CAUSES OF GULLY EROSION, IMPACTS AND POSSIBLE SOLUTIONS IN EKOSODIN AREA BEHIND UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, SOUTHERN NIGERIA.

By
Kingsley Ogechukwu AGBO

PSC1908964

DEPARTMENT OF GEOLOGY,
FACULTY OF PHYSICAL SCIENCES,
UNIVERSITY OF BENIN,
BENIN CITY, EDO STATE.

MAY, 2024.

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF GEOLOGY, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENIN, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF SCIENCE DEGREE (B.Sc) GEOLOGY

MAY, 2024.

CERTIFICATION

This is to certify that this project work was submitted and approved by the Department of Geology in partial fulfilment for the requirements for the award of Bachelor of Science in Geology, University of Benin, Benin City.

_________________________ ________________

Dr (Mrs.) O. Andre-Obayanju Date

(Supervisor)

_________________________ ________________

Dr. Salami S.A. Date

(Head of Department)

DEDICATION

I dedicate this project work in honor of my late brother, Mr. Agbo Chigozie Jude, who was not only a sibling but also a supportive figure akin to a father, having funded my academic journey since my secondary school days. His unwavering faith in my abilities and his constant encouragement have been the bedrock upon which I have built my ambitions. This achievement is not only mine but also a testament to his enduring influence. It is saddening that he did not live to see the conclusion of this academic pursuit, but I assure him that his memory remains very much alive in my heart.

ACKNOWLEDGEMENT

I extend my deepest appreciation to the Divine Providence for the unwavering support and guidance bestowed upon me throughout my academic journey at this esteemed university. The gift of life and the strength to persevere are blessings I cherish deeply.

My profound gratitude goes to my supervisor Dr. (Mrs.) Andre-Obayanju, whose insightful guidance and unwavering support have been the cornerstone of my research endeavors. Her wisdom has illuminated my path to academic excellence.

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I am also immensely grateful to my friends, classmates, and project colleagues, whose camaraderie and cooperation have enriched my academic experience. Your shared insights and unwavering solidarity have been invaluable.

Lastly, I express my heartfelt gratitude to my family, whose love and encouragement have been my anchor throughout my educational pursuit. Your belief in my potential has been a source of endless motivation.

This journey would not have been possible without the contributions of each one of you, and for that, I am eternally grateful.

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ABSTRACT

This research delves into the elements that lead to the creation of gullies, with a particular emphasis on the soil attributes at the gully location of the University of Benin. Soil samples were extracted from three distinct points at the site. A series of examinations were performed on these samples to ascertain their soil properties, encompassing sieve analysis, specific gravity, Atterberg limits, compaction, and triaxial tests. The results of the various tests reveals that soil samples had a medium liquid limit and relatively low plasticity for the Atterberg limits. There is a specific gravity range of 2.61 to 2.64 for the soil samples classifying them as organic soils according to classification system proposed by Bowles (2012). The compaction test revealed that soil retains a significant amount of moisture even when compacted to its densest state. The triaxial test revealed that the soil exhibits a relatively low friction angle coupled with substantial cohesion. And finally the sieve analysis shed light on the particle size distribution in the soil samples, which exhibit a reddish-brown coloration and are located below the A-line on the Unified Soil Classification System (USCS) chart, classifying them as silts. Known for their moderate infiltration rates, these silts contribute to increased surface runoff, which is a key factor in gully development.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Gully erosion is a pervasive environmental issue with extensive implications that impact both urban and rural communities. It leads to the loss of farmland and soil nutrients, and the destruction of valuable properties and infrastructure, causing detrimental effects in both urban and rural areas.

This form of erosion occurs when rainwater accumulates in narrow channels, rapidly eroding a substantial amount of soil from these restricted areas in a short time. Gully erosion represents the final stage in a series of four erosion processes: splash, sheet, rill, and gully. The process starts when raindrops fall and move across the soil surface. Splash erosion occurs when the impact of raindrops on bare or sparsely vegetated soil detaches soil particles. Sheet erosion happens when these soil particles are easily swept away in a thin, sheet-like layer by flowing water. If this sheet runoff concentrates and accelerates, it forms rills and gullies while dislodging more soil particles. As the erosive power of the flowing water increases with the length and gradient of the slope, gullies evolve into deep channels and canyons (Jibo et al, 2020).

Despite accounting for a relatively small portion of a catchment area, typically less than 5%, gullies significantly contribute to environmental and socio-economic problems due to land degradation. Gully erosion negatively affects soil and land functions by lowering the groundwater level, making soils more susceptible to drought, and resulting in reduced crop yields. Moreover, gullies improve landscape connectivity by creating efficient routes for transporting water, sediment, and other materials from the source to the destination. This has implications for flooding and the condition of reservoirs. Global soil erosion studies have consistently indicated that gully erosion is a major contributor to sediment in rivers (Selamawit et al, 2021).

Gullies are fundamental geo-hazards and pose a serious threat to environmental sustainability. They are a highly visible form of soil erosion that impacts soil productivity, limits land use, and endangers infrastructures and buildings. The environmental hazards associated with abandoned gullies in Nigeria are increasing and are a significant concern for citizens, the government, and environmental geologists. Many states in Nigeria, particularly the southeastern part of the country, are currently threatened by this phenomenal process (Ojeaga et al, 2022). Gully erosion has reached a larger and more devastating scale in Edo state, attracting international interventions. All the senatorial districts in the state are affected by the problem. The main gully erosion sites in Edo South are Queen Ede, West Moat Ekehuan Road, University of Benin (Ugbowo campus), and Costain. In Edo North, the main gully sites are the Auchi gully complex and Ikabigbo gully, while in Edo Central, the main gully sites are Ewu gully and Ibore gully.

1.2 AIM AND OBJECTIVES

The aim of this study is to address the causes of gully erosion in UNIBEN/ekosodin community in Egor Local Government Area, Benin city, Edo state and provide possible solutions. The specific objectives are outlined as follows;

1. To determine the causes of erosion in UNIBEN/ekosodin community in Egor Local Government Area, Benin city, Edo state.
2. To determine the impacts of gully erosion in UNIBEN/ekosodin community in Egor Local Government Area, Benin city, Edo state.

3. To identify solutions and control measures of gully erosion in UNIBEN/ekosodin community in Egor Local Government Area, Benin city, Edo state.

1.3 SIGNIFICANCE OF THE STUDY

The evaluation of environmental degradation resulting from gully erosion in Nigeria will enhance our understanding of its potential impact on the environment. It will raise awareness among the public about the risks associated with gully-prone areas. Additionally, this study will aid in classifying land degradation. Furthermore, it emphasizes the need for significant improvements in gully erosion management practices and contributes to academic knowledge about gully erosion mechanisms. The affected regions, being part of the country's economic hub, will also serve as a reference point for future researchers.

1.4 LOCATION OF STUDY AREA

The study area is located between Latitudes of 6024'24.2"N and longitudes of 5037'39.0"E UNIBEN/ekosodin community in Egor Local Government Area, Benin city, Edo state. The total area of Egor local government is 93 square kilometers. Three soil samples were collected at different interval in the selected gully site in UNIBEN/ekosodin community at 1m depths respectively. The tools used for sample collection includes the following; Hand Auger, Cutlass, shovel, Polythene bags and GPS device.

Table 1 below provides precise location of sample collection points.

Sample point no	Latitude	Longitude	Altitude (ft)	Accuracy(ft)
Sample point 1	6°24'24.2"	5°37'37.0"	368	40
Sample point 2	6°24'24.1"	5°37'39.0"	368	44
Sample point 3	6°24'24.5"	5°37'41.0"	368	25

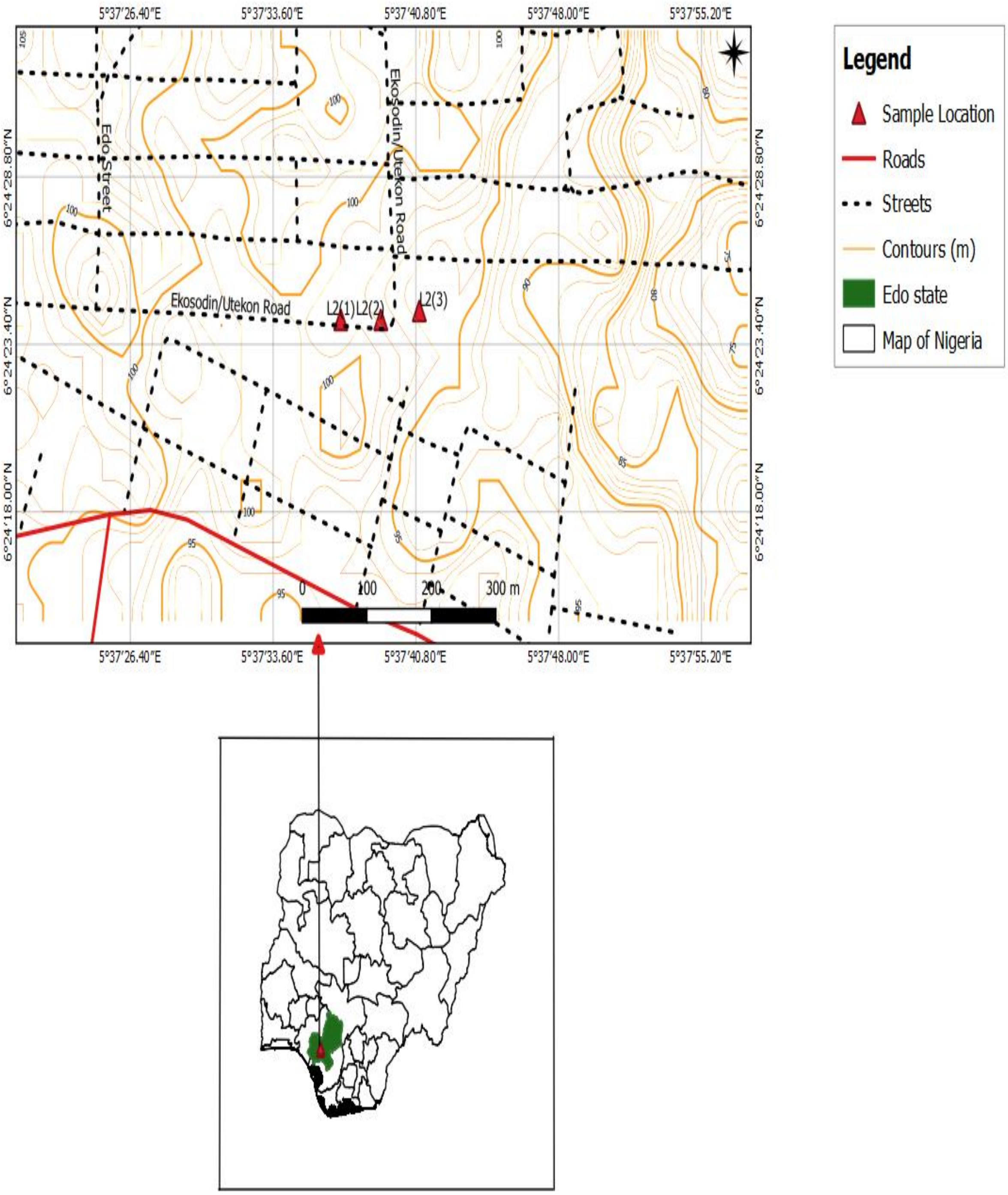

Fig 1: Location map of study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

Numerous studies have been conducted to understand gully erosion, its environmental impacts, and potential mitigation strategies.

Amangabara (2014), characterized gully erosion as an erosion process where runoff water accumulates in narrow channels, removing a significant amount of soil over a short period. This process is the final stage of a four-stage erosion process that includes splash, sheet, rill, and gully. The process begins with water falling and flowing on the soil surface. Splash occurs due to the force of raindrops stripping off soil particles, while sheet erosion results from the transportation of these loosened particles in thin layers or sheets by flowing water. As this runoff concentrates and gains velocity, it develops rills and gullies.

In his research, Amangabara discussed gully erosion control measures, categorizing them into agronomic measures, which offer the soil physical protection against erosion and work to reduce flow velocity by enhancing the hydraulic resistance of the channel, and engineering measures. The latter involves constructing various engineering structures, such as catch pits, soak-away pits, interceptor open drains, canals, and underground pipes. These structures aim to prevent runoff from reaching gullies and improve slope stability.

Jibo (2020) discussed the effects of gully erosion on physical and socio-economic activities, highlighting that gully erosion can adversely affect a city's physical infrastructure and socio-economic activities such as farming, trading, hunting, etc. His study on Akko local government area of Gombe state revealed that gully erosion primarily affected physical infrastructures, especially residential housing, roads, and electricity infrastructures. Gully erosion also caused damages such as bridge cutting, built-up structure collapse, danger pits, water pipe breakage, construction difficulties, and more. It also adversely affected the city's socio-economic activities, including washing away farmlands and produce, farming difficulties, destruction of grazing fields, uprooting of economic trees, among others.

Charles Udosen (2009), observed that erosion factors represent critical conditions or combinations of factors that trigger soil erosion. These factors may be intrinsic or extrinsic thresholds, such as changes in vegetation cover or drastic shifts in climatic conditions. In a given landscape, the initiation of a gully depends on the nature of the soil material, rainfall patterns, vegetation cover extent, and slope characteristics—all contributing to the resistance against tractive forces.

