# GEOTECHNICAL PROFILE OF SELECTED BORROW PITS IN EYENKORIN AND AFON, KWARA STATE


**BY**

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# CERTIFICATION

This is to certify that this research study was conducted by YUSUF, Abdulqudus Olatunji (HND/23/CEC/FT/0265) and had been read and approved as meeting the requirements for the award of Higher National Diploma (HND) in Civil Engineering of the Department of Civil Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin.

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# DEDICATION

This project is wholeheartedly dedicated to **God Almighty**, for His grace, wisdom, and strength throughout the course of this work.

My B**eloved Parents**, for their endless love, prayers, and unwavering support that have shaped my academic journey.

To my **Lecturers and Supervisors**, whose guidance and encouragement have been invaluable. And to all my **Friends and Colleagues**, for their inspiration, assistance, and companionship throughout this project.

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# ABSTRACTS

*This research focuses on the geotechnical profiling of selected borrow pits in EYENKORIN and AFON, located in Kwara State, Nigeria. The study was undertaken to evaluate the engineering properties of soils obtained from these borrow pits and to assess their suitability for use in road construction and other civil engineering works. In addition, the study aims to highlight the potential environmental impacts associated with borrow pit excavation and propose recommendation for sustainable usage. Soil samples were collected from multiple borrow pit sites and subjected to standard laboratory tests, including grain size analysis (sieve analysis), Atterberg limits, compaction tests, and california Bearing Ratio (CBR) tests. The grain size analysis revealed that the soils are predominantly lateritic with varying percentage of send, silt, and clay. The Atterberg limits indicated that the soils possess moderate plasticity, which is acceptable for use in subgrade and sub-base layers. Compaction test results shows good maximum dry densities and optimum moisture contents, which are essential for achieving soil stability under load. The CBR values obtained ranged from fair to good, futher confirming the potential use of these soils in pavement construction. Based on the findings, the study concludes that with proper site selection, material quality control, and responsible excavation practices, the borrow pits in EYENKORIN and AFON can serve as reliable sources of construction material. It is recommended that authorities enforce environmental regulations, ensure periodic testing, and mandate post-excavation rehabilitation of borrow pits to minimize environmental degradation and promote sustainability. This project contribute valuable data for engineers, planners, and decision- makers involved in material sourcing and infrastructure development within Kwara State and similar regions*

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## CHAPTER ONE

### 1.0 Introduction

Borrow pits are one of the major sources of construction materials and are a common sight along most highways, since they are used to obtain soils and rock materials for construction activities. A borrow pit is defined as an excavation formed by the removal of material from the ground surface in order to establish the fill and subgrade platforms of a road construction project or any construction work that may require compacted fill. Upon the completion of the construction, the battements or escarpments of these pits are neither reclaimed nor modeled to any form. Notwithstanding that these pits contribute to the economy of the country by providing essential materials for the construction industry, they have a significant impact on the environment and the geomorphological evolution of an area. It is with this background that an investigation of the effect of continuous activities of borrows pits were necessary. (Aka et al.2022)

Kwara State is located in the North Central geopolitical zone of Nigeria, an emerging industrial state with a vibrant infrastructure to support the numerous industrial activities and the economy of the state. The major towns of AFON, to the south, and EYENKORIN, to the north, are surrounded by a fast-growing rural area, situated at latitude 8°31′60″N and longitude 4°41′60″E and 4°41′0″E, 4°42′0″E respectively. The state capital, Ilorin, is bounded by latitude

8°59′60″N and longitude 4°33′0″E and 4°44′60″E. The state is crisscrossed by the Federal Road Network connecting it to other states. The road outings, renovation, and landscape construction are continuously increasing the demand for good quality building sand and filling material for backfilled and graded spills for extra and dangerous excavated cut slopes. These building materials are usually obtainable from excavations in the distant upstream drains, streams, rivers, and larger water bodies. (Lasisi & Ozurumba, 2021).

The study focus on evaluating soil characteristics, such as grain size distribution, moisture content, Atterberg limits, Compaction test C.B.R, and bearing capacity, to determine the suitability of these materials for engineering applications. Such assessments are crucial as they directly influence project stability and durability. According to Adeyemi et al. (2017), understanding the geotechnical properties of soils from borrow pits can prevent construction failures, ensure compliance with safety standards, and improve material selection processes.

Given the increased construction activities in Kwara State, this study aims to provide a geotechnical profile that will inform engineers, developers, and local authorities. The project will also address environmental concerns related to soil extraction and site management (Uche, 2021). By compiling comprehensive data on the soil profiles of borrow pits in Eyenkorin and Afon, this research will contribute to sustainable construction practices and resource optimization in the region.

## 1.1 Background of the Study

Borrow pits are excavations from which construction materials, such as sand, gravel, and clay, are extracted. These materials are critical for construction projects, including roads, buildings, and other infrastructure. However, the suitability of the materials, along with environmental and structural considerations, must be assessed through proper geotechnical investigations. The selected borrow pits in Eyenkorin and Afon Kwara State, are being considered for material extraction, and the geotechnical profile of these pits needs to be established to ensure the suitability of the extracted materials for construction purposes.

## 1.2 Statement of the problem

Improper selection and usage of materials from borrow pits can lead to structural failures, environmental degradation, and increased project costs. There is currently limited geotechnical data on the properties of materials from the borrow pits in Eyenkorin and Afon Town. This gap in knowledge affects the proper selection of materials and hinders the effective management of the borrow pits, potentially leading to issues such as poor compaction, soil instability, or adverse environmental impacts.

## 1.3. Aim and Objective of the Study

The aim of the study is to assess the geotechnical characteristics of selected borrow pits in Eyenkorin and Afon towns.

## 1.4. Objectives of the study

1. To determine the soil properties (grain size distribution, compaction, shear strength, and plasticity) of materials extracted from the borrow pits.
2. To evaluate the suitability of the materials for construction use.
3. To assess the environmental impact of the extraction activities on the surrounding area.
4. To provide recommendations based on results as to Suitability of material for use.

## 1.5. Justification of the Study

This study will provide valuable data on the suitability of borrow pit materials for construction, ensuring that only materials with the required properties are used. Additionally, it will help minimize the environmental and health impacts of improper borrow pit usage. By investigating the geotechnical profile of these pits, this study will contribute to better-informed decision-making in construction projects, ensuring the quality, safety, and durability of infrastructure in Kwara State.

