GEOTECHNICAL ASSESSMENT OF AKPULU GULLY EROSION SITE IN IDEATO NORTH LOCAL GOVERNMENT AREA OF IMO STATE, NIGERIA

BY

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CERTIFICATION

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DEDICATION

This thesis is dedicated to the glory of Almighty God for his wondrous blessings and also to my mother, brothers and sisters.

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ABSTRACT

This study was carried out to assess the surface processes and subsurface characteristics that contribute to the formation and expansion of gully erosion in Akpulu - Ideato North County, Imo State Nigeria. Part of Akpulu community especially Okwu village that is very close to the gully head may submerge in the next few years if control measures are not intensified. A gully measured 15-18 m deep, 9-12 m wide to 6.5 km long is advancing aggressively, threatening life, property, food production, and security of ecosystem in Akpulu and its environs. Analysis of soil samples collected from accessible portion of the gully depths of 3 m show peculiar geotechnical characteristics ranging from Liquid limits 27.5 – 30.4%, Plastic limits 17.35 – 22.75%, and Plasticity index 7.65-13.70%. The soil has high clay/silt content, with ranges of maximum dry density (2.01- 2.06g/m^3), Optimum moisture content (12.1-13.4%), and average shear strength of 106.9KN/m^2. It is easily erodible, as the silt gets dissolved by high velocity flood on 0.02 flow gradient. Expansion and maintenance of the main drainage channel from Umuchu to Akpakporo River in Apkulu is recommended. Secondary drainage channels to join the main channel, and increased trees planting from the gully head are also recommended.

Keywords: Geotechnical, Gully erosion, Soil, control, Impact, Assesment

CHAPTER ONE

1.0 INTRODUCTION

Over many years ago channels in some part of South East Nigeria especially Akpulu in Ideato North Local Government Area of Imo State were noticed to have entrenched their valley. These channels generally eroded in red earth and unconsolidated geologic materials establishing prominent gully with near vertical slope. This channel which caused this erosion, was as a result of road construction in which their drainage were channeled from Achina-Umuchu-Uga down to Akpulu and another road construction whose drainage were also directed to the same study area. Increased erosion activities in the vicinity of the early gully of the study area have continued to expand this gully into a complex system. This gully is advancing aggressively into residential area, constituting the most threatening environmental hazard in the area. Lithostratigraphy of the gully site comprises thick cohesionless sand stratum, overlain by a red silty sand layer and then silty topsoil. This intense gulling involved sudden and often catastrophic movement of large earth masses (landslides) causing sudden death of human beings and other animals. Properties worth millions of naira have been destroyed, wrecked homes, pollution of Akpakporo River and washed road away.

Incident of gully erosion has caused much concern to the people of Akpulu, Ideato North Local Government Authority, Imo State Government, the south-east, and Nigeria. It has generated much attention among private and institutional researchers but with limited output. Studies have been conducted, seminars and workshop also held on the immediate and remote causes of this gully. Effort was made in the past to control the erosion menace, which resulted in the design and construction of concrete channel to conduct the erosion flood into River. This channelization from Umuchu through Akokwa to Akpulu is about a distance of 24.5 km. Later development of gully erosion from Uga linked the Umuchu-Akokwa-Akpulu channelization, and resulted in the channel overflow. This overflow created an uncontrolled secondary drainage channel aggravating the present headward movement of the gully south of Akpulu residential area. This has made the present channelization program under completion and repairs inadequate.

This erosion has degraded arable land, to reduce food production in the area. It has reduced infrastructural development, and socio-economic aspect of the Akpulu community. It has necessitated an urgent administrative policy with new approach to land conservation and management in the area. From interview conducted, the gully has caused the death of many people in the community particularly about four school children were killed and the six other were seriously injured at a time in 2001 when they felt into the gully. The children were all playing near the sites of the erosion when suddenly the ground caved-in and caused them to plunge head first into the over 50 feet deep gully. They lamented that help was late in coming as the depth of the gullies scared those who had come on rescue mission. "It took about two hours before people managed to bring them out and before then four of them had died and six in serious conditions." Beside Akpulu, a number of other communities in Ideato area sharing similar erosion threat include Umuago, Obodoukwu, Osina, Urualla, Isiokpo, Uzii, Ndiejezie in Arondizuogu, and Akokwa, to mention but a few. A major cause of the many erosion problems is linked to the abandoned federal government road project which culverts and drainages were not in place.

1.2 STATEMENT PROBLEM

Human activities such as building of road and intensive farming etc. are contributing factors responsible for the erosion which is the problem of the study area. This problem has affected the following:

The value of lands, reduced the rate of physical development, resulted in loss of lives and properties, and contamination of Akpakporo river.

1.3 AIM OF THE STUDY

The aim of the study is to critically assess the gully erosion at Akpulu community in Ideato North local government area of Imo State.

1.4 OBJECTIVES OF THE STUDY

The objectives are to achieved the following:

- Find out the actual causes of erosion in Akpulu community,
- The impact of this erosion on the physical environment of the area.
- Find out the roles the affected community played in checkmating this ugly incident in their area.
- To determine the characteristics of soil within the erosion site.

1.5 JUSTIFICATION OF STUDY

There is problem of loss of lives, submerged homes, destruction of crops, pollution of rivers etc in the study area. These problems caused by gully erosion in Akpulu are now of great concern to the people of the area. Ideato north local government authority, the Imo and Anambra state governments, and Nigeria in general are all concerned. This erosion has generated much attention among institutions and private researchers. Studies have been conducted, seminars and workshops also held on the immediate and remote causes of this gully. A number of measures have been designed and constructed to control this erosion problem, but some of these measures did not work in full capacity, and the gully is still active.

If control measures are not intensified, in about five years to come this erosion will drive the residents within the gully site away from their village. It is important to commission a sustainability study yearly in order to continuously assess the advancement or otherwise effects of the control measures put in-place. This implies that proper geotechnical and environmental assessment of this gully in Akpulu be conducted, which will help in planning more effective control measures.

1.6 SIGNIFICANCE OF STUDY

This study will alert the government and the general public on the critical situation of Akpulu gully erosion site. To date there is no publication as reference material specifically on Akpulu gully. Result of this study is already sent out for publication, and consequently for public consumption. This will help people to know the magnitude of Akpulu erosion site, and will also help in the development of Akpulu community.

1.7 SCOPE OF STUDY

The scope of this study falls back to environmental impact assessment and geotechnical measurements of Akpulu gully erosion. Adequacy of the existing concrete channelization is reviewed to identification of secondary drainage channels and determination of drainage slope. Geotechnical parameters measured include plastic and liquid limit tests, compaction test, direct shear test, and grain size analysis. Others such as insitu moisture, shrinkage limit, permeability and triaxial tests are not measured for lack of instrumentation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 MEANING OF GULLY EROSION

According to Hudison 1995 define gully as a steep sided eroding watercourse which is subject to intermitted flash floods. Troeh et al., 1980 further stated that gullies are considered to be active as long as erosion keeps the side bare of vegetation and inactive when they have been stabilized by vegetation.

Gully erosion produces channels larger than rills. These channels carry water during and immediately after rains, and as distinguished from rills, gullies cannot be obliterated by tillage. Thus, gully erosion is an advanced stage of rill erosion much as rill erosion is an advanced stage of sheet erosion. A gully develops by processes that may take place either simultaneously or during different period of its growth. These processes are:

- Waterfall erosion at the gully head;
- Channel erosion caused by water flowing through the gully or by raindrop splash on unprotected soil;
- Slides or mass movement of soil in the gully.

Gully erosion is quantitatively less important than sheet erosion, but it is more apparent and locally destructive. Gully erosion is predominantly a process of incision. There is a certain development with time: the incision is followed by widening and aging of the gully until it achieves a stabilized state. The gully's increasing capacity to deal with a shower and the gradual decrease in its catchment area mean that the gully is not rejuvenated by each shower over its entire length, but, typically reveals early development characteristics only at the head and side branches. Continued extension of the gully system will not only threaten the arable land, but will also affect roads, buildings, structures, river courses, and could cause undercuts and landslides. The final result of unchecked gully erosion is the total devastation of the landscape.

2.2 CAUSES OF GULLY

In engineering terms, the cause of gully erosion is the breakdown of a state of meta-stable equilibrium in the stream of water course Hudison 1995 and Udeh et al (1980) agree that running water in many form is most agent causing erosion in study area.

Gully erosion occurs when the actual water is displaced from its state of meta-stable equilibrium, as a water course is ordinarily imbalance, that is the size of the channel, its shape and gradient, are on the whole, suitable for the flows it has to carry. Gully erosion in the forest zone of eastern Nigeria depends on the existence of other favourable condition of climate, topography and lithology.

FDALR (1980) stated that gully erosion result because the soil has failed, and concentrated run off has flowed on the failed soil, the phenomenon called gully resulted. The opined that man is a major factor in the creation of gully due to deforestation. The action of man on land degradation according to Taniya (1988) the world has lost an estimated 200 million hectares of cropland due to erosion since farming began. The reward of the natural vegetation cover for the various activities of farmers exposes the land to direct impact of the rain drop. Since impact of rain is responsible for detachment of soil particle which can then be transported by runoff water and for the breakdown surface to form a seal caused vastly increase in runoff.

According to Lai and Russel (1981) farmer is to be blamed for contribution to erosion especially when wrong technique were used or the wrong crop are grown on a soil a chain reaction of dividing productivity associated with the increased in erosion set in as soon as natural vegetation on land are removed. It is continued that land-use or vegetation type conservation carelessly designed and poorly built man made structures also help to accelerate erosion.

While Smith (1995) agreed that increase population pressure is a major accelerator of gully erosion. Below are summaries of opinion of several workers regarding the cause of gully in south – east Nigeria.

2.3 FORMATION OF GULLY EROSION

The formation of gullies has become one of the greatest environmental disasters facing many towns and villages in Southeastern Nigeriaq (Adekalu et al., 2007; Okpala, 1990). This region is fast becoming hazardous for human habitation. Hundreds of people are directly affected every year and have to be re-located. Large areas of agricultural lands are becoming unsuitable for cultivation as erosion destroys farmlands and lowers agricultural productivity (Egboka et al., 1990).

According to Abegunde (2003) gully erosion occur when deep and large channel assuming great dept are created by run-off water.

Erosivity and Erodibility are the factors that contribute to erosion and gully formation. Erosivity is a function of rainfall, a natural phenomenon which is outside human control and manipulation. Rainfall intensities can be high in /southeast Nigeria. Obi and Salako (1995) reported that rainfalls with intensities between the range of 100 to $125mmh^{-1}$ are likely to occur more than five times a year. Storms with 25mm/h intensity have been reported by Hudson (1981) to be erosive. Erodibility, on the other hand, is dependent on soil properties, topography, and land management.

One fact that is clear from the several studies and from a close field inspection of the affected areas, is that the development of the gullies is progressive through at least four main stage of

a). Formation of risks

b). Development of incipient gullies

c). Formation of shallow gully (< 15m deep)

d). Development of deep gully (> 15m deep)

2.4 PROCESS AND MECHANISM OF EROSION

2.4.1 Processes of Erosion

Erosion processes and variables consists of two major components namely (i) erodibility and (ii) erosivity. The former is an inherent property of the material being eroded while the later is the ability of the agent of erosion to initiate and accelerate soil detachment and transportation.

According to the universal soil loss equation,

Erosion = f(erosivity) (erodibility)

That is:

$A = R \times K \times L \times S \times P \times C$ *(for 9% slope)*

Where

A = Soil loss (T/ha. Year)

R = Rainfall erosivity index

K = Soil erodibility factor

L = Slope length factor

S = Slope gradient factor

P = Conservation practice factor

C = Crop management factor

a) Erodibility

Erodibility, as a soil characteristic, is a measure of the soil's susceptibility to detachment and transportation by the agents of erosion. Although soil resistance to erosion depends in part on topographic position, slope steepness and the amount of disturbance created by man, for example during tillage, the properties of the soil are the most important determinants. Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content (Morgan, 1996).

Soil erodibility process is influenced by soil properties, such a particle size distribution, structural stability, organic matter content, and nature of clay minerals. Soil parameters that affect soil structure, slaking and water transmission characteristics also affect soil erodobility.

b) Erosivity

Erosivity is an expression of the ability of an agent of erosion to cause soil detachment and its transportation. This could be defined as the driving force of erosion agents that cause soil detachment and transportation. Rates of erosion have been proved to depend largely on runoff produced due to the characteristics size and shape of the gully etc., (Lal. 1988).

c) Detachability

It is commonly assumed that impact of raindrop (splash) accounts for the bulk of soil detachment initiating water erosion. Nevertheless, the fact cannot be ignored that significant erosion by overland flow often occurs far downstream of an area directly experiencing a rainstorm or concentrated flow from culvert outlets. This is a common phenomenon under a regional flooding condition. In this case, it is not the energy of falling drops but the energy of a body of water flowing with its armour of clays, silts, sands pebbles, cobbles etc., on an erodible bed that affects the necessary detachment to start the erosion. As it flows, it "tears" the "top skin" of the bed surface by shear detachment, drag and lift.