Egboka et al. (1990) observed that the rise in the water table due to heavy rain falls in the rainy season contributes to an increase in hydraulic head, high subterranean flow rate, and the enhancement of gully formation.

Ezezika O.C. and Adetona O. (2011), observed that the 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 South-south Nigeria. Erodibility, on the other hand, is dependent on soil properties, topography, and land management.

Kayode-Ojo (2019), in his research on gully erosion problems in selected areas of Edo State, discussed the factors contributing to gully formation and prevention methods to control gully erosion to avoid further environmental degradation. His research findings concluded that the primary gully sites exhibited typical traits of erosion-prone areas. These characteristics included exceptionally intense rainfall, steep slopes leading to significant runoff, and soil composition characterized by low organic content and relatively modest shear strength, as determined through geotechnical investigations.

Ojeaga (2022), conducted a study on the Geotechnical characterization of soil susceptibility to gully erosion in the University of Benin. He noted that gullies form when there’s either a reduction in the soil's resistance to erosion forces or an increase in the erosive forces affecting the land surface. Gullies may result from natural processes, human activities, or a combination of both. He also noted that the geological composition beneath the surface significantly influences gully formation. In many instances, the emergence of gullies depends on soil type, as certain soils exhibit higher susceptibility to erosion than others.

Nwankwoala (2019), carried out a research project in Agulu-Nanka, located in southeastern Nigeria. The purpose of this study was to perform a geotechnical evaluation for the control and management of gully erosion. The research aimed to provide geotechnical parameters and data, pinpoint the factors leading to gully vulnerability in the area, and suggest sustainable solutions to tackle the issues caused by gully erosion in the impacted regions of Anambra State, particularly in Agulu-Nanka.

Nwankwoala noted that gully erosion could be naturally triggered by elements such as heavy rainfall, sparse vegetation cover, high altitudes, characteristics of soil and surface sediment, and the interaction between groundwater and soil. In his conclusion, he expressed that the research findings revealed that the soils in the study area were lacking in cohesion, were not compacted adequately, and displayed non-plastic properties. These were identified as the root causes of the gully erosion.

In response to these findings, he proposed a set of recommendations for mitigation and control strategies. These encompassed the prevention of human-induced factors contributing to erosion susceptibility, such as unauthorized and indiscriminate removal of topsoil, overgrazing, continuous cropping, waste dumping, and blocking of drainage systems. He suggested seeking advice from erosion control experts to address these issues effectively.

Idakwo Victor Iko-Ojol (2020) carried out a study with the goal of conducting Geomorphological and GIS analysis to map the susceptibility of gully erosion in Taraba State. He noted that the integration of GIS/SRS with erodibility variables, including lithology/geology, soil type, land use/land cover, and erosivity variables such as elevation/aspect, plain curvature, Stream Power Index (SPI), Topographic Wetness Index (TWI), and Length Slope Factors (LSF), is employed to map the susceptibility of an area to gully erosion.

Igwe (2020), in his study, “GIS-based gully erosion susceptibility modeling: adapting bivariate statistical method and AHP approach in Gombe town and environs Northeast Nigeria”, aimed to create a gully inventory map of the study area. He employed the Frequency Ratio and Analytical Hierarchy Process (AHP) models to generate Gully Erosion Susceptibility Maps. The frequency ratio model, a statistical method, was used to evaluate the potential correlation between gully erosion and its influencing factors. In the AHP method, weights were assigned using pairwise relative comparisons, based on expert knowledge and experience. This process resulted in the development of a reliable and comprehensive gully inventory map.

In his conclusion, Igwe emphasized the assessment of the spatial relationship between gully occurrences and ten carefully chosen causative factors. These factors included drainage buffer, soil texture, slope degree, land use, elevation, Topographic Wetness Index (TWI), lithology, road buffer, and aspect. The Frequency Ratio (FR) model revealed that drainage buffer, soil texture, slope degree, and land use had the most substantial impact on gully occurrences.

2.2 TYPES OF GULLY EROSION

There are different types of gullies, depending on their morphology, formation mechanism, and location. Some of the common gully types are:

- Base level gullies: These gullies originate at the base level streams or rivers and are brought about by the combined effects of seepage forces, soil flow and bank erosion.

They have a U-shaped cross section and a gentle gradient. They are common in areas with high water table and low relief.

- Scarp gullies: These gullies develop along the edges of escarpments or plateaus and are caused by the undercutting of the scarp face by water. They have a V-shaped cross section and a steep gradient. They are common in areas with high relief and resistant rocks.
- Fracture gullies: These gullies form along the lines of weakness or fractures in the soil or rock. They are initiated by the infiltration of water along the fractures, which causes the soil to collapse and create a channel. They have a rectangular cross section and a variable gradient. They are common in areas with fractured rocks or soils.
- Incidental gullies: These gullies are the result of human activities such as road construction, mining, deforestation, etc. They are triggered by the disturbance of the natural drainage system or the removal of the vegetative cover, which increases the runoff and soil erosion. They have an irregular cross section and a variable gradient. They are common in areas with high population density and land use pressure.

2.3 GULLY EROSION PROCESSES

Gully erosion can be caused by various factors, such as high rainfall intensity, low infiltration capacity, steep slopes, poor vegetation cover, human activities, and soil properties. Some processes involved in the development and evolution of gullies includes the following; Waterfall erosion, Channel erosion, Mass movement, Groundwater seepage, Soil dispersion. However, only those prevalent in the study area are discussed below.

- **Waterfall erosion**: This is the process of erosion at the head of the gully, where water falls over a steep edge and scours the soil below, creating a plunge pool and undercutting the bank. This can cause the bank to collapse and retreat upstream, extending the length of the gully.

- **Channel erosion**: This is the process of erosion along the bottom and sides of the gully, where water flows with high velocity and shear stress, detaching and transporting soil particles. This can cause the gully to widen and deepen, increasing its cross-sectional area and volume.
- **Mass movement**: This is the process of movement of soil or rock along the gully walls, due to gravity, water saturation, or external forces. This can include slumping, sliding, or falling of material, which can fill the gully channel or create new gully branches.

2.4 INDEX OF GEOTECHNICAL SOIL PROPERTIES

Soils possess distinct geotechnical characteristics that inform us about their vulnerability to erosion. Factors such as **permeability**, **compaction**, **shear strength**, **organic matter content**, and **slope gradient** are among the determinants of gully erosion. Here's how these properties influence gully formation:

Permeability: Highly permeable soils facilitate rapid water infiltration, diminishing surface runoff and erosion. Conversely, soils with low permeability lead to increased runoff and erosion due to their poor water absorption capacity.

Compaction: Soils that are compacted have lesser pore space and greater density, which can heighten runoff and erosion. In contrast, soils that are not compacted are more erosion-resistant.

Shear Strength: Influenced by cohesion and internal friction, a soil's shear strength determines its erosion resistance. Soils with greater shear strength are less prone to erosion.

Texture: The soil's texture, defined by the mix of sand, silt, and clay, influences its erodibility. Sandy soils, with their loose structure, are more susceptible to erosion, while clayey soils, though more resistant to erosion, can be prone to surface sealing and runoff.

Root Systems: The stability of soil is significantly affected by the presence and robustness of vegetation root systems. Soils with dense and deep roots are better anchored, thus reducing erosion.

Organic Matter Content: Soils rich in organic matter generally exhibit improved structure and stability, which curtails erosion. Organic matter helps in binding soil particles, enhancing their resistance to erosive forces.

Slope Gradient: Although not an inherent soil property, the slope gradient of the terrain is a pivotal factor. Steeper slopes have a higher erosion potential, independent of the soil properties.

These geotechnical properties can be assessed through laboratory or field tests. However, it's important to note that some parameters might remain undetermined due to practical constraints. The engineering characteristics of soil, which significantly influence gully erosion, are shaped by two main factors:

Compositional Factors: This includes the size and shape of soil particles, the variety and ratio of minerals present, and the composition of pore water. These elements collectively affect the soil's cohesion, shear strength, and erodibility, thus influencing its susceptibility to gully erosion.

Environmental Factors: The environmental conditions also play a substantial role. Factors such as water content, soil density, confining pressure, temperature, and the overall soil structure can markedly impact a soil's vulnerability to gully erosion. For instance, soils with high water content or a loose structure are at a higher risk of erosion, whereas compacted soils tend to be more erosion-resistant.

2.5 IMPACTS OF GULLY EROSION

Gully erosion in Nigeria, like in other parts of the world, has significant impacts and these impacts can be either positive or negative, some of which includes the following;

- Farmland Depletion: Gully erosion has led to the loss of a large expanse of farmland, with others on the brink of destruction. This has resulted in a sharp decline in agricultural productivity, potentially leading to food scarcity and famine.
- Vegetation Threat: The continuous spread of gully erosion in Nigeria has led to deforestation as it encroaches into previously forested areas, causing trees to fall and exposing more surface areas to erosion. If unchecked, this could lead to local or even global climate changes.
- Property Damage: Numerous properties, including houses and other assets located on floodplains, have been destroyed or are under threat from erosion. For instance, about 10 houses were lost in a single erosion event in Auchi, Edo State. It was also reported that over 450 buildings were lost in Edo State due to erosion (NTA News, Sunday 6th July 2013). Infrastructure such as pipelines, utility cables, roads, and houses also suffer from these hazardous events.
- Loss of Life: Many lives have been lost due to gully erosion, with some people falling into gullies and sustaining injuries or dying. There have been reports of people drowning in gully sites. In the past few years, about 23 people have lost their lives in a single erosion event in various communities of Edo State, Nigeria.

- Isolation of Communities: Gully erosion has led to the separation of neighboring villages and towns, often due to the collapse of connecting bridges. This has negatively impacted these areas as shared facilities such as schools, hospitals, and water supplies may become inaccessible. The transportation of farm produce has also been affected, often leading to the loss of perishable agricultural products.
- Creation of Infertile Land: Gully erosion has resulted in the formation of infertile and barren land that may need reclamation. This can cause severe hardship for the inhabitants if the land is still habitable but severely affected. For instance, Anambra State has lost over 30 percent of its land, with over 40 percent of the total land area and homes threatened by erosion, according to the Anambra State Ministry of Environment.

2.6 GEOLOGICAL SETTINGS

2.6.1 REGIONAL GEOLOGY

THE NIGER DELTA BASIN

The Benin Hinge Line separates the Niger Delta basin from the Cameroon Volcanic Line in the area bounded by the Calabar Flank and the Afikpo Syncline. The Anambra basin, situated northeast of the Niger Delta basin, stretches westward beyond the River Niger, with its western boundary being the Benin Hinge Line. The sedimentary succession from the Cretaceous to the Recent in the Benin Flank is laterally equivalent to the rocks in the Anambra Basin, covering approximately 16 sq km south of the Precambrian rocks in Edo state. The Benin Formation, together with the Agbada and Akata Formations, make up the three primary stratigraphic rock units within the Niger Delta sedimentary basin.

The study area's geology reveals that sedimentary rocks and sands from a coastal plain underlie the entire region. The crystalline basement rocks are found in the mountainous and dissected zone in the north, while the well-drained dry plains at Auchi, Agbede, and Afuze further south have lateritic soil. As per Aderemi & Iyamu (2013), the region is overlain by a sedimentary rock from the Pleistocene period, known as the Benin Formation. Around 90% of the sedimentary rock is composed of sandstone and shale intercalation. It primarily consists of sandstone, clay, shale, and lignite, which can be coarse or fine-grained. The region's relief includes the Esan Plateau, Ore Valley, and the dissected uplands of Akoko Edo Local Government Area, among other dissected plateaus and swamping creeks. The region's terrain comprises six different categories of physical elements (Aderemi & Iyamu,2013), with slopes tilted towards the southwest. The River Osse, Orihionmwon, and Ikoba are the main drainage systems in the region. Eseigbe & Ojeifo (2012) noted that other rivers in the region, except for River Osse, are characterized by deeply incised valleys in their upper courses, which broaden as they near River Ethiope in Delta State.

Aside from the northern axis, where the Northern and Esan plateau range from 183 meters at the Kukuruku Hills to 672 meters at the Somorika Hills, the state has a relatively flat terrain in the southern part with an average height above sea level of about 500m. The Esan Plateau ranges from 213 to 305m in height. Sandy claims that the Benin lowlands area contains alluvium clay and a coastal plain. According to Idehai & Egai (2014), this region is marked by sandstone hills, numerous dry valleys, steep slopes in the north and south, and moderate slopes in the west. On the other hand, the fragmented uplands of Akoko Edo range between 183 and 305m in height. The granite peaks of the uplands, exceeding 610m, and the sandstone in the south are notable features. Additionally, the terrain surfaces are predominantly stable and erosive. In the research area, the predominant soil type is a reddish-brown soil. The shallow, rocky reddish clay at the base of inselbergs in the higher areas of Akoko Edo constitutes the variety there (Idehai and Egai, 2014). According to Akujieze & Irabor (2014), the soil types in the lowlands of Benin range from alluvial and hydromorphic soils near the Niger, the Osse, and the Benin Rivers in the northeast to loose, sparsely productive sand in the southeast.

