9	1793.8	1717.2	1771.7	1813.8	1746.7	1769.9	1746.2	1714.0	1739.5	1697.6	1747.2	1859.9	1859.5
Average Wet Density (kg/m^3)		1872.9			1903.7			1916.8			1848.6			1938.4	
Average Dry Density (kg/m^3)		1759.2			1767.5			1754.3			1717.0			1822.2	

Table 4.8: Moisture Content Results for the Soil deposited by Erosion.

	Trial Pit 6						Trial Pit 7						Trial Pit 8						Trial Pit 9						Trial Pit 10					
Sample no.	1		2		3		1		2		3		1		2		3		1		2		3		1		2		3	
Container No.	401	402	403	404	405	406	001	002	003	004	005	006	501	502	503	504	505	506	201	202	203	204	205	206	300	301	302	303	304	305
Weight of Water(g)	3.0	3.0	3.9	4.1	4.7	4.7	2.9	3.0	5.4	4.7	5.7	6.6	3.6	3.5	6.4	6.2	7.2	7.2	3.8	3.3	4.1	5.0	5.7	5.8	2.0	2.3	3.0	3.0	4.5	4.5
Weight of Container + Wet Soil(g)	95.4	96.6	94.7	94.2	88.3	89.5	90.8	80.8	96.8	99.3	94.0	99.6	84.8	89.7	98.0	100.0	95.5	96.8	96.6	94.0	92.2	91.0	91.7	94.8	80.2	82.2	80.5	84.8	83.8	79.4
Weight of Container + Dry Soil(g)	92.4	93.6	90.8	90.1	83.6	84.8	87.9	77.8	91.4	94.3	88.3	93.0	81.8	86.2	91.6	93.8	88.3	89.6	92.8	90.7	86.9	86.0	86.0	89.0	78.2	79.7	77.5	81.8	79.3	74.9
Weight of Dry Soil(g)	64.8	66.0	63.0	62.5	55.9	57.0	60.3	50.2	63.7	66.7	60.5	65.3	54.2	58.4	64.0	66.1	60.6	62.0	62.5	63.1	59.2	58.5	59.5	61.2	50.4	52.2	49.9	54.0	51.5	47.2
Weight of Container(g)	27.6	27.6	27.8	27.6	27.7	27.8	27.6	27.6	27.7	27.6	27.8	27.7	27.6	27.8	27.6	27.7	27.7	27.6	30.3	27.6	27.7	27.5	26.5	27.8	27.8	27.5	27.6	27.8	27.8	27.5
Moisture Content (%)	4.6	4.5	6.2	6.6	8.4	8.2	4.8	6.0	8.5	7.0	9.4	10.1	6.6	6.0	10.0	9.4	11.9	11.6	6.1	5.2	6.9	8.5	9.6	9.5	4.0	4.4	6.0	5.6	8.7	9.5
Average Moisture Content (%)	4.6		6.4		8.3		5.4		7.8		9.8		6.3		9.7		11.8		5.7		7.7		9.6		4.2		5.7		9.1	

4.1.3 Absorption Test And Specific Gravity

The bulk specific gravity is generally used for the calculation of the volume occupied by soil or aggregate in various mixtures including Portland cement concrete, bituminous concrete and other mixtures that are proportioned or analyzed on an absolute volume basis. It is used in the computation of voids in particles. The bulk specific gravity (SSD) is used if the soil is wet, that is if absorption has been satisfied while the bulk specific gravity (oven dried) is used when the soil is dried or assumed to be dried.

Absorption is the increase in the weight of soil due to the water in the pores of the material but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry weight. Therefore, the absorption test was carried out in order to determine or calculate the change in weight of both the river soil and erosion soil due to the water absorbed in the material pores space. Tables 4.9 and 4.10 below show absorption test results and the bulk specific gravity results of the river soil and the soil deposited by erosion respectively. The absorption, bulk specific gravities and apparent specific gravity were calculated as:

$$\text{Absorption (\%)} = \frac{A - B\text{x}100}{B}$$

$$\text{Bulk Specific Gravity (SSD) [kg/dm}^2\text{]} = \frac{A}{A + C - D}$$

$$\text{Bulk Specific Gravity (oven-dried) [kg/dm}^2\text{]} = \frac{B}{A + C - D}$$

$$\text{Apparent Specific Gravity} = \frac{B}{B + C - D}$$

Tables 4.9 and 4.10 below show the absorption test results and the bulk specific gravity results of the river soil and the soil deposited by erosion respectively.

Table 4.9: Absorption test and Specific Gravity Results for the River Soil.

		Trial Pit 1		Trial Pit 2		Trial Pit 3		Trial Pit 4		Trial Pit 5	
	Sample No.	A	B	A	B	A	B	A	B	A	B
A	Weight of Wet sample(g)	568.2	565.0	566.8	570.0	575.3	589.4	573.3	569.9	571.9	575.1
B	Weight of oven-dried sample(g)	500.0	500.0	500.2	500.0	501.5	504.0	500.3	500.7	500.0	500.0
C	weight of Pycnometer bottle + water(g)	1978.5	1999.3	1972.8	2002.9	1979.8	2001.7	1975.2	2004.5	1970.3	2000.4
D	Pycnometer bottle + water + sample(g)	2283.6	2312.4	2280.9	2310.3	2274.2	2304.0	2277.5	2306.0	2275.7	2305.1
E	Absorption (%)	13.64	13.00	13.31	14.00	14.71	16.94	14.59	13.82	15.38	15.02
F	Bulk specific Gravity(SSD)[kg/dm^3)	2.16	2.24	2.19	2.17	2.05	2.05	2.12	2.12	2.15	2.13
G	Bulk specific Gravity(oven dried)[kg/dm^3]	1.90	1.98	1.93	1.90	1.79	1.76	1.85	1.85	1.88	1.85
H	Apparent specific gravity(ASG)	2.57	2.68	2.60	2.60	2.42	2.50	2.53	2.51	2.86	2.56
	Average Absorption (%)	13.32		13.66		15.83		14.21		14.70	
	Average Bulk specific Gravity(SSD)[kg/dm^3]	2.20		2.18		2.05		2.12		2.14	
	Average Bulk specific Gravity(oven dried)[kg/dm^3]	1.94		1.92		1.77		1.86		1.86	
	Average Apparent specific gravity	2.62		2.60		2.46		2.52		2.71	

Table 4.10: Asorption Test and Specific Gravity Results for the Soil deposited Erosion.

		Trial Pit 6		Trial Pit 7		Trial Pit 8		Trial Pit 9		Trial Pit 10	
	Sample No.	A	B	A	B	A	B	A	B	A	B
A	Weight of Wet sample(g)	588.0	585.0	587.0	5978.8	580.0	589.6	592.5	586.5	580.2	583.4
B	Weight of oven-dried sample(g)	500.9	500.1	500.6	500.0	500.7	500.4	500.0	500.1	500.0	500.0
C	Weight of Pycnometer bottle + water(g)	1970.2	1992.2	1969.9	1999.6	1976.8	2000.2	1973.0	2003.0	1975.1	2000.0
D	Pycnometer bottle + water + sample(g)	2278.1	2304.6	2277.9	2307.7	2270.8	2300.6	2282.6	2313.7	2280.4	2311.5
E	Absorption (%)	17.39	16.98	17.23	19.56	15.84	17.83	18.50	17.28	16.04	16.68
F	Bulk specific Gravity(SSD)[kg/dm^3]	2.10	2.15	2.10	2.06	2.02	2.04	2.09	2.13	2.11	2.25
G	Bulk specific Gravity(oven dried)[kg/dm^3]	1.79	1.83	1.79	1.73	1.73	1.73	1.77	1.81	1.82	1.84
H	Apparent specific gravity(ASG)	2.60	2.66	2.60	2.61	2.42	2.50	2.63	2.64	2.57	2.65
	Average Absorption (%)	17.18		18.40		16.84		17.89		16.36	
	Average Bulk specific Gravity(kg/dm^3)	2.12		2.08		2.03		2.11		2.13	
	Average Bulk specific Gravity(oven dried)[kg/dm^3]	1.81		1.76		1.74		1.79		1.83	
	Average Apparent specific gravity	2.63		2.60		2.46		2.64		2.61	

4.1.4 Saturated Hydraulic Conductivity

In soils with abrupt horizon changes, corresponding changes in the hydraulic conductivity values can have serious effects on the irrigation or drainage water within the profile. Conductivity increases with increase in sand and decreases with increase in clay. The texture and structure of a soil horizon mostly determine its saturated hydraulic conductivity because they usually have more macro-pore space; sandy soils generally have higher hydraulic conductivity. The test results of the hydraulic conductivity for the soil deposited by erosion is shown in Table 4.11 while Table 4.12 shows that for the river soil.

Table 4.11: Result of the Hydraulic Conductivity Test for the Soil deposited by Erosion.

Trial Pit No.	Profile Depth(m)	Core Rings No.	Volume of Water(cm^3)	Saturated hydraulic Conductivity(K_{sat})[cm/hr]	Elapsed Time(min)
6	0.5	5	30.5	18.72	5
7	0.5	18	25.0	15.34	5
8	0.5	8	24.5	15.04	5
9	0.5	1	26.2	16.08	5
10	0.5	16	30.2	18.54	5
Average			27.3	16.74	5

Table 4.12: Result of the Hydraulic Conductivity Test for the River Soil.

Trial Pit No.	Profile Depth(m)	Core Rings No.	Volume of Water(cm^3)	Saturated hydraulic Conductivity(K_{sat})[cm/hr]	Elapsed Time(min)
1	0.28	7	28.2	17.31	5
2	0.31	10	22.5	13.81	5
3	0.33	13	17.9	10.99	5
4	0.35	14	35.8	15.83	5
5	0.38	2	27.0	16.57	5
Average			24.3	14.90	5

4.1.5 Atterberg Limits Test

The results of the Atterberg limits test for the river soil are presented in Table 4.14 while that for the soil deposited by erosion are in Table 4.15. The mean or average values for the liquid limit, plastic limit and plasticity index for the soil deposited by erosion are 40.5%, 18.7% and 21.8% respectively and that for the river soil are 48.5%, 20.2% and 28.6% respectively. Table 4.16 and 4.17 show the classifications of the river soil and the soil deposited by erosion using the Unified Classification Scheme (USCS) and British Soil Classification Scheme (BSCS) respectively.

Table 4.13: Clay shrinkage potentials (Curtin et al, 1997)

Plasticity Index	Clay Fraction (%)	Shrinkage Potential
Greater than 35	Greater than 95	Very High
22-48	60-95	High
12-32	30-60	Medium
Less than 12	Less than 32	Low

Table 4.14: Summary of Results obtained from Atterberg Limit and Compaction Tests for the River Soil.