2.4.2 Mechanism of Erosion

Almost a prerequisite for water-borne erosion is the unhampered impact of raindrops on the soil, resulting in the detachment of the soil aggregates and causing surface runoff. Runoff is that part of the water falling on the soil surface, which does not penetrate into the soil and, due to the land slope, runs off the surface, together with soil particles and aggregates.

a) Splash Erosion

The erosion process begins with the impact of raindrops, which may have a speed of 30 km/h. They have great energy and splash the fine particles in all directions, especially downhill, breaking the structural elements into parts and tearing off fine particles. The small loose particles are washed away from the field or are deposited nearby and may lead to a sealing of the surface. Moistening of dried out soil aggregates by water from all sides can cause the entrapped air to breakout of the aggregates by force, thus destroying the soil as by an explosion. This phenomenon is especially likely in silty and sandy soils, where the inner coherence of the particles is less than in clay, and the potential for a gradual change of form (plasticity) is low or absent (BERGSMA. 1977).

b). Sheet Erosion

Sheet erosion is a process caused by surface runoff, where 'runoff actually is concentrated in many small rivulets of water' (Toy et al, 2002). Overland flow is of very high frequency and very low magnitude, and thus, occurs area-wide between rills (Hogg, 1982). This area is also called the inter-rill area and erosion occurring here is defined as inter-ill erosion (Toy et al, 2002).

In sheet erosion, raindrop beats the ground surface, making it almost impermeable and the run of maundering in large sheet (Duprier et al 1992). This type of runoff occurs in gently sloping land, the force of water is slight in the ground. It transports only the finest clay particles, which it picks up at the time of splash and lightest material such as organic waste and humus are picked as well. According to Elison (2003), it is very dangerous for the farmer because it gradually wears their fertile humus topsoil and these renders the land unfertile. It operates, however, over large area of the land and generally causes most of the soil loss. Denudation occur rather than incision Berssma (1977).

The runoff is often coloured by the material in suspension, mainly clay particles and organic material. Larger particles, like silt, sand and gravel, are moved by a process of saltation, rolling, or creep. Transport by runoff is selective. It is principally the fine material which is removed by erosion. The coarse material of the soil is often left on the surface as a cover which protects the soil from further severe erosion.

Micro-relief, plants and surface roughness will soon provide small local concentrations in the sheet flow where protection is less than it is elsewhere. At these places the depth, and consequently the speed, of the flow becomes higher and a process of minute rilling takes place. The speed of the flow is about 1-2 km/h. local eddies may occur as a transition to turbulent flows.

Recognizable characteristics of continuous sheet erosion are:

- Thin topsoil and subsoil exposure (light - coloured patches) and possibly even bedrock exposure;
- Relatively large amounts of coarse sand, gravel and pebbles in the arable layer, the finer material being washed out;
- Exposure of roots;
- Deposits of replaced material at the lower side of the field.

Factually the removal of soil in thin layers from sloping land does not occur. Minute riling takes place almost simultaneously with the first detachment and movement of soil particles.

b) Rill Erosion

Rill erosion is a process caused by the concentration of surface runoff. 'Rills are channels that are so small (that) they can be obliterated by normal tillage operations' (Toy et al., 2002). Rill erosion is of lesser frequency but higher magnitude than sheet erosion. Areas f both, rill erosion and inter-rill erosion 'make up the overland flow areas of landscapes' (Toy et al., 2002).

Kurby *et al* (1981) observed that rill erosion is most serious when intense storm are accompanied by high velocity and energy that influence detachability and transportability of soil particles. Although the impact of rain drops on the shallow streams result to splash soil, it does increase turbulence, thus providing greater sediment carrying capacity (Collinet and Valentine 2002) and if these, minor channels are neglected or under estimated, with subsequent rainfall and run-off, it will develop to gully erosion (Duley 2008)

Farm management may interrupt the development of rills and ploughing may obliterate the rills for some time. But eventually the process will begin again, with new rills. Rill erosion is most serious where intense storms occur on soils having high runoff –producing characteristics and loose, shallow topsoil. Rills have s depth up to 0,3 – 0,5m and the walls at their sides are vertical for a time immediately after a shower. Only very light rains do not affect the shape of the rill and may leave some walls as they had been, in a collapsed or smothed state.

2.5 FACTOR AFFECTING GULLY FORMATION

Smith (1993) stated that measured rate of gully erosion are variable and depend on the catchment size and slope, as well as soil type, vegetation cover and management of man practices. But these factors to an extent can be controlled. The climatic factors are beyond the power of human control. These are entire make up the natural factors affecting soil erosion. The factors affecting gully formation can be categorized into two groups, man-made factors, and physical factors.

(A) MAN-MADE FACTOR

(1) Improper Land Use

In developing country of Nigeria especially Akpulu in Ideato North LGA of Imo State, erosion can start, proceed, and stop in almost any terrain. Man's activities in agriculture, animal husbandry, forestry, mining, etc. cause soil erosion to occur. While soil erosion typically proceeds on its own after it has begun, considerable effort is often needed to bring it to a halt again. In this way, soil erosion itself is an erosion factor in which time plays a role. One can say that erosion invites erosion.

On a world scale man's non-agricultural activities which accelerate the erosion processes are hardly significant: they interfere with only a small part of the earth's surface. But agriculture is so widespread that agricultural activities which materially alter the speed of the erosion processes are much more important. Nearly all agricultural operations do tend to encourage erosion. Whenever vegetation is cleared and the ground is more expose, there is less vegetation to absorb the energy of the falling rain and so more rainfall erosion, more surface runoff, more cattle to crush the rock and soil. By ploughing and tilling the soil man disturbs and aerates the soil millions of times more quickly and effectively than the burrowing animals – in fact all the physical processes of nature are accelerated, and so is erosion (Hudison, 1995).

In fact the method of road construction in Ideato North and South east Nigeria encourages gully erosion. Almost all the road in Ideato North local government area are constructed to run down ward instead of crossing hill (Report on erosion menace in Ideato North local government area 2007).

(2) Road Construction

In fact, from the field observation, method of road construction in Akpulu, Ideato North LGA and its environs if not properly revegetated during or immediately following road construction, gullies may form on both sides of the road. The present gully site in the study area was cause as a result of road construction. Inadequate drainage system for roads (small number of culverts, insufficient capacity of road ditches, etc) are major cause of gulling. Widening operation along roadsides do not often follow road construction but, where widening is practiced, the operation usually causes landslide erosion and then gulling during the first rainy season.

(3) Mining

Presently there is a massive road construction work that is on going in that community, and they mined their soil for this construction. Mining is another factor that can cause gulling. Initially, cracks in the ground and soil creep (a kind of gravity erosion) are observed in the mining areas. Then, during rainy season, gullies are formed. Gulling in open-pit mining areas is also a big problem in many countries. Morgan et al., 1998 says that the anthropogenic impact of this type (mining) amplifies natural erosion

(4) Vehicle Trails

Gullies are also formed on livestock and vehicle trails that run along hillsides. This is because the traffic on them compacts the soil and reduces the water holding capacity.

(B) PHYSICAL FACTOR

As mentioned before, gullies are formed by increased surface run-off which acts as a cutting agent. The main physical factor affecting the rate and amount of surface run-off are precipitation, topography, soil and vegetative cover.

(1) Precipitation

Ellison (2007) stated that the erosion capacity of rainfall result from three factors, the amount of raindrops, the intensity and diameter of the drop as the strike the soil.

However, rainfall intensity is more important than total amount. In many instances one or two high intensity may cause as much soil loss as all other storms during a season.

In considering the influence of precipitation the following elements are of importance:

Energy of the precipitation;

Intensity of the precipitation;

Quantity of the precipitation;

- Duration;
- Distribution;

Erosivity.

Energy of the precipitation

The kinetic energy of falling raindrops ($E = ½\ ^{mv2}$) is the most important factor. A free falling raindrop reaches an erosive energy level after a 5m fall and a maximum energy level is reached for any size raindrop after a 10m fall, but big droplets formed on leaves and falling only 1-2m may cause splash erosion. A drop falling on a bare soil surface detaches the soil aggregates by a splash effect.

Intensity of the precipitation

The rain intensity is very important. If rainfall intensity is higher that the infiltration rate, runoff will occur quickly, causing erosion. Furthermore, the erosivity is highly correlated with the intensity of precipitation; in formula:

$$E = 0,199 + 0,0873 \log I$$

With

E = kinetic energy of the rainfall per mm of rain amount

(MJ/ha mm rainfall)

I = rainfall intensity (mm/h)

In tropical and sub-tropical areas, the rain intensities are much higher than those in the temperate regions. This explains why the erosion hazards in the former are much higher than in the latter.

Quantity of the precipitation

In general, higher rainfall results in higher erosion hazards. Especially with showers of long duration, the topsoil gets saturated with water, decreasing the soil stability, and consequently promoting erosion risks and runoff; the structural stability of the soil plays an important role here. When a big quantity of rainfall is well distributed the soil can more easily cope with the hazards, resulting in less erosion.

From eq. (1) can be understood, that the erosivity is related, too, with the quantity of rainfall:

$$E_t = p.E$$

With

Et = total kinetic energy of the rainfall (MJ/ha)

P = quantity of precipitation (mm)

(2) Topography

The size and shape of a drainage area, as well as the length and gradient of its slopes have an effect on the runoff rate and amount of surface water. Therefore, all topographic characteristics should be studied in detail before gully control work begins.

(a) The length of the slope.

The slopes of the land surface over which water flow influences runoff velocity and volume and hence erosiviness (Troeh *et al* 2002). Topographic features that influence erosion are degree of slope, length of slope and size and shape of the watershed. On steeps high velocities cause serious erosion by scour and by sediment transportation. The velocity of runoff water varies as the square root of the vertical drop, but the erosion increases exponentially.

Furthermore, the length of the slope is very important. The longer the slope, the greater will be the volume of excess water accumulating upon it, all of which will run down the slope at an ever-increasing volume and velocity.

It is not possible to predict the erodibility based only on the steepness and length of the slope. The concave or convex curvature of the slope must be kept in mind as well as the vegetation, the soil structure and types of soil. To prevent the gully formation, this water (runoff) should be conducted safely downhill over a long distance to stable, natural water courses or vegetated outlets otherwise the water should be infiltrated into the ground by land treatment measure such as contour ditches (infiltration trench), level terraces, staking etc.

In many countries the land scarcity and population density have an effect upon the slope, which is considered to be acceptable for arable land.

More so, the soil can either be sand, silt, clay or a mixture of (sand and silt, sand and clay, clay and silt). Greater infiltration takes place in sandy soil than in clay soil because of its loose structure and in clay soil less infiltration occurs because of its compact structure and as a result more runoff occur in clay than in sandy soil (Troeh *et al* 1980)

(b) Shape of Catchment

From the observation the catchments have the same area, but have different shapes. Both have symmetrical drainage patterns, but the distance to the outlet in the long catchment is greater than in the short one. Therefore, the long catchment's gathering time (time of concentration) will be longer, its corresponding intensity lower, and its maximum run-off rate (Q max, cubic m/second) less. This explains why, if all other factors are equal, long narrow catchment have fewer flash floods than square or round catchments.

(3) Vegetative Cover

The role of vegetative cover is to intercept rainfall, to keep the soil covered with litter, to maintain soil structure and pore space, and to create openings and cavities by root penetration. This is best achieved by an undisturbed multistory forest cover. Under special conditions, however, a well-protected, dense grass cover may also provide the necessary protection.

In general, it is management and protection rather than the type of the vegetative cover which determines its effectiveness in gully control.

Any vegetation which is well-adapted to local conditions and which shows vigorous growth may be used. In some cases, these may be broadleaf species, in others conifers, tall grasses, etc. in critical areas, it may be necessary to exclude any use of the protecting vegetation. Whenever possible, however, it is desirable to establish a vegetative cover which serves a dual purpose, for example, provision of fodder fuel wood, fruit, etc.

(4) Soil Properties

The following seven soil classes are based on soil texture: sand, loamy sand, sandy loam, loam, silt, clay loam and clay. The infiltration rate increases from clay to sand (for loamy sand 2.5-5 cm/hour), but resistance against erosion decreases.

2.6 DEVELOPMENT AND CLASSIFICATION OF GULLIES

2.6.1 Development of Gullies

Gullies may develop in watercourses or other places where run-off concentrates. In cultivation or pastures, advanced rill erosion can develop into gully erosion if no protective measures are taken. Cattle pads can be a starting point for a small rill that can develop into a large gully.

A watercourse is ordinarily in a state of balance where its size, shape and gradient are suitable for the flows it carries. If the balance is disturbed, for example by larger than normal flows, gully formation may begin. Gullies generally create far more capacity than they need to accommodate the run-off they are likely to carry.

Widening of the gully sides may occur by slumping and mass movement especially on the outside curve and mass movement especially on the outside curve of meanders. Scouring of the toe slope can lead to mass failure of the side of the gully under gravity. This soil is then washed away by subsequent flows.

Active gully sides are usually vertical but may adopt an oblique shape once they start to stabilize. This process may occur naturally but can be hastened by the adoption of various gully treatment measures.