Benin city, serving as the state capital, along with Abudu, Ekpoma, Uromi, Auchi, and Sabongida Ora, are significant towns in the state. Edo State is renowned for its agricultural, commercial, and rich historical virtues. The population is primarily composed of farmers and traders with a strong connection to the land.

2.6.2 GEOLOGY OF STUDY AREA

The Miocene – Recent Benin Formation underlies the study area. This formation stretches from the west across the entire Niger Delta Area and southward beyond the current coastline. The Benin Formation's lithostratigraphy (pebbles and cobbles), clays, peat, and lignite were deposited in a continental coastal plain depositional setting. It is coarse grained, gravelly, locally fine grained, poorly sorted, subangular, well rounded, and has lignite streaks and wood fragments. It is a continental deposit of likely upper deltaic depositional environment. This formation's thickness exceeds 6000ft. It has very little hydrocarbon accumulation. The Benin Formation is thought to originate from the Benin-Onitsha area and extend beyond the present coastal line. The sandstone is believed to be Miocene to Recent in age. The Benin Region is part of the Niger Delta Basin's sedimentary formation. The region's geology is undergoing continuous and intense physiochemical transformation. It is generally marked by red tropical soils composed of low silica sesquioxide ratio clay sand, which is soft when wet and considerably hard when dry. The coastal plain sands name describes the red tropical soils formation underlain by sands and clay that indicate an ancient coastal plain environment. However, the Benin Formation name is used to identify the reddish-brown-yellow, generally white sands, often with clayey and pebbly horizons, with type locality around Benin.

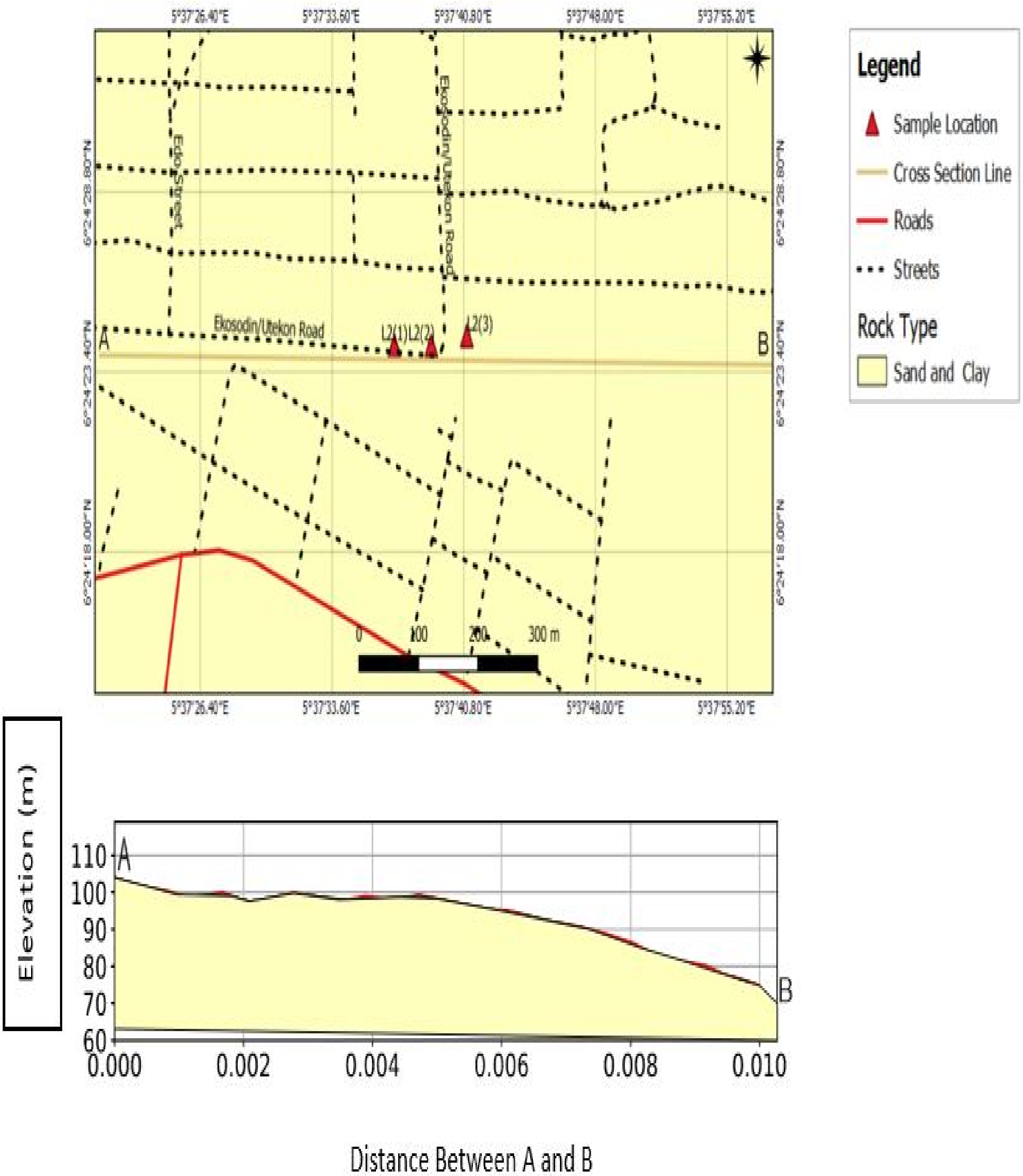

Fig 2:Geological map of study area.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

The soil samples for this research work were collected from gully sites in UNIBEN/Ekosodin community in Egor Local Government Area, Benin city, Edo state. Various laboratory tests was carried out on these samples including Atterberge Limit, Compaction, Sieve Analysis, Triaxial, Specific Gravity, and Natural Moisture Content. These tests aim to determine the soil's mechanical properties and strength.

Plate 1 : Gully site at ekosodin community.

Plate 1.1: Gully site at ekosodin community.

3.3 PREPARATION OF SAMPLE

The preparation process involves spreading the soil sample on trays for air drying and subsequently pulverizing it to break up the lumped soil aggregates.

3.4 LABORATORY TEST

This section explains the experimental methods and lab tests that this research project used. The tests that were done are as follows:

i. Atterberg limit test
ii. Compaction test
iii. Sieve Analysis
iv. Triaxial Test
v. Specific Gravity Test
vi. Moisture content Test

3.4.1. ATTERBERG LIMIT TEST

Aim

The aim of this test is to determine the plasticity of the soil using liquid limit(LL), plastic limit(PL) and plastic index of the soil.

LIQUID LIMIT

Apparatus:

Brass cup, spatula, A glass plate, Two palette knives of different size, An evaporated dish and pestle, An evaporating dish and rubber pestle, A grooving tool and gauge, A corrosion a resistant container, A sieve number 40, Moisture content cans, Cassangrande mechanical device machine.

Procedure

The liquid limit determines the moist content at which the soil will flow under its own weight. Each soil sample has different weights sample material passing through the 425µm aperture sieve was tested. The soil sample was combined with water to create a homogeneous paste. The paste was then placed in the cup of the Cassagrande apparatus, leveled off and parted by drawing a groove across the center of the sample. The device's crank was then cranked, and it measured how many blows (2 revolution per seconds) were required to close the groove. The number of blows at which this occurred was recorded and a little quantity of this sample was taken and its moisture content was determined. The test was repeated at varying moisture content. On a semi log graph sheet, the amount of moisture was plotted against number of blows. The liquid limit was obtained at the moisture content corresponding to 25 blows.

PLASTIC LIMIT

Wet samples were placed between palms, rolled and then split into two sub samples, each of which was divided into four equal pieces. The moisture content of each sub sample was then measured after being rolled into a thread with a diameter of three millimeters. The average of the obtained moisture content was used to record the plastic limit

PLASTIC INDEX (PI)

This is the difference between liquid limit(LL) and plastic limit(PL). It represents the range of soil moisture content over which soil is plastic.

PI = LL- PL

3.4.2 COMPACTION TEST

Aim

1. To determine the maximum dry density and optimum content of the soil sample when compacted.
2. To determine the rate of soil permeability of the soil sample.

Apparatus:

A cylindrical metal mould having an internal diameter of 105mm, an internal effective height of 115.5m and a volume of 1000cm, Detachable base plate, 2.5kg metal hammer, A balance readable to 1g, Palette knife, Straight edge, 20mm BS sieve and a receiver, A large metal tray of about 60mm *500mm with sides 80mm deep, Moisture can and scoop and trowel

Procedure

An air dried sample of the soil will be pretreated and passed through the 20mm BS sieve with the particle retained being discarded and those passing being collected for the compaction. The empty weight of the mould will be taken using a balance readable to 1g and recorded. A quantity of the soil will be weight and mixed with a measured volume of water. The volume of water used will not be fixed but based on the soil texture and for subsequent trials. The soil mixing will be done manually using a scoop and trowel and three layers of the soil will be introduced into the mould whose base plate would have been covered with filter paper to prevent adherence.

This procedure will be repeated four times. Maximum dry density and optimum moisture content will be determined. A compaction curve will be obtained by plotting dry density against moisture content, maximum dry density and optimum moisture will be determined from the graph.

Dry density, pd = 100p/(100+w)

Where;

P = Bulk density

W= moisture content

3.4.3 SIEVE ANALYSIS

Aim

The aim of the analysis is to ascertain the particle size distribution.

Apparatus:

Stack of test sieves, weighing balance, rubber pestle and mortal(for crushing the test material if lumped), Sieve shaker and oven.

Procedure

The dried sample were sieved through the following set of sieve sizes (14,25,36,52,100 and 200)µm. The weight retained on each of the sieve was measured and recorded. The weight retained, percentage retained, cumulative percentage retained and percentage passing was calculated. The percentage passing was plotted against sieve sizes.

3.4.4 TRIAXIAL TEST

Aim

The aim of the test is to determine the mechanical properties and shear strength of the soil.

Apparatus:

Triaxial testing machine, rubber rings, open ended cylindrical section and weighing balance.

Procedure

1. The soil sample is prepared and set in the triaxial cell. Then the confining pressure is applied.

2. Here, deviator stress is applied, which is an additional axial stress. This induces shear stresses within the sample. The axial stress applied is increased until the soil sample fails.

3. The applied stresses, axial strain and the pore water pressure is measured for both the above steps.

4. Mohr's circle was draw by plotting normal stress against shear stress.

From the test, the following parameter were derived;

σ = Normal stress

τ = Shear Strenght

c = Cohension

ϕ = Angle of internal friction

3.4.5 SPECIFIC GRAVITY TEST

Aim

This test is aimed at determining the specific gravity of the natural soil sample.

Apparatus:

Pycnometer, Weighing Balance, Glass rod.

Procedure

The method will involve the use of pycnometer. The pycnometer will first be carefully dried and weighed as W1. It will be filled with clean water and weighed as W2. The water will be emptied and the bottle will be dried again. Some amount of the oven dried soil will be introduced into the pycnometer and contents will be weighed as W3. Water will be added to the soil and stirred with a glass rod during the process to allow entrapped air to be released. Finally, the bottle will be filled completely with water, dried on the outside and weighed again as W4. The specific gravity of the soil will be calculated using the formula below.

Specific gravity = (W2 – W1)/W

W= (W4-W1)(W3-W2)

3.4.6 NATURAL MOISTURE CONTENT

Aim

This test is aimed at determining the natural moisture content of the soil sample.

Apparatus:

Weighing balance, Containers, Electric oven, Dessicator.

Procedure

An empty container will be weighed to 0.01g on the electronic weighing balance and filled with representative specimen of the soil sample. The container with the soil will then be weighed and recorded. The weight of the empty and filled containers will be taken as M1 and M2 respectively. Afterwards, oven drying for about 24hours will be done at 105 to 110^0c. Then, the container will be placed in desiccators to cool and then reweighed to give M3. The moisture content of the soil will be calculated as a percentage of the dry weight using the equation below:

M= (M2- M3)/ (M3 – M1) x 100%.

Where M = Moisture content in %

M2 = Weight of container + wet soil

M3 = Weight of container + dried soil

M1 = Weight of empty container

CHAPTER FOUR

4.0 RESULTS AND INTERPRETATION

The results of the various geotechnical analysis that were carried out are presented and discussed below.

4.1 ATTERBERG LIMIT TEST RESULT

LIQUID AND PLASTIC LIMITS,LINEAR SHRINKAGE

Sample No:...**SAMPLE P0INT 1, 1.0m** Liquid Limit**: 37.98** Plastic Limit**: 18.71**

Date**: 27/02/2024** Plastic Index**: 19.27**

Location…**EKOSODIN GULLY...**

Description of Soil:…**REDDISH BROWN SOIL....** Operator**....KINGSLEY.**
Proportion of sample retained on No. 36 B.S. Steve = Per cent
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear Shrinkage.
Liquid limit marked L.L. plastic limit marked P.L. Linear shrinkage marked L.S.