Trial No.	Pit	Depth (m)	Atterberg Limit			Shrinkage Potentials	Cc=0.009(LL-10)	Compaction Test	
			LL (%)	PL (%)	PL (%)			OMC (%)	MDD (kg/m³)
1		0.28	26.1	15.8	10.4	Low	0.144	4.7	1745
2		0.31	48.8	23.4	25.4	Medium	0.350	5.8	1695
3		0.33	59.9	25.3	35.7	High	0.450	7.5	1850
4		0.35	58.1	21.6	36.5	High	0.433	6.6	1790

5	0.38	49.8	14.9	34.9	Medium	0.360	7.4	1890
Average		48.5	20.2	28.6		0.347	6.4	1794

Table 4.15: Summary of Results obtained from Atterberg Limit and Compaction Tests for the Soil deposited by Erosion.

Trial Pit No.	Depth (m)	Atterberg Limit			Shrinkage Potentials	Cc=0.009(LL-10)	Compaction Test	
		LL (%)	PL (%)	PL (%)			OMC (%)	MDD (kg/m^3)
6	0.5	55.2	23.8	31.4	Medium	0.410	8.1	1795
7	0.5	37.8	15.9	21.9	Medium	0.250	9.5	1815
8	0.5	36.4	17.3	19.1	Medium	0.240	9.1	1770
9	0.5	42.3	20.6	21.7	Low	0.291	7.3	1740
10	0.5	30.8	16.1	14.7	Low	0.187	7.5	1750
Average		40.5	18.7	21.8			8.3	1774

Table 4.16: Classification of the River Soil and Erosion Soil using the Unified Soil Classification Scheme (U.S.C.S)

Trial pit No.	Liquid Limit LL (%)	Plasticity Index PI (%)	U.S.C.S	Soil Description
1	26.1	10.4	SC/SM	Brown,gravelly,clayey,silty SAND
2	48.8	25.4	SC/SM	Brown,gravelly,clayey,silty SAND
3	59.9	35.7	SC/SM	Brown,gravelly,clayey,silty

				SAND
4	58.1	36.5	SC/SM	Brown,gravelly,clayey,silty SAND
5	49.8	34.9	SC/SM	Brown,gravelly,clayey,silty SAND
6	55.2	31.4	MH/CH	Brown,gravelly,clayey,silty SAND
7	37.8	21.9	CL/ML	Brown,gravelly,sandy,clayey, SAND
8	36.4	19.1	SC/SM	Brown,gravelly,clayey,silty SAND
9	42.3	21.7	CL/ML	Brown,gravelly,sandy,clayey, SAND
10	30.8	14.7	CL/ML	Brown,gravelly,sandy,clayey, SAND

Table 4.17: Classification of the River Soil and Erosion Soil using the British Soil Classification Scheme (BSCS)

Trial pit No.	Liquid Limit LL (%)	Plasticity Index PI (%)	B.S.C.S	Soil Description
1	26.1	10.4	FG/CLG	Brown,gravelly,clayey,silty SAND
2	48.8	25.4	FG/CLG	Brown,gravelly,clayey,silty SAND
3	59.9	35.7	FG/CHG	Brown,gravelly,clayey,silty

				SAND
4	58.1	36.5	FG/CLG	Brown,gravelly,clayey,silty SAND
5	49.8	34.9	FG/CLG	Brown,gravelly,clayey,silty SAND
6	55.2	31.4	FG/CLG	Brown,gravelly,clayey,silty SAND
7	37.8	21.9	FG/CIG	Brown,gravelly,sandy,clayey, SAND
8	36.4	19.1	FG/CLG	Brown,gravelly,clayey,silty SAND
9	42.3	21.7	FG/CIG	Brown,gravelly,sandy,clayey, SAND
10	30.8	14.7	FG/CIG	Brown,gravelly,sandy,clayey, SAND

4.2 Discussion of Results

4.2.1 Physical Parameters

The particle size distribution curves of the river soil are illustrated in figures 4.1-4.5 while that of the soil deposited by erosion are in figures 4.6-4.10. One type of curve was identified. The whole of the soil samples have the ratio of sand > gravel > silt + clay (brown, clayey, silty, gravely sand). The group of soil is classified as FG/CLG according to the British scheme (Curtain et.al, 1997).

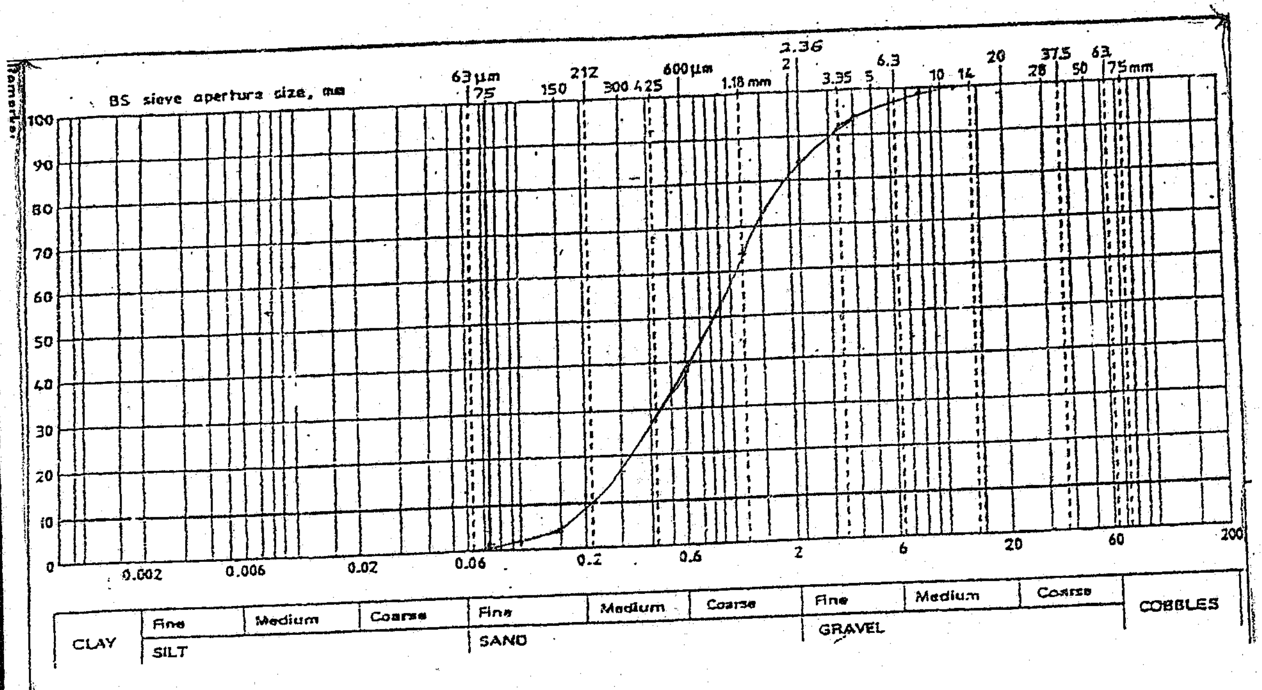


Fig.4.1: Particle Size Distribution of Trial Pit1.

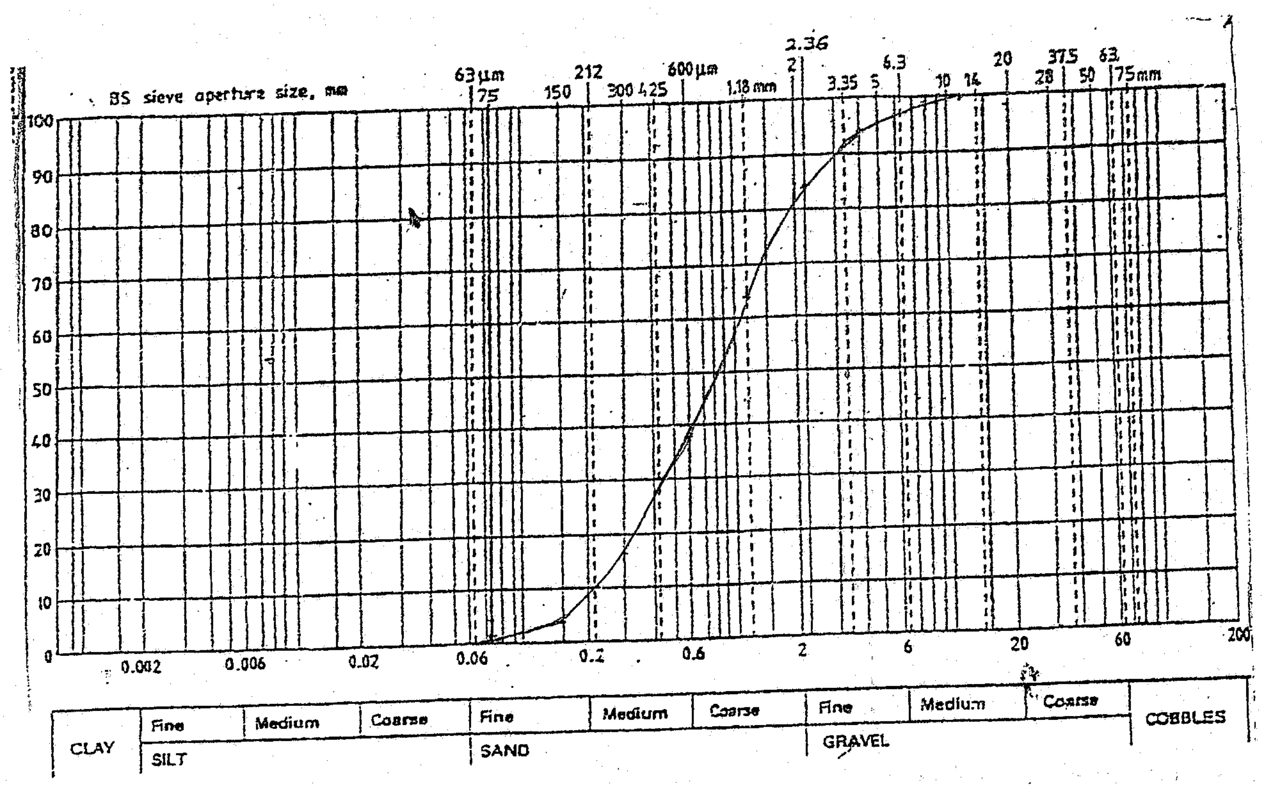


Fig.4.2: Particle Size Distribution of Trial Pit2.