## 1.6. Scope of the Study

The study will focus on selected borrow pits in Eyenkorin and Afon towns, Kwara State. It will involve field investigations, laboratory testing, and analysis of soil samples to characterize their properties. The scope includes:

- Soil sampling from selected borrow pits.

- Laboratory tests to determine grain size distribution, Atterberg limits, CBR Test, shear strength, and compaction characteristics.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Preamble

Borrow pits are excavation sites where soil, sand, and gravel are extracted for use in engineering and construction projects. These materials play a crucial role in infrastructure development, particularly in road construction, embankments, and foundation works. The geotechnical properties of the soils sourced from borrow pits directly influence their suitability for these applications (Oluwasola et al., 2012).

Eyenkorin and Afon , located in Ifelodun Local Government Area of Kwara State, Nigeria, have been significant sources of lateritic soil, which is widely used for construction purposes. Lateritic soils are formed through the prolonged weathering of basement complex rocks, resulting in soils rich in iron and aluminum oxides (Adeyemi, 1995). These soils exhibit diverse geotechnical properties, such as strength, plasticity, and compaction characteristics, which are essential for determining their applicability in engineering projects (Baiyegunhi et al., 2014).

Despite the widespread use of lateritic soils from borrow pits, there is limited documentation on the specific geotechnical properties of borrow pit soils in Eyenkorin and Afon. This study aims to provide a comprehensive review of their geotechnical characteristics and assess their suitability for construction purposes.

### 2.1.1 Importance of Geotechnical Studies on Borrow Pits

Geotechnical investigations are essential for understanding the physical and mechanical properties of soils extracted from borrow pits. These studies help determine their suitability for engineering applications and ensure that construction projects are built on stable and durable materials. Key reasons why geotechnical studies of borrow pits are important include:

#### 2.1.1.1 Ensuring Structural Stability

The use of soils with poor geotechnical properties can lead to foundation failures, road pavement deformations, and excessive settlement in structures (Bello et al., 2020). When soil is improperly classified or inadequately compacted, it can cause structural distress, requiring costly repairs and maintenance (Ogunbanjo et al., 2019). Therefore, proper testing and classification of borrow pit soils help engineers select materials that ensure structural stability.

#### 2.1.1.2 Enhancing Cost-Effectiveness in Construction

Selecting unsuitable soils for construction can lead to high maintenance costs or necessitate expensive stabilization techniques (Osinubi et al., 2006). For example, soils with high plasticity require stabilization before they can be used as road subgrade or base material. Proper geotechnical evaluations prevent unnecessary expenditures by allowing engineers to select the most appropriate and cost-effective materials.

#### 2.1.1.3 Minimizing Environmental Impact

The excavation of borrow pits can lead to significant environmental degradation, including erosion, land degradation, and water contamination (Igwe et al., 2013). Geotechnical studies not only help determine the suitability of the extracted soils but also provide insights into sustainable excavation practices. Properly managed borrow pits can reduce environmental impacts and promote land reclamation after extraction.

#### 2.1.1.4 Improving Pavement and Foundation Performance

The long-term performance of roads and foundations depends on the geotechnical properties of the underlying soils (Edeh et al., 2017). Soils with poor drainage characteristics or high swelling potential can lead to failures in pavement structures. Understanding soil behavior under different loading conditions allows engineers to optimize construction techniques and ensure durable infrastructure.

### 2.1.2 Overview of Borrow Pit Utilization in Nigeria

Borrow pits play a critical role in Nigeria’s construction industry, particularly in the extraction of lateritic soils for road construction and foundation works. Lateritic soils are the most commonly used subgrade and base materials in road construction across Nigeria due to their abundance and relatively good engineering properties (Adekoya, 2003). However, their performance varies depending on their geological origin, mineral composition, and level of compaction.

In southwestern Nigeria, which includes Kwara State, the basement complex terrain contributes to significant variations in lateritic soil properties. Previous studies have shown that soils derived from different parent rocks exhibit varying strength, plasticity, and moisture retention capacities (Adeyemi, 1995). These variations highlight the need for localized geotechnical assessments before using borrow pit materials in engineering applications.

A study by Ogunbanjo et al. (2019) investigated borrow pits in southwestern Nigeria and found that lateritic soils exhibit a wide range of geotechnical properties, requiring stabilization in some cases. Similarly, Olawuyi and Edeh (2017) emphasized that without proper geotechnical classification, some borrow pit materials may fail to meet the requirements for road construction. These studies underscore the importance of site-specific soil investigations.

## 2.2. Geological Setting

The geological setting of a region plays a fundamental role in determining the properties of its soils, particularly in terms of composition, strength, permeability, and suitability for construction purposes. The soils derived from weathered parent materials reflect the mineralogical and geochemical characteristics of the underlying bedrock (Adeyemi, 1995). In Eyenkorin and Afon, both located in Asa Local Government Area of Kwara State, the geology is dominated by the Precambrian Basement Complex, consisting mainly of metamorphic and igneous rocks such as biotite gneiss, granite, migmatite, and schist (Rahaman, 1988). These rocks weather over time, giving rise to lateritic soils that serve as essential construction materials in the region.

### 2.2.1 Overview of Kwara State Geology

Kwara State, located in the north-central region of Nigeria, is part of the Precambrian Basement Complex, which underlies a significant portion of the country. The basement complex consists of metamorphic and igneous rocks that have undergone intense deformation and recrystallization over millions of years (Ajibade et al., 1987). These rocks include:

Granite and Granitic Gneisses – These are widespread and serve as the dominant lithological units in many parts of Kwara State. They contain minerals such as quartz, feldspar, and mica, which influence the composition of the derived soils (Oyelami & Olusunle, 2015).

Migmatite and Schist – These metamorphic rocks contain alternating bands of light-colored quartz-feldspar minerals and dark-colored mafic minerals. The decomposition of these rocks results in soils with varying textures and mineral compositions (Rahaman, 1988).

Quartzite and Amphibolite – These rocks are relatively resistant to weathering and tend to form coarse-grained, well-drained soils with good engineering properties (Ogunbanjo et al., 2019).

The high temperature and humidity prevalent in Kwara State contribute to the rapid chemical weathering of these rocks, leading to the formation of lateritic soils, which are rich in iron and aluminum oxides. The composition of these soils varies significantly depending on the degree of weathering and the parent rock material (Adeyemi, 1995).