Type of Test	**LL**		**LL**		**LL**		**LL**		**LL**	
No. of Blows/shrinkage %	48.00		33.00		23.00		17.00		12.00	
Container No.	NO		AC		JA		KM		MI	
Wt of wet soil & container (g)	40.44		37.37		39.16		37.75		37.05	
Wt of dried soil & container (g)	35.28		31.70		33.10		31.70		31.20	
Wt of container (g)	18.86		15.45		17.16		16.76		17.46	
Wt of dry soil (Wd) (g)	16.42		16.25		15.94		14.94		13.74	
Wt of moisture (Wm) (g)	5.16		5.67		6.06		6.05		5.85	
Moisture contain 100 (Wm/Wd)	31.43		34.89		38.02		40.50		42.58	
Type of Test		**PL**		**PL**		**PL**				**PL**
No. of Blows/shrinkage %										
Container No.		TA		MP		FH				
Wt of wet soil & container (g)		29.49		33.95		29.46				
Wt of dried soil & container (g)		27.57		31.78		27.53				
Wt of container (g)		17.13		20.44		17.15				
Wt of dry soil (Wd) (g)		10.44		11.34		10.38				
Wt of moisture (Wm) (g)		1.92		2.17		1.93				
Moisture contain 100 (Wm/Wd)		18.39		19.14		18.59				

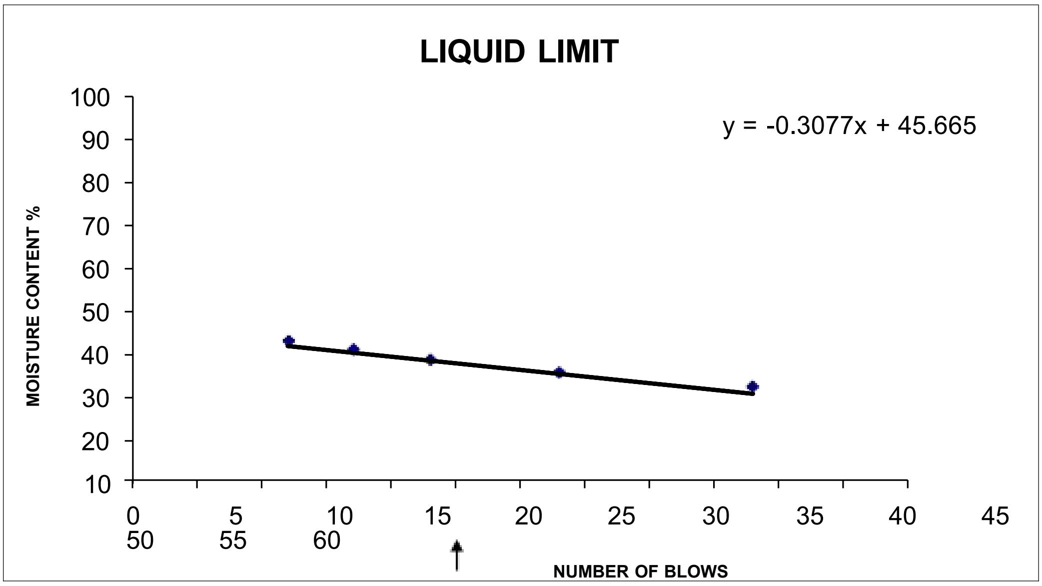

Figure 3: Atterberg limit result for sample point 1,1.0m

LIQUID AND PLASTIC LIMITS,LINEAR SHRINKAGE

Sample No:...**SAMPLE POINT 2, 1.0m** Liquid Limit**: 41.49** Plastic Limit**: 19.95**

Date**: 27/02/2024** Plastic Index**: 21.54**

Location**…EKOSODIN GULLY...**

Description of Soil:…**REDDISH BROWN SOIL....** Operator**.....KINGSLEY**

Proportion of sample retained on No. 36 B.S. Steve = Per cent
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear Shrinkage.
Liquid limit marked L.L. plastic limit marked P.L. Linear shrinkage marked L.S.

Type of Test	**LL**		**LL**		**LL**		**LL**		**LL**	
No. of Blows/shrinkage %	46.00		31.00		25.00		19.00		14.00	
Container No.	PA		GG		FA		UU		SE	
Wt of wet soil & container (g)	41.70		42.15		37.71		41.55		38.21	
Wt of dried soil & container (g)	34.92		35.80		31.17		34.34		32.08	
Wt of container (g)	17.34		19.83		15.05		17.50		18.16	
Wt of dry soil (Wd) (g)	17.58		15.97		16.12		16.84		13.92	
Wt of moisture (Wm) (g)	6.78		6.35		6.54		7.21		6.13	
Moisture contain 100 (Wm/Wd)	38.57		39.76		40.57		42.81		44.04	
Type of Test		**PL**		**PL**		**PL**				**PL**
No. of Blows/shrinkage %										
Container No.		EN		EX		OZ				
Wt of wet soil & container (g)		28.49		31.71		31.36				
Wt of dried soil & container (g)		26.40		29.39		29.06				
Wt of container (g)		15.98		17.95		17.28				
Wt of dry soil (Wd) (g)		10.42		11.44		11.78				
Wt of moisture (Wm) (g)		2.09		2.32		2.30				
Moisture contain 100 (Wm/Wd)		20.06		20.28		19.52				

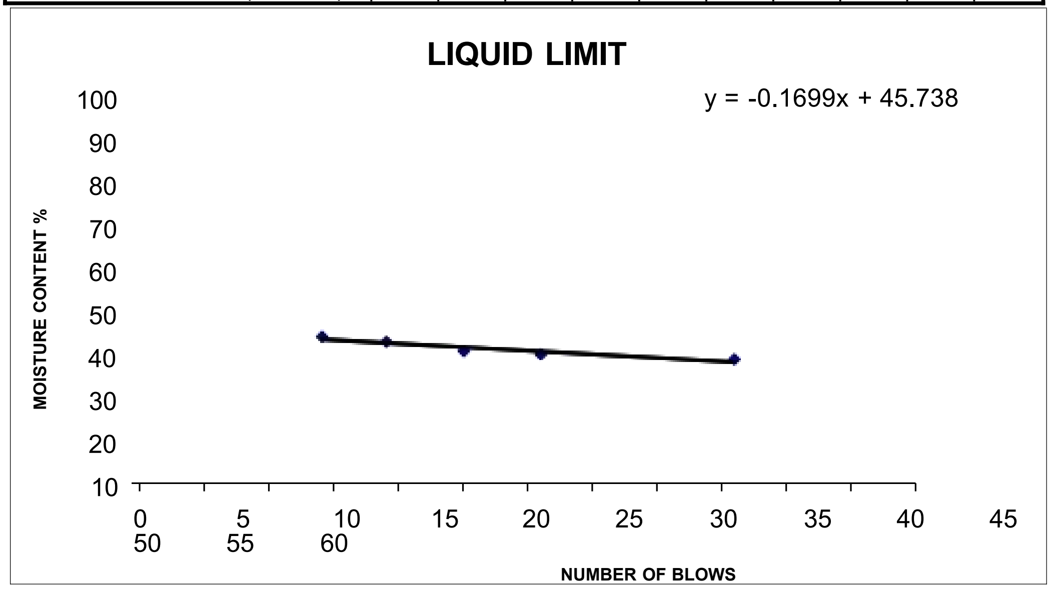

Figure 4: Atterberg limit result for sample point 2,1.0m

LIQUID AND PLASTIC LIMITS,LINEAR SHRINKAGE

Sample No:...**SAMPLE POINT 3, 1.0m** Liquid Limit**: 47.42** Plastic Limit**: 21.16**

Date**: 27/02/2024** Plastic Index**: 26.26**

Location**…EKOSODIN GULLY...**

Description of Soil:…**REDDISH BROWN SOIL....** Operator**....KINGSLEY.**

Proportion of sample retained on No. 36 B.S. Steve = Per cent
No. of blows refers to liquid limit determination.
Shrinkage % refers to linear Shrinkage.
Liquid limit marked L.L. plastic limit marked P.L. Linear shrinkage marked L.S.

Type of Test	**LL**		**LL**		**LL**		**LL**		**LL**	
No. of Blows/shrinkage %	46.00		35.00		24.00		18.00		13.00	
Container No.	UT		NO		RE		PC		NP	
Wt of wet soil & container (g)	37.09		40.58		39.46		37.89		37.61	
Wt of dried soil & container (g)	30.80		33.70		32.40		30.90		31.40	
Wt of container (g)	15.16		18.01		17.51		16.81		19.49	
Wt of dry soil (Wd) (g)	15.64		15.69		14.89		14.09		11.91	
Wt of moisture (Wm) (g)	6.29		6.88		7.06		6.99		6.21	
Moisture contain 100 (Wm/Wd)	40.22		43.85		47.41		49.61		52.14	
Type of Test		**PL**		**PL**		**PL**				**PL**
No. of Blows/shrinkage %										
Container No.		AC		CO		W				
Wt of wet soil & container (g)		24.57		25.41		24.32				
Wt of dried soil & container (g)		23.39		24.01		23.42				
Wt of container (g)		17.92		17.03		19.30				
Wt of dry soil (Wd) (g)		5.47		6.98		4.12				
Wt of moisture (Wm) (g)		1.18		1.40		0.90				
Moisture contain 100 (Wm/Wd)		21.57		20.06		21.84				

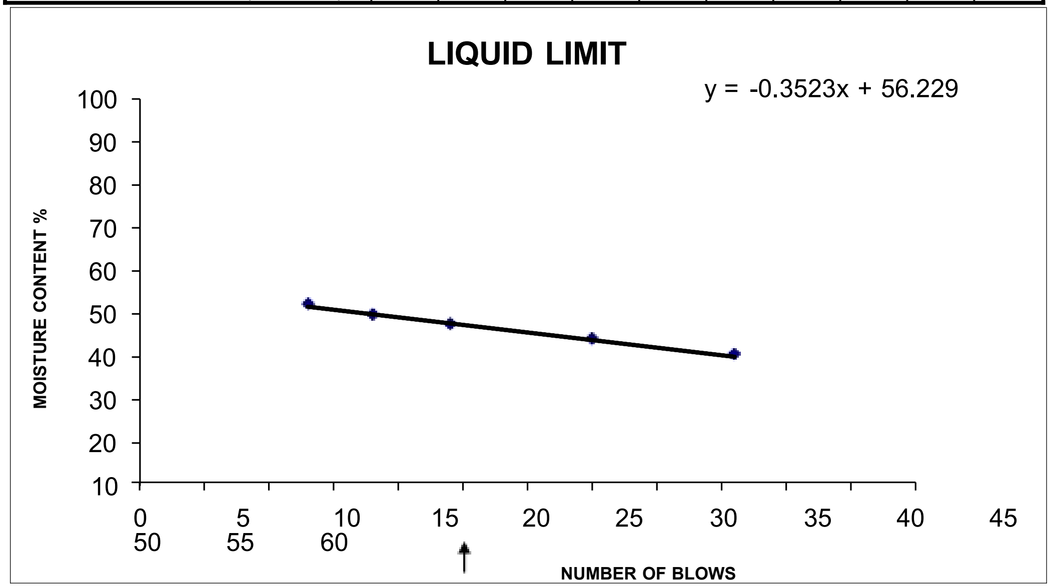

Figure 5: Atterberg limit result for sample point 3,1.0m

4.1.2 COMPACTION TEST RESULTS

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOILUSING STANDARD/HEAVY COMPACTION.

Location...**EKOSODIN GULLY…** Date**: 27/02/2024…**

Site**:........** Sample No**: SAMPLE 1** Depth**:.....1.0m..**

Total weight of Sample**:…3000g……** MDD: **1.71g/cm^3** OPT.MC:**14.3%**

B.S. / C.B.R. Mould….**4723g**

Wt. of mould & wet Soil (W2) g	6329.00	6480.00	6643.00	6635.00	6576.00		
Wt. of mould (W1) g	4723.00	4723.00	4723.00	4723.00	4723.00		
Wt. of wet soil (W2-W1) g	1606.00	1757.00	1920.00	1912.00	1853.00		
Bulk Density (Pb) (W2-W1)/xg/cm^3	1.61	1.76	1.93	1.92	1.86		

MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 995.79cm^3

Container No.	NI	RT	TN	PA	JA	TH	TS	FI	OH	HT				
Wt. of wet soil & container (g)	49.60	53.90	51.40	59.40	44.80	52.00	60.80	56.60	53.50	48.60				
Wt. of Dry soil & container (g)	46.50	50.00	47.30	54.70	41.50	47.40	55.00	51.10	48.65	44.10				
Wt. of Container (g)	20.60	17.10	15.00	17.30	17.50	14.50	17.20	15.50	18.60	16.20				
Wt. of dry soil (Wd) g	25.90	32.90	32.30	37.40	24.00	32.90	37.80	35.60	30.05	27.90				
Wt. of Moisture (Wm) g	3.10	3.90	4.10	4.70	3.30	4.60	5.80	5.50	4.85	4.50				
Moistur Content 100(Wm/Wd) %	11.97	11.85	12.69	12.57	13.75	13.98	15.34	15.45	16.14	16.13				
Average Moisture Content (m) %	11.91		12.63		13.87		15.40		16.13					
Dry Density = Pb/1+ (m/100) (g/cm^3)	1.44		1.57		1.69		1.66		1.60					
C.B.R. (mseen of top & bottom) %														