Run-off may enter a gully from the sides, causing secondary gullies or branching resulting in a 'badlands' effect. The gully floor may be subject to further down-cutting as secondary gullies advance up the channel. Sediment deposition below gully heads results in a "steps and stairs" pattern.

A gully develops in three distinct stages; waterfall erosion; channel erosion along the gully bed; and landslide erosion on gully banks. Correct gully control measures must be determined according to these development stages.

(1) Waterfall Erosion

Waterfall erosion can also be broken down into three steps:

(a) First Stage

First, sheet erosion develops into rills, then the rills gain depth and reach the B-horizon of the soil.

(b) Second Stage

The gully reaches the C-horizon and the weak parent material is removed. A gully head often develops where flowing water plunges from the upstream segment to the bottom of the gully.

(c) Third Stage

The falling water from the gully head starts carving a hollow at the bottom of the gully by direct action as well as by splashing. When the excavation has become too deep, the steep gully-head wall collapses. This process is repeated again and again, so that the gully head progresses backwards to the upper end of the watershed. This process is called gully-head advancement

As the gully head advances backwards and crosses lateral drainage ways caused by waterfall erosion, new gully branches develop. Branching of the gully may continue until a gully network or multiple-gully systems cover the entire watershed.

(2) Channel erosion along gully beds

Channel erosion along gully bed is a scouring away of the soil from the bottom and sides of the gully by flowing water. The length of the gully channel increases as waterfall erosion causes the gully head to advance backwards. At the same time, the gully becomes deeper and wider because of channel erosion. In some cases, a main gully channel may become as long as one kilometer.

(3) Land-slide Erosion On Gully Banks

Channel erosion along gully beds is the main cause of landslides on gully banks. During the rainy season, when the soil becomes saturated, and the gully banks are undermined and scoured by channel erosion, big soil blocks start sliding down the banks and are washed away through the gully channel.

Land-slide erosion on gully banks also occurs in regions with temperatures that alternate between freezing and thawing. When the temperature drops below zero (Celsius), wet gully banks freeze. After the temperature rises above zero, the banks thaw, the soil loosens, and the loose gully banks easily slide during the first rainy season. After landslides have occurred on all gully banks, a considerable number of new branch gullies may begin along the disturbed banks. During the third stage of gully development, gullies become deeper and longer as well as wider.

The three stages of gully development (waterfall erosion, channel erosion along the gully bed, and landslides on gully banks) will continue unless the gully is stabilized by structural control measures and revegetation.

2.6.2 Classification of Gullies

Gullies are classified under several systems based on the their different characteristics.

(1) Gully classes based on size

One gully classification system is based on size-depth and drainage area. Table 1 describes small, medium and large gullies and is commonly used in manuals on erosion.

Table 2.2: Gully classes based on size

Gully classes		**Gully depth m**	**Gully drainage area ha**
(a)	Small gully	less than 1	less than 2
(b)	Medium Gully	1 to 5	2 to 20
(c)	Large gully	More than 5	More than 20

Source: Frevert et. al., (1955).

(2) Gully classes based on shape

This system classifies gullies according to the shape of their cross-sections. U-shaped gullies are formed where both the topsoil and subsoil have the same resistance against erosion. Because the subsoil is eroded as easily as the topsoil nearly vertical walls are developed on each side of the gully. It is typically the same with that of study area.

V-shaped gullies develop where the subsoil has more resistance than topsoil against erosion. This is the most common gully form. Trapezoidal gullies can be formed where the gully bottom is made of more resistant material than the topsoil.

2.7 INCIDENCE OF GULLY EROSION

Gully erosion has always been with us, probably not as wide spread as it is today. Ofomata (1982) stated that soil erosion is very widespread throughout Nigeria but posed more disastrous in the South eastern Nigeria as a resulting high rainfall. Omafra staff (2003) erosion, as it affects man and its environment is natural and as old as the earth itself. Therefore, the incidence of gully erosion in the forest zone is not new and good examples of gullies are wide spreading. The situation is worse in Anambra and Imo State where comparable figure are 1.90% active and 5.5% (all type) Ofomata (1980). The effect of this erosive action are made more severe by recent and rapid population growth in the South-east region of Nigeria. Loss of Agricultural outputs is one of the greatest economic lost of gully erosion (Pimental et al., 1995)

2.8. IMPACT OF GULLY EROSION

The gully erosion remains the world highest environmental problem, threaten sustainability of both plant and animal in the world. The main impact of gully erosion on soil, is to reduce the soil depth and hence its capacity to store water, nutrient which plant require for growth. Smith (1993), Foth and Troeh *et al* (1980) vividly stated that damages resulting from gully formation includes field dissection, damage of engineering structures, water pollution, sedimentation and exposing the underlying horizons. Over 65 percent of the soil on earth is said to have displayed degradation phenomena as a result of soil erosion, salinity and desertification (Okin, 2002) stated that soil is the most vital of earth natural resources, it host both animate and inanimate beings. Over three quarters of the worlds man-made developments are on it. And it's existences in the basis for the performance of most disciplines of the world. Most earth's natural resource are directly linked to or found in the soil. Threat to soil is therefore threat to life.

Smith (1980) noted that erosion is responsible with the reduction of economic productivity, production cost increase and as well as reduction in cultivatable land and crop yields Ofomata (1982) and Stock (1984) remarked soil erosion as a form of environmental degradation. Gully erosion as it affects man, is natural and as old as the earth itself. This gully has been identified as the direct cause of environmental deterioration and poverty in many parts of the world (Beijing time, May 28, 2002).

United Nations (UN) Convention to combat land degradation (CCD) opines that gully erosion automatically result in reduction in economic productivity in which man depend on for survival. These issue of gully erosion in Akpulu had resulted to loss of live and properties.

In another dimension, Scherr and Yadau argue that the year 2020, erosion may pose a serious threat to food production on the rural area as well as urban livelihood particularly in poor and densely populated area of the developing world. Erosion has created a number of problem that requires huge amount of money in other to tackle them effectively. The cost of dredging site and canals etc. are raised. According to report on erosion menace in Ideato North 2007, many erosion communities has been studied, evaluated and contracted in 2007 which its total cost was estimated to 10.5 billion naira, and this is a waste of economy.

As soils particles travels, it comes into contact with vast quantities of chemical of various level of toxicity. The most frequent sources of these chemicals are fertilizer, pesticides, herbicides, fungicides, germicides etc applied in agricultural practice. Industrial waste and agricultural waste are discharged into the soil and pollutes the soil. The chemicals are transported from the positional sites to a different place due to erosion runoff.

CHAPTER THREE

MATERIALS AND METHOD

3.1 STUDY AREA

Akpulu is bounded in the East by Uga, in the North by Isiokpo, in the West by Obodoukwu and in the South by Akwa ihedi in the south eastern Nigeria (Figure 1a). Akpulu lies between latitude 4^0 45'N and 7^0 15'N and Longitude 6^0 05'E and 7^0 25'E in Ideato North (Figure 1b). Akpulu is located North-West of Ideato North Local Government Area of Imo State with landmass of about 5 km. It has a population density of about 1100 person/km^2 (Figure 1c). The soil of the study area is silty, well graded to poor graded sands and containing low to medium plasticity clay.

3.1.1 Geology of the Study Area

The subsurface geology of the project site fall within the Bende-Ameki Group, it start from Njaba – Ideato – Uga in Anambra State. The Ameki Formation consists of greenish grey clay, sandstone, shale and mudstone with thin interbeded limestone. The sandy-sandstone unit of the Formation at lower depth constitutes the prospective unit for groundwater development. Aquifer of very prolific yield may be intercepted especially, where the sand-sandstone unit is properly confined by shale, clay-mudstone horizons.

3.1.2 Geomorphology

The geomorphology of Akpulu is undulated but generally dips southwards with a 3% slope on the average. Thus, the undulating nature of Akpulu contributed to the problem of the gully in the area.

3.1.3 Soil Characteristics

The soil of the study area is characterized by well graded to poor graded sands and low to medium plasticity clay.

3.1.4 Gully Characteristics

The average size of Akpulu gully is more than 15- 18m deep by visual assessment at the head cut. The Akpulu gully width is about 9-12m, and over 6.5km long. Bottom of the gully rests on undulated sandstone overlain by a sequence of brownish to reddish sands, with interlayer of silt and clay. The gully sides fail by slumping while its head falls mainly by toppling and sliding. The discharge velocity into the gully at peak flow is estimated at 108m/sec and this may continue for over two hours after a heavy down pour (Owuama, 2010). The topography of Akpulu is undulated but generally dips southwards with a 3% slope on the average. Thus the undulating nature of Apkulu contributed to the problem of the gully in the area.

Figure 1. a: Map of Nigeria showing Imo state

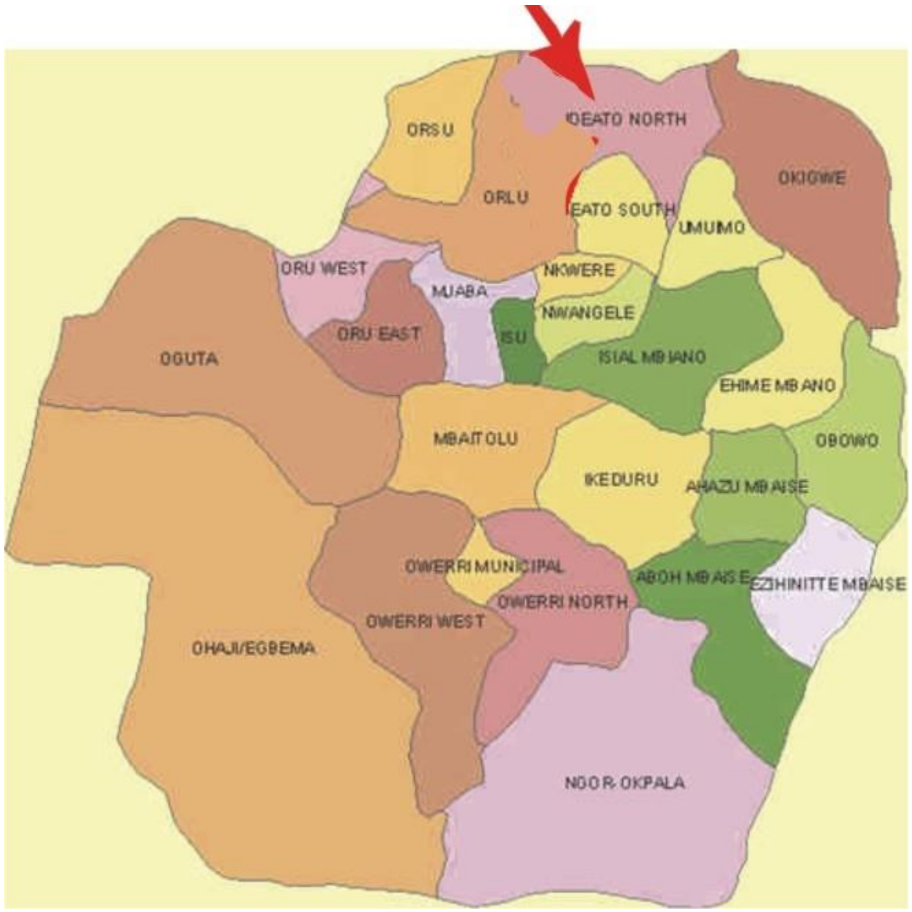

Fig. b: Map of Imo state showing Ideato North Local Government Area

Fig. c: Map of Ideato North/South showing erosion channel from Umuchu-Akokwa-Isiokpo-Akpulu; Umuchu-Uga-Akpulu

3.1.5 Climate

The local climate of the study area is the same with the general climate of Imo State. The elements of the climate of the study area are as follows; rainfall season usually starts from March to October. This average yearly rainfall is about 2200mm with a monthly peak of 450mm in August. Its runoff from a distance of over 6km enters into Akpulu gully enroute to the Akpakporo River. Temperature of the study area is similar to the rest of other communities in Ideato north county area. The mean annual temperature ranges in the other of 20^0c and 30^0c respectively. The relative humidity of the study area varies normally within the period of the year. It ranges from 100% - 125% within April to other (wet season) and from 60% during the dry period (November - February). From Ideato North Local Government Authority.

3.1.6 Vegetation

The study area falls within the high rain forest belt of West Africa. Its vegetative cover consists of the canopies of economic trees such as Palm tree, Melina and Oil bean tree. Other intermediate canopies consist of moderately populated trees such as Pears, Mangoes, and Bamboos etc.

The under growth canopy is composed of shrubs, herbs and grasses. As a result of interplay between man and climate this original vegetation has been seriously altered. Deforestation, lumbering, bush burning and over farming activities by man has reduced the original forest to successive or secondary vegetation with patches of grasses shrubs and few economics trees (Figure 2a).

3.1.6 Economics Activities

According to field observation about 85% of Akpulu people are predominantly traditional subsistence farmer. They drive their main income from sales of agricultural produces like cassava, melon, yam, cocoyam, maize , vegetable and fruit others depends in hunting and other agro forestry by-product for their little income.