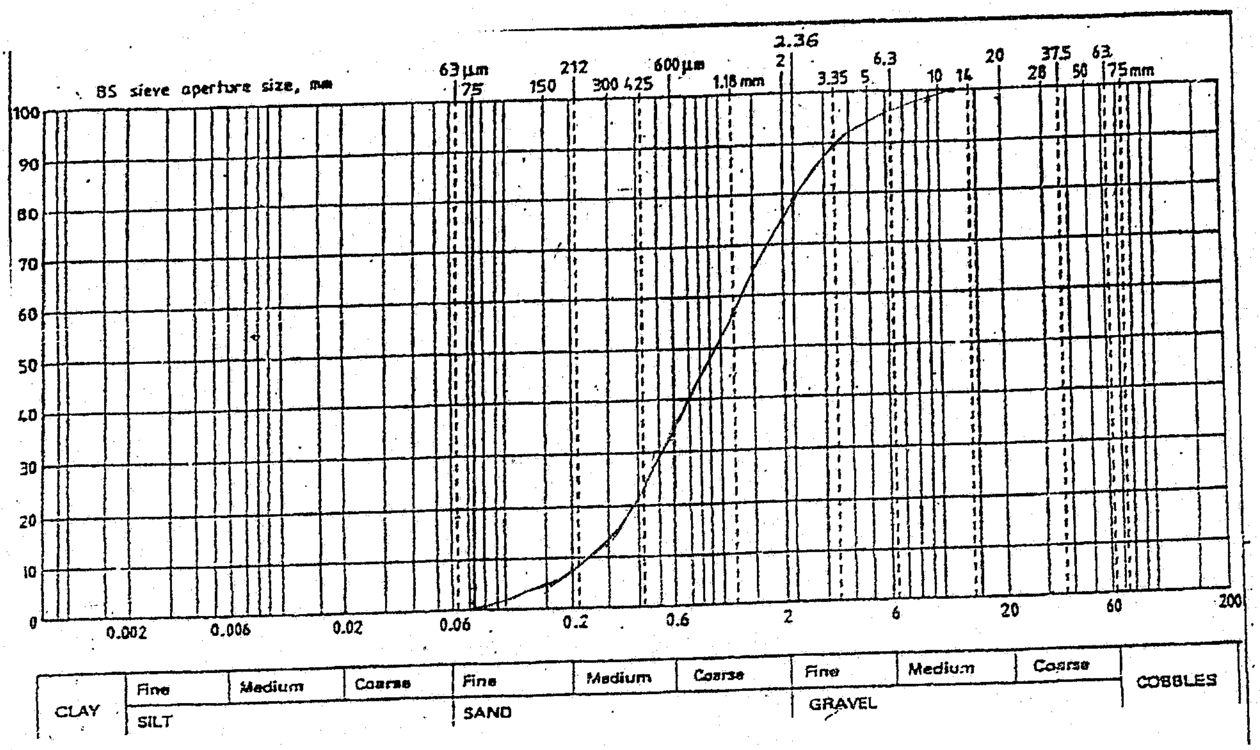


Fig.4.3: Particle Size Distribution of Trial Pit3.

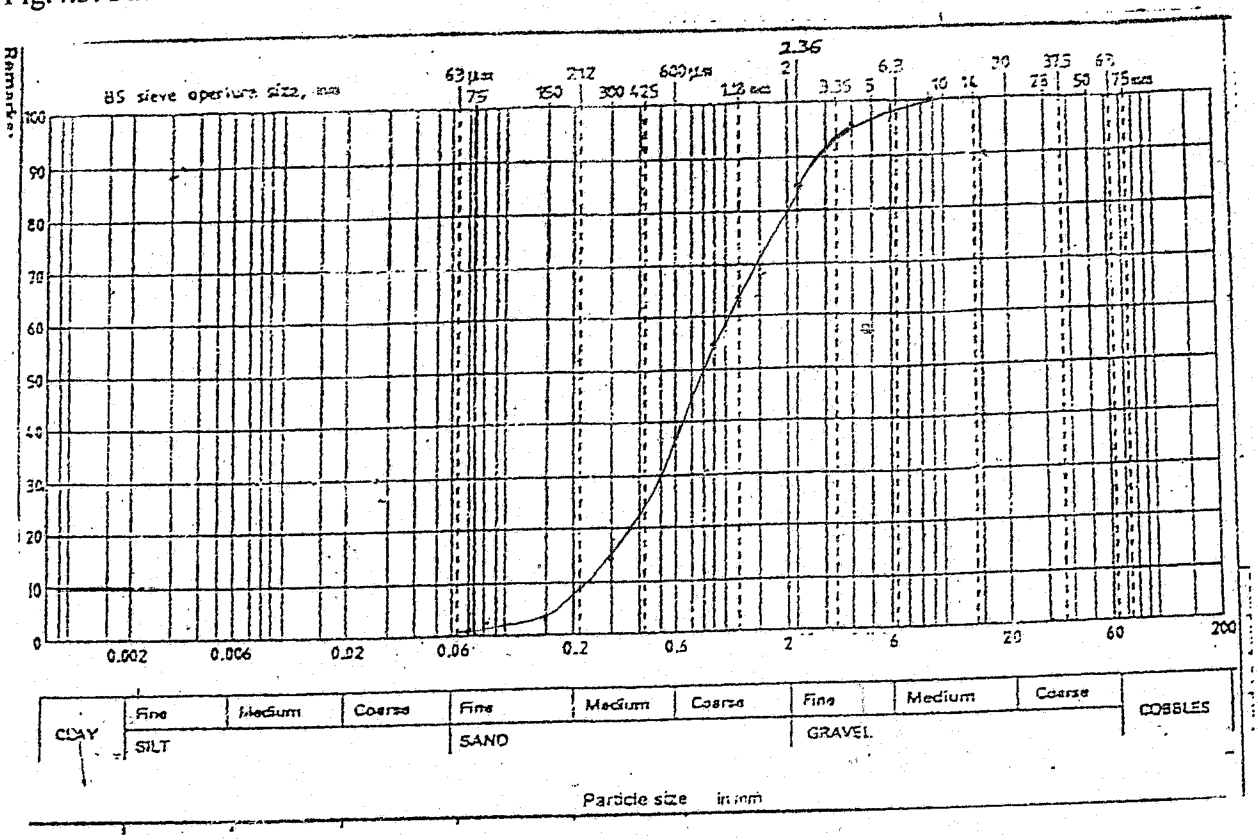


Fig.4.4: Particle Size Distribution of Trial Pit4.

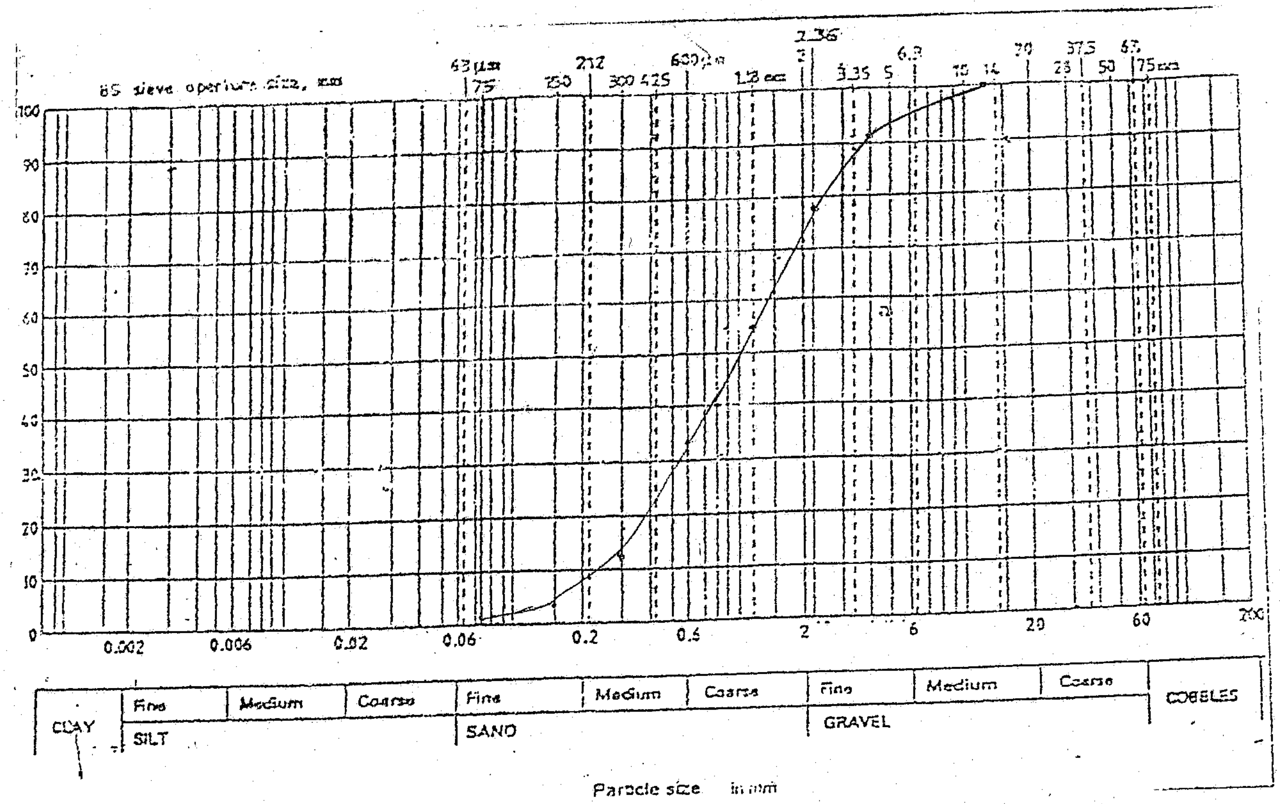


Fig.4.5: Particle Size Distribution of Trial Pit5.

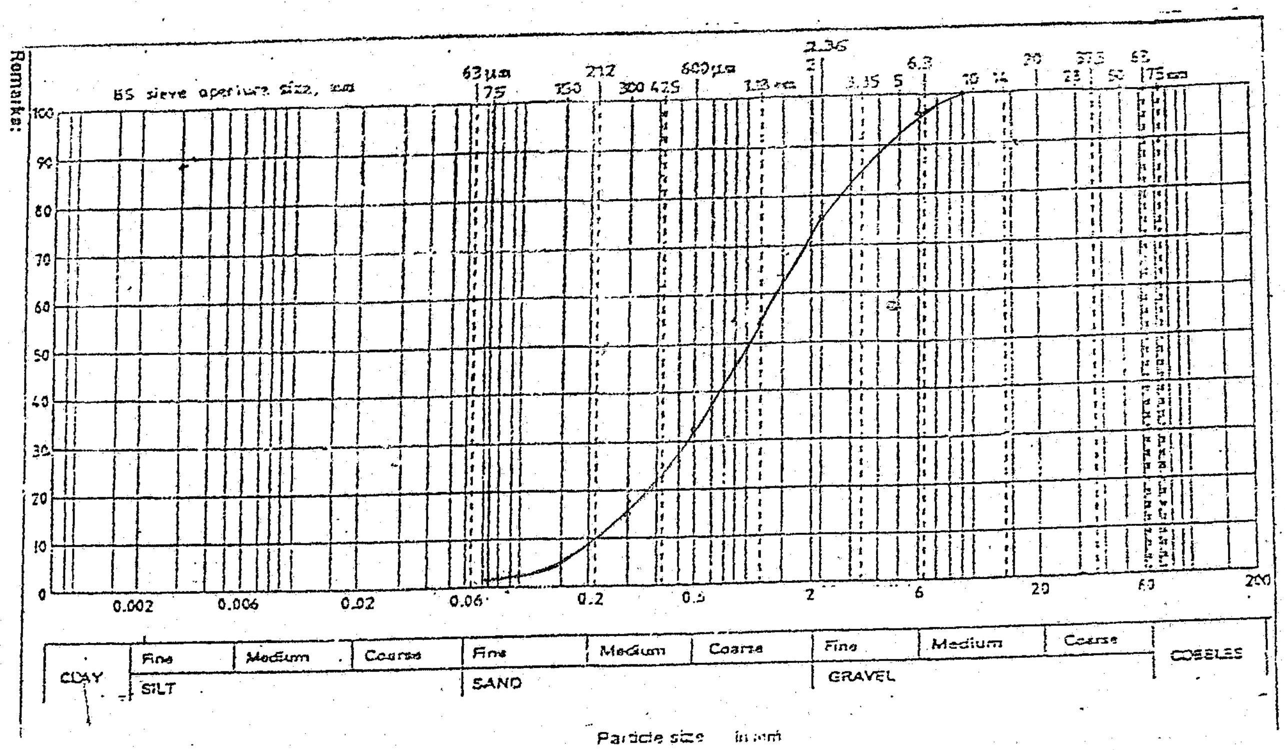


Fig.4.6: Particle Size Distribution of Trial Pit6.