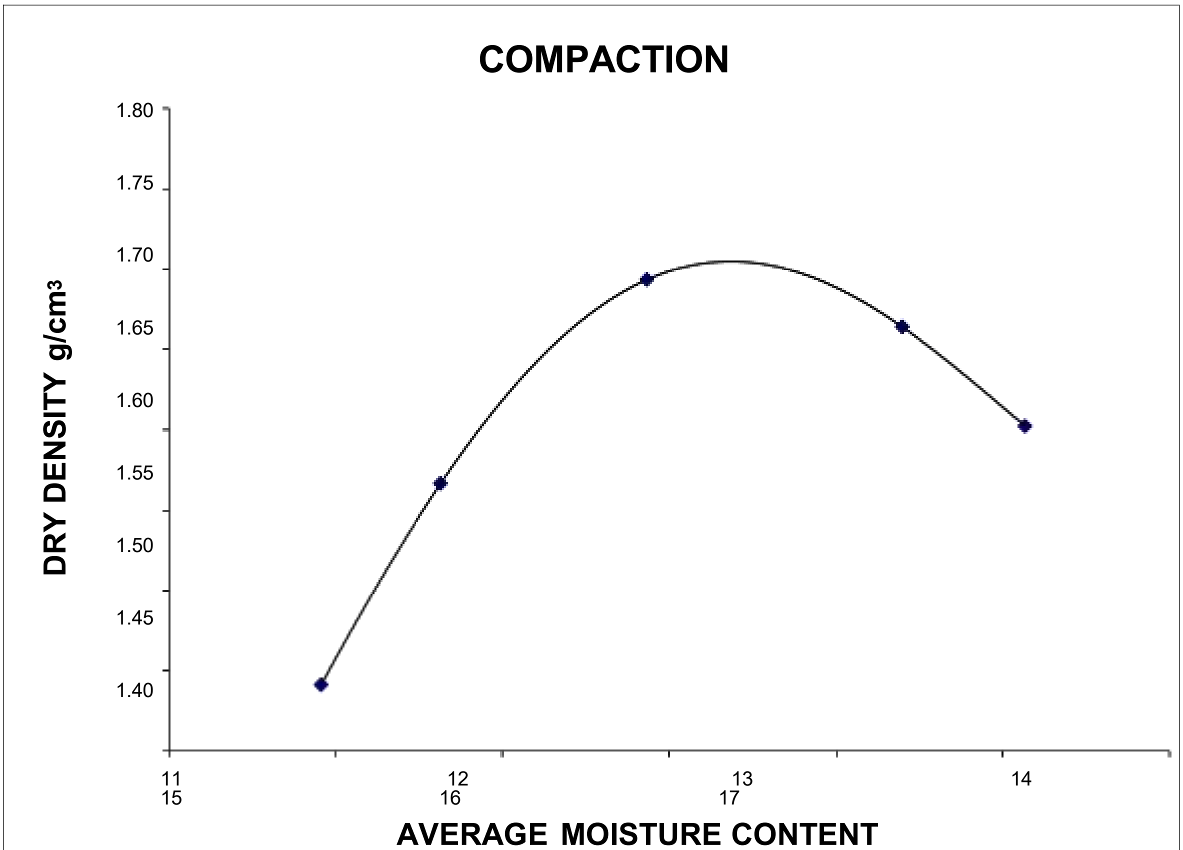

Figure 6: Compaction chart for sample point 1, 1.0m

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOILUSING STANDARD/HEAVY COMPACTION.

Location...**EKOSODIN GULLY...** Date**: 27/02/2024...**

Site**:........** Sample No**: SAMPLE 2** Depth**:.....1.0m..**

Total weight of Sample**:...3000g......** MDD: **1.63g/cm^3** OPT.MC:**16.0%**

B.S. / C.B.R. Mould....**4723g**

Wt. of mould & wet Soil (W2) g	6210.00	6397.00	6590.00	6570.00	6475.00		
Wt. of mould (W1) g	4720.00	4720.00	4720.00	4720.00	4720.00		
Wt. of wet soil (W2-W1) g	1490.00	1677.00	1870.00	1850.00	1755.00		
Bulk Density (Pb) (W2-W1)/xg/cm^3	1.50	1.68	1.88	1.86	1.76		

MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 995.79cm^3

Container No.	RT	BB	OB	TE	JA	NP	PA	PY	CB	BU				
Wt. of wet soil & container (g)	53.80	51.50	51.50	51.10	57.60	51.30	54.10	71.00	48.40	52.80				
Wt. of Dry soil & container (g)	50.20	48.30	47.80	47.40	52.10	46.30	48.40	62.90	43.50	47.20				
Wt. of Container (g)	17.20	18.40	17.70	18.30	16.90	13.90	16.80	18.00	18.20	18.10				
Wt. of dry soil (Wd) g	33.00	29.90	30.10	29.10	35.20	32.40	31.60	44.90	25.30	29.10				
Wt. of Moisture (Wm) g	3.60	3.20	3.70	3.70	5.50	5.00	5.70	8.10	4.90	5.60				
Moistur Content 100(Wm/Wd) %	10.91	10.70	12.29	12.71	15.63	15.43	18.04	18.04	19.37	19.24				
Average Moisture Content (m) %	10.81		12.50		15.53		18.04		19.31					
Dry Density = Pb/1+ (m/100) (g/cm^3)	1.35		1.50		1.63		1.57		1.48					
C.B.R. (mseen of top & bottom) %														

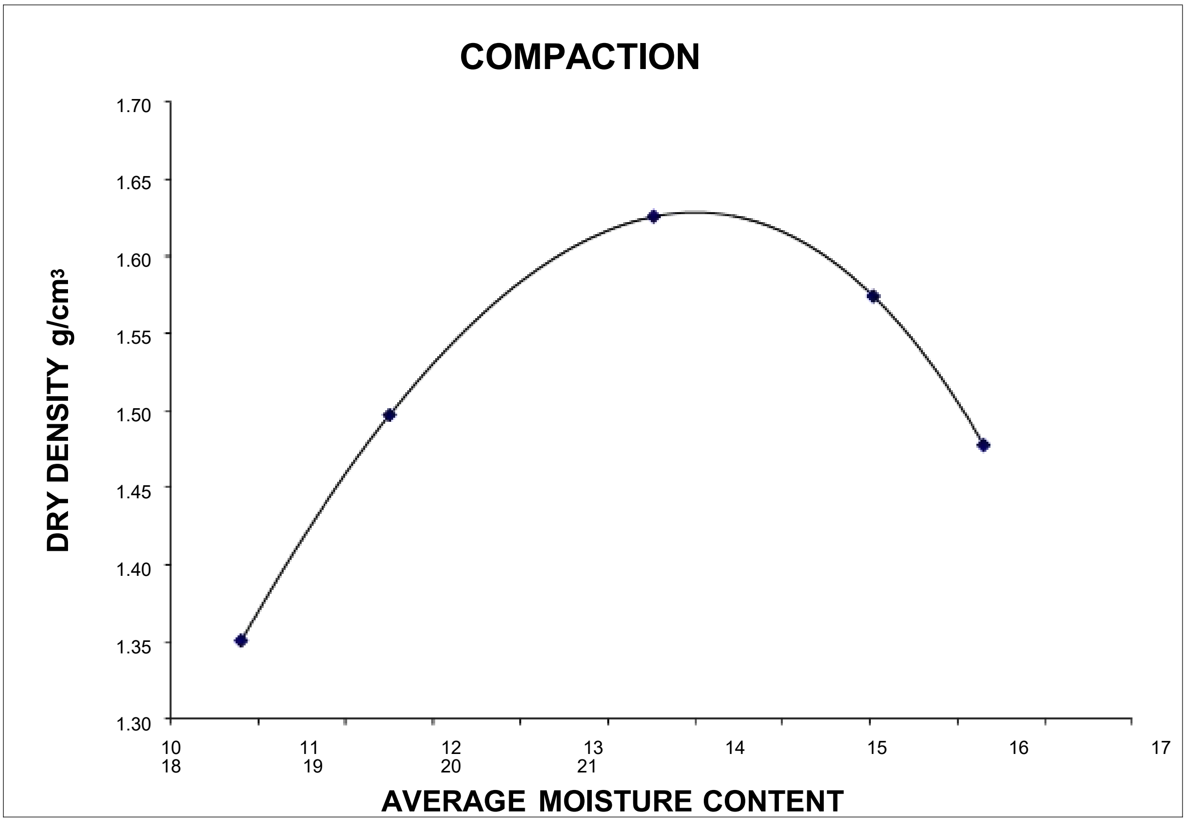

Figure 7: Compaction chart for sample point 2, 1.0m

DETERMINATION OF THE MOISTURE/DENSITY RELATION OF SOILUSING STANDARD/HEAVY COMPACTION.

Location...**EKOSODIN GULLY…** Date**: 27/02/2024…**

Site**:........** Sample No**: SAMPLE 3** Depth**:.....1.0m..**

Total weight of Sample**:…3000g……** MDD: **1.66g/cm^3** OPT.MC:17.2**%**

B.S. / C.B.R. Mould….3078**g**

Wt. of mould & wet Soil (W2) g	4670.00		4858.00		5010.00		4958.00		4850.00					
Wt. of mould (W1) g	3078.00		3078.00		3078.00		3078.00		3078.00					
Wt. of wet soil (W2-W1) g	1592.00		1780.00		1932.00		1880.00		1772.00					
Bulk Density (Pb) (W2-W1)/xg/cm^3	1.60		1.79		1.94		1.89		1.78					
MOISTURE CONTENT DETERMINATIONS	for B.S. Mould, X = 995.79cm^3													
Container No.	OB	AM	OO	PA	IT	CO	AD	XX	UR	KZ				
Wt. of wet soil & container (g)	57.70	60.20	52.30	49.20	59.60	72.60	57.90	67.00	59.00	56.40				
Wt. of Dry soil & container (g)	52.70	54.50	47.70	44.90	53.40	64.80	51.60	59.20	52.10	49.70				
Wt. of Container (g)	17.60	14.10	17.40	17.30	17.70	17.80	18.30	17.90	17.60	16.60				
Wt. of dry soil (Wd) g	35.10	40.40	30.30	27.60	35.70	47.00	33.30	41.30	34.50	33.10				
Wt. of Moisture (Wm) g	5.00	5.70	4.60	4.30	6.20	7.80	6.30	7.80	6.90	6.70				
Moistur Content 100(Wm/Wd) %	14.25	14.11	15.18	15.58	17.37	16.60	18.92	18.89	20.00	20.24				
Average Moisture Content (m) %	14.18		15.38		16.98		18.90		20.12					
Dry Density = Pb/1+ (m/100) (g/cm^3)	1.40		1.55		1.66		1.59		1.48					
C.B.R. (mseen of top & bottom) %														

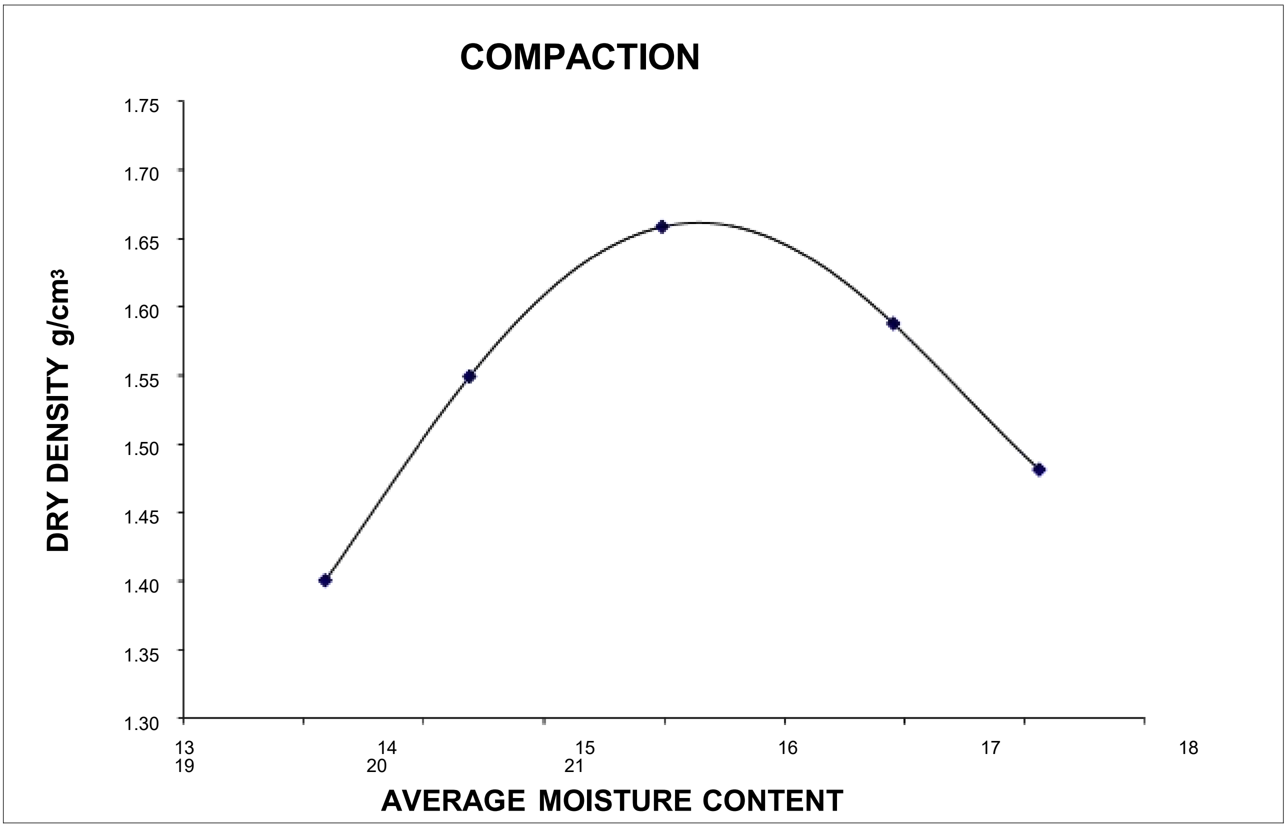

Figure 8: Compaction chart for sample point 3, 1.0m

4.1.3 SIEVE ANALYSIS RESULTS

UNIBEN GEOTECH RESEARCH
GRAIN SIZE ANALYSIS BY WET-SIEVING

LOCATION: **EKOSODIN** DATE: **27/02/2024**

DEPTH: **SAMPLE POINT 1, 1.m** TESTED BY:**…KINGSLEY………**

WEIGHT OF DRY MATERIAL AND CONTAINER IN GRAMMS:……

WEIGHT OF CONTAINER IN GRAMMS...

