USE OF SHREDDED PURE WATER SACHETS (LPDE) IN STABILIZING LATERITIC SOIL FOR ROAD CONSTRUCTION

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PLAGIARISM

This work USE OF SHREDDED PURE WATER SACHETS (LPDE) IN STABILIZING LATERITIC SOIL FOR ROAD CONSTRUCTION by SUNDAY, Favour Itoro with matriculation number ENG2006241 of the department of Structural Engineering, Faculty of Engineering, University of Benin City, Edo State, Nigeria, has PASSED the PLAGIARISM TEST.

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DEDICATION

This project is first and foremost dedicated to the Almighty God, whose divine grace granted me the health, perseverance, and intellectual capacity necessary to complete this journey.

I dedicate this achievement to my incredible parents, **Mr. and Mrs. SUNDAY AKPAN**, whose relentless sacrifices are the foundation of my education. You are the bedrock upon which my life is built. Your ceaseless prayers, your profound belief in the power of education, and your willingness to sacrifice your own comfort to ensure my success provided the fuel I needed to persevere. This achievement is as much yours as it is mine, a return on the infinite investment of your love.

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Specifically, to my Elder sister **IDARA**, your support was more than just generous; it was a deliberate partnership in my education.

Finally, I am dedicating this work to **SUNDAY FAVOUR ITORO** for never giving up even when the road became rocky. I am proud of you.

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ABSTRACT

This research addresses a critical dual problem in Nigeria: the premature failure of road infrastructure due to the poor geotechnical properties of locally abundant lateritic soil and the severe environmental pollution caused by carelessly discarded Low-Density Polyethylene (LDPE) pure water sachets. This plastic waste, being non-biodegradable, clogs vital drainage systems, exacerbating seasonal flooding and creating long-term hazards by breaking down into harmful microplastics. The project seeks to provide a sustainable and cost-effective alternative to traditional, resource-intensive stabilizers like cement and lime.

The core objective is to determine the effectiveness of utilizing shredded LDPE sachets as a stabilizing additive to enhance the engineering properties of lateritic soil for road construction. The methodology involves collecting and processing lateritic soil and waste LDPE sachets, which are then blended at varying proportions: 0%, 2%, 4%, and 6% by weight of the soil. Standard geotechnical tests, strictly following BS 1377 (1990) procedures. The unsoaked CBR value increased by approximately 227%, rising from 3.8% at 0% plastic content to 12.69% at 6% content. Similarly, the soaked CBR value improved by 93.5% increasing from 4.91% to 9.50%. These results demonstrate that the modified soil at 6% stabilization meets the standard requirements for road subgrade materials, offering a superior alternative to unstable lateritic soil.

In conclusion, the results of this investigation demonstrate that incorporating waste LDPE sachets into lateritic soil successfully improves its engineering performance. This approach presents a pragmatic, two-pronged solution that simultaneously addresses a pervasive national pollution problem and offers a sustainable, cost-effective method for strengthening Nigeria’s essential road infrastructure, leading to a longer service life for flexible pavements.

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LDPE Low-Density Polyethylene

CBR California Bearing Ratio

LL Liquid Limit

PL Plastic Limit

PI Plasticity Index

MDD Maximum Dry Density

OMC Optimum Moisture Content

BS British Standard

ASTM American Society for Testing and Materials

SDG Sustainable Development Goal

UNEP United Nations Environment Programme

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In Nigeria, the consumption of sachet water has become a daily practice because it is cheap and easy to access. However, after use, most people throw the sachets away carelessly. Since these sachets are made of low-density polyethylene (LDPE), they do not decay easily and stay in the environment for many years (Osinubi, Eberemu, & Ijimdiya, 2009). The careless disposal of pure water sachets has led to serious environmental problems such as blocked drainages, flooding, and pollution.

At the same time, road construction in Nigeria relies heavily on lateritic soil as subgrade and subbase material. Lateritic soils are common and available across the country, but in many cases, they do not have good engineering properties. Under traffic load and rainy conditions, these soils become weak and cause early road failure (Akinwumi, 2014). The result is poor roads, potholes, and high maintenance costs.

Cement and lime are usually applied as stabilizers to improve soil strength, but they are expensive and not environmentally friendly because their production releases a large amount of carbon dioxide, which contributes to climate change (Ali, Adnan, & Choy, 2012). To reduce both cost and environmental impact, researchers have been studying waste materials like plastics as alternatives. Using shredded pure water sachets to stabilize soil offers a way to reduce environmental waste while improving road construction materials (Muntohar, 2011).

1.2 Problem Statement

Nigeria faces two interconnected problems. On one side, there is the environmental issue of sachet waste. Pure water sachets are everywhere, and because they are non-biodegradable, they remain in the environment for decades. Their improper disposal causes blocked drainage systems, flooding, visual pollution, and health hazards (Ogunrinola, Adejumo, & Awogbemi, 2021). The recycling rate of plastics in Nigeria is very low, with millions of tonnes of plastic ending up in dumpsites, rivers, and streets every year (Ikechukwu, 2020).

On the other side, there is the engineering problem of weak soils used in road construction. Nigerian roads are known to fail prematurely because lateritic soils used as subgrade and subbase are often not strong enough to carry heavy vehicles, especially when soaked with rainwater. This leads to potholes, cracks, and rutting, which increase accidents and transportation costs (Akinwumi, 2014). Although cement and lime can stabilize soil, they are costly and their production contributes significantly to greenhouse gas emissions (Muntohar, 2011).

Therefore, there is a strong need for a solution that addresses both environmental and engineering challenges. The use of shredded pure water sachets in soil stabilization is promising because it provides a cheaper, eco-friendly, and locally available material that can both reduce pollution and improve road performance. However, more experimental work is needed in Nigeria to prove its effectiveness and determine the best percentage of sachet addition.

1.3 Aim and Objectives

The aim of this study is to investigate the effect of shredded pure water sachets on the strength properties of lateritic soil for road construction.

The objectives of this study is to;

1. Collect and prepare lateritic soil and pure water sachets for testing.
2. Mix the soil with different percentages of shredded sachets (0%, 2%, 4%, and 6%).
3. Carry out compaction tests to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).
4. Perform California Bearing Ratio (CBR) tests on the soil sachet mixes.
5. Compare the results and recommend the best percentage of sachet for soil stabilization.

1.4 Scope of the Study

The scope of the study is itemized as follows;

1. **Soil and Sachet Collection:** Lateritic soil will be collected from a borrow pit, while pure water sachets will be washed, dried, and shredded into small pieces.
2. **Mix Preparation:** Soil will be mixed with shredded sachets at 0%, 2%, 4%, and 6% by weight of dry soil.
3. **Compaction Test:** Standard Proctor test will be carried out to obtain Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).
4. **CBR Test:** California Bearing Ratio (CBR) test will be conducted under soaked conditions to determine the strength of the soil mixes.
5. **Result Comparison:** Results of mixes containing sachets will be compared with the control sample (0% sachet) to determine the effectiveness of stabilization.

1.5 Justification of the Study

This study is justified because it helps solve both environmental and engineering problems at the same time. From the environmental point of view, pure water sachets are one of the most common plastic wastes in Nigeria. Since they are non-biodegradable, they accumulate in the environment for decades, blocking drainages and causing floods, especially in cities during the rainy season (Thompson, Moore, Vom Saal, & Swan, 2009). Nigeria generates over 2.5 million tonnes of plastic waste annually, but less than 12% is recycled (Ikechukwu, 2020). The remaining plastic waste ends up in open dumpsites, drains, and rivers. By reusing sachets in road construction, this study supports sustainable waste management and aligns with the United Nations Sustainable Development Goals (SDG 11 and 12) on sustainable cities and responsible consumption (United Nations, 2015). Nigerian roads face early failure due to weak lateritic soils. These soils lose strength when soaked and cannot meet the required standards for road subgrade and subbase (Akinwumi, 2014). Road failure leads to high maintenance costs, longer travel times, accidents, and reduced economic growth. Cement and lime can improve soil strength, but they are costly and environmentally harmful since their production releases large amounts of carbon dioxide (Ali et al., 2012). By using shredded sachets, a cheap and available material, the cost of stabilization can reduce while also promoting eco-friendly construction.