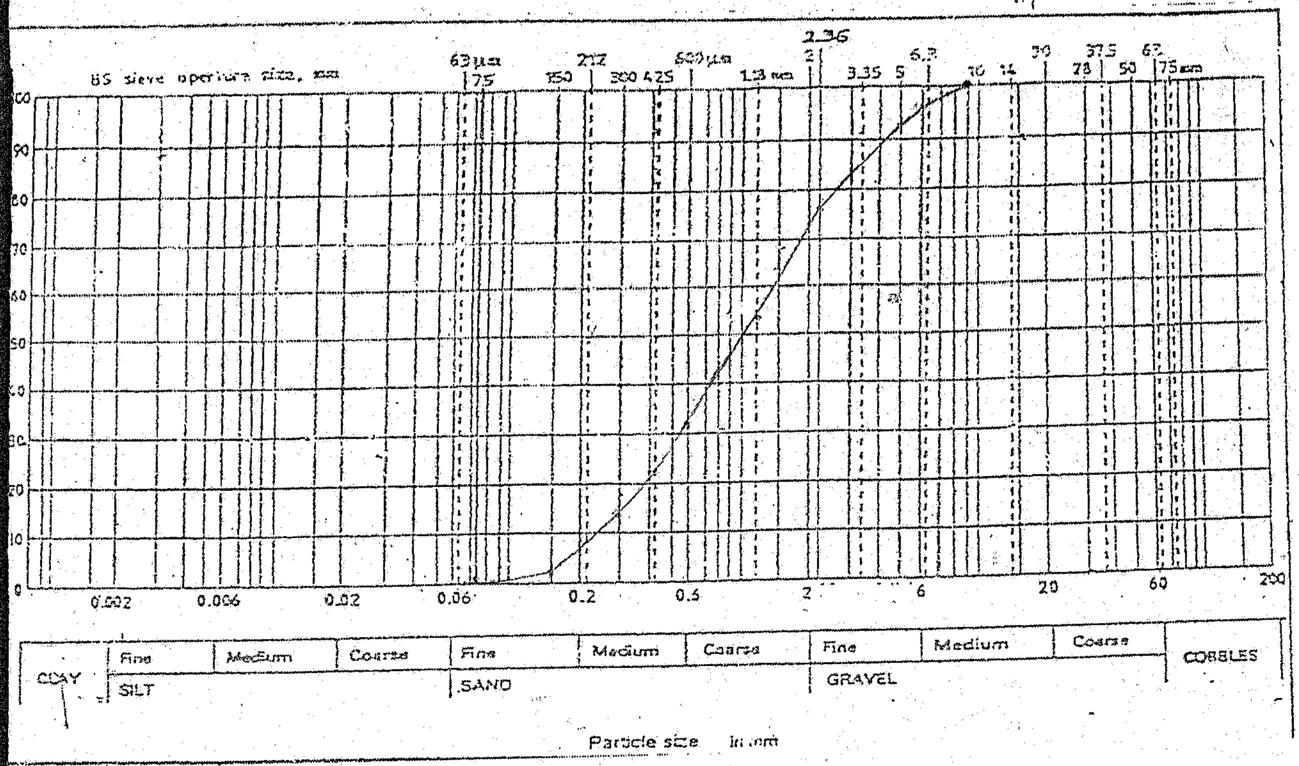


Fig.4.7: Particle Size Distribution of Trial Pit7.

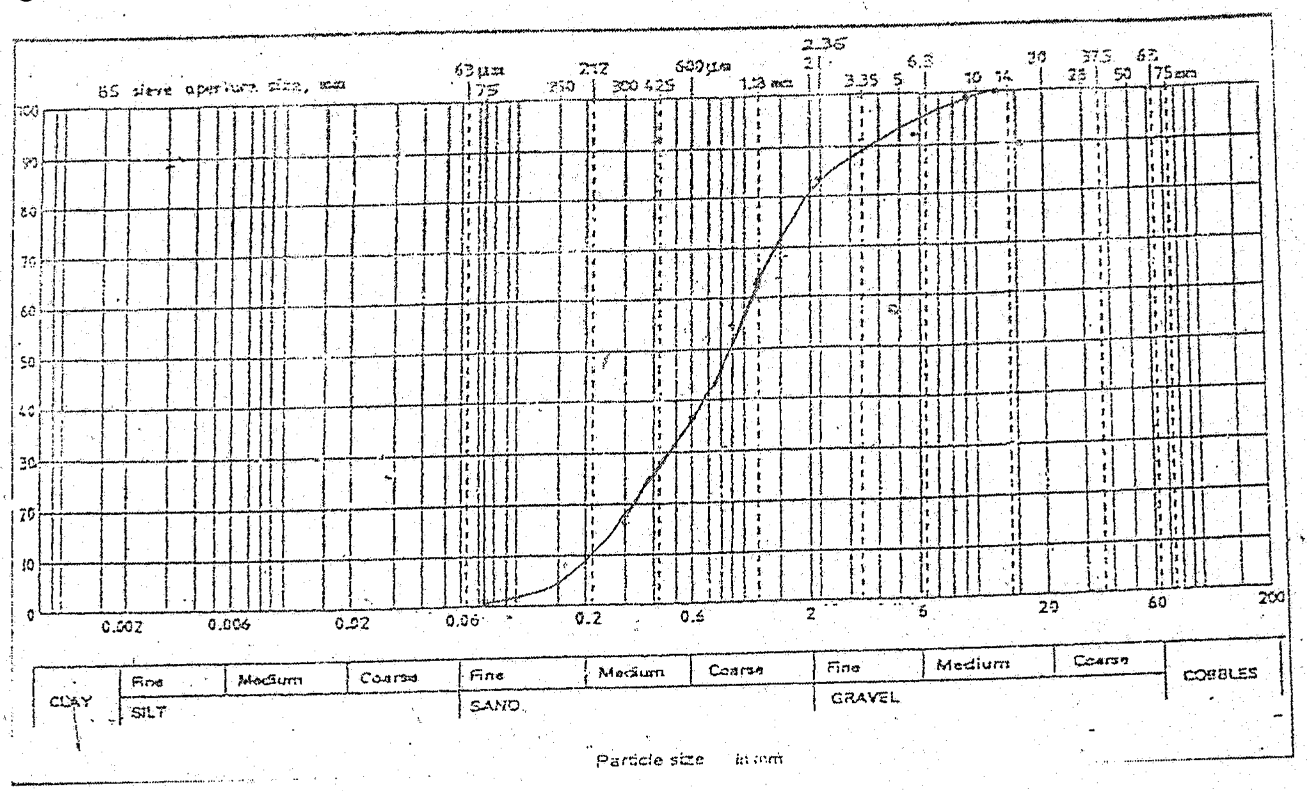
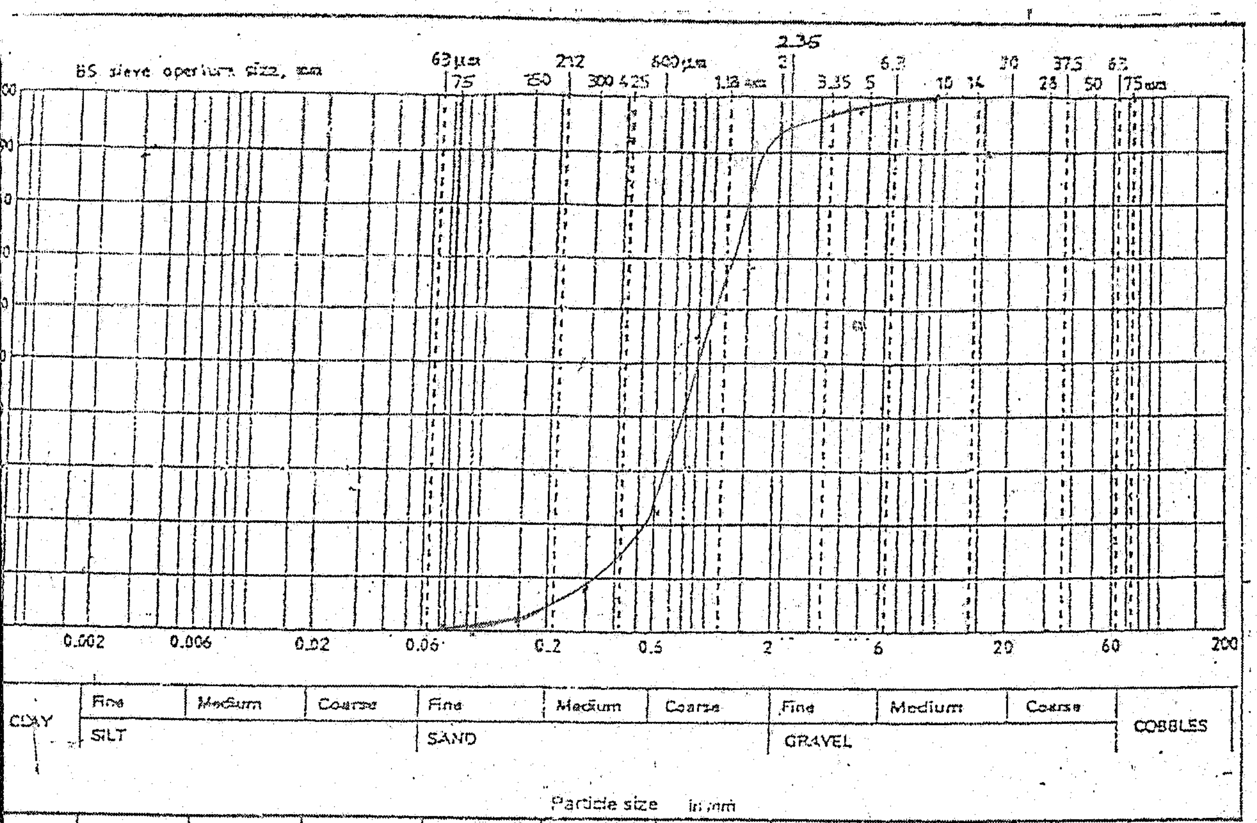
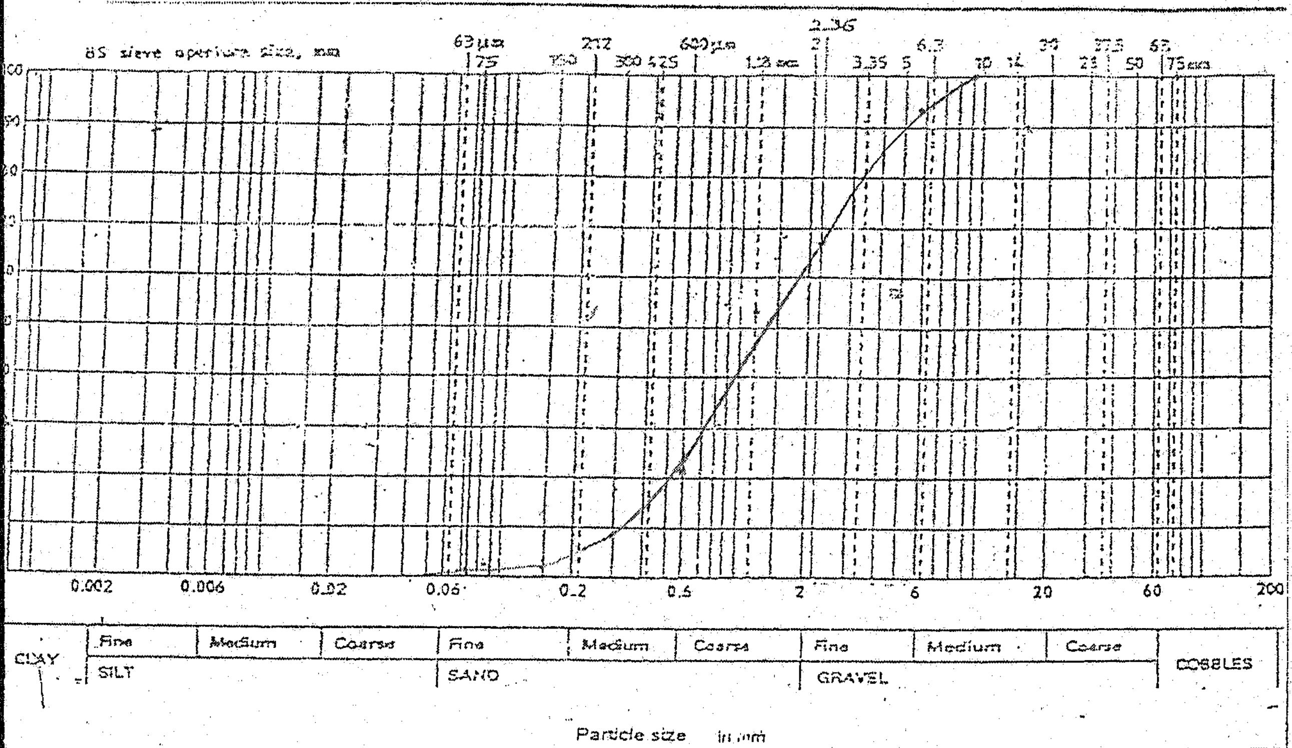