3.2 Field Work

The research work was carried out in Akpulu in Ideato North Local Government Area of Imo State. It involves three stages. The first stage is the identification of the gully erosion study area. The second stage involved description of the study area with geologic tools such as measuring tape, sample bag (green polythene bags) and G.P.S. was used to measure the coordinate of the gully erosion site and also oral interview was also conducted. During this stage, gully sites were located and the depth of incision and with were measured. The outcrops were properly studied and the soil sample at different horizon were collected, sealed and labeled and transported to laboratory for analysis.

The third stage involved laboratory analysis of the collected sample which are subsequently subjected to a number of laboratory test, to test the geo-technical parameter of the following grain size distribution (Sieve analysis), compaction test and atterberg limit test to determine their soil characteristics.

3.2.1 'Insitu' Measurement

At the field, the depth of incision and width of the gully were measured with tape and the depth of incision is 15-18m and width is 9-12m. The estimated incision point distance is 200meter to residential area.

3.3 Field Sample Collection and Preparation

At the field, three soil sample were collected from different soil horizon on a scrape gully walls. The soil were described in the field and put in green nylon bag sealed and labeled subsequently taken to the laboratory for testing. This was done on a gully spot with depth 7m (Hazard free area) to test the following geotechnical parameters.

3.4 Geotechnical Parameters And Preparation

a) Grain size distribution

Soil texture refer to the degree of coarseness or fine of the material particle of the soil. As the soil parent material may have been derived from the rock in any of several ways and weathering breaks up the small particle, a soil has a mixture of small particle which are of different size. The relative proportions of particle of the grain size distribution, give the soil its texture.

The understanding of soil texture is a crucial step in the investigation of soil character and behaviour of the study area. This is because it influences many other factors especially structure and availability of water in the soil.

- **Sample Preparation for Grain Size Distribution**

Apparatus: Materials used for the test include the following: Nest of sieves, electronic weighing balance, soil tray and sieve shaker.

The soil samples collected from the field of study were oven dried to expel any moisture contents. Then a known weight in grams (g) of the sample was taken. Water was added to the sample and then allowed to stand for twenty four (24) hours. This is aimed at disintegrating all the soil materials. The soaked sample was washed over 150 microns sieve until the water is free of the fine particles. The washed sample will be oven dried for twenty four hours and the weight of the sample and container will be determined. The weight of the oven dried sample will also be determined as well as the weight of the final material. The sieve was arranged in stalk with largest to smallest aperture sieve at the top with the aperture decreasing downward. The sample was then run through the sieve while shaking manually and the weight retain on each sieve was determined using heavy duty balance.

Calculation

$$\% \text{ RETAINED} = \frac{\text{Wt. Retained x 100}}{\text{Total weight of dry sample}}$$

% PASSING = Passing 1, previous lager sieve-percentage retained

b) Atterberg Limit Test

The atterberg or consistency limit tests include liquid limit test and plastic limit test. The liquid limit has been defined as a moisture content at which a standard groove cut on a remoulded soil material closes at twenty five blows of the liquid limit apparatus. In other words, it is that moisture content at which the soil will flow under its own weight. Plastic limit is the percentage moisture content at which a soil can be rolled without breaking into threads three (3 mm) millimeters in diameter (Bell, 1983). The numerical difference between the liquid limit (LL) and plastic limit (PL) is called the plasticity index (PI), which is the change in moisture content of a soil giving rise to a one hundred fold change in the strength of the soil.

- **Sample Preparation For Atterberg Limit Test**

Apparatus: Liquid limit (Cassagrande) apparatus, mortar and pestle, an electric oven, 13SNo 425 sieves, a grooving tool, glass plates, a balance for weighing water and numbered specimen container.

The sample of soil was dried and disaggregated in a mortar using a rubber pestle. The material was then sieved using the no. 425 sieve. Only the material passing the sieve was used for the test. The sieved sample was then soaked in distilled water to form a paste and then left over night, while reserving a portion of the dry sieve materials.

- **Liquid limit Test**

A portion of the paste was remoulded on a glass platen and placed in the liquid limit apparatus. It was grooved using a standard grooving tool. The handle of the Cassagrande apparatus was then rotated which caused the blows to be jarred against the base plate. The number of blows required to close the groove was recorded. The sample of material was then taken into a specimen container and weighed. The above procedure was repeated four more times each time adding a little amount of the dry material to the paste in order to effect a change in the moisture content. The specimens collected were then placed into an oven for twenty four (24) hours; the moisture content is determined by measuring the weight. The result that will be obtained will be plotted on a graph and the best straight line will be drawn between the points. The moisture content at twenty-five blows defines the liquid limits.

- **Plastic Limit**

The plastic limit has a similar procedure like the liquid limit test except for the absence of the liquid limit apparatus. The soil paste at different moisture content was rolled with the palm on a glass plate into threads. The threads were put into containers like those in the liquid limit test and weighted. They were then placed in an oven for twenty four hours after which they were reweighed and the weight difference gives the plastic limit. The results of the two test when analyzed gave the plasticity index (P1) which is the numerical difference between the liquid limit (LL) and plastic Limit (P1=LL-PL)

c) Compaction Test

Compaction test is carried out with the aim of determining the moisture density relationships of soils. Among the method available, the standard compaction method (proctor mede) will be adopted for the work due to its accessibility, it was introduced by proctor in (BS 1377, 1967, Test II).

- **Sample Preparation for Compaction Test**

Apparatus: Materials used for the test include the following: Riffle box, weighing balance (up to 50kg with sensitivity of 1-5g) metal tray, rubber hammer, measuring cylinder, oven (105 – 110^{0}C), small balance numbered specimen container, Cee spanner and water.

A sample of know weigh of air dried soil was subdivided into three parts of approximately the equal surface of each was roughened in order to obtain a better bond between them. After compaction, the mould and its content were then weighed and representative samples was taken and used in the determination of moisture content. The specimen was oven dried for twenty four hours and the moisture content was obtained by determining the weight difference. This procedure was carried out three times on each sample. The result of the analyses was then used to determine the optimum moisture content and the corresponding maximum dry density.

- **Sample Preparation for Shear Strength**

Apparatus: The following equipment were used for the test of shear strength; box apparatus, timing device (stop watch), weight, means of collecting undisturbed sample.

Soil was prepared to the required moisture content. Then it was packed to the calculated height in shear box, which gives the desired bulk density. Dial gages were adjusted to zero reading; one gage on the proving ring was for measuring the shearing force, while the other was for measuring the movement of the upper half of the shear box for strain calculations. The upper half of the shear box was covered by its gripper plate and the loading bar was adjusted to floot above it to give zero normal loads on the hanger.

3.5 Statistical Analysis

Statistical method used were atterberg limit test, compaction and grain size distribution method. Table and graph were also used in analyzing the laboratory result of this geotechnical parameter analyzed. Data obtained were subjected to statistical analysis to produce the following curves: Liquid limit flow curves as number of blows against percentage moisture. Dry density against percentage moisture to obtain optimum moisture content (OMC) and maximum dry density (MDD) mg/m^3

Percent passing vs. Sieve size and percent retained vs. sieve size

Shear stress (KN/m^2) vs. Normal stress (KN/m^2)

CHAPTER FOUR

RESULTS AND DISCUSSION

Gully site has thick vegetation cover to have aided erosion control, but the prevailing natural trees and plants, and nature of soil are not supportive (Appendix 1a). A secondary erosion channel to the active gully head is developed off the concrete control channel following frequent overflow or the inadequate size, and alignment of the concrete channel at spill points. At some locations, palm tree trunks are used by villagers for improvised pedestrian bridge (Appendix 1b). Different waste and valuable materials, including shoes, clothing, and household items can be found along the erosion channel. Villagers testified horrible cases of buried corps exhumed from another community and transported to Akpulu by erosion. Full length wood planks previously used for improvised bridge can be found in the drainage channels (Appendix 1c). Appendix 1d is a section of the Akpulu gully showing width of recent slide surface; Slope (ɑ) of gully wall varies from 55^{o} around gully deep (15-18 m) to 75^{o} around gully top. The laboratory result anaylsis were presented in a graph form and the tables are shown in appendix 2.

4.1 Natural slope of erosion drainage channel

Five elevation points were measured at 200 m interval from the gully head, and along the natural drainage channel (Figure 2) . A gradual increase in elevation was observed from the gully head to 1.0 km upland. By direct reading using a GPS, the following data were collected (Apendix 2a);

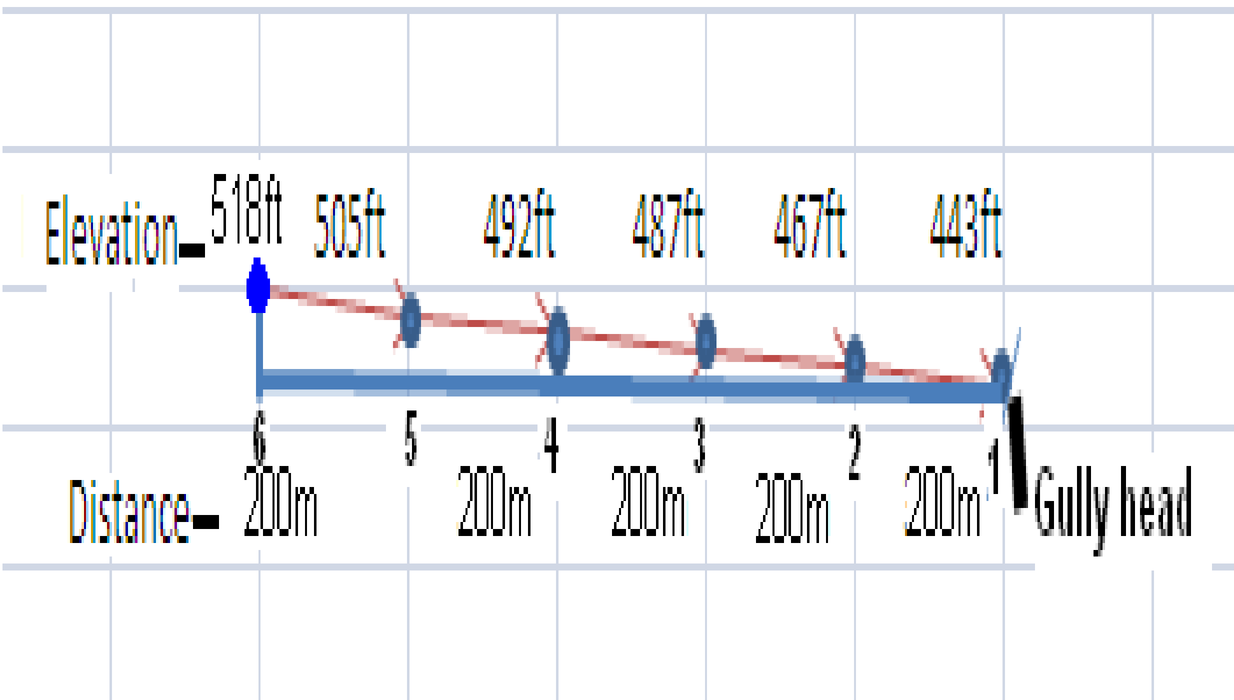

Fig. 2 Natural slope of erosion channel

4.2 Result Of Grain Size Analysis

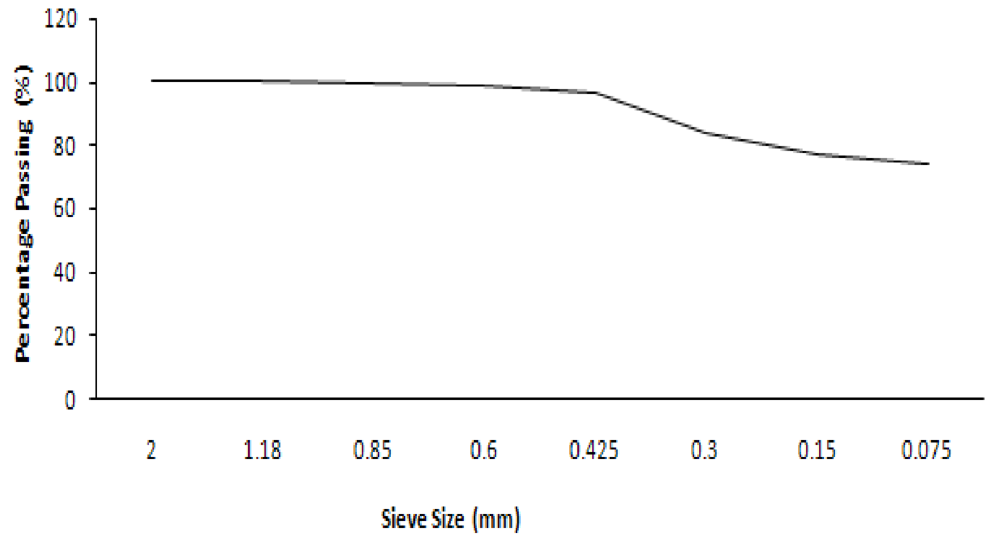

Figure 3a: Grain size distribution showing percentage (%) passing vs sieve size of sample 1

Percentage (%) Gravel: 0.0%
Percentage (%) Sand: 25.3%
Percentage (%) Silt } Fine: 74.7%
Percentage (%) Clay