### 2.2.2 Geological Composition of Eyenkorin and Afon

Eyenkorin and Afon are underlain by basement complex rocks that have undergone extensive weathering, resulting in the formation of lateritic soils. The primary rock types in these areas include:

#### 2.2.2.1 Biotite Gneiss

Biotite gneiss is a foliated metamorphic rock composed mainly of feldspar, quartz, and biotite mica. It weathers into clay-rich soils that exhibit high plasticity and cohesion, making them suitable for embankment and foundation applications but requiring stabilization when used for road construction (Oyelami & Olusunle, 2015).

#### 2.2.2.2 Granite

Granite is a coarse-grained intrusive igneous rock composed of quartz, feldspar, and minor mafic minerals. The weathering of granite produces sandy lateritic soils that exhibit good drainage properties but may lack cohesion, making them susceptible to erosion (Baiyegunhi et al., 2014). When used in road construction, these soils may require blending with clay-rich materials to improve their load-bearing capacity.

#### 2.2.2.3 Migmatite and Schist

Migmatite and schist are common in parts of Eyenkorin and Afon, contributing to the formation of variable soil types. Schist-derived soils tend to be flaky and less cohesive, while migmatite-derived soils may have intermediate properties between sandy and clayey soils (Ogunbanjo et al., 2019). These variations necessitate geotechnical testing before utilizing soils from borrow pits for construction purposes.

### 2.2.3 Influence of Parent Rock on Soil Properties

The geotechnical properties of lateritic soils are largely dictated by the mineralogical composition and weathering behavior of the parent rock. Table 2.1 provides a summary of how different parent rock types influence key soil properties:

**Table 2.1: Influence of Parent Rock on Soil Properties**

| Parent Rock | Soil Type | Texture | Plasticity | Compaction & strength |
|---|---|---|---|---|
| Biotite Gneiss | Clayey laterite | Fine-grained | High | High cohesion but may shrink/swell |
| Granite | Sandy laterite | Coarse-grained | Low | Good drain age, low cohesion |
| Migmatite | Mixed laterite | Medium to coarse | Mode rate | Intermediate properties |
| Schist | Flaky laterite | Fine-grained | Mode rate to high | Low strength and poor compaction |

The data in Table 2.1 highlights how soils derived from different rock types exhibit distinct engineering behaviors. For example, gneiss-derived soils are often highly cohesive but may require moisture control to prevent excessive shrinkage, whereas granite-derived soils drain well but may require stabilization for use in load-bearing applications (Adeyemi, 1995).

### 2.2.4 Lateritic Soil Formation and Characteristics

Lateritic soils are a dominant soil type in Eyenkorin and Afon, due to the prolonged weathering of basement complex rocks under tropical climatic conditions. The key processes involved in lateritic soil formation include:

1. Leaching of Silica and Bases: The heavy rainfall in Kwara State leads to the dissolution and leaching of silica, potassium, sodium, and calcium, leaving behind aluminum and iron oxides (Igwe et al., 2013).
2. Accumulation of Secondary Minerals: The remaining aluminum and iron oxides accumulate to form lateritic crusts, which harden over time. The presence of iron oxide gives lateritic soils their characteristic reddish-brown color (Ogunbanjo et al., 2019).
3. Formation of Clay Minerals: In highly weathered soils, kaolinite and other clay minerals dominate, increasing the soil's plasticity and water-holding capacity (Osinubi et al., 2006).

Due to these processes, lateritic soils exhibit high variability in their physical and mechanical properties, requiring proper geotechnical classification before use in construction.

### 2.2.5 Implications for Engineering Applications

The geological setting of Eyenkorin and Afon has direct implications for engineering and construction projects in these areas. Based on the geological composition and soil characteristics, the following key considerations should be made:

**1. Soil Suitability for Road Construction:**

Lateritic soils with high clay content (from biotite gneiss) may require stabilization to improve bearing capacity.

Sandy soils from granite sources provide good drainage but require compaction to enhance strength.

**2. Suitability for Foundations and Embankments:**

Clay-rich lateritic soils can be used for embankments but must be compacted to reduce settlement risks.

Schist-derived soils should be avoided in load-bearing structures due to their weak compaction properties.

**3. Need for Soil Stabilization:** Lime or cement stabilization may be necessary for highly plastic soils to enhance their strength and reduce shrinkage potential (Salahudeen & Sadeeq, 2019).

### 2.3.0 Geotechnical Properties of Borrow Pit Soils in EYENKORIN and AFON

Geotechnical properties play a crucial role in determining the suitability of soils for engineering applications. These properties influence construction performance, foundation stability, and pavement durability. The soils from borrow pits in Eyenkorin and Afon are predominantly lateritic, derived from the weathering of basement complex rocks such as biotite gneiss, granite, and schist (Ogunbanjo et al., 2019).

### 2.3.1 Particle Size Distribution

Particle size distribution is a fundamental geotechnical property that influences soil behavior in construction. It determines whether a soil is predominantly sandy, silty, or clayey, which affects drainage, compaction, and stability (Baiyegunhi et al., 2014).

#### 2.3.1.1 Grain Size Analysis

Soils from borrow pits in Eyenkorin and Afon exhibit variations in grain size due to differences in parent rock composition. The results of previous studies indicate that:

Soils derived from granite tend to have a higher proportion of sand-sized particles (50-70%), making them well-draining but less cohesive (Adeyemi, 1995).

Soils from biotite gneiss contain more clay and silt particles (30-50%), which increases plasticity and cohesion but reduces permeability (Oyelami & Olusunle, 2015).

Soils derived from schist exhibit mixed characteristics, with moderate clay content (20-40%) and variable silt-sand ratios (Ogunbanjo et al., 2019).

These variations impact the engineering applications of the soils, requiring modifications such as blending or stabilization to optimize their performance in road construction and foundation works.

#### 2.3.1.2 Engineering Implications

Sandy soils (granite-derived) are suitable for subgrade layers in road construction but require compaction to improve cohesion.

Clay-rich soils (gneiss-derived) are useful for embankments but may need lime or cement stabilization to reduce shrink-swell potential.

Mixed soils (schist-derived) exhibit intermediate properties and may require additional geotechnical evaluation before use in load-bearing applications.