Fig.4.8: Particle Size Distribution of Trial Pit8.



.4.9: Particle Size Distribution of Trial Pit9.



.4.10: Particle Size Distribution of Trial Pit10

The optimum moisture content and maximum dry density of the river soil are 6.4% and 1794kg/m^3 respectively while that for the soil deposited by erosion are 8.3% and 1774kg/m^3 respectively. The normal soils like those in the tropics, water content at saturation decreases because of the increase in clay content, this is reflected in the river soil. The increase in percentage saturation is as a result of increase in sand content in the soil deposited by erosion.

Compaction brings about decrease in hydraulic conductivity due to moulding water control as a result of reduction of particle orientation and reduction in size of the largest flow channels. As compaction increases, the dry densities increases and the moisture content decreases. The laboratory measured bulk densities are higher in the river soil due to the high clay content of the river soil than those of the soil deposited by erosion due to its high sand content. Bulk density decreases with increase in sand, and increases with increase in clay. Bulk density is affected by compaction, the more the compaction the higher the bulk density, and therefore, rate of infiltration is reduced. Plots of dry density against moisture content of the river soil are presented as Figures 4.11-4.15 while that for the soil deposited are in Figures4.16-4.20.

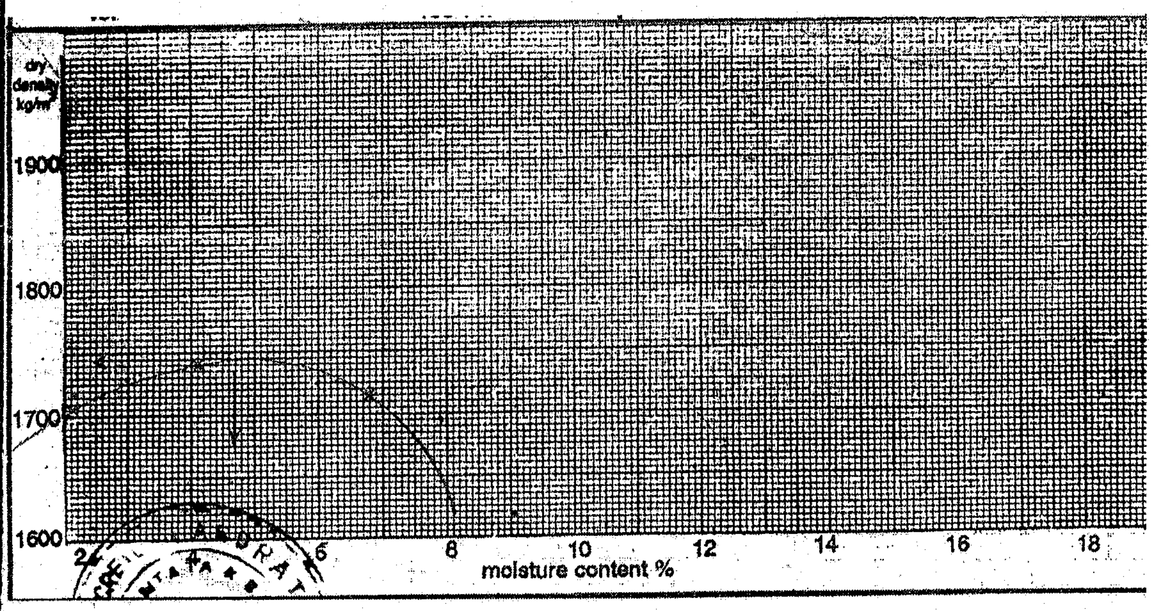


Fig.4.11: Plot of Dry Density against Moisture Content of Trial Pit1.

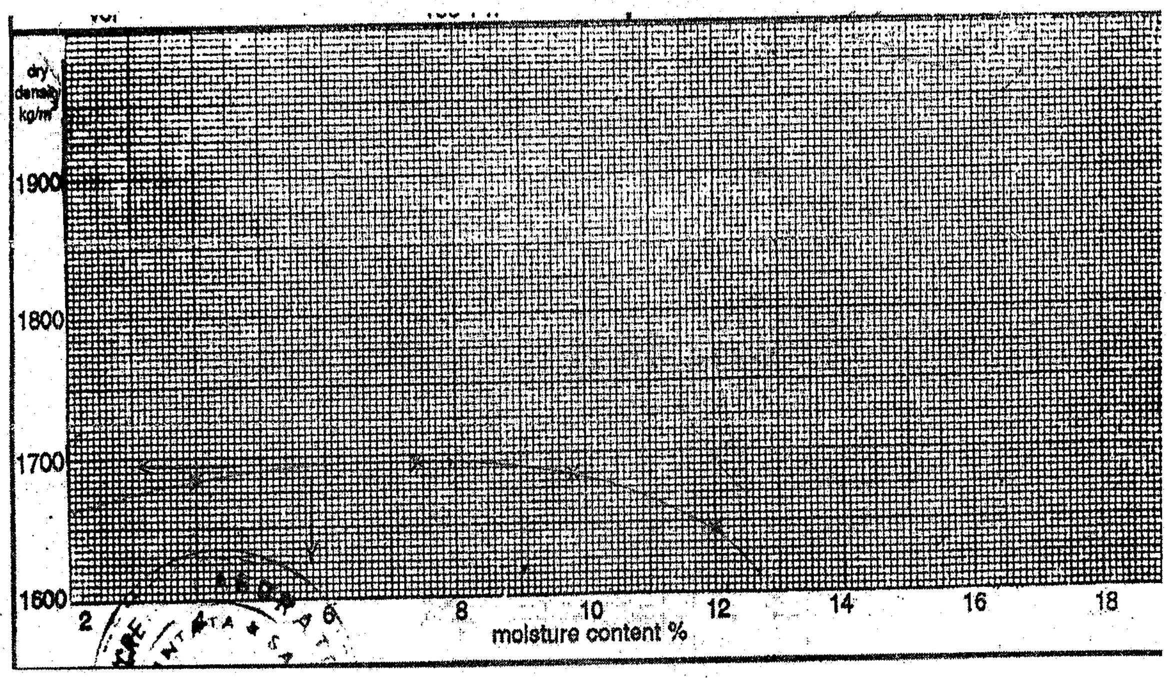


Fig.4.12: Plot of Dry Density against Moisture Content of Trial Pit2.

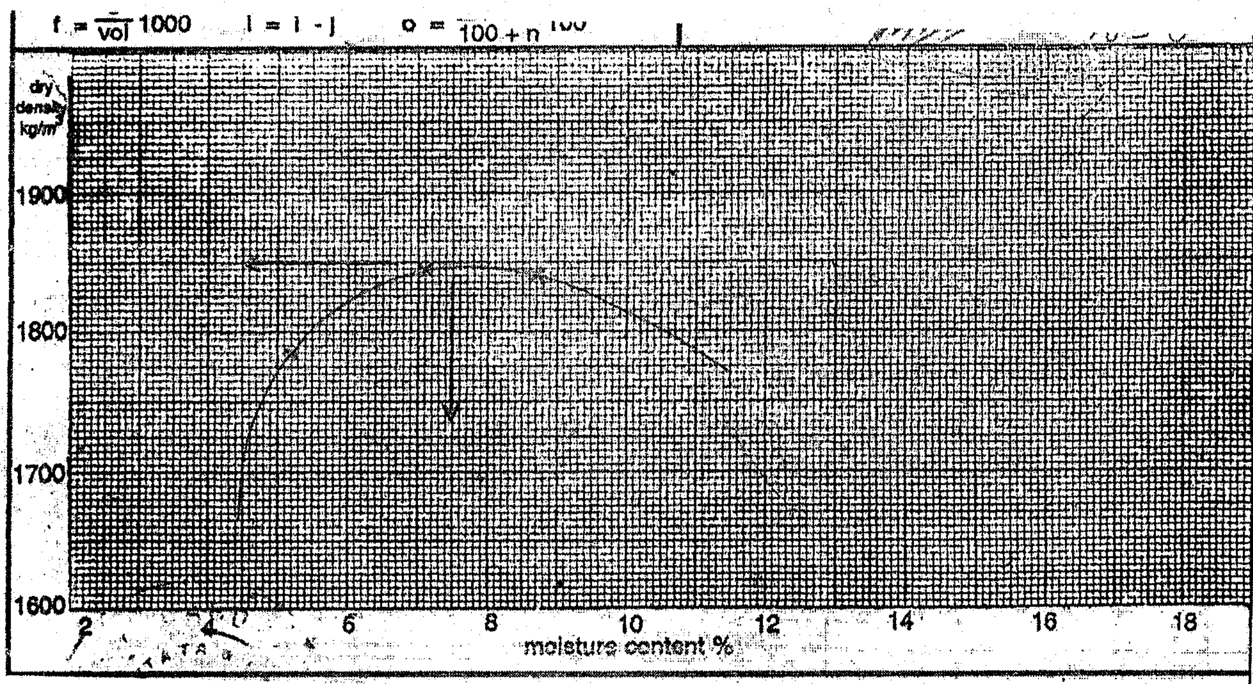


Fig.4.13: Plot of Dry Density against Moisture Content of Trial Pit3.