WEIGHT OF DRY MATERIAL IN GRAMMS:..

SIEVE NO.				
APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
3	75			
2 ½				
2	50			
1 ½	37.5			
1	26.5			
¾	20			
½	14			
⅜	10			
¼	6.3			
3/16	5			
⅛	3.35		100	
7	2.36		100	100
10	2		100	100
14	1.18	2.01	97.99	97.99
25	0.6	15.33	82.66	82.66
36	0.425	9.38	73.28	73.28
52	0.3	15.13	58.15	58.15
72	0.212	10.26	47.89	47.89
100	0.15	3.71	44.18	44.18
200	0.075	4.53	39.65	39.65

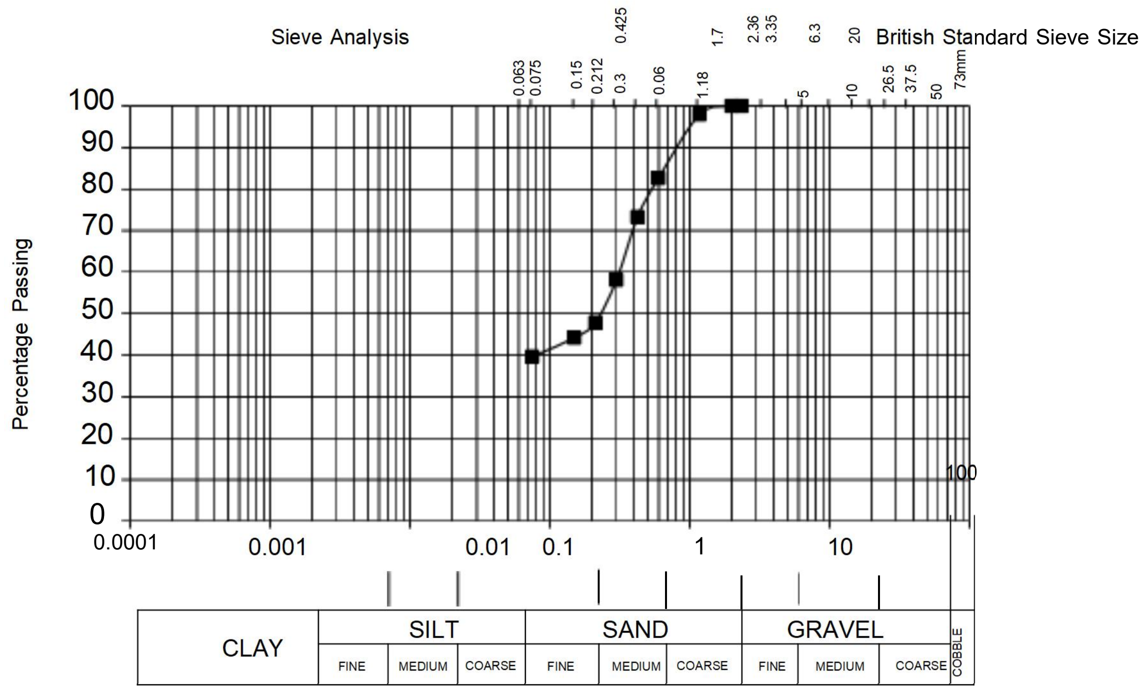

Figure 9: Sieve analysis chart for sample point 1, 1.0m

UNIBEN GEOTECH RESEARCH
GRAIN SIZE ANALYSIS BY WET-SIEVING

LOCATION: **EKOSODIN** DATE: **27/02/2024**

DEPTH: **SAMPLE POINT 2, 1.0m** TESTED BY:**…KINGSLEY………**

WEIGHT OF DRY MATERIAL AND CONTAINER IN GRAMMS:……

WEIGHT OF CONTAINER IN GRAMMS...

WEIGHT OF DRY MATERIAL IN GRAMMS:..

SIEVE NO.				
APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
3	75			
2 ½				
2	50			
1 ½	37.5			
1	26.5			
¾	20			
½	14			
⅜	10			
¼	6.3			
3/16	5			
⅛	3.35		100	
7	2.36		100	100
10	2		100	100
14	1.18	1.5	98.5	98.5
25	0.6	13.8	84.7	84.7
36	0.425	6.4	78.3	78.3
52	0.3	21.7	56.6	56.6
72	0.212	12.3	44.3	44.3
100	0.15	3.5	40.8	40.8
200	0.075	3.3	37.5	37.5

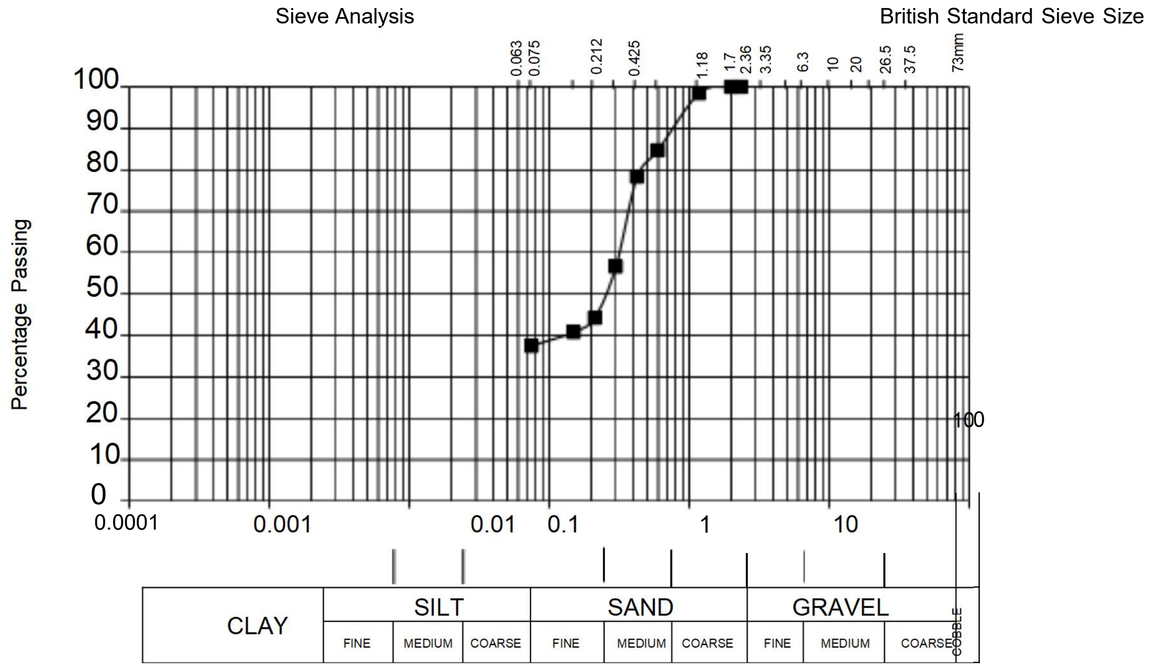

Figure 10: Sieve analysis chart for sample point 2, 1.0m

UNIBEN GEOTECH RESEARCH
GRAIN SIZE ANALYSIS BY WET-SIEVING

LOCATION: **EKOSODIN GULLY** DATE: **27/02/2024**

DEPTH: **SAMPLE 3, 1.0m** TESTED BY:**…KINGSLEY………**

WEIGHT OF DRY MATERIAL AND CONTAINER IN GRAMMS:……

WEIGHT OF CONTAINER IN GRAMMS...

WEIGHT OF DRY MATERIAL IN GRAMMS:...

SIEVE NO.				
APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
3	75			
2 ½				
2	50			
1 ½	37.5			
1	26.5			
¾	20			
½	14			
⅜	10			
¼	6.3			
3/16	5			
⅛	3.35		100	
7	2.36		100	100
10	2	0.7	99.3	99.3
14	1.18	2.4	96.9	96.9
25	0.6	14.3	82.6	82.6
36	0.425	3.8	78.8	78.8
52	0.3	17.2	61.6	61.6
72	0.212	9.8	51.8	51.8
100	0.15	2.7	49.1	49.1
200	0.075	3.7	45.4	45.4

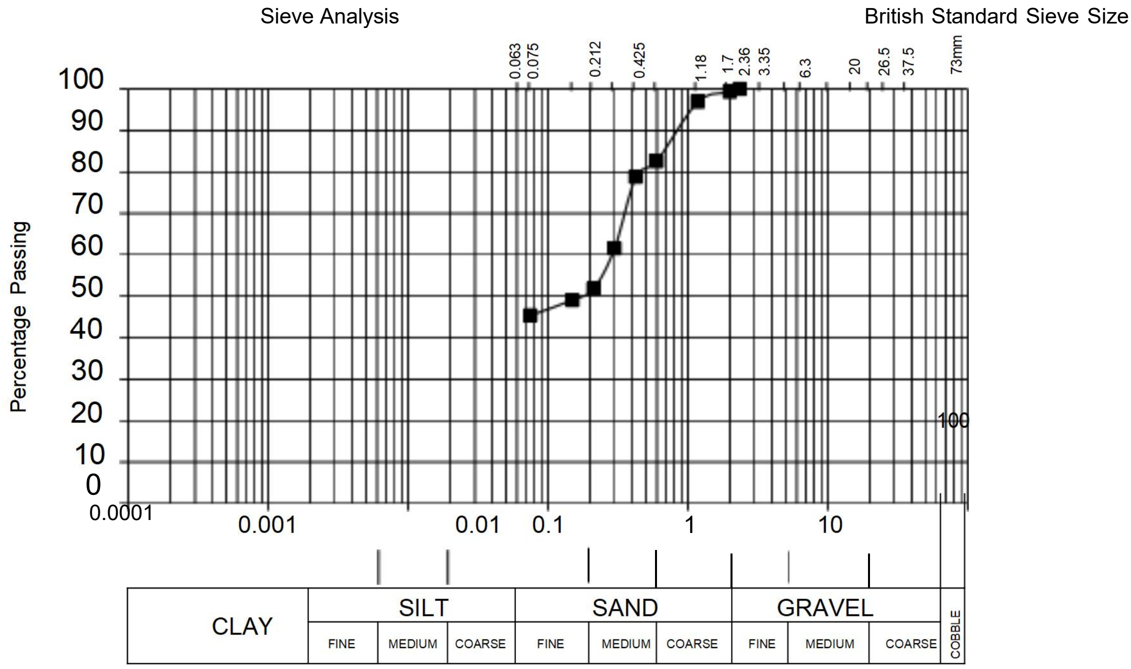

Figure 11: Sieve analysis chart for sample point 3, 1.0m

4.1.4 MOISTURE CONTENT TEST RESULTS

DETERMINATION OF MOISTURE CONTENT OF SOIL PARTICLES
(Standard Laboratory Method)

SITE: EKOSODIN GULLY DATE: **27-02-2024** LOCATION:

S/N	LOCATION	DEPT	CN	WWS+WC	WDS+WC	WC	WDS	WM	MC	AMC
1	**SAMPLE 1**	1.00	OS	124.60	107.40	17.50	89.90	17.20	19.13	18.55
			OS	133.20	116.10	20.90	95.20	17.10	17.96	
2	**SAMPLE 2**	1.00	ZG	132.70	113.40	17.60	95.80	19.30	20.15	19.68
			TB	119.20	102.60	16.20	86.40	16.60	19.21	
3	**SAMPLE 3**	1.00	JA	125.70	107.70	17.10	90.60	18.00	19.87	19.77
			MM	124.70	106.80	15.80	91.00	17.90	19.67	
	MC = Moisture Content ((M2-M3)/(M3-M1))*100 **AMC = average moisture content (MC/2)**									

Figure 12: Moisture content results for sample points 1,2 and 3 at depth 1.0m

4.1.5 SPECIFIC GRAVITY TEST RESULTS

DETERMINATION OF SPECIFIC GRAVITY OF SOIL PARTICLES

(Standard Laboratory Method)

OPERATOR:..KINGSLEY.......