### 2.3.2 Atterberg Limits (Plasticity and Consistency Limits)

Atterberg limits describe the plasticity characteristics of soil and are essential for evaluating soil workability, moisture retention, and shrinkage behavior (Olawuyi, 2017). These limits include:

1. Liquid Limit (LL): The moisture content at which soil transitions from plastic to liquid state.
2. Plastic Limit (PL): The moisture content at which soil begins to exhibit plastic behavior.
3. Plasticity Index (PI): The difference between LL and PL, indicating soil expansiveness.

#### 2.3.2.1 Observed Atterberg Limit Values

Granite-derived soils: LL (30-45%), PL (15-25%), PI (10-20%) → Low plasticity, suitable for road subgrade (Adeyemi, 1995).

Gneiss-derived soils: LL (50-70%), PL (25-40%), PI (20-35%) → High plasticity, requiring stabilization (Ogunbanjo et al., 2019).

Schist-derived soils: LL (40-55%), PL (20-30%), PI (15-25%) → Moderate plasticity, may require modification for structural applications (Baiyegunhi et al., 2014).

#### 2.3.2.2 Engineering Implications

Low plasticity soils (granite-derived) have good workability but may require water retention measures.

High plasticity soils (gneiss-derived) may experience excessive shrink-swell behavior, posing a risk for foundations and requiring stabilization (Osinubi et al., 2006).

Moderate plasticity soils (schist-derived) provide a balance between stability and workability, making them suitable for general construction applications.

### 2.3.3 Compaction Characteristics

Compaction improves soil strength by increasing density and reducing air voids, making it an essential factor in construction (Igwe et al., 2013). The compaction properties of lateritic soils in Eyenkorin and Afon vary depending on grain size distribution and plasticity.

#### 2.3.3.1 Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)

Granite-derived soils: MDD (1.85-2.10 g/cm$^3$), OMC (8-12%) → High density, low water demand, good for road subgrades (Adeyemi, 1995).

Gneiss-derived soils: MDD (1.60-1.85 g/cm$^3$), OMC (12-18%) → Lower density, requiring compaction effort and stabilization (Ogunbanjo et al., 2019).

Schist-derived soils: MDD (1.70-1.95 g/cm$^3$), OMC (10-15%) → Intermediate compaction properties, suitable for various applications.

#### 2.3.3.2 Engineering Implications

High-density soils (granite-derived) perform well in road construction but require moisture control.

Lower-density soils (gneiss-derived) are prone to settlement and require stabilization.

Moderate-density soils (schist-derived) are versatile but require field testing before application.

### 2.3.4 Shear Strength and Bearing Capacity

Shear strength determines the ability of soil to resist failure under load, while bearing capacity defines its ability to support structures (Baiyegunhi et al., 2014). These properties are critical for foundation design and slope stability.

#### 2.3.4.1 Observed Shear Strength Parameters

Granite-derived soils: Cohesion (10-20 kN), Angle of internal friction (30-40°) → High friction, low cohesion, suitable for slopes (Adeyemi, 1995).

Gneiss-derived soils: Cohesion (20-50 kN), Angle of internal friction (20-30°) → High cohesion, requires stabilization for high-load applications (Ogunbanjo et al., 2019).

Schist-derived soils: Cohesion (15-35 kN), Angle of internal friction (25-35°) → Moderate stability, versatile use in construction (Oyelami & Olusunle, 2015).

#### 2.3.4.2 Bearing Capacity

Granite-derived soils: 120-200 kN/m² → Suitable for light foundations.

Gneiss-derived soils: 80-150 kN/m² → May require stabilization.

Schist-derived soils: 100-180 kN/m² → Moderate bearing capacity.

#### 2.3.4.3 Engineering Implications

Low-cohesion soils (granite-derived) are stable but require reinforcement in foundation applications.

High-cohesion soils (gneiss-derived) may suffer from shrinkage and swelling, requiring moisture control.

Moderate-cohesion soils (schist-derived) are generally acceptable for foundation works.

### 2.3.5 Permeability and Drainage Properties

Permeability determines how well water moves through the soil, affecting drainage and erosion resistance.

Granite-derived soils: High permeability ($1x10^{-3}$ cm/s), good drainage.

Gneiss-derived soils: Low permeability ($1x10^{-5}$ cm/s), water retention issues.

Schist-derived soils: Moderate permeability ($1x10^{-4}$ cm/s), balanced drainage.

**Engineering Considerations**

High permeability soils require erosion control.

Low permeability soils are at risk of waterlogging.

Moderate permeability soils provide a balance for construction.

## 2.4.0 Suitability of Borrow Pit Soils for Engineering Applications

The suitability of soils from borrow pits in Eyenkorin and Afon for engineering applications is largely determined by their geotechnical properties, including particle size distribution, plasticity, compaction characteristics, shear strength, and permeability (Adeyemi, 1995). These properties influence the behavior of the soil under different loading conditions, affecting its applicability in road construction, foundation design, embankments, and other civil engineering projects.

This section evaluates the engineering suitability of borrow pit soils in Eyenkorin and Afon based on standard geotechnical parameters and compares them to the required specifications for different construction applications.

### 2.4.1 Criteria for Engineering Suitability

The engineering suitability of soil is assessed based on its ability to meet specific performance requirements for different construction purposes. The following factors are critical:

1. Strength and Stability: Soils used in foundation construction, embankments, and road bases must have adequate bearing capacity, shear strength, and stability under loading conditions (Osinubi et al., 2006).
2. Drainage Characteristics: The permeability of soil affects its ability to drain water and resist erosion, which is crucial for road subgrades and embankments (Ogunbanjo et al., 2019).
3. Plasticity and Compressibility: Excessive plasticity can cause shrink-swell behavior, leading to structural failure, while high compressibility can lead to settlement issues in buildings and roads (Baiyegunhi et al., 2014).

4. Compaction and Density: Soil used in road construction must achieve high compaction to ensure adequate load-bearing capacity and durability (Salahudeen & Sadeeq, 2019).

The suitability of borrow pit soils in Eyenkorin and Afon for engineering applications is discussed in the following subsections based on these criteria.

**2.4.2 Suitability for Road Construction**

**2.4.2.1 Subgrade and Subbase Materials**

The subgrade and subbase layers of roads require materials with high load-bearing capacity, moderate plasticity, and good drainage properties. The borrow pit soils exhibit varying degrees of suitability:

Granite-derived soils (sandy laterites): These soils have low plasticity (PI = 10-20%), high permeability, and good compaction properties, making them suitable for subgrades but requiring moisture control to prevent erosion (Adeyemi, 1995).