Previous studies have shown that plastic waste can improve soil strength. For instance, Osinubi et al. (2009) found that shredded polyethylene waste increased the California Bearing Ratio (CBR) of lateritic soil. Similarly, Muntohar (2011) reported that plastic strips improved soil stability in Indonesia. These findings support the idea that reusing sachet waste in Nigeria can work both in practice and in research.

Therefore, this study is justified because it reduces environmental pollution, provides a cheaper alternative to traditional stabilizers, improves road construction quality, and contributes to sustainable engineering practices. It also adds to the body of knowledge by showing how local waste materials can be reused for development.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Waste is one of the biggest problems in the world today. As people grow in number and use more things, more waste is produced. Among all the waste, plastics are the hardest to manage because they do not decay easily. While food and paper waste rot away in some weeks or months, plastics can stay in the environment for hundreds of years without breaking down (Thompson et al., 2009).

In Nigeria and other developing countries, one of the most common plastic wastes is the pure water sachet. These sachets are cheap and used by millions of people every day. After drinking the water, the sachets are usually thrown on the road, in the gutter, or in dumpsites. Because they are light, they spread everywhere and block drainage systems. They also mix with soil and disturb the environment (Akinwumi, 2014). The effect of plastic waste on soil is very serious. It reduces how soil behaves naturally and can cause problems in farming and construction. But on the other hand, plastics can also be reused. Some studies have shown that shredded plastics can make soil stronger for road work (Osinubi et al., 2009).

2.2 Global Perspective on Plastic Waste: Soil and Environmental Impacts

All over the world, plastic is seen as both useful and dangerous. It is useful because it is light, cheap, and easy to produce. But it is dangerous because it does not go away when it becomes waste. Every year, the world produces more than 350 million tonnes of plastics, and a large part of it becomes waste (UNEP, 2018). Most of this waste is thrown into the soil through dumping or landfilling. Since plastics do not decay, they stay in the soil and change how the soil works (Barnes et al., 2009).

Plastics in soil stop water from going into the ground, they disturb compaction, and they can even release chemicals into the environment. Over time, plastics also break into very small pieces called microplastics, which mix with soil minerals and can enter plants and crops (Thompson et al., 2009).

2.2.1 Effects of Plastic Waste on Soil

When plastics enter the soil, they disturb its natural condition. Pure water sachets and nylon bags are very common examples. They make the soil less porous, meaning water cannot pass through easily. This leads to more surface water and erosion (Akinwumi, 2014).

Plastics also make soil weaker. For example, when lateritic soil has plastics inside, the soil compacts poorly and cannot carry heavy loads. This is bad for road construction because weak soil leads to quick road failure (Osinubi et al., 2009). For farming, plastics reduce fertility. Roots of crops find it hard to penetrate the soil when plastics block the way. Plastics also change the way the soil holds water and air, which crops need to grow. When plastics break into small pieces (microplastics), they mix with soil and may be taken up by plants. This can reduce crop quality and affect food safety (Ogunrinola et al., 2021).

Another problem is chemicals inside plastics. Things like dyes and stabilizers can slowly leak out into the soil. Over time, these chemicals reduce soil fertility and may pollute groundwater (Ali et al., 2012). Even soil animals like earthworms are affected. Research shows that earthworms can eat microplastics, and this reduces how well they grow and reproduce (Huerta Lwanga et al., 2016). Since earthworms help soil to stay healthy, this is another way plastics damage soil. Plastics in soil block water, reduce strength, lower fertility, and disturb living organisms. This makes soil less useful for both farming and engineering.

2.2.2 Environmental Impacts of Plastic Waste

Plastics do not only affect soil directly; they also create bigger problems in the environment. One of the biggest issues is blocked drainage. When sachets and bags fill gutters, water cannot flow well, and this causes flooding. During heavy rain, this flooding washes away soil and spoils roads (Ikechukwu, 2020). Plastic waste also takes up land. Dumpsites full of plastics cannot be used for farming or building. Since plastics last very long, such lands stay polluted for many years (Barnes et al., 2009). Another issue is chemical leaching. Plastics slowly release harmful substances like phthalates into the ground. These substances can move into groundwater, which people use for drinking and farming. This makes the environment unsafe (Ali et al., 2012).

The presence of plastics also makes the environment look dirty. Pure water sachets and plastic bottles are scattered everywhere in towns and villages, which spoils the beauty of the environment. Many people burn plastics in open spaces to reduce the waste, but this causes air pollution and leaves harmful ash in the soil (UNEP, 2018).

Finally, plastics contribute to erosion and other climate-related issues. By blocking drains and holding water on the surface, they make soil wash away easily. This spoils farmland and weakens infrastructure. Still, plastics can also be reused in a positive way. For example, shredded sachets can be mixed with lateritic soil to make it stronger for road work (Muntohar, 2011).

2.3 Nigerian Perspective on Plastic Waste: Soil and Environment

Nigeria is a special case because of its very high use of sachet water and nylon bags. Every day, millions of Nigerians consume water in sachets and throw the plastics away, creating large amounts of waste (Ikechukwu, 2020). Unlike many developed countries with strong recycling systems, Nigeria has weak waste management. Because of this, most plastics end up on the streets, in open dumpsites, in gutters, or mixed with soil. This makes Nigeria one of the countries most affected by plastic waste problems in Africa (UNEP, 2018).

2.3.1 Plastic Waste Generation in Nigeria

Plastic waste generation in Nigeria is very high compared to many other African countries. This is mainly because of the country's very large population, which is above 200 million people, and the heavy reliance on single-use plastics in daily life (World Bank, 2019). Among the most common plastic products in Nigeria are nylon shopping bags and pure water sachets. Sachet water, popularly known as "pure water," is the cheapest and most accessible form of drinking water in both urban and rural areas. Millions of sachets are consumed every day, and after use, most of them are discarded carelessly on streets, in drains, or on farmlands. Since the material does not decay, the sachets accumulate over time and add to the country's growing waste problem (Ikechukwu, 2020; Nworie et al., 2021).

The lack of an effective waste management system makes the problem worse. Many cities do not have adequate waste collection trucks, and in areas where they exist, waste is often not separated or recycled. As a result, plastics end up in open dumpsites or scattered in the environment. UNEP (2018) noted that Nigeria produces more than 2.5 million tonnes of plastic waste every year, and only a very small fraction of this is recycled. This means that almost all of it remains in the environment. The situation is different from developed countries where plastics are collected, sorted, and reprocessed into new products (Adewuyi, 2022).

Another reason why plastic waste is high in Nigeria is the absence of strong government policies and enforcement. In many developed countries, laws have been introduced to ban or reduce single-use plastics. In Nigeria, such policies are either weak or not enforced (Adewuyi, 2022). People continue to use sachets and nylon freely without paying attention to how they are disposed of. The low level of environmental awareness among the population also contributes to this problem, as most people are more concerned with immediate convenience than long-term environmental impact (Ikechukwu, 2020).

The problem of plastic waste in Nigeria is therefore a result of a combination of high population, dependence on cheap plastic products, weak waste collection, poor recycling culture, and lack of strict policies. Because plastics do not rot like food waste, they remain in the soil and environment for hundreds of years. This explains why the volume of plastic pollution in Nigeria continues to grow daily and why it has become a serious challenge for both soil and the environment (UNEP, 2018; Ogunrinola et al., 2021).