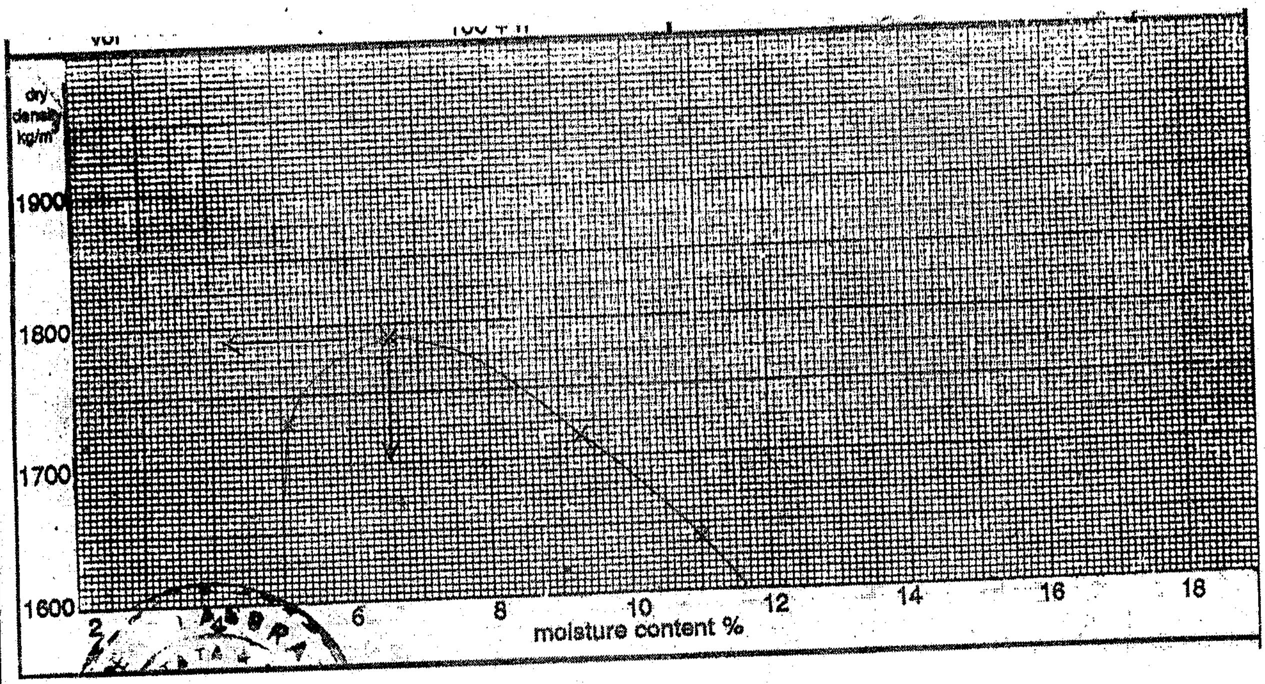


Fig.4.14: Plot of Dry Density against Moisture Content of Trial Pit4.

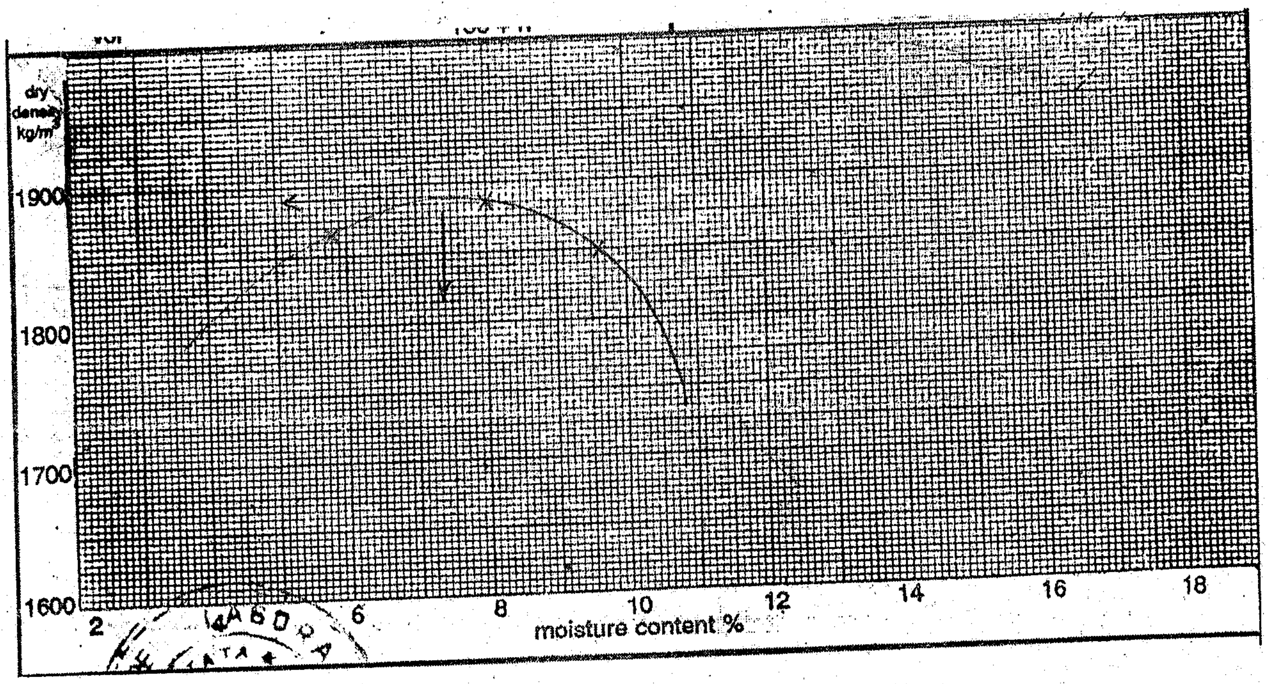


Fig.4.15: Plot of Dry Density against Moisture Content of Trial Pit5.

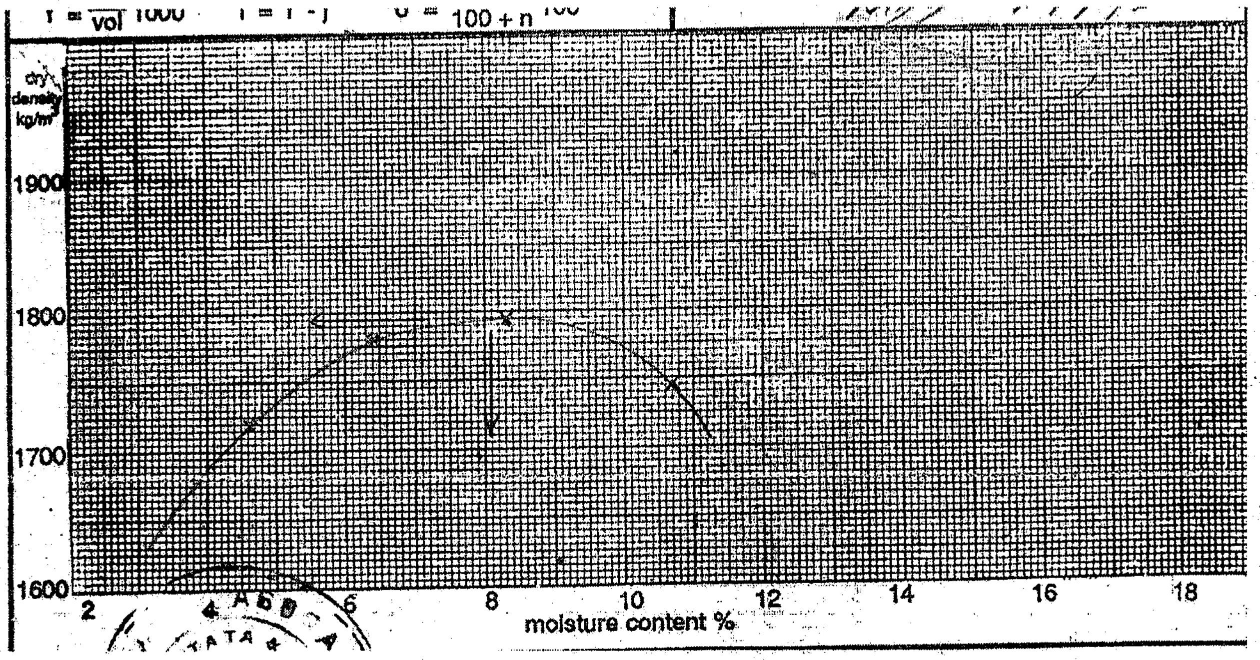


Fig.4.16: Plot of Dry Density against Moisture Content of Trial Pit6.