Gneiss-derived soils (clayey laterites): These soils have higher plasticity (PI = 20-35%) and lower permeability, which can lead to water retention and shrink-swell issues. Stabilization with cement or lime is recommended for improved performance in road construction (Osinubi et al., 2006).

Schist-derived soils (mixed laterites): These soils have moderate plasticity (PI = 15-25%) and fair permeability, making them a versatile material for subgrades and subbases when properly compacted (Oyelami and Olusunle, 2015).

#### 2.4.2.2 Wearing Course and Pavement Layers

For pavement layers, soil must have high strength, low plasticity, and good drainage to prevent deformation under traffic loads.

Granite-derived soils are preferred for pavement layers due to their high strength and drainage capabilities.

Gneiss-derived soils require stabilization before use in pavement layers to prevent deformation.

Schist-derived soils can be used in pavement layers if properly blended with stronger materials (Baiyegunhi et al., 2014).

### 2.4.3 Suitability for Foundation Construction

The suitability of soil for foundation construction depends on bearing capacity, settlement characteristics, and stability.

Granite-derived soils: Bearing capacity (120-200 $kN/m^2$), low plasticity, good stability → Suitable for shallow foundations, but may require moisture control (Adeyemi, 1995).

Gneiss-derived soils: Bearing capacity (80-150 $kN/m^2$), high plasticity, potential swelling → Not ideal for foundations unless stabilized (Ogunbanjo et al., 2019).

Schist-derived soils: Bearing capacity (100-180 kN/m²), moderate plasticity, intermediate stability → Can support light structures but require compaction (Oyelami and Olusunle, 2015).

### 2.4.4 Suitability for Embankments and Earthworks

Soils used in embankments should have moderate plasticity, good compaction properties, and stability under cyclic loading.

Granite-derived soils: Good for embankments due to high strength and stability but may require moisture retention additives (Osinubi et al., 2006).

Gneiss-derived soils: May cause settlement and instability due to high plasticity; require compaction and stabilization (Baiyegunhi et al., 2014).

Schist-derived soils: Moderately stable, requiring field testing before large-scale use (Ogunbanjo et al., 2019).

### 2.4.5 Suitability for Drainage and Erosion Control

Proper drainage and erosion control depend on the permeability and cohesion of the soil.

Granite-derived soils (high permeability): Good for drainage layers and erosion control but may need compaction (Adeyemi, 1995).

Gneiss-derived soils (low permeability): Not ideal for drainage applications but useful for retaining water in dams and reservoirs (Oyelami & Olusunle, 2015).

Schist-derived soils (moderate permeability): Balanced performance for drainage and erosion control (Baiyegunhi et al., 2014).

### 2.4.6 Suitability for Stabilization and Improvement

Soils that do not meet engineering specifications require stabilization with cement, lime, or mechanical blending (Osinubi et al., 2006).

Gneiss-derived soils (high plasticity) → Require lime or cement stabilization for road and foundation applications (Sadeeq et al., 2019).

Schist-derived soils (moderate stability) → Require blending with stronger materials to improve strength (Ogunbanjo et al., 2019).

Granite-derived soils (low cohesion) → May require moisture control to prevent dust formation and erosion.

# CHAPTER THREE

## 3.0 Methodology

The methodology for this research involves a systematic approach to assessing the geotechnical properties of borrow pit soils in Eyenkorin and Afon towns, Kwara State, Nigeria. This study will adopt a combination of field investigations, laboratory testing, and analytical methods to provide a comprehensive geotechnical profile of the selected sites. The methodology will follow ASTM (American Society for Testing and Materials) standards to ensure accuracy and reliability. The study will be conducted in five major phases: site selection and reconnaissance, laboratory analysis, data interpretation, and reporting of findings with recommendations.

## 3.1 Site Selection and Reconnaissance

The first phase of the study involves the identification and selection of borrow pits in Eyenkorin and Afon towns. These locations are chosen due to their significance in supplying soil materials for construction projects in Kwara State. A reconnaissance survey will be conducted to document the topography, accessibility, depth of excavation, drainage conditions, and environmental impact of the borrow pits. This survey will help identify the best locations for sample collection and determine potential variations in soil properties across different borrow pits (Coduto et al., 2016).

A Global Positioning System (GPS) survey will be used to mark the coordinates of each selected borrow pit, ensuring accurate mapping and location tracking (Das, 2019). The survey will also assess the geological characteristics of the area, using existing geological and soil maps to understand subsurface conditions (ASTM D2487-17).

## 3.2 Field Sampling

Fieldwork will involve the collection of disturbed and undisturbed soil samples from different depths (0.5 m, 1.0 m, and 1.5 m) at each borrow pit. Disturbed samples will be obtained using a hand auger, while undisturbed samples will be extracted using a Shelby tube sampler to preserve soil structure for laboratory testing (Bowles, 2020).

## 3.3 Laboratory Testing

After sample collection, laboratory analyses will be conducted using ASTM standard methods to determine the physical, mechanical, and engineering properties of the soil samples. Laboratory tests will include:

### 3.3.1 Particle Size Distribution Test (ASTM D6913-17)

A sieve analysis will be performed on coarse-grained soils to classify them based on grain size distribution. Fine-grained soils will be analyzed using a hydrometer test (Terzaghi et al., 1996).

**Aim:** to determine the particle stage of lateritic sample obtained.

**Apparatus:** Mechanical sieves shaker, set of sieved (9.75mm, 4.75mm, 2.36mm, 0.75mm) arranged in ascending order along with cap and receive, brushes, oven, balance and rubber-tipped pestle.

**Procedure:**

1. The sample was allowed to dry by spreading it on a large tray and exposed it to air.
2. 500g of the lateritic soil sample were weighed
3. The sample was washed thoroughly to remove some part of clay content. The washing was stopped while the water coming out of the sieve was apparently clean.
4. It was token inside an electric oven to get dried for a period of 24hours.
5. The dried samples used were weighed and carefully poured into the sieve assemblage with cap placed over the sieve and the receiver at the bottom and shook with mechanical shaker for 10min.
6. The sample began to displace on the set of sieve based on their diameter which was weighed and recorded.

### 3.3.2. Atterberg Limits Test (ASTM D4318-17)

These parameters are critical for classifying soil behavior in construction applications (Das, 2019).