2.3.2 Effects of Plastic Waste on Soil in Nigeria

Plastics affect Nigerian soils in two important ways: agricultural soils and engineering soils.

a. **Agricultural Soils**: Plastics reduce soil fertility by blocking air and water flow in the soil. This affects the natural balance needed for crops to grow. Roots of plants cannot penetrate the soil freely because plastics form a barrier, leading to weak crops. Microplastics have already been found in Nigerian farmlands, and these particles can enter food crops, which may cause health problems for humans (Ogunrinola et al., 2021). The presence of plastics also changes soil texture and reduces its ability to hold nutrients, making it less productive. In rural areas, farmers often complain that sachets from nearby towns blow into farms and disturb cultivation.

b. **Engineering Soils (Laterite)**: Lateritic soil is the common material used for road construction in Nigeria. When plastic waste gets mixed into laterite naturally, it reduces soil compaction. Osinubi et al. (2009) found that soils with plastics have low California Bearing Ratio (CBR), meaning they cannot carry heavy traffic loads. This contributes to why many Nigerian roads crack and fail soon after being built. Instead of stabilizing, random plastics act as weak spots inside the soil, lowering its engineering quality.

2.3.3 Environmental Problems Caused by Plastic Waste in Nigeria

Plastic waste also creates many environmental problems beyond just the soil. These include:

1. **Drainage blockage:** Pure water sachets and nylon bags often block gutters, culverts, and canals. During the rainy season, this causes floods in cities like Lagos and Port Harcourt (Akinwumi, 2014).
2. **Flooding and erosion:** Blocked drains lead to water overflow. This destroys roads, washes away farmlands, and erodes fertile topsoil.
3. **Loss of useful land:** Dumpsites in Nigeria are filled with plastics, making land unavailable for farming or housing (Barnes et al., 2009). Plastics stay for decades without decaying.
4. **Open burning:** Because waste collection is weak, many Nigerians burn plastics to reduce waste volume. This practice releases harmful smoke and leaves toxic ash that pollutes the soil (UNEP, 2018).
5. **Groundwater pollution:** Chemicals from plastics, when dumped, can leach into underground water. This contaminates wells and boreholes used for drinking.
6. **Animal deaths:** Sometimes plastics are eaten by goats, cows, and fish. This not only kills animals but also affects humans who eat them later (Nworie et al., 2021).

2.3.4 Opportunities for Reuse in Nigeria

Although plastics cause big problems, they can also be reused in civil engineering and other ways:

1. **Soil stabilization**

   Shredded sachets can be added to weak lateritic soils in small amounts (2–6%). This improves compaction and increases California Bearing Ratio (CBR), making the soil stronger (Osinubi et al., 2009). Stronger soils reduce road failure in Nigeria.

2. **Erosion control**

Plastics can be used as reinforcement in soils on riverbanks and gullies. This helps reduce soil erosion during heavy rains.

3. **Road construction materials**

   Plastics can be melted and mixed with asphalt to produce stronger pavements. Akinwumi (2014) suggested this method as an alternative to reduce the cost of bitumen in Nigerian roads.

4. **Cheaper engineering solutions**

   Cement and lime are very expensive stabilizers. Using plastic sachets is cheaper and also cleans the environment. This creates a "two-in-one" solution—less pollution and stronger soils.

5. **Job creation**

   Collecting, shredding, and preparing sachets for engineering use can create jobs for unemployed Nigerians.

2.4 Plastic Waste in Civil Engineering Applications

Plastic waste is becoming one of the biggest environmental problems in the world today, and Nigeria is not left out. Every day, millions of pure water sachets, bottles, and cans are thrown away. These plastics end up on the streets, in drains, and on farmland, where they cause pollution and flooding. But instead of throwing them away, plastics can be reused in civil engineering. This idea is important because it solves two problems at the same time: waste management and shortage of affordable construction materials.

In civil engineering, plastics can be used to improve weak soils, build better roads, control erosion, and even improve foundations. They also help to protect the environment by reducing the amount of waste in open dumpsites. This section explains the different ways plastics are used in civil engineering, focusing on soil stabilization, road construction, erosion and drainage control, foundation and embankment improvement, environmental benefits, and challenges of usage.

2.4.1 Concept of Soil Stabilization

Soil stabilization means improving the properties of soil so that it can carry more load and perform better in engineering projects. Soil is the base of every structure. If the soil is weak, then roads, buildings, and embankments will fail. In Nigeria, lateritic soil is very common, and it is widely used for road and building construction. But sometimes laterite is not strong enough and must be stabilized.

Traditionally, stabilization is done using cement, lime, or other chemicals. Cement and lime are good because they increase the California Bearing Ratio (CBR) and shear strength of soil, making it more stable (Bell, 1993). But they are also expensive. In Nigeria, many projects fail because there is not enough money to buy stabilizers, and this leads to poor roads and collapsed structures (Osinubi et al., 2009).

Plastic waste provides a cheaper option. Instead of using only cement or lime, shredded plastics can be mixed with soil. Plastics are lightweight, durable, and resistant to water, which makes them good stabilizers. According to Akinwumi (2014), adding small percentages of plastic strips to soil improves flexibility and reduces cracking. This shows that soil stabilization does not always require expensive imported materials.

2.4.2 Plastic Waste in Soil Stabilization

Plastic waste can be used as reinforcement in weak soils. Pure water sachets and bottles can be collected, washed, shredded, and mixed into soil at different percentages. When plastics are added, they change the soil properties in the following ways:

1. **Compaction:**

   Plastics reduce the maximum dry density (MDD) but increase the optimum moisture content (OMC). This means the soil becomes lighter but requires more water for compaction (Osinubi et al., 2009). Even though the density reduces, the soil becomes tougher and more resistant to cracking.

2. **Soil Strength:**

   Strength is measured using the California Bearing Ratio (CBR). When shredded plastics are added at 2–6%, the CBR value improves compared to untreated soil (Akinwumi, 2014). This shows that soil can now carry heavier loads, which is good for road subgrades and building foundations.

3. **Durability:**

   Plastic-reinforced soils resist water infiltration. Pure water sachets are waterproof, so when they are mixed into soil, they reduce the effect of rainfall and flooding (Ogunrinola et al., 2021).

4. **Swelling and Shrinkage:**

   Expansive soils swell when wet and shrink when dry, causing cracks in buildings. Plastics reduce this effect by acting like small barriers inside the soil.

These improvements show that plastic waste is not just trash but a useful engineering material.

2.4.3 Plastic Waste in Road Construction

Nigeria has serious road problems. Many roads fail within a few years of construction because of weak soils, poor drainage, and lack of maintenance. Plastics can be used to improve road quality in two main ways:

a. **Plastics in soil subgrades**

   When plastics are mixed into road subgrade soils, they act as reinforcement. They hold soil particles together, reduce settlement, and improve load distribution. Osinubi et al. (2009) tested lateritic soils reinforced with polyethylene strips and reported better CBR values. This is very useful in Nigeria's rural roads, where cement or lime is too costly.

b. Plastics in asphalt

Plastics can also be melted and added to bitumen to produce plastic-modified asphalt. India has successfully used this method for years. Roads built with plastic asphalt are stronger, more flexible, and resist rutting (Sharma et al., 2014). In Nigeria, Akinwumi (2014) suggested that pure water sachets could be used in asphalt, reducing the amount of imported bitumen and lowering costs.

The benefits of using plastics in roads are many:

a. Lower cost of construction
b. Stronger and longer-lasting pavements
c. Reduced environmental pollution
d. Better performance during rainfall

2.4.4 Use of Plastic Waste in Erosion and Drainage Control

Erosion is one of the biggest environmental problems in Nigeria, especially in the southeastern states like Anambra and Imo. Gully erosion destroys farmland, roads, and even houses. Plastics can be reused to help control this problem.