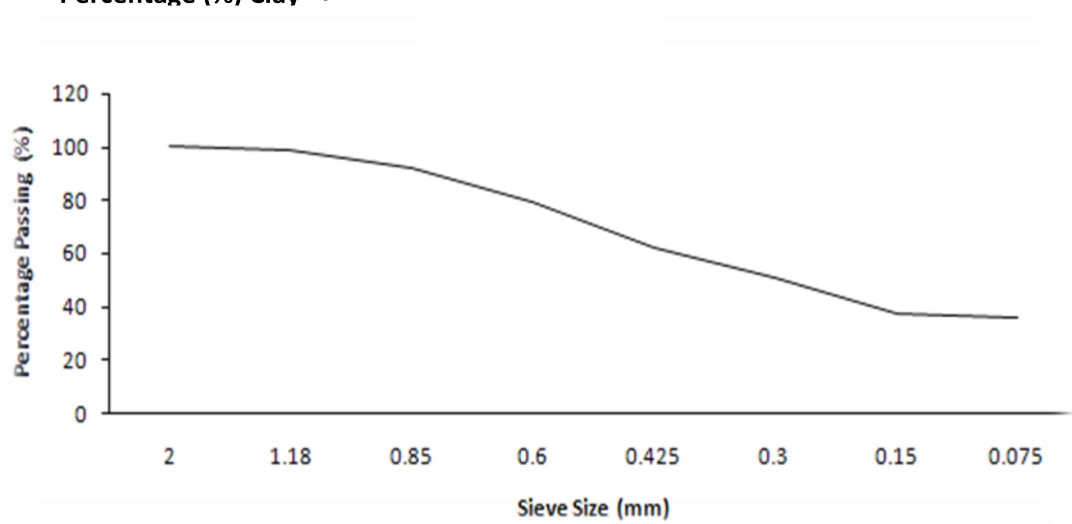

Figure 3b: Grain size distribution showing percentage (%) passing vs sieve size of sample 2

Percentage (%) Gravel: 0.0%
Percentage (%) Sand: 63%
Percentage (%) Silt } Fine: 37.0%
Percentage (%) Clay

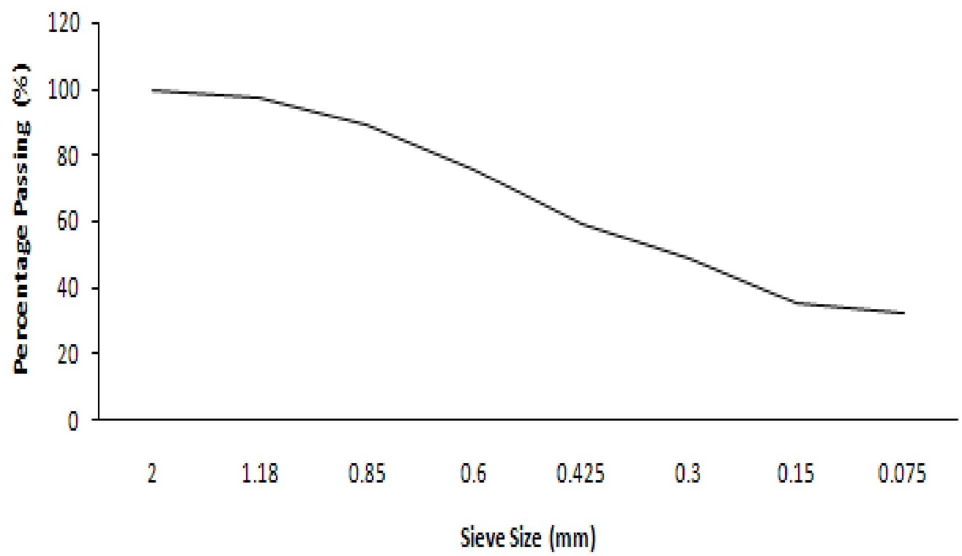

Figure 3c: Grain size distribution showing percentage (%) passing vs sieve size of sample 3

Percentage (%) Gravel: 0.3%

Percentage (%) Sand: 67.7%

Percentage (%) Silt
Percentage (%) Clay } **Fine: 32%**

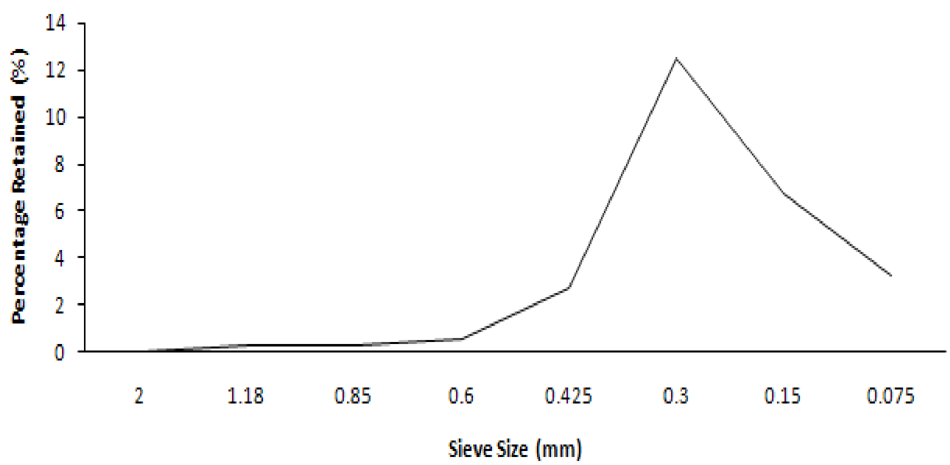

Figure 4a: Grain size distribution showing percentage (%) retained vs sieve size of sample 1

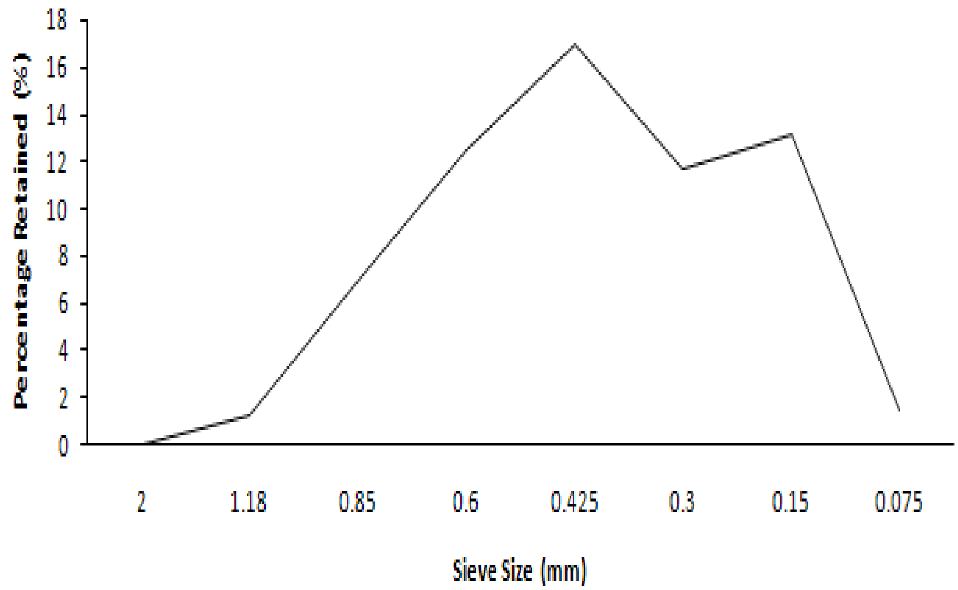

Figure 4b: Grain size distribution showing percentage (%) retained vs sieve size of sample 2

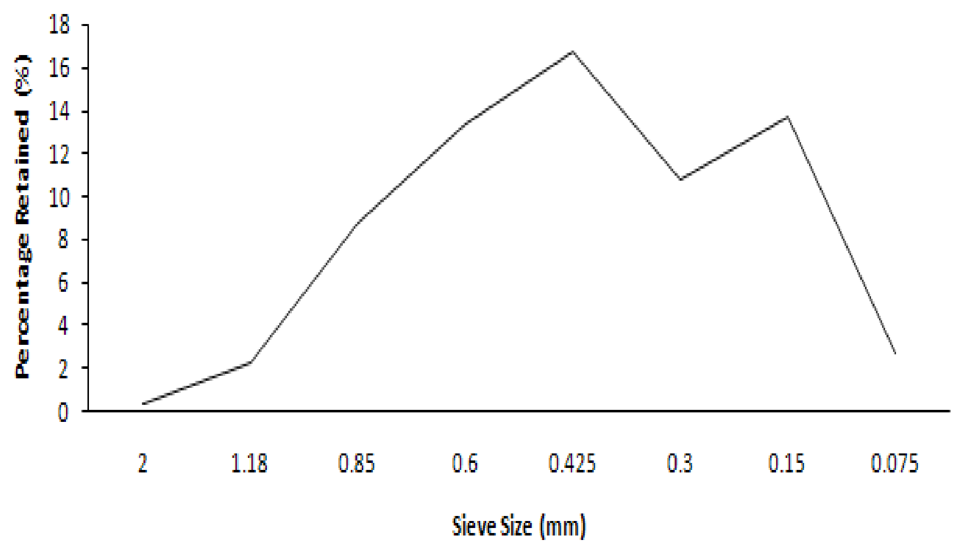

Figure 4c: Grain size distribution showing percentage (%) retained vs sieve size of sample 3