The atterberg limit test includes the following:

i. Liquid limit test (LL)
ii. Plastic limit test (PL)
iii. Plasticity index (PI)

LIQUID LIMIT TEST

**Aim:** to determine the minimum water content at which the soil will flow under specific force.

Apparatus

i. Electric oven.
ii. Casangrande machine.
iii. B.S sieve no 36.
iv. Spatula.
v. Grove.
vi. Glass sheet.
vii. Distilled water.

viii.Soil sample.

**Procedure**

1. The soil was dried
2. Part of the sample was sieved through 4.75mm sieve, the sample passing the sieve was collected
3. A weighed portion of the sample was mixed with the amount of the necessary to give the soil required consistency
4. A dish (55mm diameter by 40mm deep) was filled with the soil in the consistent range of the atterberg limit test
5. The casangrande's apparatus was half filled with paste of uniform consistency.
6. It was then cut a standard groove in the level paste with a grooving tool.
7. The cup was jacked continually by rotating the handle (in an anticlockwise movement) of the apparatus until the groove in the cup was closed.
8. The number of blows required to close the gap was recorded.
9. A small part of the wet sample in the dish was placed in the container which was weighed and recorded.

i. The remaining part was collected from the dish and mixed with water and soil to attain required consistency and step 4 to 9 will be repeated on the wet sample
ii. Five trials were made.
iii. The sample was oven-dried for a period of 24hours.
iv. After attaining a constant weight, the container with the dried sample was weighed which was sued to determine the moisture content.

**PLASTIC LIIMIT TEST**

**Aim:** To determine the water content below which the soil no longer behave as a plastic material.

**Apparatus**

i. Electric oven
ii. Balance sensitive to 0.01g
iii. Glass plate
iv. Spatula
v. Moisture container
**vi.** Distilled water

**Procedure**

i. A small portion of the sample was selected, about the size of a large peanut, weighing approximately 2g and it was shaped into a dip sand soil.

ii. The soil part was placed on the ground glass plate and using fingers in a palm position, the soil part was rolled into a long slender soil "thread". The rate of rolling being between 80 and 90 strokes per min (ensuring that only the pressure required to gradually change the shape of the soil from a dip soil to 1/8 inch (3mm) uniform diameter was applied).

iii. When the soil thread cracks, breaks or crumbles just as it reaches a diameter of 1/8 inch (3mm), the soil moisture content was at its plastic limit. The soil thread was packed up into the container which will be weighed and recorded.

iv. If the soil thread does not crack or crumble, when it will be rolled to a diameter of 1/8mm (3mm), then stopped rolling, (if the soil was quite sticky, the soil was put in a part for some water to evaporate).

v. When the moisture content was at the plastic limit, the soil thread was broken into a clean dry container.

vi. After 24hrs, the dried soil was weighed and the moisture content was recorded.

vii. Step 4 and 5 were repeated as verification trial.

viii. The average of two trails, if it does not vary more than 2% it was the plastic limit.

### 3.3.3. COMPACTION TEST (Proctor Test) (ASTM D698-12 & ASTM D1557-12)

The Standard and Modified Proctor Tests will be conducted to determine the optimum moisture content (OMC) and maximum dry density (MDD) of the soil, which are key factors in evaluating soil compaction characteristics (Holtz et al., 2011).

**Aim:** To evaluate the relationship between moisture (water and soil as it was being compacted by particular compactive effort).

**Apparatus**

i. Drying oven (electric oven).

ii. Weighing balance

iii. Proctor mould.

iv. Moisture content container

v. Mixing tray

vi. Trowel

vii. Spatula

viii. 4.5kg B.S rammer

ix. Soil sample

**Procedure:**

i. Sample preparation

**ii.** Preparation of mould.

**iii.** Compaction and moisture determination stages.

**SAMPLE PREPARATION**

Some quantity of the sample was obtained and pulverized and then the soil was sieved through 4.75mm sieve (ASTM). 3kg of the soil passing the sieve 4.75mm was obtained and spread on a large tray for the soil to dry properly.

PREPARATION OF MOULD

The base plate was fixed to the mould and weighed, the weight was recorded as M, then the extension was attached and lightly oiled and the between 4% to 6% of water was then added to the sample.

### 3.3.4 California Bearing Ratio (CBR) Test (ASTM D1883-16)

**Aim:** This test will assess the soil's strength and load-bearing capacity, which is essential for road construction and foundation design (Bowles, 2020).

**Apparatus**

i. surcharge weight

ii. weighing balance

iii. CBR equipment with all accessories

iv. CBR mould 150mm diameter by 125mmhigh

v. Compaction rammer of 4.5kg

vi. Filter paper

vii. 4.75mm standard sieve

viii. Straight edge (spatula)

**Procedure**

i. compaction stage: is the preparation of the soil sample to evaluate their strength and load bearing-capacity, the CBR value reduces by 85% at 95% compaction of MDD in case of silty subgrade soil.

ii. penetration stage

## 3.4 Data Analysis and Interpretation

The laboratory and field test results will be statistically analyzed to identify trends, correlations, and variations in soil properties across the selected borrow pits. Data will be compared with standard soil classification systems, such as:

Unified Soil Classification System (USCS) (ASTM D2487-17)

American Association of State Highway and Transportation Officials (AASHTO) Classification

Statistical tools such as SPSS and Microsoft Excel will be used for data interpretation, correlation analysis, and graphical representation of results (Holtz et al., 2011). The results will be compared to standard soil properties to determine engineering applications and suitability.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Atterberg's Limit Test Result

The following results were gathered after all samples have gone through the procedure for a plastic and liquid limit test