Plastic strips can be mixed with soils along slopes and gully edges to strengthen them. This makes the soil more resistant to being washed away during rain. Plastic nets and grids made from recycled plastics are also used in other countries to stabilize slopes and control erosion (Barnes et al., 2009). Nigeria can adopt this method for erosion-prone areas.

In drainage systems, plastics can also be helpful. Right now, plastics are the main cause of blocked drains and flooding in cities like Lagos. But if plastics are recycled into drainage blocks or permeable pavers, they can improve water flow while also reusing waste. This prevents urban flooding and keeps the environment cleaner.

2.4.5 Plastic Waste in Foundation and Embankment Improvement

Buildings and embankments need strong soils to avoid collapse. Weak soils lead to settlement, cracks, and failure of structures. Plastics can be reused to strengthen foundations and embankments in the following ways:

1. **Reinforcement:** Adding shredded plastics to foundation soils increases shear strength and reduces settlement.
2. **Lightweight Fill:** Plastics are lighter than soil. When used in embankments, they reduce the total load on weak soils.
3. **Water Resistance:** Plastics reduce water infiltration into soils, making them stronger during rainfall.

Osinubi et al. (2009) and Akinwumi (2014) both confirmed that plastic waste improves soil load-bearing capacity. This makes it suitable for housing projects, especially in rural communities where foundation failure is common.

2.4.6 Environmental Benefits of Using Plastics in Civil Engineering

Reusing plastics in civil engineering has many environmental benefits. Nigeria is struggling with plastic waste pollution, flooding, and blocked drainage (UNEP, 2018). Using plastics in construction helps to:

1. Reduce the amount of plastic waste in open dumps
2. Minimize flooding by removing plastics from drains
3. Provide a cleaner environment and reduce burning of plastics, which releases harmful smoke
4. Save land space by reducing dumpsites
5. Support recycling and reduce dependence on expensive imported materials like cement and bitumen

Therefore, using plastics is not just an engineering solution but also an environmental one. It provides cleaner streets, reduces health risks, and promotes sustainable development.

2.5 SHREDDED PURE WATER SACHETS IN LATERITE STABILIZATION

One promising approach is the reuse of waste plastics, particularly shredded pure water sachets, the most common form of low-density polyethylene (LDPE) waste in Nigeria. The reuse of these sachets not only addresses environmental pollution caused by indiscriminate disposal but also provides a locally available material capable of improving soil performance under saturated conditions (Osinubi, Eberemu, & Ijimdiya, 2009). When appropriately incorporated into lateritic soil, shredded sachets act as synthetic fibers that reinforce the soil structure, reduce permeability, and enhance shear resistance.

2.5.1 Chemical Composition of Pure Water Sachets (LDPE)

Pure water sachets used across Nigeria are made from low-density polyethylene (LDPE), a thermoplastic polymer derived from the polymerization of ethylene gas under high pressure. The polymer consists of long carbon–hydrogen chains with minimal branching, giving it flexibility, low density, and chemical inertness (Thompson, Moore, Vom Saal, & Swan, 2009). The fundamental repeating unit of the polymer is the ethylene monomer ($–CH_2–CH_2–$), which forms the backbone of LDPE.

Chemically, LDPE is composed primarily of carbon (85–87%) and hydrogen (12–14%), with trace quantities of stabilizers, antioxidants, pigments, and plasticizers added during manufacturing. These additives are intended to improve mechanical performance, resistance to ultraviolet radiation, and long-term durability.

LDPE’s polymeric structure exhibits high molecular weight and significant chain branching, which contribute to its low crystallinity and light weight (specific gravity ≈ 0.92). These characteristics make LDPE flexible, resistant to moisture, and nearly impermeable to water molecules. From an environmental perspective, this resistance to chemical and biological degradation is problematic because it prevents natural decomposition. However, in controlled geotechnical applications, this same persistence becomes advantageous, as the plastic pieces remain intact for years, providing long-term reinforcement to the soil matrix.

Unlike organic waste materials that can decay or react with soil minerals, LDPE is chemically inert—it neither dissolves in water nor releases toxic ions under normal environmental conditions (Muntohar, 2011). Its carbon–hydrogen composition also ensures that it is non-corrosive and compatible with a wide range of soil types, including acidic or alkaline environments. Therefore, when shredded sachets are incorporated into soil, they remain stable, forming a durable matrix that strengthens the soil structure through mechanical interlocking rather than chemical reaction.

2.5.2 Properties of LDPE That Influence Soil Stabilization

The suitability of shredded LDPE as a stabilizing material is attributed to its unique physical and mechanical characteristics. These properties affect how it interacts with soil particles and water, influencing compaction, strength, and durability.

I. Low Density and Lightweight Behavior: LDPE has a density of approximately **0.91–0.94 g/cm^3**, which is significantly lower than the density of soil minerals (2.6–2.7 g/cm^3). When blended with soil, shredded sachets reduce the overall dry density of the mixture, leading to a lighter but more flexible mass. In road subgrades laid over soft or waterlogged grounds, this lower density minimizes settlement and differential deformation, improving the pavement's overall stability (Osinubi et al., 2009).

II. High Tensile Strength and Flexibility: Although LDPE is lightweight, it possesses moderate tensile strength ranging from 8–12 MPa and elongation at break values up to 400% (Barnes et al., 2009). These properties enable the shredded sachets to behave like micro-reinforcing fibers that bridge soil particles and resist tensile cracking. Under applied loads, the plastic strips distribute stress more evenly through the soil mass, reducing the development of localized failure planes. The flexible nature of LDPE allows it to deform under stress without breaking, thereby improving soil ductility and post-peak strength.

III. Hydrophobic and Impermeable Nature: One of the most valuable characteristics of LDPE for soil stabilization is its hydrophobic surface. LDPE does not absorb or transmit water molecules. When incorporated into lateritic soil, it acts as a barrier that reduces water infiltration and moisture-induced softening of the clay fraction. This property is especially beneficial for waterlogged laterite, where controlling pore-water pressure and minimizing swelling is critical to maintaining strength (Akinwumi, 2014). By creating a discontinuous internal structure, shredded sachets enhance drainage and reduce capillary rise, preventing continuous water films from forming between particles a primary cause of reduced shear strength in saturated soils.

IV. Durability and Chemical Inertness: LDPE's nonpolar molecular structure makes it resistant to acids, alkalis, and salts found naturally in soil or groundwater. This ensures that the stabilizing material does not degrade chemically or lose strength over time. The polymer's melting point (≈110 °C) and operational temperature range (–40 °C to +80 °C) also guarantee thermal stability under field conditions (Muntohar, 2011).

V. Such chemical and thermal resistance distinguishes LDPE from other organic stabilizers such as rice husk ash or sawdust, which are susceptible to microbial decomposition. Hence, soils stabilized with shredded sachets maintain long-term performance even under harsh environmental conditions.

VI. Toughness and Resistance to Cracking: The addition of flexible LDPE particles enhances the toughness of stabilized soil, meaning the mixture can absorb more energy before failure. This toughness helps to mitigate surface cracking commonly observed in cement-stabilized lateritic soils during drying. Moreover, the plastic inclusions reduce brittleness and improve the soil's capacity to withstand cyclic wetting and drying without disintegration (Osinubi et al., 2009).

VII. Environmental Compatibility: LDPE sachets are non-toxic and non-biodegradable; hence, their reuse in soil does not generate harmful by-products. Instead of persisting as litter that clogs drainages and pollutes waterways, they are repurposed into useful engineering applications. This conversion supports sustainable construction and aligns with circular economy goals (United Nations, 2015).