4.3 Shear Strength Test Analysis

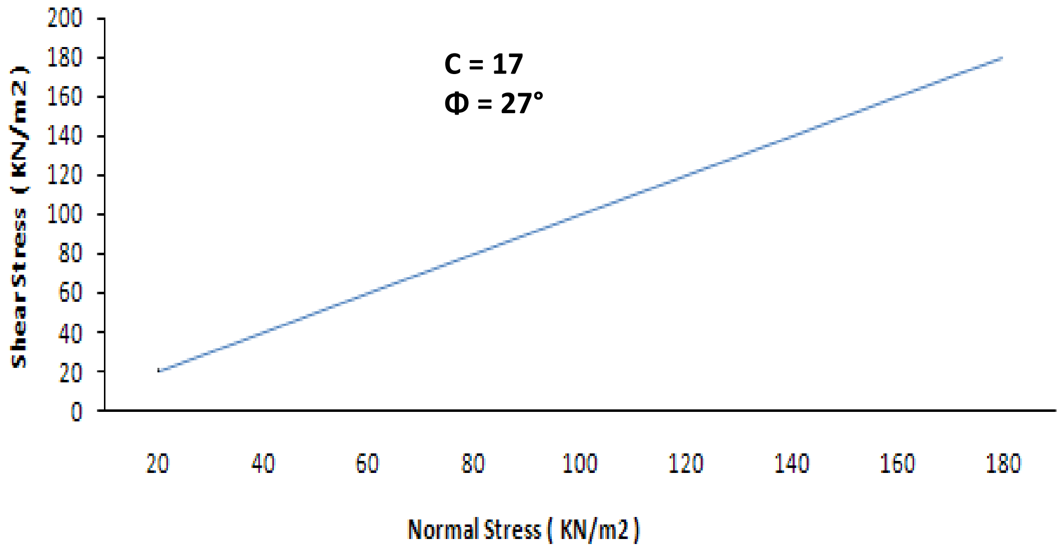

Figure 5a: Shear strength for Sample 1

Average shear strength: 105.6KN/m^2

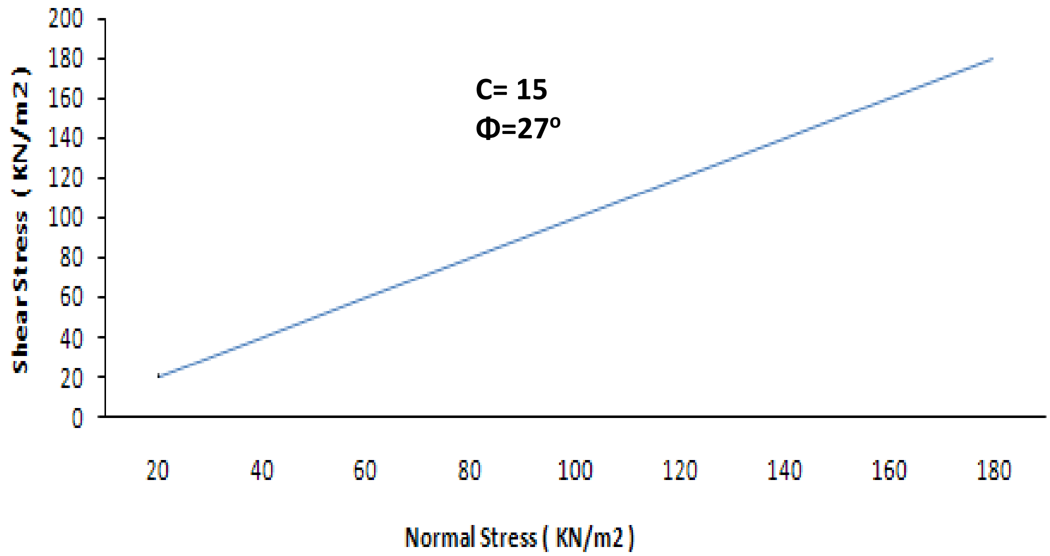

Figure 5b: Shear strength for Sample 2

Average shear strength: 107.6KN/m^2

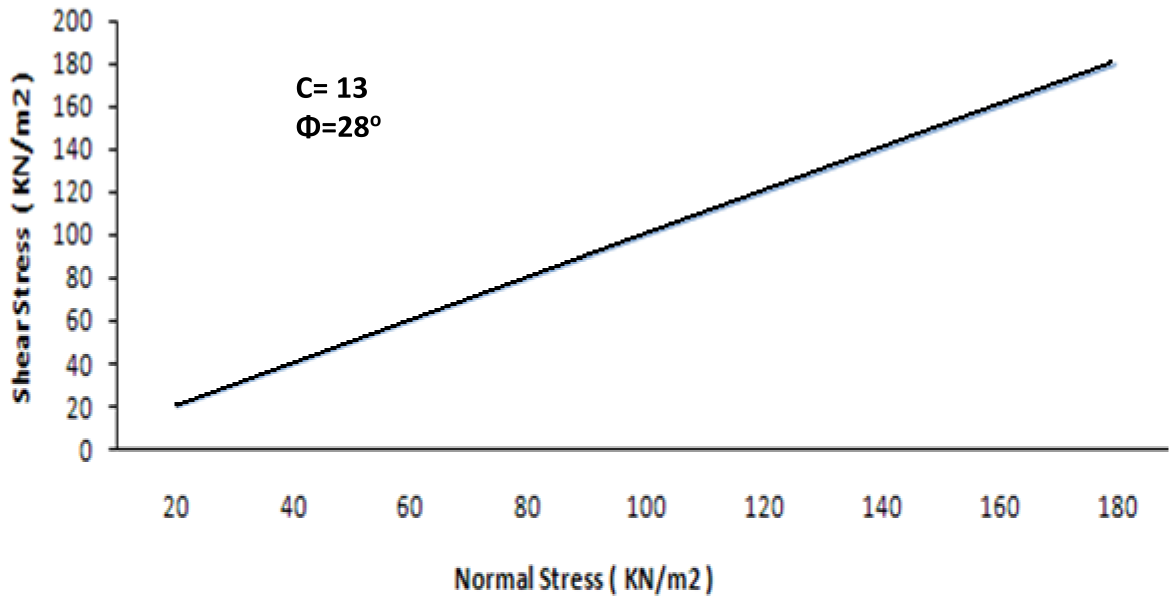

Figure 5c: Shear strength for Sample 3

Average shear strength: 107.5KN/m^2

4.4 Atterberg Limit Test Analysis

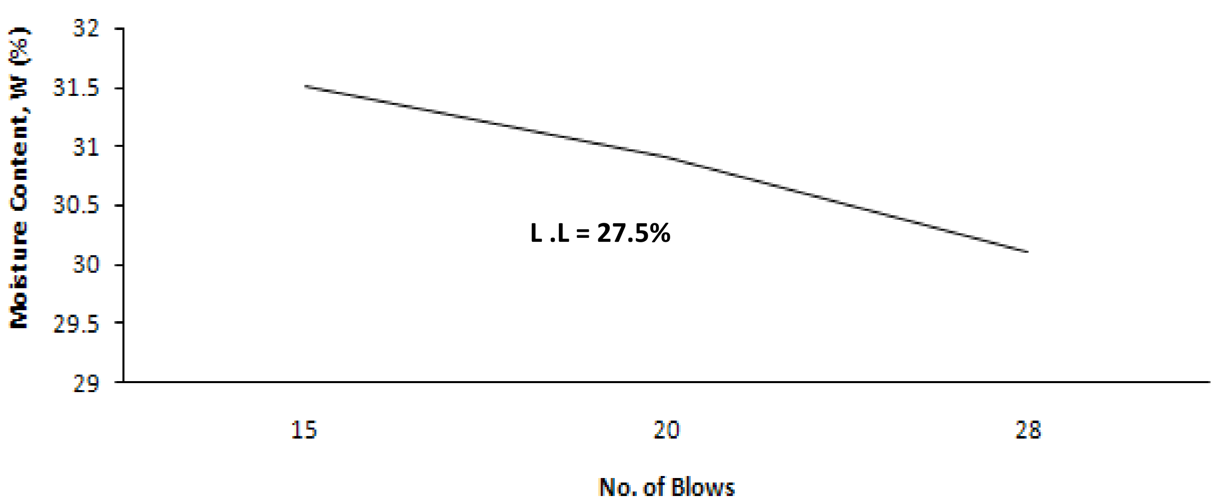

Figure 6a: Plastic and Liquid limit for sample 1

Liquid Limit (LL): 27.5%

Plastic Limit (PL): 1

Plasticity Index (PI)