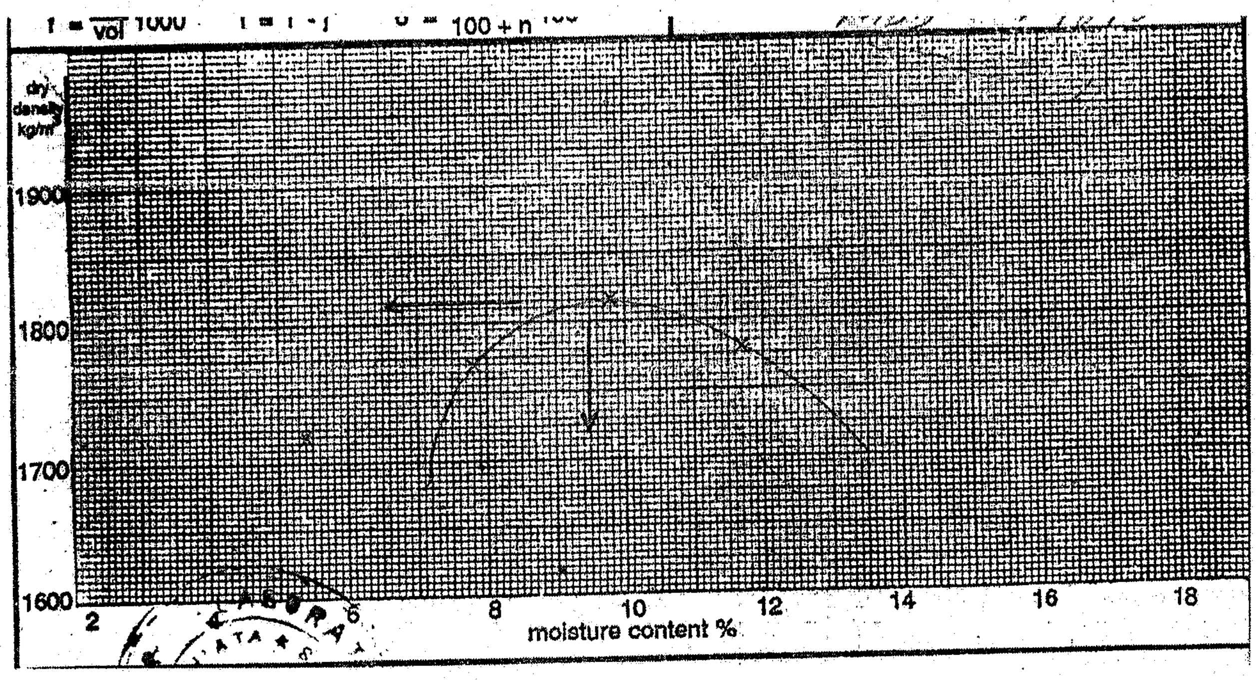


Fig.4.17: Plot of Dry Density against Moisture Content of Trial Pit7.

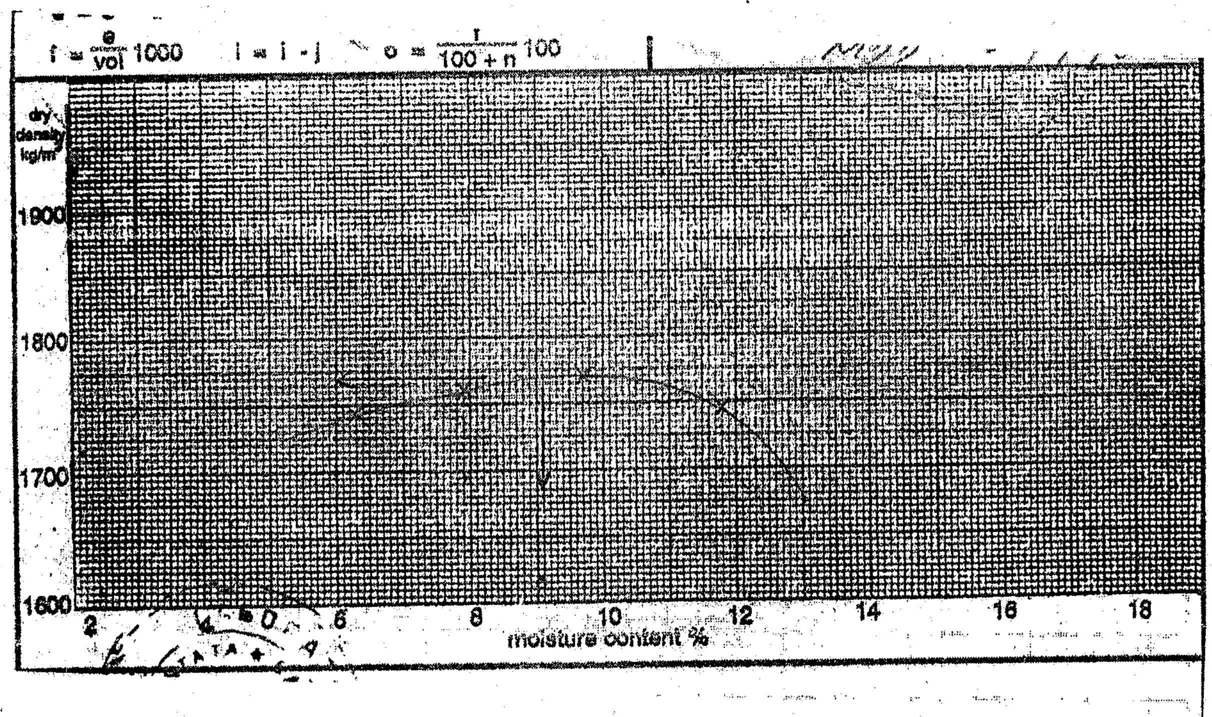


Fig.4.18: Plot of Dry Density against Moisture Content of Trial Pit8.

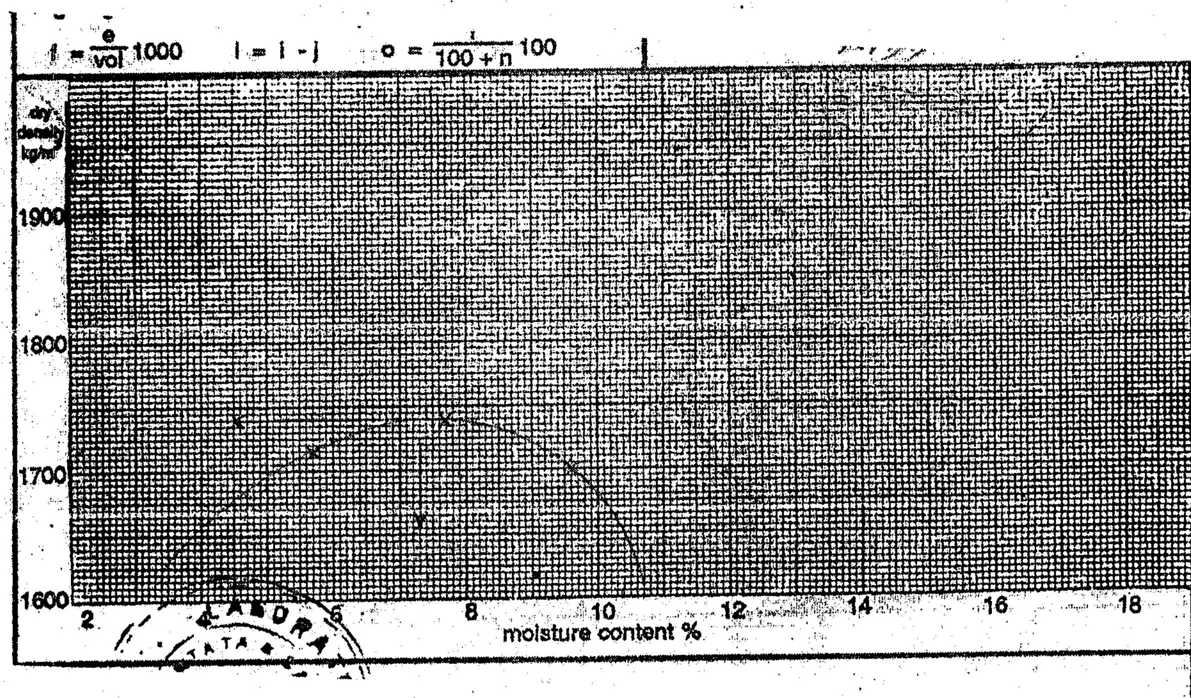


Fig.4.19: Plot of Dry Density against Moisture Content of Trial Pit9.

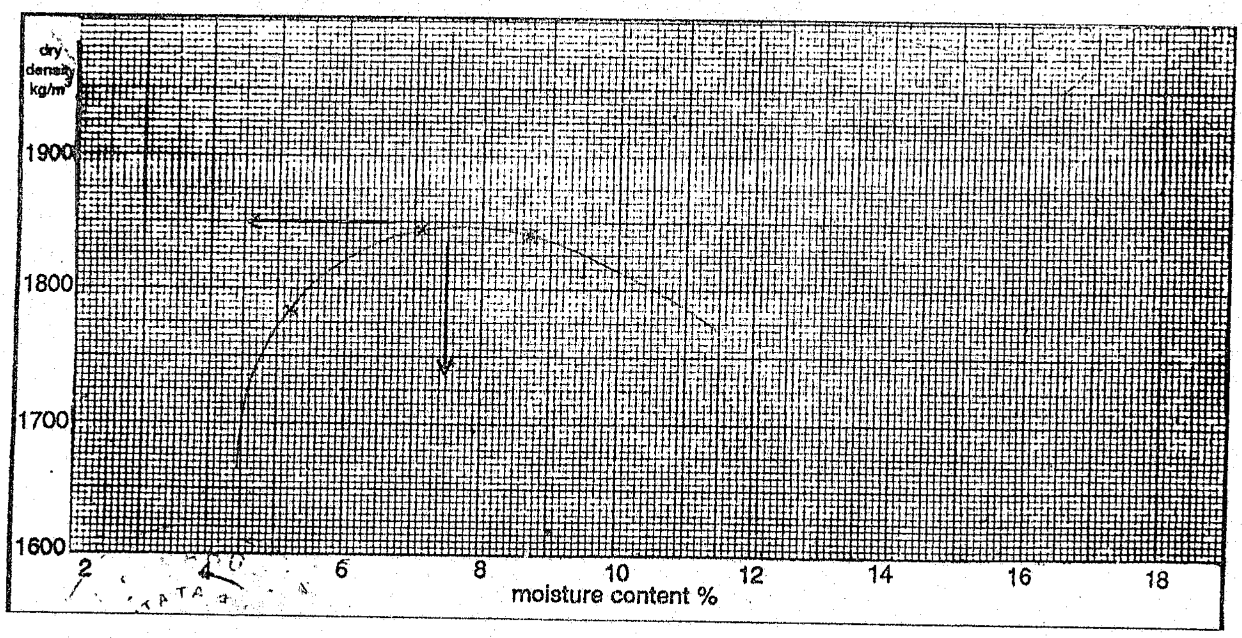


Fig.4.20: Plot of Dry Density against Moisture Content of Trial Pit10.

4.2.2 Hydraulic Parameters

From the saturated hydraulic conductivity test carried out, erosion soil averages at 16.75cm/hr while that of the river soil averages at 14.90cm/hr. The higher value of the saturated hydraulic conductivity of the erosion soil is as a result of relatively high sand and relatively low clay present in the soil. Conductivity increases with increase in sand and decreases with increase in clay.

The apparent specific gravity of the river soil are of the range 2.46 - 2.70 while that of the erosion soil is 2.46 – 2.64. The lower value of the specific gravity for the erosion soil is an indication that there exist higher percentages of finer particles in the erosion soil. The values of the absorption test ranges between 13.32% to 15.83% for the river soil and 16.36% to 18.40% for the erosion soil deposited. The high values in the erosion soil are due to the higher percentage of finer materials in the soil.