2.5.3 Effects of Shredded Pure Water Sachets on Soil Properties

The inclusion of shredded LDPE sachets in lateritic soil modifies several engineering properties relevant to road subgrade and foundation performance. Laboratory results from previous studies consistently show improvements in strength, durability, and resistance to moisture effects. The major effects are summarized below.

1. Strength and Load-Bearing Capacity: The improvement in strength is one of the most significant effects of adding shredded sachets to lateritic soil. In geotechnical terms, strength is often measured using the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) tests. Osinubi et al. (2009) reported that adding 2–6% shredded polyethylene waste to lateritic soil increased soaked CBR values from 5% to between 8% and 12%, depending on soil type and compaction energy. Similar improvements were observed in UCS values, with gains ranging between 25% and 40%. The strength enhancement results from a fiber-reinforcement mechanism, in which the plastic pieces act as stress bridges within the soil. Under load, tensile stresses that would normally cause cracking or shearing are transferred to the LDPE strips, which resist elongation and distribute stress throughout the matrix. This interaction improves the soil's shear resistance and its ability to carry higher loads without significant deformation (Akinwumi, 2014).

2. Reduction in Plasticity and Volume Change: Plasticity, defined by the Plasticity Index (PI), indicates the soil's tendency to undergo large volume changes due to moisture fluctuations. High plasticity in lateritic soils often leads to swelling during wet periods and shrinkage during dry conditions, which causes surface cracking and structural failure when LDPE sachets are mixed into the soil, they dilute the clay fraction and disrupt the continuity of water-holding films around soil particles. This effectively reduces the liquid limit (LL) and plasticity index (PI), resulting in a more dimensionally stable material (Osinubi et al., 2009). Akinwumi (2014) observed that adding 4% plastic waste reduced the PI of lateritic soil from 24% to 17%, demonstrating improved stability against swelling and shrinkage cycles.
3. Compaction and Density Characteristics: The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are essential parameters governing the compaction behavior of soils. Studies show that the inclusion of lightweight LDPE reduces MDD slightly due to its low specific gravity but increases OMC (Muntohar, 2011). For example, a lateritic soil with an MDD of 1.85 Mg/m^3 and OMC of 12% exhibited new values of 1.78 Mg/m^3 and 13.5% respectively after incorporating 4% LDPE by weight. The higher OMC is beneficial in waterlogged zones because it allows the soil to retain moisture without excessive loss of strength, while the lower density decreases settlement potential. The net effect is a soil that, although lighter, is more resilient to deformation and easier to compact in the field.
4. Permeability and Moisture Movement: Water infiltration and pore-pressure buildup are major causes of failure in saturated subgrades. Shredded LDPE sachets introduce discontinuities and small drainage pathways within the soil, improving permeability and facilitating drainage under load. At the same time, the hydrophobic surfaces of the sachets prevent the formation of continuous water films, which would otherwise lead

to loss of effective stress. This dual effect enhanced drainage yet reduced saturation translates to better performance under soaked conditions. Soils reinforced with LDPE exhibit slower strength loss during flooding or prolonged wet periods compared with untreated laterite (Ogunrinola, Adejumo, & Awogbemi, 2021).

5. Resistance to Erosion and Shear Deformation: Erosion and shear failure are common in road embankments and slopes constructed over weak soils. The incorporation of LDPE strips improves the soil's resistance to scouring and shear deformation by enhancing internal friction and binding strength. Under shear testing, LDPE-reinforced soils display higher cohesion and friction angles than natural soils. The plastic inclusions also help retain soil mass on slopes, making the material suitable for erosion-prone areas (Muntohar, 2011). In addition, the flexible fibers absorb part of the deformation energy, reducing raveling and surface cracking during dry spells. This enhances the long-term durability of road subgrades and embankments exposed to alternating wet and dry conditions.
6. Durability Under Cyclic Wetting and Drying: In tropical regions, soils undergo repeated cycles of saturation during rainfall and drying during the dry season. These cycles weaken cementitious or clayey soils by causing micro-cracks and reducing cohesion. LDPE reinforcement mitigates this problem by acting as a flexible skeleton that maintains soil integrity even when pore water evaporates. Osinubi et al. (2009) reported that after five wet-dry cycles, LDPE-reinforced soils retained up to 85% of their original UCS, compared to only 60% for untreated soil. The improved durability is attributed to the elastic recovery and water-repelling nature of the plastic inclusions.
7. Environmental and Economic Benefits: From an environmental standpoint, using shredded pure water sachets for soil stabilization represents a sustainable waste management strategy. Nigeria generates millions of tonnes of plastic waste annually,

with less than 15% recycled (Ikechukwu, 2020). Diverting this waste into geotechnical applications reduces landfill pressure, mitigates urban flooding caused by blocked drains, and supports the principles of the UN Sustainable Development Goals (SDGs 11 and 12) on sustainable cities and responsible consumption (United Nations, 2015). Economically, the reuse of sachet plastics reduces dependence on expensive stabilizers such as cement and lime. The cost of collecting, washing, and shredding sachets is significantly lower than that of purchasing imported chemical additives. This makes LDPE stabilization a viable option for local road projects, particularly in rural and low-income communities. Moreover, the process promotes job creation in the recycling sector local youth and women can engage in the collection and preparation of sachet waste for engineering applications. This aligns with Nigeria's drive toward circular economy initiatives and community-based waste recovery programs (UNEP, 2018).

2.6 Gap in Literature

From the review of past works, it is clear that plastic waste has been studied in different parts of the world as both an environmental problem and a construction material. Many studies have confirmed that plastics can improve soil strength, durability, and resistance to water when mixed in small amounts with weak soils (Osinubi et al., 2009; Akinwumi, 2014). Other works also showed that plastics can be melted into asphalt to make stronger roads, and some countries like India have already adopted this practice on a large scale (Sharma et al., 2014). In addition, plastics have been tested for erosion control and in slope reinforcement, showing promising results for preventing soil loss (Barnes et al., 2009).

But in all these studies, there are still many gaps that need to be filled. One major gap is that most of the works are done outside Nigeria, in countries where waste management and construction practices are different. For example, while India has successfully used plastic asphalt for highways, in Nigeria the application is still very limited and remains mostly in experimental research (Sharma et al., 2014). This shows that there is a lack of local data to guide the use of plastics in Nigerian conditions.

Another gap is that most studies have focused on plastic use in asphalt, concrete, or slope protection, but there are fewer works that focus directly on soil stabilization using plastics, especially lateritic soils. Lateritic soils are very common in Nigeria, and they are the main material for road subgrades and housing foundations. Yet not much has been done to test how sachet water plastics, which are the biggest source of plastic waste in Nigeria, can improve the engineering properties of laterite (Akinwumi, 2014). This makes the gap very clear because even though lateritic soil and sachet plastics are both abundant in Nigeria, the connection between them has not been fully studied.

Another issue is that while many works talk about the environmental problems of plastic waste, such as flooding, blocked drains, and pollution (UNEP, 2018; Ogunrinola et al., 2021), very few of them directly link these problems with soil stabilization as a solution. In other words, the environmental problem is always treated separately from the engineering solution. There is still a missing link that shows how reusing sachet plastics in soil not only improves soil strength but also reduces waste pollution in the environment. This connection is very important for sustainable development, but most past studies have not made it clear (Barnes et al., 2009).

There is also the problem of lack of standards in Nigeria. In developed countries, there are already technical guides and codes that specify how plastics can be used in roads and soils. But in Nigeria, there are no official standards for plastic-stabilized soils or plastic asphalt. This makes engineers and contractors doubtful about using the method because they do not have official documents to rely on (Adewuyi, 2022). This lack of standards is a major gap because even if laboratory studies show that plastics are effective, without national policies or design codes, the adoption will remain slow.