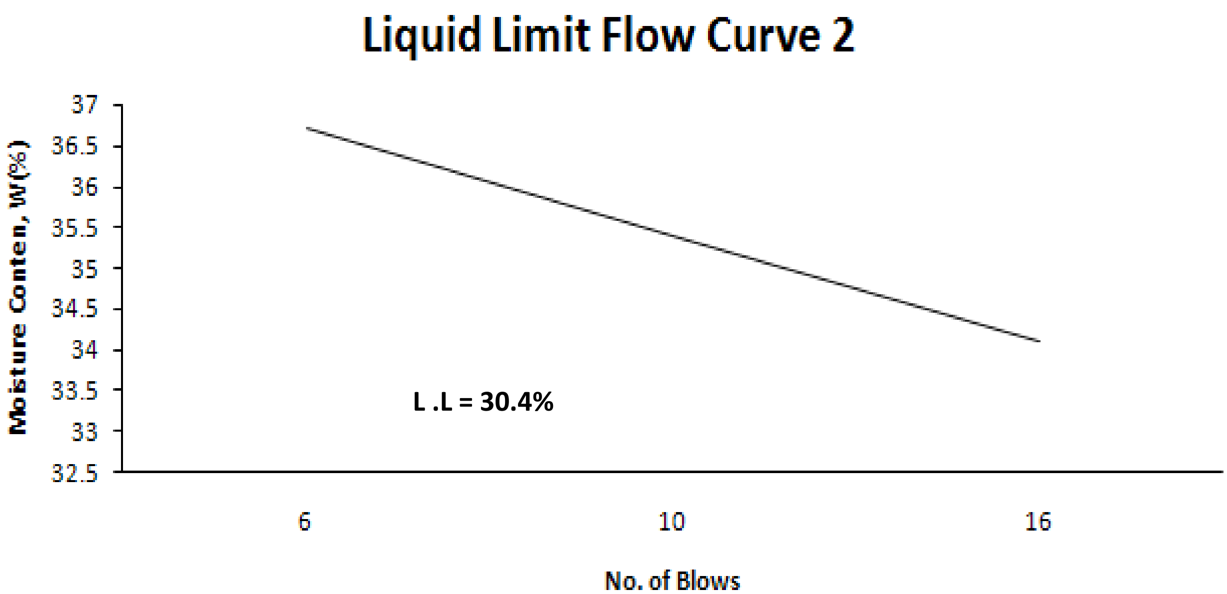

Figure 6b: Plastic and Liquid limit for sample 2

Liquid Limit (LL): 30.4%
Plastic Limit (PL): 22.75%
Plasticity Index (PI): 7.65%

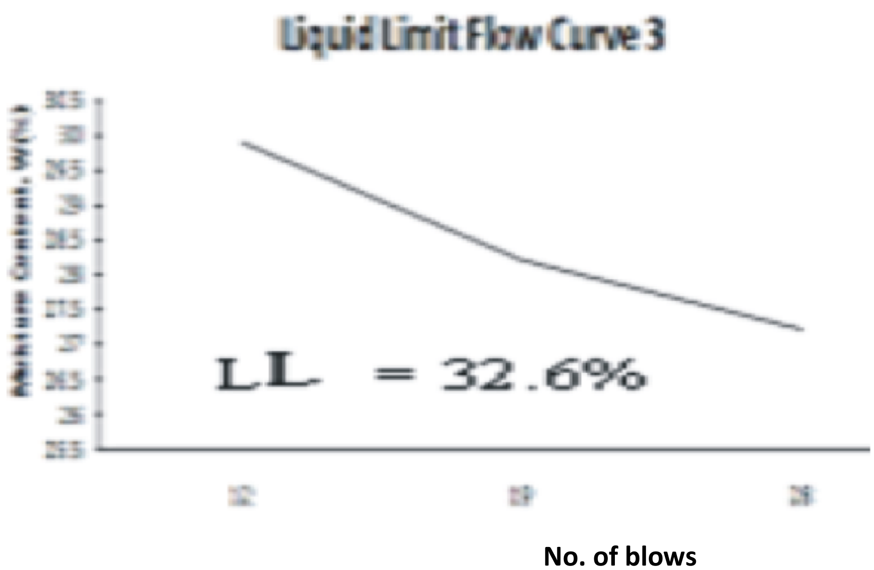

Figure 6c: Plastic and Liquid limit for sample 3

Liquid Limit (LL): 32.6%
Plastic Limit (PL): 18.9%
Plasticity Index (PI): 13.7%

4.5 Compaction Test Analysis

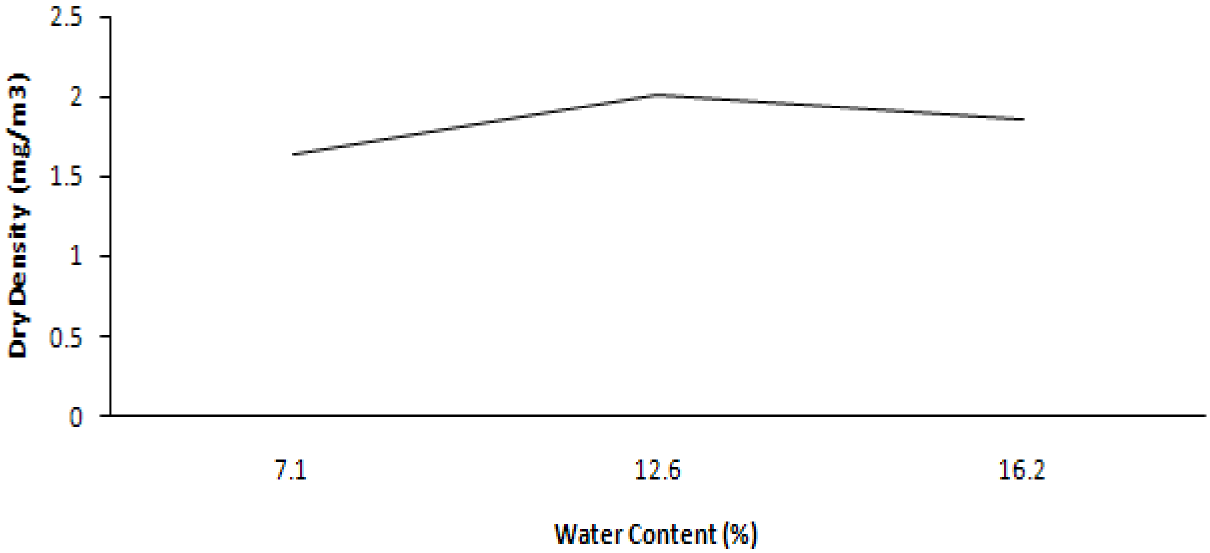

Figure 7a: Compact test for sample 1

M.D.D: 2.01mg/m^2

O.M.C: 12.6%

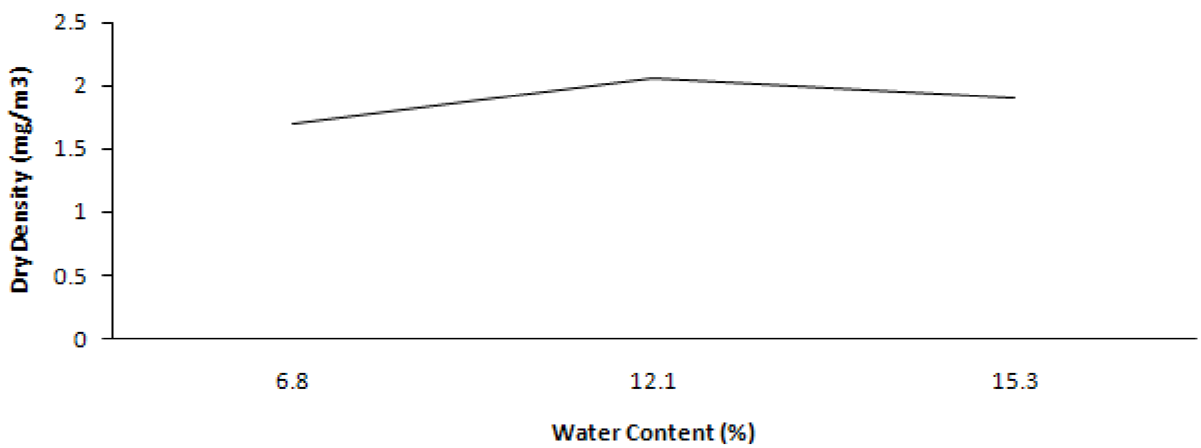

Figure 7b: Compact test for sample 2

M.D.D: 2.06mg/m^2

O.M.C: 12.1%

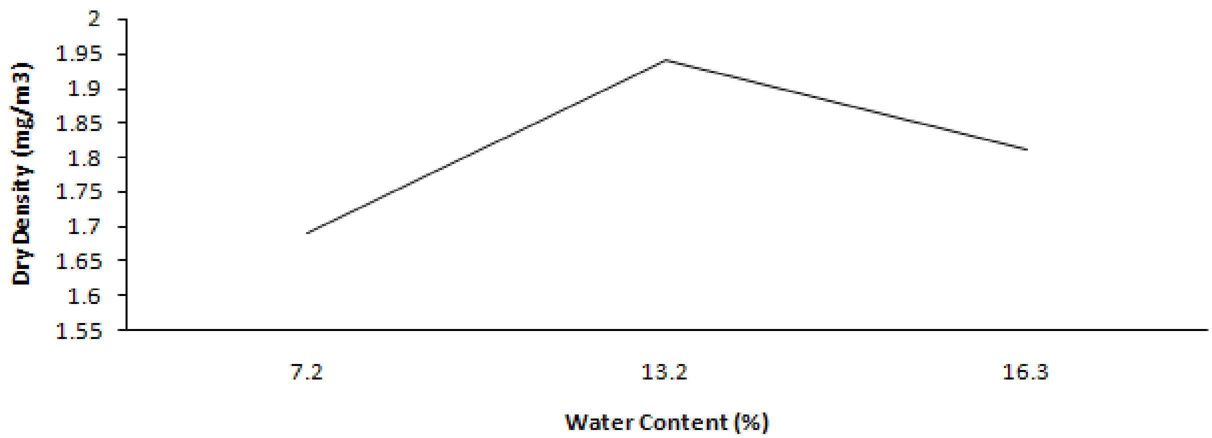

Figure 7c: Compact test for sample 3
M.D.D: 1.95mg/m^2
O.M.C: 13.4%

Figure 3 and 4: Grains Size Distribution showing percentage grain passing sieve and percent grain retained on sieve against sieve size of the three samples. Sample 1, collected 1 m from surface has 74.7% fines. This is the highest percentage of fines less 0.075mm or clay/silt content of the three sample depths. Sample 2, collected 2 m depth from surface contains 37.8% fines, about half the clay/silt content of sample 1. Sample 3, collected 3 m from surface has 31.5% of fines. The three samples consist of red earth cohesionless soil. This result confirms that the Akpulu soil has increasing downward coarse sequence. The topsoil is predominantly silty, making the soil easily erodible. Presently a gully measuring 15-18m deep, 9-12 m wide to hundreds of meter long is observed. The basic principle of

Akpulu gully erosion is the fast dissolution of the prevailing high silt content of the topsoil. The silt easily dissolve and transported as wash load carried within the water column as part of the flow.

Because of the low sand grain content, high flow velocities, the significant channel slope, greater of the grains will become suspended load, compelling low shear strength to the soil. Figure 5 illustrates the result of direct shear test for samples 1-3. Result show average shear stress of 106.9KN/m^2. This is naturally low to resist erosion even under reserved vegetation canopy.

Figure 6 illustrates the result of liquid limit test on the three samples with average liquid limit of 30.16%. The plastic limit (PL) tests for each of the samples gave 17.35%, and plasticity index (PI) = LL-PL gave 10.15% for sample 1. Sample 2 has average PL of 22.75%, and a PI of 7.65%, while sample 3 has PL of 18.9, and a PI of 13.7%. Then the average plastic limit is 19.6% and average plasticity index 10.5%. Onweremadu *et al.* (2007) related pedality and soil moisture retention characteristics to erodibility of selected soils. They observed that liquid limit of 10-62%, plastic limit of 10-

45%, and plasticity index of 0.0-17.8% ranges, show high variation that increases erodibility of soil. Comparing these values with our findings confirms Akpulu soil as naturally highly erosive.

Figure 7: Optimum Moisture Content (OMC): The moisture content at which the maximum possible dry density is achieved *for a particular compaction energy or compaction method.* Figure 8 show dry densities in mg/m^3 corresponding to the maximum point on the moisture content/dry density curve reported as the maximum dry density (MDD) to the nearest 0.01. The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve is reported as the optimum moisture content (OMC) and quoted to the nearest 0.2. Result show plasticity index 10.15-13.7%, average OMC of 12.7%, and average MDD of 2.01Mg/m^3 for the erosive top layer of Akpulu soil. Okunade (2007a), working on the geotechnical properties of major problem soils of parts of Imo state, including around the study area, reported the following properties; liquid limits 20 – 70%, plasticity indices (5 – 55) %, plastic limits 10 – 50) %. He found MDD between 1.7- 2.1g/m^3 and OMC between 9- 24%. Okunade's work justifies our findings with respect to

liquid limit, OMC, plasticity index, and MDD. It is imperative therefore to conclude that Akpulu soil on its own is a major problem soil; highly susceptible to gully erosion.

4.6 Geometry Of Akpulu Gully

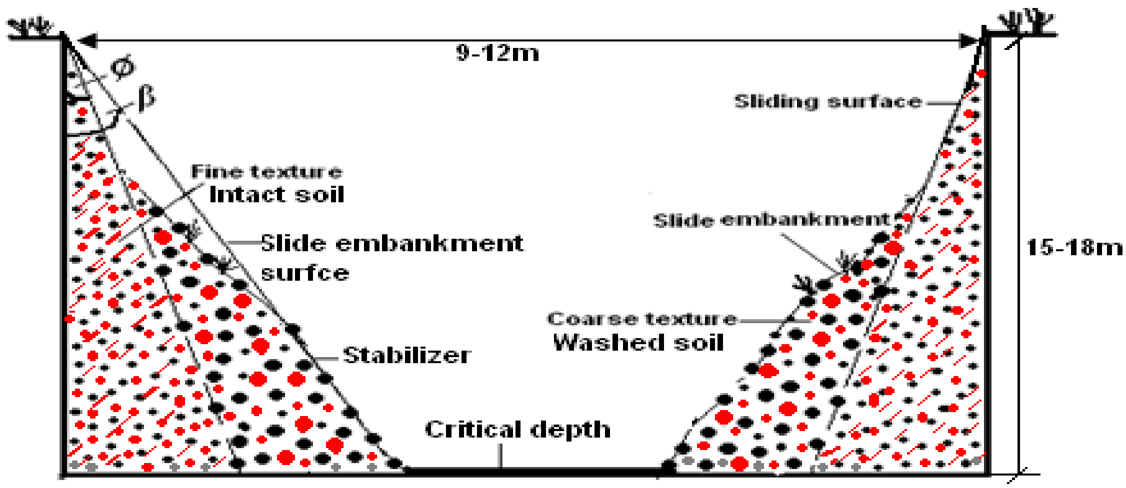

Figure 8. Typical geometry of Akpulu erosion gully; Sliding angle (ϕ = 75º), Slide embankment angle (β = 60º)

Figure 8 illustrates the head section geometry of Akpulu gully. The fine texture of Akpulu intact soil with high silt content and fines supports gully erosion. This is particularly effective with the silt content increasing upwards (fining upward sequence). A situation of this nature reduces soil strength and cohesion, thereby enhances soil erosivity to a critical depth. The critical depth is the depth where erosion has stabilized due to increased slide embankment. Slide embankment consist soil dislodged by sliding, partially washed, with greater percent of the silt dissolved, thereby increasing cohesion. In Akpulu gully, a critical depth of 15-18 m was estimated, as provided by the amount of sliding and grain retention supporting stabilization. Gully width varies from 9 to 12 m, which combines with the gully depth to make the gully area terrible, impassable, and a living environmental hazard to the immediate affected area of Akpulu community.

CHAPTER FIVE

5.0 SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

The following findings have been compiled after comprehensive research in the study area;

- The major cause of the erosion was as a result of road construction in which there drainage were channeled from Achina - Uga down to Akpulu and another road construction whose drainage were also directed to the same study area. The activities of man such as building of roads, intensive farming etc. contributed to the factors responsible for erosion in the study area.
- The topographic nature and the climatic condition are also the contributing factors in the study area.
- Inadequate maintenance of drainage channel and other regular construction work in the study area lead to the diversion of the erosion headway to another place.
- The affected community and other relevant authorities have not made much effort in combating the menace of this gully erosion.

- The impact of gully erosion has affected the value of land, lives, properties and rivers etc.
- The soil of the study area are characterized by well graded to poor graded sand and low to medium plasticity clay.
- The gully size was measured 15-18m deep, 19-12m wide to 6.5km long. Bottom of the gully rest on undulating sand stone overlain by a sequence of brownish to reddish sand with interlayer of silt and clay. The gully site falls by slumping while its head falls mainly by toppling and sliding.

5.2 CONCLUSION

This study has confirmed that soil characteristics such as high silt content is the major factor to compel gully erosion. The study has also showed that this environmental hazard has remained active and has continued to defy control measures put in place to checkmate it. The effects of this menace on the indigence has been enormous ranging from loss of access road to neighbouring communities, farmland, and crops, ancestral homes, livestock, properties, and even human lives.

Government, communities and individuals have continued to combat this monster with little or no success. This is attributed to the peculiar geology of the area and generalized and non specific control method employed to the peculiar geology of the area and generalized and non-specific control method employed in combating gully erosion. A scientific and systematic approach which integrates the influence of all factors responsible for gully development and growth should be adopted for the control of gullies within the state and region. These control measures should be extensively applied and monitored for effectiveness.

5.3 RECOMMENDATIONS

The problems of gully erosion, and landslides in the South-east are no exception. They can be successfully tackled and solved by Nigerians if they sincerely decide to do so. Man-made problems can equally be successfully-dealt with by the perpetrator, man. the following suggestions and recommendations that can be handled presented for your consideration and actions. They can be taken one or two or more at a time as one so desires. We now do suggest and recommend as follows:

Environmental impact assessment: Road contractors will present environmental impact assessment (EIA) of their road project for approval by the government authority prior to commencement of the project. The EIA must contain a proper drainage design at both sides of the road channeled to the nearest water way.

EIA implementation: Government regulation through a special trained environmentalist should monitor the EIA implementation during execution of the road project.

Community efforts: The affected communities will help in conserving their natural environment through monitoring their activities to avoid initiating erosion.

The soil of Akpulu gully erosion site in Ideato North Imo State should be declared as bad soil and needed emergency remedial action by the Federal and State government.

Establishment of Soil and Gully Erosion Commission: A soil and Gully Erosion Commission (SOGEC) that shall take care of erosion matters in Nigeria should be established by a Bill of the National assembly, later assented to by the President.

Working Modalities: The Federal Ministry of Environment should urgently come out with a working document that shall culminate in the establishment of SOGEC that shall spell out policies on combating ecological problems of floods, soil and gully erosion.

More Detailed Work: More detailed studies and investigations should be carried out to produce maps, designs, costing and reports on Geotechnical assessment of Akpulu gully erosion site for remedial work and control.

Public enlightenment: Government and public officials must know about erosion problems. There must be a regular environmental education program to educate civil servants, teachers and the rural masses. This environmental education program may hold in market squares, and in churches, courtesy of institutional linkage with the ministry of environment. Farmers will be informed about the best farming method so that their farm practice will not have negative impact on the environment. This program will help to enlightened the public on environment best manage practice (EBMP).

Sustainability studies: There is urgent need for sustainability studies by universities, polytechnics, and the colleges of education in Nigeria. For example, a sustainability study on Akpulu gully erosion site has been approved by the Federal University of Technology Environment and

Sustainability Study Group (FUTO-ESSG). The study implies yearly monitoring and assessment of Akpulu gully erosion site, and reporting every two years. Sustainability study of this nature will enable close monitoring and assessment of control measures put in-place, ecosystem management, and early warning or environmental alert. Sustainability studies of this nature are recommended for hundreds of other similar and greater erosion sites in the south-eastern Nigeria.

REFERENCES

Adekalu KO, Olorunfemi IA, Osunbitan JA (2007). Grass mulching effect on Infilteration, Surface runoff and Soil loss of thre agricultural soils in Nigeria Bioresour. Technol, 98(4):912-917

Abegunde, A.A., Adeyinka S. A., Olawuni P. O., Oluodo A. O (2003):"The impact of Erosion on Rural Economy: The Case of Nanka in Anambra State of Nigeria". In Urban Finance and Infrastructure Development in Nigeria. Yomi Fawehinmi (ed.) Atlantis Books. PP227-243.

Ananda J. and Herath S. (2003) – "*soil erosion in Developing countries*: Ps 343 – 53

Beijing, T. (2002) Soil erosion, biggest global environmental problem.

Bell, F.G. (1983). Fundamentals of engineering geology Buther Worth Publishers. London pp. 18-23.

Collinet, J. and Valentine, C, 1985. Evaluation of factors influencing water erosion in West Africa using rainfall simulation. Challenges in African hydrology and water resources IAHS Publ, 144: 451-461.

Donahue, Miller and Shiculina (1990). Introduction to soil and plant growth (5th ed.) Prentice Hall Incorporated. Englewood Cliff pp.421-433.

Egboka B.C.E and Nwankwo, G.I (1985) – The hydrogeological and geotechnical parameter as causative agent in the generation of erosion in the rain forest belt of Nigeria. J.AFR Barth Sci 3(4), pp 417 – 425.