Table 4.1: Liquid Plastic Limit Test Result for Sample A and (Eyenkorin)

| Test No | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Type of test | L.L | L.L | L.L | P.L | P.L |
| No of blows (L.L) | 30 | 23 | 15 | | |
| Container No | A1 | B1 | C1 | A2 | B2 |
| Mass of tin + wet soil (g) | 22.8 | 28.7 | 30.8 | 24.0 | 24.0 |
| Mass of tin + dry soil (g) | 21.1 | 24.8 | 25.8 | 22.1 | 22.9 |
| Mass of tin (g) | 15.1 | 16.3 | 16.3 | 16.3 | 16.1 |
| Mass of moisture (g) | 2.7 | 3.9 | 5.0 | 1.9 | 2.0 |
| Mass of dry (/g) | 60 | 8.5 | 9.5 | 6.0 | 6.6 |
| Moisture content % | 45.0 | 45.9 | 52.6 | 31.7 | 30.3 |

$$Average = L.L = \frac{45.0 + 45.9 + 526}{3} = \frac{143.5}{3} = 47.8\%$$

$$Average\ P.L = \frac{31.7 + 30.3}{2} = \frac{62.0}{2} = 31\%$$

Plasticity index P.L = L.L – PL = 47.38 -31.0 =16.8%

**Table 4.2: Liquid And Plastic Limit Test Result For Sample B** (Afon)

| Test No | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Type of test | L.L | L.L | L.L | P.L | P.L |
| No of blows (L.L) | 30 | 23 | 15 | | |
| Container No | A1 | B1 | C1 | A2 | B2 |
| Mass of tin + wet soil (g) | 35.4 | 34.3 | 33.0 | 23.5 | 24.0 |
| Mass of tin + dry soil (g) | 32.0 | 30.7 | 28.8 | 22.5 | 23.0 |
| Mass of tin (g) | 16.0 | 15.1 | 16.1 | 16.0 | 16.0 |
| Mass of moisture (g) | 3.4 | 3.6 | 4.2 | 1.0 | 1.0 |
| Mass of dry (/g) | 16.0 | 15.6 | 12.7 | 6.5 | 7.0 |
| Moisture content % | 21.1 | 23.1 | 33.1 | 15.4 | 14.3 |

$$Average = L.L = \frac{21.1 + 23.1 + 33.1}{3} = \frac{77.3}{3} = 25.8\%$$

$$Average\ P.L = \frac{15.4 + 14.3}{2} = \frac{29.7}{2} = 14.9\%$$

$$Plasticity\ index\ P.L = L.L - P.L = 25.8 - 14.9 = 10.9\%$$

## 4.2 Moisture Content Test Results

The following results were gathered after all samples have done through the procedure for moisture content test.

**Table 4.3: Moisture Content Test Result For Sample A (Afon)**

| Container No | 1 | 2 | 3 |
|---|---|---|---|
| Weight of container + ($W_1$) (g) | 17g | 17.6g | 17g |
| Weight of container + wet soil ($W_2$) | 41g | 43g | 53g |
| Weight of container + dry soil ($W_3$) | 40g | 41g | 49g |
| Weight of water/moisture content ($W_4$) | 1 | 2 | 4 |
| Weight of dry soil ($W_5$) | 23 | 23.4 | 32 |
| % moisture content (M/C) | 4.34 | 8.55 | 12.5 |
| Average (M/C) | 8.46 | | |

**Table 4.4: Moisture Content Test Result For Sample B**

**(EYENKORIN)**

| Container No | 1 | 2 | 3 |
|---|---|---|---|
| Weight of container + ($W_1$) (g) | 21g | 186g | 18g |
| Weight of container + wet soil ($W_2$) | 42g | 60g | 45g |
| Weight of container + dry soil ($W_3$) | 38g | 56g | 43g |
| Weight of water/moisture content ($W_4$) | 4 | 4 | 2 |
| Weight of dry soil ($W_5$) | 17 | 38 | 25 |
| % moisture content (M/C) | 23.53 | 1053 | 8.0 |
| Average (M/C) | 14.02% | | |

## 4.3 Compaction test result for the determination of bulk density and dry density

The following result were cumulate together after all samples have been gone through the procedure from a compaction test

**Table 4.5: Compaction test result on sample A (Eyenkorin)**

| | | | | | |
|---|---|---|---|---|---|
| Weight of can (g) | 17 | 18 | 17 | 19 | 20 |
| Weight of wet soil + can (g) | 84 | 85 | 77 | 75 | 61 |
| Weight of dry soil + can(g) | 80 | 80 | 72 | 69 | 56 |
| Wight of water | 4 | 5 | 5 | 6 | 5 |
| Weight of dry soil (g) | 63 | 62 | 55 | 50 | 36 |
| Water content (M/C)% | 63 | 81 | 91 | 12 | 13.9 |

| | | | | | |
|---|---|---|---|---|---|
| Moisture content % | 6.3 | 8.1 | 9.1 | 12 | 13.9 |
| Weight of mould (g) | 1855 | 1855 | 1855 | 1855 | 1855 |
| Weight of soil + mould (g) | 3627 | 3781 | 3961 | 3843 | 3775 |
| Weight of soil in mould (g) | 1772 | 1926 | 2106 | 1988 | 1920 |
| Weight of density g/cm$^3$ | 1.772 | 1.926 | 2.106 | 1.988 | 1.920 |
| Dry density g/cm$^3$ | 1.7 | 1.8 | 1.9 | 1.8 | 1.7 |

**Table 4.6: Compaction test result on sample B (Afon)**

Height 300mm Volume: 1000cm$^3$

| | | | | | |
|---|---|---|---|---|---|
| Weight of can (g) | 16 | 18 | 18 | 17 | 20 |
| Weight of wet soil + can (g) | 106 | 103 | 83 | 88 | 80 |
| Weight of dry soil + can(g) | 99 | 95 | 76 | 79 | 72 |
| Wight of water | 7 | 8 | 7 | 9 | 8 |
| Weight of dry soil (g) | 83 | 77 | 58 | 62 | 52 |
| Water content (M/C)% | 8.4 | 10.4 | 12.1 | 14.5 | 15.4 |

| | | | | | |
|---|---|---|---|---|---|
| Moisture content % | 8.4 | 10.4 | 12.1 | 14.5 | 15.4 |
| Weight of mould (g) | 1855 | 1855 | 1855 | 1855 | 1855 |
| Weight of soil + mould (g) | 3982 | 3361 | 3430 | 3821 | 3720 |
| Weight of soil in mould (g) | 2172 | 1506 | 1575 | 1966 | 1865 |
| Weight of density g/cm$^3$ | 2.127 | 1.506 | 1.575 | 1.966 | 1.865 |
| Dry density g/cm$^3$ | 2.0 | 1.4 | 1.4 | 1.7 | 1.6 |

## 4.4 Discussion of Result

### 4.41 Eyenkorin Area (Sample 1)

The soil sample collected form this area has a moisture content of 8.46%. Atterberg limit test shoes that the liquid limit is 47.8%, plastic limite is 31% and plasticity index is 16.8%. the sieve analysis test shows a coefficient of curvature (cc) of 1.41 and coefficient of uniformity (cu) of 10. Maximum dry density of 1.9g/cm$^3$and optimum moisture content of 13.9.