LOCATION: **EKOSODIN GULLY.**

S/N	SAMPLE NO	DEPTH (m)	BN	B+W	B+S+W	B+S	B	Ad. W	WWAS	WS	WOWDS	Gs	AGs
1	SAMPLE 1	1.0	VE	73.90	91.00	50.10	22.80	51.10	40.90	27.30	10.20	2.68	2.63
			SB	78.20	93.00	47.70	23.60	54.60	45.30	24.10	9.30	2.59	
2	SAMPLE 2	1.0	SIV	73.30	92.70	51.20	19.60	53.70	41.50	31.60	12.20	2.59	2.64
			UH	74.90	91.50	49.20	22.80	52.10	42.30	26.40	9.80	2.69	
3	SAMPLE 3	1.0	CY	74.40	93.90	51.70	20.10	54.30	42.20	31.60	12.10	2.61	2.61
			JTI	73.20	94.50	54.40	19.90	53.30	40.10	34.50	13.20	2.61	

B+W = Wt. of Bottle + Water (full) W4
B+S+W = Wt. of Bottle + Soil+ Water W3
B+S = Wt. of Bottle + Soil W2
B = Wt. of Bottle W1
Ad.W = Wt. of Added Water (full) (W4-W1)
WWAS = Wt. of Water added to Soil (W3-W2)
WS = Wt. of Soil (W2-W1)
WOWDS = Wt. of Water Displaced by Soil (W4-W1)-(W3-W2) = W
GS= Specific Gravity (W2-W1)/W

Figure 13: Specific gravity results for sample points 1,2 and 3 at depth 1.0m

4.1.6 TRIAXIAL TEST RESULTS

GEOTECHNICAL ENGINEERING LABORATORY TEST

TRIAXIAL COMPRESSION TEST

SITE…**EKOSODIN GULLY**…… LOCATION: **………..** DATE:27/**02/2024**………

SAMPLE NO …**SAMPLE 1, 1.00m**…… BULK DENSITY:…**1.75Kg/m³**… CELL PRESSURE: **100, 205, 310KN/m**

FRICTION ANGLE:. …**5.19º**.… COHESION **:…32.0kN/m²**….. WET WEIGHT:…**140g,154g,156g**..

Strain Dial	Stress Dial 1	SD2	SD3	Stress Dial Diff	SDD2	SDD3	Area Sq m	Compressive Stress	CS2	CS3	Strain %			
0	0	0	0	0.00	0.00	0.00	0.00114	0.00	0.00	0.00	0.00			
15	4.5	5	9.5	0.02	0.02	0.04	0.00115	16.70	18.55	35.25	0.50			
30	6	6	14	0.03	0.03	0.06	0.00115	22.26	22.26	51.95	1.00			
45	7	7.8	17	0.03	0.03	0.07	0.00116	25.75	28.69	62.5	1.50			
60	9.5	10.8	19	0.04	0.05	0.08	0.00116	34.95	39.73	4	2.00			
75	11	12.2	20.5	0.05	0.05	0.09	0.00117	40.12	44.5	69.90	2.50			
90	12.5	13.8	22	0.05	0.06	0.09	0.00118	45.20	0	74.77	3.00			
105	13	14.2	23	0.06	0.06	0.10	0.00118	47.01	49.91	79.56	3.50			
120	14	16	24	0.06	0.07	0.10	0.00119	50.20	51.35	83.18	4.00			
135	15	18.2	25.8	0.06	0.08	0.11	0.00119	53.79	57.38	86.06	4.50			
150	16	19.5	27	0.07	0.08	0.12	0.00120	56.90	65.27	92.52	5.00			
165	16.5	20	28	0.07	0.09	0.12	0.00121	58.19	69.34	96.02	5.50			
180	17	21.3	29	0.07	0.09	0.12	0.00121	59.95	70.53	98.75	6.00			
210	18	22	31.5	0.08	0.09	0.13	0.00122	62.96	75.12	102.28	7.00			
240	19	23.5	34	0.09	0.10	0.15	0.00124	70.55	76.95	110.18	8.00			
270	20.5	25	36	0.09	0.11	0.15	0.00125	75.11	80.87	117.01	9.00			
300	22	26.8	37	0.10	0.11	0.16	0.00127	77.28	85.35	122.90	10.00			
330	23	28	38	0.11	0.12	0.16	0.00128	85.01	90.05	124.32	11.00			
360	25.5	29.5	39	0.11	0.13	0.17	0.00130	86.99	93.35	126.69	12.00			
390	26.5	30	39.5	0.12	0.13	0.17	0.00131	91.21	96.84	128.02	12.00			
420	28	31	40	0.12	0.13	0.17	0.00131	94.47	97.73	128.67	13.00			
450	29	32.9	40	0.13	0.14	0.17	0.00133	94.65	100.98	130.30	14.00			
480	29.5	33.2	40	0.13	0.14	0.17	0.00134	95.54	105.56	128.34	15.00			
510	30	34.5	40	0.13	0.15	0.17	0.00136	94.13	105.73	127.38	16.00			
540	30	34.5	40	0.13	0.15	0.17	0.00137	93.45	108.25	125.51	17.00			
570	30	34.5	40	0.13	0.15	0.17	0.00139	92.10	107.46	124.59	18.00			
600	30	34.5	40	0.13	0.15	0.17	0.00139	92.10	105.92	122.80	19.00			
630	30	34.5	40	0.13	0.15	0.17	0.00143	89.52	105.92	122.80	20.00			
660	30	34.5	40	0.13	0.15	0.17	0.00144	88.90	102.95	119.37	21.00			
690	30	34.5	40	0.13	0.15	0.17	0.00146	87.69	102.24	118.54	22.00			
720	30	34.5	40	0.13	0.15	0.17	0.00150	85.35	100.84	116.91	24.00			
750	30	34.5	40	0.13	0.15	0.17	0.00152	84.22	98.15	113.80	25.00			
				∂1	**Radius**	**Centre**								
	1	100.00	95.54	195.54	47.7688	147.769								
		0.00	26.42	35.59	41.37	45.05	47.10	**47.77**	47.10	45.05	41.37	35.59	26.42	**0.00**
		100.00	107.98	115.91	123.88	131.86	139.79	**147.77**	155.75	163.68	171.65	179.63	187.56	**195.54**
	2	205.00	108.25	313.25	54.1263	259.126								
		0.00	29.93	40.32	46.87	51.04	53.37	**54.13**	53.37	51.04	46.87	40.32	29.93	**0.00**
		205.00	214.04	223.02	232.06	241.10	250.09	**259.13**	268.17	277.15	286.19	295.23	304.21	**313.25**
	3	310.00	130.30	440.30	65.1504	375.15								
		0.00	36.03	48.54	56.42	61.44	64.24	**65.15**	64.24	61.44	56.42	48.54	36.03	**0.00**
		310.00	320.88	331.70	342.58	353.46	364.27	**375.15**	386.03	396.85	407.73	418.61	429.42	**440.30**

DESCRIPTION OF SAMPLE

……………………………………
…………………

……………………………………

SKETCH OF SAMPLE AFTER SHEAR

Compressive Sress

Corresponding Strain

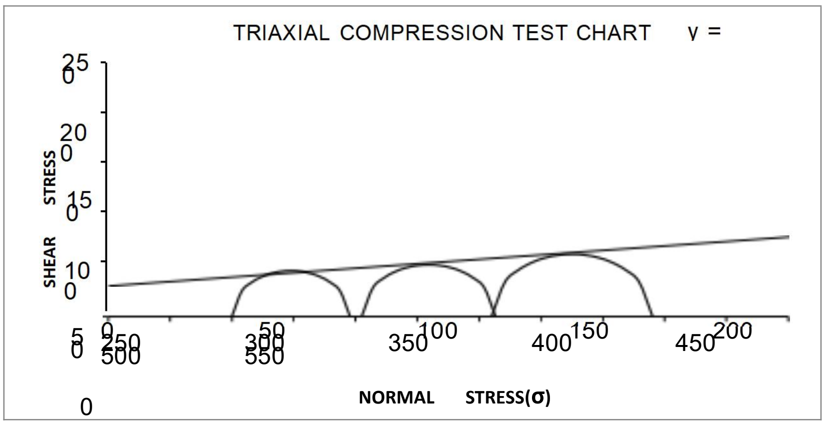

Figure 14: Triaxial compression chart for sample point 1, 1.0m

GEOTECHNICAL ENGINEERING LABORATORY TEST

TRIAXIAL COMPRESSION TEST

SITE… **EKOSODIN GULLY** …… LOCATION: **..........** DATE:27**/02/2024 ………**

SAMPLE NO **…SAMPLE 2, 1.0m** BULK DENSITY:**…1.68Kg/m³…** CELL PRESSURE: **100, 205, 310KN/m**

FRICTION ANGLE:. ...**6.28º..**… COHESION **:...30.5kN/m²** ….. WET WEIGHT:...**138g,142g,154g**..

Strain Dial	Stress Dial 1	SD2	SD3	Stress Dial Diff	SDD2	SDD3	Area Sq m	Compressive Stress	CS2	CS3	Strain %
0	0	0	0	0.00	0.00	0.00	0.00114	0.00	0.00	0.00	0.00
15	6.5	4.5	3.5	0.03	0.02	0.01	0.00115	24.12	16.70	12.99	0.50
30	8.0	6.3	4	0.03	0.03	0.02	0.00115	29.69	23.38	14.84	1.00
45	9.9	7.5	4.5	0.04	0.03	0.02	0.00116	36.42	27.59	16.55	1.50
60	11	8	5	0.05	0.03	0.02	0.00116	40.47	29.43	18.39	2.00
75	12	8.5	5.1	0.05	0.04	0.02	0.00117	43.77	31.00	18.60	2.50
90	13	9	6	0.06	0.04	0.03	0.00118	47.01	32.55	21.70	3.00
105	14.1	9.3	6.5	0.06	0.04	0.03	0.00118	50.99	33.63	23.51	3.50
120	15.1	10.5	12	0.06	0.04	0.05	0.00119	54.15	37.65	43.03	4.00
135	16.5	11	14	0.07	0.05	0.06	0.00119	59.17	39.45	50.20	4.50
150	18.0	11.8	17.5	0.08	0.05	0.07	0.00120	64.01	41.96	62.23	5.00
165	18.9	12.5	19.9	0.08	0.05	0.08	0.00121	66.66	44.08	70.18	5.50
180	19.0	13	22	0.08	0.06	0.09	0.00121	67.01	45.85	77.59	6.00
210	21.0	15	26	0.09	0.06	0.11	0.00122	73.45	52.47	90.94	7.00
240	22.5	17.5	31	0.11	0.07	0.13	0.00124	86.04	60.22	106.68	8.00
270	25	20	33.5	0.11	0.09	0.14	0.00125	85.35	68.28	114.36	9.00
300	25	22.5	36	0.11	0.10	0.15	0.00127	87.70	75.60	120.96	10.00
330	26.1	25	39	0.12	0.11	0.17	0.00128	90.01	83.35	130.02	11.00
360	27	28	41.9	0.12	0.12	0.18	0.00130	88.96	91.91	137.54	12.00
390	27.1	30.3	44	0.12	0.13	0.19	0.00131	88.60	98.70	143.33	12.00
420	27.2	31.8	46	0.12	0.14	0.20	0.00131	88.60	103.59	149.85	13.00
450	27.2	33	48	0.12	0.14	0.20	0.00133	87.27	105.88	154.01	14.00
480	27.2	34.9	50	0.12	0.15	0.21	0.00134	86.62	111.14	159.23	15.00
510	27.2	36	51.5	0.12	0.15	0.22	0.00136	85.35	112.96	161.59	16.00
540	27.2	36.9	52.5	0.12	0.16	0.22	0.00137	84.72	114.94	163.53	17.00
570	27.2	37.5	52.9	0.12	0.16	0.23	0.00139	83.50	115.13	162.40	18.00
600	27.2	38	52.9	0.12	0.16	0.23	0.00139	83.50	116.66	162.40	19.00
630	27.2	38.3	52.9	0.12	0.16	0.23	0.00143	81.17	114.29	157.86	20.00
660	27.2	38.5	52.9	0.12	0.16	0.23	0.00144	80.61	114.09	156.77	21.00
690	27.2	39	52.9	0.12	0.17	0.23	0.00146	79.50	113.99	154.62	22.00
720	27.2	39.5	52.9	0.12	0.17	0.23	0.00150	77.38	112.37	150.50	24.00
750	27.2	39.8	52.9	0.12	0.17	0.23	0.00152	76.36	111.74	148.52	25.00

			∂1	Radius	Centre								
1	100.00	90.01	190.01	45.0072	145.007								
	0.00	24.89	33.53	38.98	42.44	44.38	**45.01**	44.38	42.44	38.98	33.53	24.89	**0.00**
	100.00	107.52	114.99	122.50	130.02	137.49	**145.01**	152.52	159.99	167.51	175.03	182.50	**190.01**
2	205.00	116.66	321.66	58.3307	263.331								
	0.00	32.26	43.46	50.51	55.01	57.51	**58.33**	57.51	55.01	50.51	43.46	32.26	**0.00**
	205.00	214.74	224.42	234.17	243.91	253.59	**263.33**	273.07	282.75	292.50	302.24	311.92	**321.66**
3	310.00	163.53	473.53	81.7649	391.765								
	0.00	45.22	60.91	70.81	77.10	80.62	**81.76**	80.62	77.10	70.81	60.91	45.22	**0.00**
	310.00	323.65	337.23	350.88	364.54	378.11	**391.76**	405.42	418.99	432.65	446.30	459.88	**473.53**