Egboka BCE, Nwakwor GI, Orajaka IP (1990). Immplications of Palaeo and neotectonics in gully erosion-prone areas of south esastern Nigeria. Natural Hazards, 3:219-220-231.

Elison, W.D. (2003). Physical geography pg. 10-30

Federal Department of Agriculture and Land Resources (1980) Technical Report on erosion and wetland of south-eastern Nigeria

Gobin AM, Campling P, Deckers JA, Feyen J, Poesen J (1999). Soil erosion assessment at the Udi-Nsukka cuesta (Southeasten Nigeria). Land Degrad Dev. 10(2): 141-160.

Hudson NW (1981). Soil Conservation. New York Cornell University Press.

Hogg: R. 1982. A Report on the Social and Economic Organization of the Boron of Isiolo District Kenya, London. ESRC.

Morgan, R.D.C. (1996). *Editor soil erosion and conservation problem and prospects*. John Wiley and Sons Chischester

Obiefuna G. I. and Adamu J. (2011). Geological and Geotechnical Assessment of Selected Gully Sites in Wuro Bayare Area NE Nigeria; *Research Journal of Environmental and Earth Sciences 4(3): 282-302,*

Obi ME, Salako FK (1995). Rainfall parameters influencing erosivity in South-eastern Nigeria. Catena, 24:275-275-287.

Ofomata, G.E. (1984). The management of soil erosion in Nigeria; Paper presented at the 24th Annual Conference of the Nigeria Geographical Association Kano, April 6-10.

Okagbue CO. Uma KO (1987). Performance of gully erosion control measures in South-eastern Nigeria. Forest Hydrol Watershed Manag., 167: 163-172.

Okin, G.S. (2002). Towards a unified view of biophysical land degradation processes in Arid and semi arid lands pp. 95-97

Okunade, E.A. (2007c). Engineering properties of lateritic Adobe bricks for local building construction and recommendations for practice. Medwell journal of engineering and applied sciences 2 Vol. 9 Pp. 1455-1459.

Okpala AO (1990). Nigerian Population Growth and its implications for economic development. Scandinavian. J. Dev. Altern., 9(4): 63-77.

Omafra. S.(2003). "Soil erosion, causes and effects" Ridge Town and College of Agricultural Technology, Ontario Institute of Pedelogy.

Onweremadu E. U., Akamigbo F.O.R., Igwe C. A. (2007) Pedality and soil moisture retention characteristics in relation to erodibility of selected soils; Nature and Science, 5(1), 2007,

Onyewuchi, V.C. (1996). Gully erosion and its control in Nigeria. Things to knows p.7-9. National workshop on erosion control

Owuama, C.O. (2001). Gully head stabilization measure at an Erosion site in south eastern Nigeria. *Journal of the Environmental Studies* vol.2, p.48.

Pimentel D. Harvey C. Resosudarmo P, Sinclair K, Kurz D. McNair M (1995). Environmental and Economic Costs of Soil Erosion and Conservation benefits. Science (New York, N.Y.), 267(50201) 1117-1123.

Roth, C.B. (1974). Prediction of subsoil erodibility using chemical mineralogical and physical parameters E.P.A 660/2 -74-043, Washington DC USA. Environmental Protection Agency, Office of Research and Development.

Smith, P. (1993). Soil water conservation in Rowland J.P.T (ed) Dry land farming in Africa. C.T.A Macmillan, London and Basingtone p.142

Stocking, H. (1984). *Erosion and soil productivity*: A review conservation working paper No.1, F.O.A Rome.

Taniya, (1988). *Geography of Nigeria development*. Ibadan- Heinemann Educational Books Nigeria Limited

Troeh, F.R. and Donahue, D.L. (1980). *Soil and water conservation for productivity and environmental protection*. Prentice hall Inc. Englewood Cliff p. 83-110.

Toy, T.J, G.R. Foster, and K.G Renard 2002. Soil Erosion Processes Prediction Measurement and Control. New York: Jon Wiley and Sons.

Ude, N.C., Uzuakpunwa, A.B. and Ezeike, G.O.I. (1980). Gully erosion survey in Anambra State. Federal Dept. of Agric. Land Resources. Soil Conservation Centre, Owerri.

Uma, K.O and Onuoha, K.M. (1986). Groundwater fluxes and gully development in southeastern Nigeria Barth Evolution Sci.

APPENDIX 1

Appendix 1a, b, c and d showing the sections of gully in Akpulu.

Appendix 1a: showing secondary erosion channel

Appendix1b: showing palm tree trunk used by villagers for pedestrian bridge.

Appendix 1c : showing some materials carried by run-off water

Appendix 1d: showing width and recent slide surface of the study area

APPENDIX 2

The geotechnical parameter of the three sample from gully site in the study area at depth 0-7m were analyzed using atterberg limit, sieve. Compaction and direct shear test. And the Natural slope of erosion drainage channel was determine through using of GPS.

Table 1: GPS field measurements

Number	GPS Elevation	Distance (m)	GPS Coord. N	GPS Coord. E
1	443	0	05.55′286″	07 08′ 541″
2	467	200	05. 55′ 286″	07. 08′ 543″
3	487	400	05. 55′ 308″	07. 03′ 556″
4	492	600	05. 55′ 321″	07. 03′ 601″
5	505	800	05. 55′ 338″	07. 03′ 613″
6	518	1000	05. 55′ 339″	07. 08′ 618″

Below Are the Results of the Geotechnical Parameters Analyzed and presented in table form

Grain size distribution analysis (wet sieving) for

Sample 1

Wt. of sample b/4 washing & drying = 60,0g

Wt. of sample after washing & drying = 15.2g

:. Wt. lost to washing (wt of fines) = 44.8g

% of fines = 74.7%

Dry sieving of residue, wt = 15.25.

Sample I

Sieve size (mm)	Mass retained (g)	Mass passing (g)	% Passing	% retained (g)
2.0	0.0	60.0	100.	0.0
1.18	0.2	59.8	99.7	0.3
0.85	0.2	59.6	99.3	0.3
0.600	0.3	59.3	98.8	0.5
0.425	1.6	57.7	96.2	2.7
0.300	7.5	50.2	83.7	12.5
0.150	4.0	46.2	77.0	6.7
0.075	1.9	44.3	73.8	3.2
pan				

For sample II

Wt. of sample b/4 washing & drying = 60.00g

Wt. of sample after washing & drying = 37.8g

Wt. lot to washing = 22.2g

% of fines = 37.0%

Dry sieving of residue, wt = 37.8g

sample II

Sieve size (mm)	Mass retained (g)	Mass passing (g)	% Passing	% retained (g)
2.0	0.0	60.0	100.00	0.0
1.18	0.7	59.3	98.8	1.2
0.85	4.2	55.1	91.8	7.0
0.60	7.5	47.6	79.3	12.5
0.425	10.2	37.4	62.3	17.0
0.300	7.0	30.4	50.7	11.7
0.150	7.9	22.5	37.5	13.2
0.075	0.9	21.6	36.0	1.5
Pan				

Sample III

Wt. of sample b/4 washing & drying = 60.0g

Wt of sample after washing & drying = 41.1g

:. Mass lost of washing = 18.9g

% of fines = 31.5%

Dry sieving of residue, wt = 41.5%

Sample III

Sieve size (mm)	Mass retained (g)	Mass passing (g)	% Passing	% retained (g)
2.0	0.2	59.8	99.7	0.3
1.18	1.3	58.5	97.5	2.2
0.85	5.2	53.3	88.8	8.7
0.60	8.0	45.3	75.5	13.3
0.425	10.0	35.3	58.8	16.7
0.300	6.4	28.9	48.2	10.7
0.150	8.2	20.7	34.5	13.7
0.075	1.6	19.1	31.8	2.7

FOR COMPACTION TEST

Sample Bulk Density Test.

Sample	1			2			3		
Trial No	1	2	3	1	2	3	1	2	3
Wt of mould + Compacted soil (g)	6250	6750	6650	6300	6800	6700	6300	6700	6600
Wt of mould (g)	4500	4500	4500	4500	4500	4500	4500	4500	4500
:. Wt of compacts Soil (g)	1750	2250	2150	1800	2300	2200	1800	2200	2100
Volume of mould cm^2	996	996	996	996	996	996	996	996	996
Build density (mg/cm^3	1.76	2.01	1.86	1.81	2.31	2.20	1.81	2.20	2.11

Moisture Content/ Dry Density Test

	1			2			3		
Can identification	3 6	B	F	60	36	B	20B	4	F
Can + wet soil (g)	71.8	90.8	81.4	70.9	95.0	55.9	86.5	88.8	76.8
Can + dry soil (g)	68.3	83.3	72.7	66.7	86.8	47.7	79.3	75.6	68.7
Can (g)	19.0	23.8	19.0	4.9	19.0	23.8	19.6	19.5	19.0
Dry soil (g)	49.3	59.5	53.7	61.8	67.8	55.6	59.7	56.1	49.7
Water (g)	3.5	7.5	8.7	4.2	8.2	8.5	4.3	7.4	8.1
Water Content, %	7.1	12.6	16.2	6.8	12.1	15.3	7.2	13.2	16.3
Dry density (Mg/m^3)	1.64	2.01	1.86	1.70	2.06	1.91	1.69	1.94	1.81

ATTERBERG LIMIT

Liquid Limit

Sample	**1**			**2**			**3**		
Trial No.	1	2	3	1	2	3	1	2	3
Can identification No.	36	30	13	T	58	M	4	41	33
No. of blows	15	20	28	6	10	16	12	19	28
Can + wet soil (g)	33.5	32.3	36.4	33.3	28.2	35.7	33.4	31.9	32.4
Can + dry soil (g)	30.0	29.3	32.4	30.4	25.4	32.7	30.2	28.8	29.6
Can (g)	18.9	19.6	19.1	22.5	17.5	23.9	19.5	17.8	19.3
Dry soil (g)	11.1	9.7	13.3	7.9	7.9	8.8	10.7	11.0	10.3
Water (g)	3.5	3.0	4.0	2.9	2.8	3.0	3.2	3.1	2.8
Water content, w(%)	31.5	30.9	30.1	36.7	35.4	34.1	29.9	28.2	27.2

Plastic Limit

Can identification	W	X	46	V	Tm	62
Can + wet soil (g)	10.3	12.2	27.3	29.8	35.1	33.3
Can + dry soil (g)	9.3	11.1	25.5	27.9	33.3	31.2
Can (g)	3.5	4.8	17.7	19.4	23.9	19.9
Dry soil (g)	5.8	6.3	7.8	8.5	9.4	11.3
Water (g)	1.0	1.1	1.8	1.9	1.8	2.1
W (%)	17.2	17.5	23.1	22.4	19.2	18.6

Result: Sample 1

From flow curve, Liquid Limit (LL) = 27.5%

Plastic Limit (PL) = $\frac{17.2 + 17.5}{2}$ = 17.35%

∴ Plasticity index, P.I = LL - PL
= 27.5 – 17.35
= 10.15%

Sample 2

Liquid Limit (LL) = 30.4%

Plastic Limit (PL) = $\frac{23.1 + 22.4}{2}$ = 22.75%

∴ Plasticity index, P.I = LL - PL
= 30.4 – 22.75
= 7.65%

Sample 3

Liquid Limit (LL) = 32.6%

Plastic Limit (PL) = $\frac{19.2 + 18.6}{2}$ = 18.9%

∴ Plasticity index, P.I = LL - PL
= 32.6 – 18.9
= 13.7%

DIRECT SHEAR TEST

Sample Dimensions (for all samples)

Length (l)	=	60mm
Width (w)	=	60mm
Area (A)	=	60 x 60 = 3600mm^2
	=	0.0036m^2

Normal stress computation (σ) KN/m^2

Load (kg)	Load (kw)	Area (m^2)	δ (KN/m^2)
24	0.24	0.0036	66.7
44	0.44	0.0036	122.2
64	0.64	0.0036	177.8

Shear Stress τ Computation (KN/m^2)

Sample	Load	Max H.R	(3) x 0.02	(4) x 0.88	(5) ÷ A(KN/m^2)
	24	103	0.206	0.18128	50.4
1	44	103	0.326	0.28688	79.7
	64	221	0.442	0.38896	108.0
	24	108	0.216	0.19008	52.8
2	44	171	0.342	0.30096	83.6
	64	231	0.462	0.40656	112.9
	24	102	0.204	0.17952	49.9
3	44	168	0.336	0.29568	82.1
	64	225	0.45	0.396	110

0.002 = Did guage correction
Max. H.R = maximum horizontal reading

Computation of Shear Strength

1. Sample 1 from graph, C = 15, $\phi = 27^0$

Shear strength $\sigma = C + \sigma n \tan\phi$

where max normal stress

$$\sigma = 15 + 177.8\tan 27^0$$

$$= 105.6KN/m^2$$

2. Sample 2 C = 17, $\phi = 27^0$

$$\sigma = 17 + 177.8\tan 27^0$$

$$= 107.6KN/m^2$$

2. Sample 3 C = 13, $\phi = 28^0$

$$\sigma = 13 + 177.8\tan 28^0$$

$$= 107.5KN/m^2$$