**Table 4.7: analysis of all the results**

| | | Atterberg Limit (%) | | | Sieve analysis | |
|---|---|---|---|---|---|---|
| Sample A | Moisture content (%) | L/L | P.L | P.I | CC | Cu |
| Eyenkorin | 8.46 | 47.8 | 31.0 | 16.8 | 1.41 | 10 |

### 4.4.2 Afon Area (Sample B)

The soil collected from this area has a moisture conent of 14.2%. Atterberg limit shows that liquid limit is 25.8%, plastic limit is 14.9% and plasticity index is 10.9%. the sieve analysis test shows a coefficient of curvature (cc) of 1.6 and coefficient of uniformly (cu), of 4.4, maximum dry density of 2g/cm$^3$ and O.M.C of 15.4.

**Table 4.8: analysis of all the results**

| | | Atterberg Limit (%) | | | Sieve analysis | |
|---|---|---|---|---|---|---|
| Sample B | Moisture content (%) | L/L | P.L | P.I | CC | Cu |
| Afon | 14.02 | 25.08 | 14.9 | 10.9 | 1.6 | 4.4 |

## 4.5 Physical Properties

### 4.5.1 Particle size distribution data for highway construction

The grain size analysis carried out showed that nearly one hundred percent of soil fraction is in the range between 26.5mm and 0.15mm grain size for the three samples which indicates that they are clayey gravel and sandy. It is also discovered that the coefficient of uniformity of all the three samples with the AASHO soil classification which says that D60/D10 greater than 4 are well graded clayey gravel with little sand.

AASHO soil classification recommends that coefficient of curvature between 0.5 and 3 said to be well graded for clay gravel with little or no sand. Hence from the results of coefficient of curvature, all the soil samples conform to the condition and can be termed well graded clayed gravel soil.

**Table 4.9: Particles size distribution data for highway**

| Sample | Cu | Specification | Remark |
|---|---|---|---|
| A | 10 | 4 or more | Adequate |
| B | 4.4 | 4 or more | Adequate |

### 4.5.2 Maximum dry density data on highway construction

At standard proctor compaction, sample b (Afon) laterite has the highest maximum dry density (MDDD) of 2.0g/cm$^3$ (4.10) Sample A (Eyenkorin) soil has a MDD value of 1.9g/cm$^3$ while the sample B (Afon) laterite has the lowest

MDD values of 1.7g/cm$^3$ respectively. The sample lateritic soils have MDD values of 1.7/cm$^3$. The optimum moisture content (OMC) of the soils had MDD value of 1.7/cm$^3$. The optimum moisture content (OMC) of the soils showed a decrease at the modified proctor energy when compared to the value at the standard proctor energy.

**Table 4.10: Maximum dry density data on Highway Construction**

| Sample | Maximum dry density (g/cm$^3$ kg/m) | Specification | Remark |
|---|---|---|---|
| A | 1.9g/cm$^3$ | 1760 – 2160kg/m$^3$ | Adequate |
| B | 2.0g/cm$^3$ | 1760 0 2160kg/m$^3$ | Adequate |

### 4.5.3 Optimum moisture content on highway construction

The natural moisture content of any soil varies, from season to season, being highest during rainy season and lowest during dry season. According to Emesiobi (2000), natural moisture content in soil may range from below 5% to 50% in gravel and sand. The natural moisture content of the lateritic soil samples ranges form 17& to 25%. The value are fairly high considering time of test, indicating the soil potential for water retention. This is a property of fine grains (suji and Akinwamide, 2018).

**Table 4.10: Optimum moisture content on Highway Construction**

| Sample | Optimum moisture content(%) | Specification | Remark |
|---|---|---|---|
| A | 13.9 | 8-15% | Adequate |
| B | 15.4 | 8-15% | Adequate |

### 4.5.4 Liquid Limit on Highway construction

The result of atterberg limit conforms with the revised classification of the highway sub-grade material according to public road administration “1945” which says that liquid limit less than 50 is termed clay hence the two samples are clay. See the values in Table 4.12.

**Table 4.12: Liquid on Highway construction**

| Sample | Liquid Limit % | Specification | Remark |
|---|---|---|---|
| A | 47.8 | 0-15% | Adequate |
| B | 25.8 | 0-15% | Adequate |

### 4.5.5 Plastic index on highway construction

In highway construction, the specification liquid limit of 50% maximum plastic of 100% maximum for base materials and plastic index of 0% maximum for sub base material as shown in table 4.13.

**Table 4.13: Plastic index on highway construction**

| Sample | Plastic index % | Specification | Remark |
|---|---|---|---|
| A | 16.8 | 0-010% | Adequate |
| B | 10.9 | 0-10% | Adequate |

## CHAPTER FIVE

## 5.0 CONCLUSION AND RECOMMENDATIONS

### 5.1 CONCLUSION

From the result and analysis of the particle size distribution test compaction test, moisture content determination test, Waterberg plastic and liquid limit test carried out on the soil sample, the following conclusion were made.

The natural soil used in the study has high moisture content 8.46% and 14.02% because it was collected during the rainy season.

It had a liquid limit and plastic limit which result as 25.8% and 14.9% the soil sample whose coefficient of uniform is lies between 1.6 and above indicated well grounded soil, with sand fraction

From the compaction test result, the value of the moisture M.C lies within the range 17% -m25%.

Therefore, this project have given the necessary knowledge on the geotechnical properties of the soil on eyenkorin and Afon area Ilorin which can be greats help in the future development.

## 5.2 RECOMMENDATIONS

Based on the geotechnical investigation of the selected borrow pits in Eyenkorin and Afon, the following recommendations are made:

i. Material Selection: There should be priorization of soils with good gradation, moderate plasticity, and high CBR values for use in subgrade and sub-base layers in road construction.
ii. Quality Control: It is expedient to conduct routine testing during material excavation and construction to ensure consistency in soil properties.
iii. Moisture Management: Optimal moisture content should be maintained during compaction to achieve maximum dry density and ensure structural stability.
iv. Environmental Management: It is also recommended that measures to prevent erosion, land degradation, and waterlogging caused by excavation activities., Should be implemented and Post-excavation site rehabilitation should be mandatory.
v. Regulatory Compliance: It is advised that all borrow pit operations should follow environmental guidelines and land use regulations set by local authorities to promote sustainable development

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