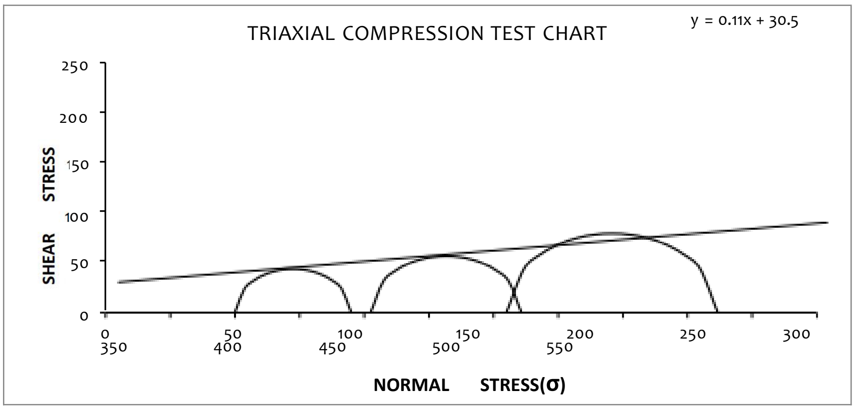

Figure 15: Triaxial compression chart for sample point 2, 1.0m

GEOTECHNICAL ENGINEERING LABORATORY TEST

TRIAXIAL COMPRESSION TEST

SITE… **EKOSODIN GULLY** …… LOCATION: **...........** DATE: **27/02/2024** ………

SAMPLE NO…**SAMPLE 3, 1.0m**…… BULK DENSITY:…**1.75Kg/m^3**… CELL PRESSURE: **100, 205, 310KN/m^2**

FRICTION ANGLE:. ...**2.71º**..… COHESION **:...30.0kN/m²**..… WET WEIGHT:...**148g,145g,158g**

Strain Dial	Stress Dial 1	SD2	SD3	Stress Dial Diff	SDD2	SDD3	Area Sq m	Compressive Stress	CS2	CS3	Strain %
0	0	0	0	0.00	0.00	0.00	0.00114	0.00	0.00	0.00	0.00
15	8	5	6	0.03	0.02	0.03	0.00115	29.69	18.55	22.26	0.50
30	10.0	6	8	0.04	0.03	0.03	0.00115	37.11	22.26	29.69	1.00
45	11	6	9	0.05	0.03	0.04	0.00116	40.47	22.07	33.11	1.50
60	12.2	6.5	9	0.05	0.03	0.04	0.00116	44.88	23.91	33.11	2.00
75	12.3	7	9.8	0.05	0.03	0.04	0.00117	44.86	25.53	35.74	2.50
90	12.4	7.5	10.2	0.05	0.03	0.04	0.00118	44.84	27.12	36.89	3.00
105	12.5	8	11	0.05	0.03	0.05	0.00118	45.20	28.93	39.78	3.50
120	12.7	8.8	11.5	0.05	0.04	0.05	0.00119	45.54	31.56	41.24	4.00
135	12.8	9	11.8	0.05	0.04	0.05	0.00119	45.90	32.27	42.31	4.50
150	12.9	10	12	0.06	0.04	0.05	0.00120	45.87	35.56	42.67	5.00
165	13	10.5	12.2	0.06	0.04	0.05	0.00121	45.85	37.03	43.03	5.50
180	13.2	12	13	0.06	0.05	0.06	0.00121	46.55	42.32	45.85	6.00
210	14.2	13	15	0.06	0.06	0.06	0.00122	49.67	45.47	52.47	7.00
240	15	15	16.5	0.07	0.06	0.07	0.00124	52.65	51.62	56.78	8.00
270	15.3	15	19	0.07	0.06	0.08	0.00125	55.30	51.21	64.86	9.00
300	16.2	17	20	0.07	0.07	0.09	0.00127	58.13	57.12	67.20	10.00
330	17.3	17	22	0.08	0.07	0.09	0.00128	60.01	56.68	73.35	11.00
360	18	20	24	0.08	0.09	0.10	0.00130	59.09	65.65	78.78	12.00
390	18	22	24	0.08	0.09	0.10	0.00131	61.89	71.67	78.18	12.00
420	19	22.5	25	0.08	0.10	0.11	0.00131	63.52	73.29	81.44	13.00
450	19.5	24	25.5	0.09	0.10	0.11	0.00133	64.17	77.00	81.82	14.00
480	20	25	27	0.09	0.11	0.12	0.00134	66.88	79.61	85.98	15.00
510	21	26	28	0.09	0.11	0.12	0.00136	66.83	81.58	87.86	16.00
540	21.3	26	28	0.09	0.11	0.12	0.00137	66.97	80.99	87.22	17.00
570	21.5	26	29.2	0.09	0.11	0.12	0.00139	66.01	79.82	89.65	18.00
600	21.5	26	30	0.09	0.11	0.13	0.00139	66.01	79.82	92.10	19.00
630	21.5	26	30	0.09	0.11	0.13	0.00143	64.16	77.59	89.52	20.00
660	21.5	26	30	0.09	0.11	0.13	0.00144	63.71	77.05	88.90	21.00
690	21.5	26	30	0.09	0.11	0.13	0.00146	62.84	75.99	87.69	22.00
720	21.5	26	30	0.09	0.11	0.13	0.00150	61.17	73.97	85.35	24.00
750	21.5	26	30	0.09	0.11	0.13	0.00152	60.36	72.99	84.22	25.00

			∂1	Radius	Centre								
1	100.00	66.97	166.97	33.4847	133.485								
	0.00	18.52	24.95	29.00	31.58	33.02	**33.48**	33.02	31.58	29.00	24.95	18.52	**0.00**
	100.00	105.59	111.15	116.74	122.33	127.89	**133.48**	139.08	144.64	150.23	155.82	161.38	**166.97**
2 205.00		81.58	286.58	40.7908	245.791								
	0.00	22.56	30.39	35.32	38.47	40.22	**40.79**	40.22	38.47	35.32	30.39	22.56	**0.00**
	205.00	211.81	218.58	225.40	232.21	238.98	**245.79**	252.60	259.37	266.19	273.00	279.77	**286.58**
3 310.00		92.10	402.10	46.0505	356.051								
	0.00	25.47	34.31	39.88	43.43	45.41	**46.05**	45.41	43.43	39.88	34.31	25.47	**0.00**
	310.00	317.69	325.33	333.03	340.72	348.36	**356.05**	363.74	371.39	379.08	386.77	394.41	**402.10**

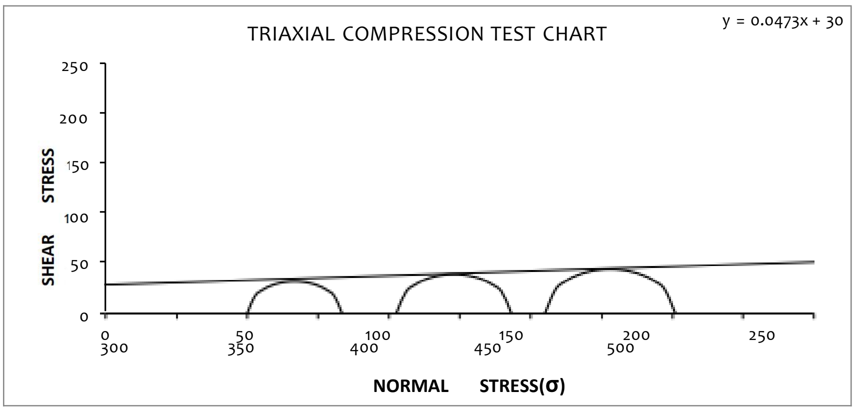

Figure 16: Triaxial compression chart for sample point 3, 1.0m

4.2 DISCUSSION

The sieve analysis results provide a detailed look at the particle size distribution within the soil samples. These samples (*as seen in figures 9,10 and 11*), characterized by their reddish-brown hue, are positioned below the A-line on the Unified Soil Classification System (USCS) chart. This placement categorizes them as silts, which are known for their moderate infiltration rates. Such rates often lead to increased surface runoff, a contributing factor in the development of gullies.

In examining the specific gravity of samples(*Figure 13*) from the gully site, we find a range between 2.61 and 2.64. Specifically, sample point 1 has a specific gravity of 2.63, sample point 2 has 2.64, and sample point 3 has 2.61. Referencing the classification system proposed by Bowles (2012), these values suggest a notable presence of organic content within the soil, classifying them as organic soils. The significance of organic matter in soils is twofold: it can absorb and retain rainfall, thereby reducing the volume of surface runoff, and it can support the growth of vegetation. Vegetation plays a pivotal role in slope stabilization and erosion prevention, as plant roots help anchor the soil. However, there are potential downsides to this. In instances where rainfall is excessive and the soil retains water to the point of saturation, the likelihood of runoff increases. This runoff can initiate erosion by transporting away loose organic materials. As the organic-rich topsoil is eroded, the more erosion-prone mineral soil beneath is exposed, leading to the formation of channels and gullies.

The Atterberg limit tests(*Figures 3, 4 and 5*) offer further insight into the soil's properties. For sample point 1, the liquid limit is 37.98%, the plastic limit is 18.71%, and the plastic index is 19.27%. For sample point 2, the liquid limit is 41.49%, the plastic limit is 19.95%, and the plastic index is 21.54%. Lastly, for sample point 3, the liquid limit is 47.42%, the plastic limit is 21.16%, and the plastic index is 26.26%. The liquid limit indicates the moisture content at which soil transitions from a plastic to a liquid state. Given the liquid limits of the samples from the gully site, it can be inferred that the soil has a medium liquid limit. Soils with medium liquid limits tend to become quite fluid upon reaching this moisture content, making them susceptible to becoming soft and unstable when saturated. This instability can lead to issues such as landslides or slumps, which contribute to gully erosion. The plastic limit, on the other hand, represents the moisture content at which soil can be molded and retain its shape but cannot be rolled into threads without crumbling. Soils with low plastic limits are less likely to experience significant volume changes with varying water content, which can enhance their resistance to erosion. Considering the plastic limits of the gully site samples, the soil exhibits relatively low plasticity. Additionally, the plasticity index, which is the difference between the liquid limit and the plastic limit (PI = LL - PL), provides an indication of the range of moisture contents over which the soil remains plastic. Soils with higher plasticity indices contain a larger proportion of fine particles and exhibit greater plasticity. The plasticity index values from the gully site suggest that the soil has a medium to high plasticity index, indicating a propensity for volume changes with moisture content variations, making the soil softer and more prone to erosion when saturated.

Compaction tests (*figures 6, 7 and 8*) conducted on the soil samples yield maximum dry density (MDD) and optimum moisture content (OMC) values that are crucial for understanding soil stability. The first sample point has an MDD of 1.71g/cm^3 and an OMC of 14.3%, the second sample point has an MDD of 1.63g/cm^3 and an OMC of 16.0%, and the third sample point has an MDD of 1.66g/cm^3 and an OMC of 17.2%. The MDD represents the highest density that soil can achieve under compaction, while the OMC is the moisture content at which the soil reaches its MDD. The test results suggest that the soil from the gully site achieves its maximum density within a moisture content range of 14.3% to 17.2%. A higher OMC indicates that the soil retains a significant amount of moisture even when compacted to its densest state. Soils with a higher moisture content can be less stable and more susceptible to erosion because the excess water can weaken the soil structure, making it more vulnerable to erosion processes.

The triaxial test results (*Figures 14, 15 and 16)* reveal critical aspects of the soil's mechanical properties. The soil exhibits a relatively low friction angle coupled with substantial cohesion. A low friction angle indicates a high susceptibility to shearing forces and deformation, particularly under external pressures such as flowing water. This characteristic points to a low bearing capacity of the soil, which, when subjected to the erosive forces of water, is likely to be easily mobilized and carried away, thus promoting gully formation. Conversely, the observed substantial cohesion suggests that the soil possesses a significant amount of internal bonding strength. Cohesion is a key factor in resisting erosion and maintaining soil integrity, especially when water flow is slow or intermittent. However, this cohesion may not be sufficient to counteract the low friction angle when the soil is exposed to intense water flow or prolonged rainfall, which can exacerbate erosion and contribute to gully development.

CHAPTER FIVE

5.0 CONCLUSION

Gully erosion has proven to pose a significant environmental challenge in the study area in Ekosodin. Geotechnical results gotten from the investigations so far (The sieve analysis, specific gravity, Atterberg and plasticity, compaction and triaxial tests), has shown that the soil in the area has a high water runoff due to its low infiltration rate, low plasticity and a relatively high optimum moisture content, hence the occurrence of the gully in that area. The shear strength of the soil due to it's low bearing capacity also contributes significantly to the cause of the gully erosion. The impacts includes but not limited to; Loss of farmlands, Destruction of valuable properties, Loss of vegetation etc.

5.1 RECOMMENDATION

In efforts to mitigate the impacts presented by the gully, the following solutions are proffered to avoid further spread of the gully.

i. Drainage control: By designing proper drainage management systems to help reduce excess water which can reduce the friction angle. Effective drainage systems can help maintain optimal soil conditions.

ii. Vegetation: By planting vegetations with strong root systems which help stabilize the soil and increase its friction degree.

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