A plot of plasticity index (PI) against liquid limit (LL) is presented as figure 21. The shrinkage potential of the erosion soil ranges from low to medium while that of the river soil ranges from low to high and table 4.13 presents clay shrinkage potentials by curtain et al (1997).

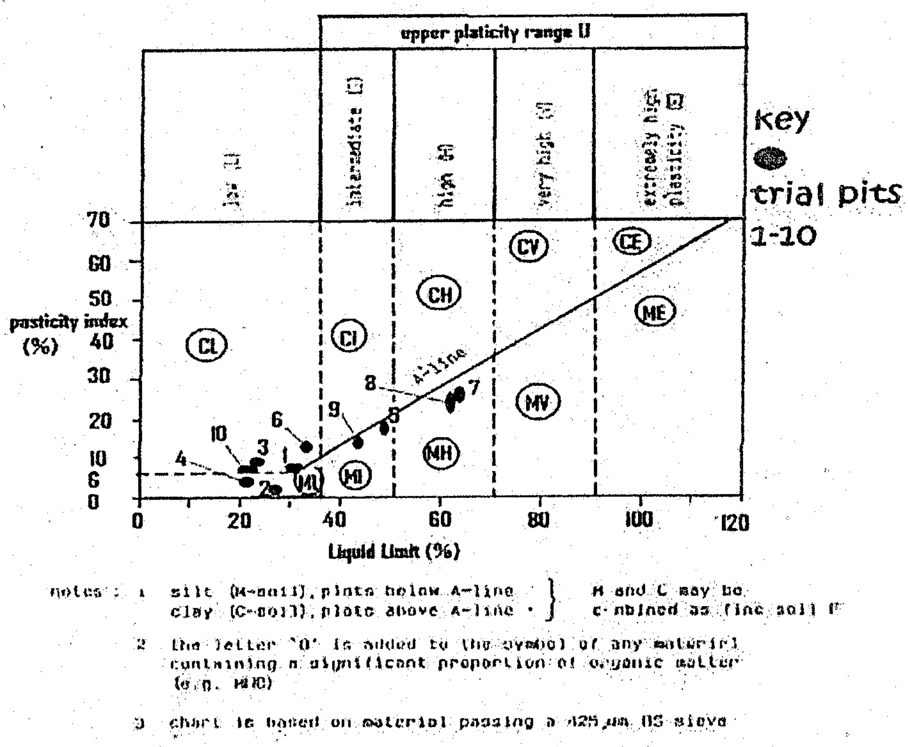


Fig.4.21: A plot of plasticity index against liquid limit for soil in the study area

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This project work had examined the physical and hydraulic properties of Chanchaga river soil and the soil deposited by erosion. From the analysis and tests carried out, the following conclusions were made.

Considering the particle distribution curves obtained from sieve analysis, both the erosion soil and the river soil exhibit almost the same characteristics (i.e. well graded sand) hence their curves resemble each other in all respects.

It is seen from the hydraulic conductivity test carried out that the erosion soil conducts more water than the river soil. This implies that the infiltration rate of the erosion soil would be very much too since both of them are closely related. The hydraulic conductivity of the erosion soil is sufficiently high with a relatively stable soil aggregates and this shows good permeability and this makes the erosion soil deposited not suitable for farm structures.

That the effect or the presence of greater finer particles in the erosion soil is attributed as being the cause of the low specific gravity but higher absorption as a result of the finer grains fill-in-between the void spaces of the coarser sand. The higher absorption makes the erosion soil not good also for farm structures.

The higher values of bulk densities of the river soil are an indication of its cleanliness, free from impurities and lesser amount of fine sand. Based on the compaction test, it can be concluded that the river soil has reduced shrinkage, high strength and cohesion, high durability and waterproof in nature. All these are indications that the river soil is more suitable for farm structures than the soil deposited by erosion.

The soil removed during excavation should not be used for back filling. Fine to medium sand of the erosion mixed with cement should be utilized since this will reduce water infiltration into the ground around foundation.

5.2 **Recommendations**

The following recommendations are suggested based on the physical and hydraulic properties of the soils.

(i) The organic matter (carbon) in the soil should be determined because it helps to estimate the extent of binding aggregates. This can be determined by the method of Walkley and Black using normal potassium dichromate.

(ii) That more research should be carried out in dry season to see it there will be much variation in the values obtained since this study was carried out in the wet season.

(iii) More research should be carried out on different soils from different river to see if river soil and soil deposited by erosion will always vary.

REFERENCES

Wilford,R.G., William A. and Walter H. (1991): "Soil Physics", John Wiley and sons , Incorporated, 5th Edition, Pp77.

Nyle, C.B. and Ray R.W. (1991): "The Nature and Properties of Soils", Prentice hall upper saddle river New Jersey, 12th Edition, Pp668-720.

John, A. (1993): Introduction to the Mechanics of Soil and Foundation", McGraw-Hall book company London, 12th Edition, Pp45-47.

Glenn, O.S., Delmer,D.F., William, J.F. and Richard, K.F. (1993): "Soil and Water Conservation Engineering", Hamilton printed company USA, Pp48-49.

Gerrit H. (1995): Agrohydrology and Ground Water Management. World journal of United State Geological Survey, Pp811-824.

Clayton, C.R., Mathews, M.C., and Simous, N.E., (1995): Site investigation and structural foundation. Blackwell science Ltd, Britain, Pp1-59.

Ayers, D.A., (1996): Influence of land use on some Aggregate properties. Agriculture et Agroalimenatre, pp44-46, ete-foy, Canada.

Caron, J. and Espindola, C.R., (1996): Soil Structural Stability during Rapid Welting. Universite Laval, Pp4 ete-foy, Canada.

Horton, R.E., (1996): Water content and infiltration of soil. World journal of soil science society of America, 60:Pp901-908.

Dekker, M. (2002): Test for soils for Civil Engineering purpose: Compressiblity, Permeability and Durability. World journal of British Standard Institution, 5:Pp2-5.

Jones, L. (2002): Shrinking and Swelling Soil. World journal of British Geological survey, 18:Pp733.

Nyle, C.B., and Ray, R.W., (2002): "The Nature and Properties of soils", Prentice hall upper saddle river New Jersey, 13th Edition, Pp211-212.

Dane, J.H. and Topp, G.C., (2004): Methods of soil Analysis. World journal of soil science society of America, 3:Pp722-723.

Oke, S.A., Okeke, O.E., Amadi, N.A., and Onuduku, U.S., (2007): Geotechnical Properties of subsoil for designing shallow foundation in some selected parts of Chanchaga area, Minna, Nigeria. Proceedings of Annual lectures of Geologist, federal university of technology, Minna, 2007, Pp1-10.

APPENDICES

APPENDIX A

A certain weight of the soil sample each trial pits was weighed and sun dried for 5hrs. it was sun dried to eliminate the natural moisture content (water content).

The dried sun mass was then sieve through a Standard British sieve set in a mechanical shaker for about 10 minutes.

The amount of soil rained in each sieve was transferred into the electrical measuring scale and the value recovered.

The percentage retained in each sieve was calculated as follows:

$$\text{Percentage retained} = \frac{\text{amount retained in each sieve} \times 100}{\text{Total weight of the sample}}$$

APPENDIX B

The sample from each trial pit was dried, weighed and divided into four points to determine the percentage of moisture the material can absorb for effective compatibility.

Each of the four point can was then mixed with some certain volume of water and compacted three layers of twenty-five blows (3/25).

After the layers and the blows, the top of the mould was lost and the wet and leveled equally with the mould's level, and then weighed.

Water was removed from the wet sand inside and collected into a container and weighed, also with the wet sand. The wet sand was again kept in the ovum for not less than 12hrs.

The result obtained was then used to plot a graph to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).

APPENDIX C

* The sample from each of the trial pit was dried to at a temperature of 110±5^{0}c (23±9^{0}F), cool in air at room temperature from one to four until the samples comfortable to handle and subsequently immersed in water at room temperature for a period of 24±4hrs.
* The sample was then removed from the water and weighed in the saturated surface-dry condition recovered to the nearest 0.5g or 0.5% of the sample weight.
* After weighing, the surface-dry test sample was immediately placed in a contained in which the weight in water at 23±17^{0}c (73.4±3^{0}F) was determined. All trapped air must be removed before weighing by shaking the container while immersed.
* The sample was again dried to content weight at a temperature of 110±5^{0}c (230±9^{0}F), cool in air at room temperature of until the sample was comfortable to handle (50^{0}c) and then weighed to obtain results.

APPENDIX D

* Each sample from the trial pits was immersing in water for approximate 24hrs for water to essentially fill the pores.
* The sample was then removed from the water in which the water was kept to dried out from the surface of the particles and the wet particles was then weighed on a balance.
* Subsequently, the sample was weighed while submerged in water. Finally, the sample was then dried and weighed a third time.

APPENDIX E

* Water was slowly introduced into the core cylinder and a constant head was maintained for 5 minutes.

* Water was then allowed to drain gradually through the soil sample into the graduated beaker and the volume of the percolate that passed through the sample in a known time was measured.
* This was repeated for the remaining 9 samples.
* The saturated hydraulic conductivity = $\frac{\text{volume of water per hr}}{\text{cross sectional area of the core}}$

APPENDIX F

* The mass of each of the cans were determined by weighing them.
* It was ensured that the drops of the cups were calibrated using the other end of the grooving tool so that there is consistency in the height of drops.
* About 250g of air dried soil sample passing the 425μm sieve was measured and put in the mixing trey. A little quantity of water was added and used to mix the soil until a unform paste was formed.
* The soil as then placed in the casagrande cup and using a spatula, the surface was smoothening to achieve a maximum depth of 8mm.
* The groove tool was then euse to cut a groove at the center line of the soil cup.
* The liquid limit device was then cranked at a rate of 2 revolution per seconds until there is a clear visible closure of ½' (12.7mm). the number of blows at which the closure occured was noted.
* Soil samples were collected from the closed parts of the cup using a spatula and the moisture content determined.
* The cups were cleaned after each trials and a minimum of three trials were carried out for each samples.

The samples obtained were oven dried for 24 hours and the moisture content were determined.

APPENDIX G

Soil samples of about 20g were taten from the paste made for the liquid limit test. The sample was then placed on the glass plate.

The soil was allowed to dry partially on the plates until it became plastic enough to be shaped into a ball

The balls were then moulded between the fingers and then rolled between the palms of the and until the heat of the hands dried the soil sufficiently enough to cause crack on the surface.

* The samples were then divided into two samples of about 10g each. The samples were then rolled as done earlier.

* The subsamples were further divided into four. The samples were then moulded between the fingers to equalize the moisture. The soil were then formed into threads of about 6mm diameter between the fingers and thumbs of each hands.

* The soil at this stage were then rolled into about 3mm diameter in five to ten complete forward and backward movement on the plates

* The soil at this point is picked up, moulded abd rolled again until the thread shears the
* The crumbled soil were gathered together and put into a suitable container
* The processes are then repeated for a minimum of three other samples
* The moisture contents of the obtained samples were then determined.