Finally, it can be observed that most studies do not test pure water sachets specifically, even though they are the most common form of plastic waste in Nigeria. Instead, researchers often use generic polyethylene plastics or imported waste plastics in their tests. This creates a gap because the properties of sachet plastics may be slightly different from other plastics (Ikechukwu, 2020). Since sachet waste is the real problem in Nigeria, it should also be the main focus of engineering research.

These gaps show that more work still needs to be done, especially in Nigeria, to provide local knowledge and practical evidence on how sachet plastics can be reused for soil stabilization. Filling these gaps will not only improve the performance of construction works but will also help reduce plastic pollution and its harmful effects on the environment.

2.7 Previous Studies

Many studies have been done on the use of plastic waste in soil and civil engineering, and they show that plastics can improve strength and reduce environmental pollution. For example, Osinubi et al. (2009) studied lateritic soil mixed with shredded polyethylene and found that the plastic improved the California Bearing Ratio (CBR) and made the soil better for road construction. This shows that plastics, even though they are waste, can serve as a soil stabilizer. In another work, Akinwumi (2014) also studied shredded polyethylene waste in soil and reported that it increased maximum dry density and reduced plasticity index of weak soils. The study concluded that polyethylene can be used for engineering purposes, especially in subgrade soil stabilization. This result agrees with Osinubi et al. (2009) and proves that plastics can work well with Nigerian soils.

Outside Nigeria, Sharma et al. (2014) used plastic waste in flexible pavements in India. Their study showed that mixing plastics with asphalt improved pavement durability, reduced rutting, and solved plastic waste disposal problems. This is important because India faces similar sachet and bag waste problems like Nigeria, and their success suggests Nigeria can also apply the same method.

Barnes et al. (2009) worked more on environmental aspects, showing how plastic debris accumulates in soils, rivers, and oceans, creating pollution and blocking natural systems. Their study did not directly test plastics in soil stabilization, but it highlighted why reuse is necessary to reduce waste impact.

Locally, Ikechukwu (2020) studied sachet water waste in Nigerian cities and explained how it blocks drains, increases flooding, and causes littering everywhere. But the study stopped at describing the environmental problem and did not link sachet plastics to engineering solutions like soil stabilization. This gap shows that more practical research is needed in Nigeria.

UNEP (2018) also reported that single-use plastics are one of the biggest waste problems in the world. The report encouraged countries to find new uses for plastics, including construction. But the UNEP document was more of a policy guide and did not give laboratory results or Nigerian examples.

Ogunrinola et al. (2021) reviewed plastic pollution in Nigeria and pointed out that plastic waste is rising every year because of population growth and sachet water consumption. They also suggested recycling and reuse in civil works as possible solutions, but they did not provide experiments. This again shows a missing link between waste management and soil engineering.

From these past studies, it is clear that plastic waste has potential as a construction material, and it has already been tested in many places. But most of the work i

CHAPTER THREE

METHODOLOGY

3.1 Background of Study

The study area for this research is Textile Mill Road, Benin City, Edo State, Nigeria. This location was strategically selected based on several critical factors that make it ideal for investigating lateritic soil stabilization using shredded pure water sachets.

Textile Mill Road is situated in the industrial zone of Benin City and experiences moderate to heavy traffic loads due to commercial and industrial activities in the area. The road has exhibited recurring pavement distress, including rutting, potholes, and edge failures, particularly during the rainy season when the lateritic subgrade becomes saturated and loses bearing capacity.

The selection of Textile Mill Road was based on the following considerations:

1. **Soil Type:** The area is predominantly underlain by lateritic soil, which is common throughout Edo State and much of southern Nigeria. Lateritic soils, while widely available, often exhibit poor engineering properties such as high plasticity, low bearing capacity when saturated, and susceptibility to erosion.
2. **Accessibility:** The location is easily accessible for sample collection and potential future field trials, facilitating both research activities and practical application of findings.
3. **Practical Relevance:** Textile Mill Road serves as a vital transportation link for industrial activities. Improving its pavement performance through sustainable stabilization methods would have immediate socioeconomic benefits for the local community.
4. **Environmental Concern:** Benin City, like many Nigerian cities, faces significant challenges with plastic waste management. Pure water sachets constitute a substantial

portion of urban waste streams. Using this waste material for road construction addresses both an engineering problem and an environmental issue.

5. **Representative Conditions:** The soil and traffic conditions at this location are representative of many urban and peri-urban roads in the region, making the research findings transferable to other similar contexts.

Fig 3.1: Study Area Location Map (maps, 2025)

3.2 Sample Collection Procedure

3.2.1 Lateritic Soil Sample Collection

Soil samples were collected from multiple points along Textile Mill Road to ensure representative characterization of the subgrade material. The sampling procedure was conducted in accordance with ASTM D420 (Standard Guide to Site Characterization for Engineering Design and Construction Purposes) and BS 1377 (Methods of Test for Soils for Civil Engineering Purposes).

Sampling Equipment:

1. Hand auger (for depths 0-1.5 m)
2. Spade and shovel (for surface excavation)
3. Trowel and scoop (for sample transfer)
4. Measuring tape and depth gauge
5. Clean, labeled polyethylene bags
6. Sample identification tags and waterproof markers
7. GPS device for coordinate recording
8. Field notebook for documentation

Sampling Procedure:

1. **Site Preparation:** Vegetation and surface debris were cleared from each sampling location. Surface organic material (topsoil) was removed to a depth of approximately 15-20 cm to avoid contamination of samples with organic matter.
2. **Sampling Depth:** Samples were collected at a uniform depth of 1.0 meter below the cleared surface. This depth was selected because it represents the typical subgrade zone for road construction, where stabilization is most critical for load distribution and pavement performance.
3. **Sampling Points:** Five sampling points were established at 50-meter intervals along a 200-meter stretch of Textile Mill Road. This spacing ensured adequate coverage while accounting for potential spatial variability in soil properties.
4. **Sample Extraction:** At each location, a hand auger was used to bore to the target depth. Soil samples were carefully extracted, ensuring minimal disturbance to soil structure. Approximately 20-25 kg of soil was collected from each point to provide sufficient material for all planned laboratory tests and multiple replications.

5. **Sample Handling:** Immediately after extraction, samples were placed in clean, heavy-duty polyethylene bags. Each bag was double-sealed to prevent moisture loss and labeled.
6. **Transportation and Storage:** Samples were transported to the Soil Mechanics Laboratory, Department of Civil Engineering, University of Benin, within 4 hours of collection. They were stored in a cool, dry environment away from direct sunlight to preserve their natural moisture content until testing commenced.
7. **Sample Homogenization:** In the laboratory, samples from the location were air-dried, broken down manually (avoiding pulverization of individual particles), and thoroughly mixed to create a composite sample.

3.2.2 Pure Water Sachet Collection and Processing

Pure water sachets were collected from multiple sources within the Faculty of Engineering, University of Benin.

Collection Procedure:

1. **Material Selection:** Only pure water sachets made from Low-Density Polyethylene (LDPE) were collected.
2. **Cleaning Process:** Collected sachets were washed thoroughly with clean water to remove dirt, organic matter, and any residual contents. They were then spread out on clean surfaces and allowed to air-dry completely for 48-72 hours.
3. **Shredding Process:** Dried sachets were manually cut into smaller pieces using scissors, then processed through a mechanical shredder to achieve uniform dimensions. The shredding was performed using a laboratory-scale plastic shredder with adjustable blade settings in Production engineering laboratory.
4. **Storage:** Shredded sachets were stored in clean, dry containers, labeled with processing date and size classification, until ready for mixing with soil samples.

Approximately 300g of shredded pure water sachets were prepared to accommodate all planned stabilization ratios and replicate tests.

3.3 MATERIALS AND METHODS

3.3.1 Materials

a) Soil Sample: Lateritic or clayey soil commonly found in water-logged areas, which are Collected from a depth of 1.0 meters in a water-logged site.
b) Bamboo Leaf Ash (BLA)
c) Water: Clean potable water used for mixing and compaction.
d) Hand auger o (for 0–60 cm depth)
e) Spade or shovel (for surface sampling or clearing vegetation)
f) Trowel or scoop (for transferring soil into containers)
g) Clean, labeled polyethylene or zip-lock bags

3.3.2 Methods

All test such as California Bearing Ratio (CBR), atterberg limit (liquid and plastic limit), Grain size distribution and Compaction test were carried out at University of Benin A Civil/Structural Engineering Laboratory located inside the school campus.

3.4 Laboratory Testing

This phase of the research involved the laboratory evaluation of selected engineering properties of the lateritic soil before and after stabilization with shredded pure water sachets. The aim was to determine how the inclusion of the shredded sachet material influences the soil's compaction characteristics, plasticity, and load-bearing capacity. Three key tests were conducted in accordance with the relevant British Standard (BS 1377, 1990) and the Nigerian General Specification for Roads and Bridges (FGN, 1997). These tests include:

i. Compaction Test
ii. California Bearing Ratio (CBR) Test
iii. Atterberg Limits Test
iv. Sieve Analysis

All laboratory analyses were carried out at ambient temperature using lateritic soil samples collected from a waterlogged site. The soil samples were air-dried, pulverized, and passed through a 4.75 mm sieve prior to testing. Shredded pure water sachets were incorporated at varying proportions of 0%, 2%, 4%, and 6% by dry weight of soil to examine the effects of the plastic content on the soil properties.

3.4.1 Compaction Test

The purpose of the compaction test was to determine the relationship between the dry density and moisture content of the soil, and to establish the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for both untreated and plastic-stabilized soil samples. These parameters are essential in assessing the field compaction requirements for subgrade and sub-base layers.

Apparatus

1. Standard Proctor compaction mould (1000 cm^3 capacity)
2. Rammer of 2.5 kg weight, with a 300 mm drop height
3. Balance (accuracy ±0.01 g)
4. Oven maintained at 105–110 °C
5. Straightedge and spatula
6. Sieve (No. 4, 4.75 mm)
7. Mixing bowls and graduated cylinders

Procedure

The compaction test was carried out in accordance with BS 1377: Part 4 (1990) using the Standard Proctor method. The following steps were observed:

1. A representative sample of air-dried soil passing the 4.75 mm sieve was obtained.
2. Shredded pure water sachets were mixed uniformly with the soil at 0%, 2%, 4%, and 6% by dry weight.
3. The sample was thoroughly mixed with water to achieve a predetermined moisture content and was then compacted into the Proctor mould in three layers, each receiving 27 blows from the rammer.
4. After compaction, the mould was weighed to determine the bulk density.
5. A small portion of the compacted soil was taken and oven-dried to determine the moisture content.
6. The process was repeated for several moisture contents (typically 6%–18%) to obtain a series of density moisture data.
7. The dry density was calculated
8. A graph of dry density versus moisture content was plotted, and the peak point of the curve was used to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).

3.4.2 California Bearing Ratio (CBR) Test

The California Bearing Ratio (CBR) test was conducted to evaluate the bearing capacity and strength characteristics of the soil, both in its natural state and when stabilized with shredded pure water sachets. The CBR value is used in pavement design to classify subgrade strength and determine the required thickness of pavement layers.

Apparatus

1. CBR mould (150 mm diameter, 175 mm height) with detachable base plate
2. CBR loading machine with proving ring and penetration piston (50 mm diameter)
3. Dial gauge (accuracy ±0.01 mm)
4. Soaking tank with surcharge weights
5. Compaction rammer (2.5 kg)
6. Water and balance

Procedure

The test was carried out following BS 1377: Part 4 (1990) procedure:

1. Soil samples were prepared at their respective Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) obtained from the compaction test.
2. Shredded LDPE sachets were mixed into the soil at varying percentages (0%, 2%, 4%, 6%) by dry weight.
3. The mixture was compacted in the CBR mould in three layers, each layer receiving 56 blows of the rammer.
4. After compaction, the specimens were extruded carefully and soaked in water for 96 hours (4 days) to simulate field waterlogged conditions. Surcharge weights were applied to simulate the overburden pressure.
5. After soaking, the specimen was placed under the CBR testing machine, and the penetration piston was allowed to penetrate the soil at a rate of 1.25 mm/min.
6. The load–penetration readings were recorded at 0.5 mm intervals up to 7.5 mm penetration.
7. The CBR value was determined
8. The higher of the two values (2.5 mm or 5.0 mm) was taken as the CBR value for that sample.

3.4.3 Atterberg Limits Test

The Atterberg Limits Test was carried out to determine the Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) of the natural and stabilized soil samples. These parameters indicate the soil's consistency, workability, and potential for volume change when exposed to moisture.

Apparatus

1. Casagrande liquid limit device
2. Grooving tool and flat spatula
3. Glass plate for rolling plastic threads
4. Balance (accuracy ±0.01 g)
5. Moisture tins
6. Oven (105–110 °C)
7. Wash bottle and distilled water

Procedure

The procedure was performed in accordance with BS 1377: Part 2 (1990):

Determination of Liquid Limit (LL):

1. The soil sample passing the 425 μm sieve was mixed with varying amounts of water until a paste was formed.

2. The paste was placed in the Casagrande cup, and a groove was cut through the center using a standard grooving tool.

3. The cup was dropped at a rate of 2 drops per second until the two halves of the soil met over a distance of 12 mm.

4. The number of blows required to close the groove was recorded.

5. The process was repeated at different moisture contents to obtain four or more readings.

6. A graph of moisture content versus number of blows (log scale) was plotted, and the moisture content corresponding to 25 blows was recorded as the Liquid Limit (LL).

Determination of Plastic Limit (PL):

1. Another portion of the soil was rolled on a glass plate into threads approximately 3 mm in diameter.

2. The moisture content at which the thread crumbled and could no longer be rolled was recorded as the Plastic Limit (PL).

Calculation of Plasticity Index (PI):

PI = LL – PL

3.4.4 Unconfined Compressive Strength (UCS) Test

The Unconfined Compressive Strength (UCS) test measures the maximum axial compressive stress that a cohesive soil can withstand before failure under unconfined conditions (no lateral support). This test provides a direct measure of soil strength and is particularly useful for evaluating the effectiveness of stabilization treatments.

Procedure

1. Cylindrical specimens were prepared with a standard diameter of 38 mm and a height of 76 mm, maintaining a height-to-diameter ratio of 2:1. The specimens were compacted or molded at their respective Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), as determined from the Standard Proctor Compaction Test.
2. After preparation, the specimens will be carefully wrapped in plastic film or stored in sealed containers to prevent moisture loss and will be cured under controlled conditions for 7, 14, and 28 days. Curing will be done at room temperature in a humidity-controlled environment to simulate field conditions and allow pozzolanic reactions to develop in stabilized samples.

3. At the end of each curing period, the specimens will be removed and their dimensions (diameter and height) were measured using a Vernier caliper to the nearest 0.1 mm. The specimens will be then placed vertically between the platens of a UCS testing machine. The axial load is applied at a constant strain rate, typically 1% per minute, until the specimen failed either by bulging or by developing a shear plane.

   UCS = P / A_0,

   where P is the maximum applied load and A_0 is the original cross-sectional area of the specimen.
4. During the test, the axial load and corresponding deformation were recorded continuously. The compressive stress was calculated by dividing the applied load by the corrected cross-sectional area of the specimen, which accounts for lateral expansion during loading. The maximum stress sustained by the specimen before failure was recorded as the Unconfined Compressive Strength (qu). The undrained shear strength (su) was then estimated as half of the UCS value

3.4.5 Grain Size Distribution

The grain size distribution test is conducted to determine the proportions of different particle sizes within a soil sample. This classification helps in understanding the soil's drainage characteristics, compaction behavior, and suitability for construction purposes. The results are typically used to classify the soil according to systems such as the Unified Soil Classification System (USCS) or AASHTO.

Procedure

1. The test was carried out using the sieve analysis method, which is suitable for soils with particle sizes ranging from coarse gravel to fine sand (typically particles larger than 75 µm). The procedure followed is as outlined below:

2. First, the soil sample was oven-dried at a temperature of 105–110°C for a minimum of 24 hours to remove all moisture. Once dried, the sample was allowed to cool and then weighed to determine the total dry mass.
3. A stack of standard sieves was arranged in descending order of mesh size, typically starting from 4.75 mm down to 75 µm. The sieves were securely placed on a mechanical sieve shaker, with a pan at the bottom to collect the finest particles.
4. The dried soil sample was poured into the top sieve, and the entire stack was shaken mechanically for 10 –15 minutes to ensure thorough separation of particles by size. After shaking, each sieve was carefully removed, and the mass of soil retained on each sieve was recorded.
5. The percentage of soil retained on each sieve was calculated by dividing the mass retained by the total sample mass and multiplying by 100. The cumulative percentage retained was then determined, and the percentage passing through each sieve was obtained by subtracting the cumulative retained from 100%.
6. Finally, the results were plotted on a semi-logarithmic graph to produce a grain size distribution curve. This curve was used to determine key parameters such as the effective size (D_{10}), uniformity coefficient (C_u), and coefficient of curvature (C_c), which are essential for soil classification and engineering analysis.

Apparatus

a) Set of Standard Sieves
b) Balance (0.01 g sensitivity)
c) Oven (105–110°C)
d) Weighing Dishes or Trays
e) Brush and Spatula
f) Mortar and Pestle
g) Sieve Pan and Lid The pan

CHAPTER FOUR

DISCUSSION AND ANALYSIS

4.1 INTRODUCTION

This chapter presents a comprehensive discussion and analysis of the results obtained from the experimental investigation into the stabilization of laterite soil using shredded pure water sachets. The analysis focuses on interpreting the changes observed in the material's consistency (Atterberg Limits) and strength characteristics (California Bearing Ratio, CBR) across the varying percentages of plastic content (0% to 6%).

4.2 SIEVE ANALYSIS

Sieve analysis determines the particle size distribution of soil, which is essential for classification and identifying its suitability as a base, sub-base, or subgrade material. From table 4.1, the percentage passing through the 0.075-micron sieve is 37.8% which falls under the A-7 classification of soil according to AASHTO standard classification.

Table 4.1 Sieve Analysis Table

S/N	**% Passing through the sieves (mm)**		
	2	0.425	0.075
1	9.82	85.5	37.8

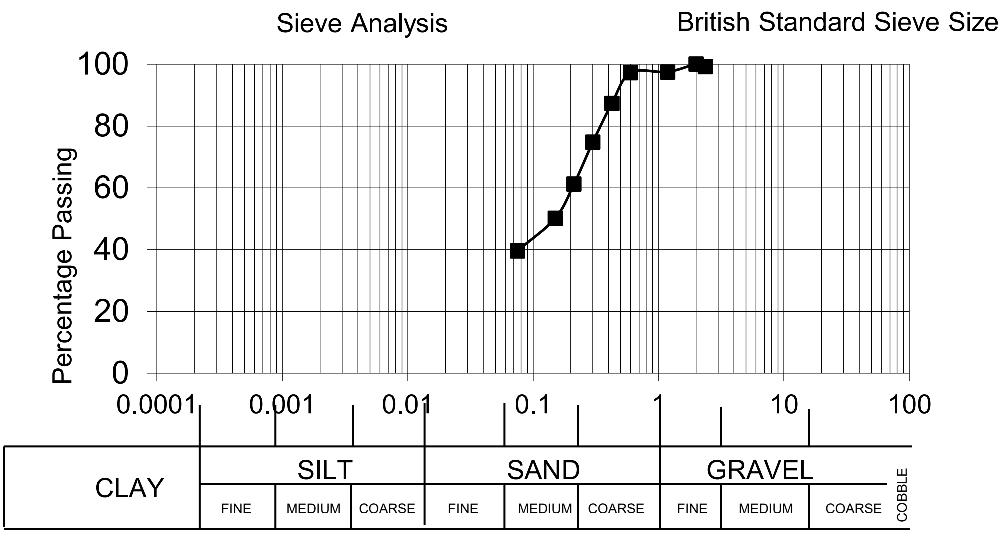

Fig 4.1 Sieve analysis graph

The curve shows a smooth transition from fine to coarse particles. The soil is well-graded, indicating a wide range of particle sizes. The presence of both fine and coarse fractions suggests good compaction potential and load-bearing capacity.

4.3 SPECIFIC GRAVITY ANALYSIS

The table below shows the specific gravity test conducted on the soil sample

Table 4.2 Specific Gravity Readings

S/N	Sample	Gs
1	Soil	2.26

4.4 ATTERBERG LIMITS

The atterberg limit tests were performed to evaluate the plastic and liquid states soil at different percents of the shredded pure water sachets.

Table 4.3 Atterberg Limit Analysis

SPWS (%)	LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX	CLASSIFICATION
0	31.60	19.85	11.75	CL
2	31.85	15.91	15.94	CL
4	31.28	18.99	12.29	CL
6	28.24	19.63	8.61	CL

From the result, the liquid limit of the soil samples ranges from 28.36 to 34.83%, the plastic limit range from to 23.90% And the PI ranges from 6.87 to 12.28% . According to the British System (BS 5930. 1999) plasticity chart they are qualified as low clay soils (CL).

According to AASHTO classification standards, the reduction of the plasticity index to 8.61% shows significant improvement in reducing the soil plasticity which is suitable for use as a subgrade. It is observed that PI reduces at higher percents.

4.5 COMPACTION TEST ANALYSIS

The standard proctor compaction test was carried out and the table below shows the moisture content and dry density obtained at various percents.

Table 4.4 Compaction test readings

SPWS	0%	2%	4%	6%
MOISTURE CONTENT	15.73	13.45	14.55	10.10
DRY DENSITY	1.65	1.70	1.48	1.55

4.6 CALIFORNIA BEARING RATIO ANALYSIS

Table 4.5. CBR Average Values

S/N	SPWS (%)	Soaked		Unsoaked	
		2.5mm	5.0mm	2.5mm	5.0mm
1	0	4.91	4.96	3.88	4.55
2	2	4.46	5.23	6.24	7.34
3	4	7.06	8.34	7.9	9.34
4	6	9.50	9.46	11.29	12.69

The CBR analysis shows a significant improvement in the soils strength and bearing capacity. There was a significant increase from 0% to 6% for both soaked and unsoaked conditions. Soaked at 9.50% and unsoaked at 12.69% being the highest shows that the soil is suitable for use as a sub-grade for road construction.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This study examined how shredded pure water sachets made from Low-Density Polyethylene (LDPE) can be used to improve lateritic soil for road construction. Nigeria faces two main problems: poor-quality lateritic soils that cause early road failure and plastic waste pollution from discarded sachets. This project tried to solve both issues by mixing shredded sachets with lateritic soil in different amounts 0%, 2%, 4%, and 6% and testing the results.

The laboratory results showed that adding shredded sachets improved the soil's strength and reduced its plasticity. The California Bearing Ratio (CBR) values increased, meaning the soil became stronger and could carry more load. The Plasticity Index decreased, showing that the soil became less and more stable. The Maximum Dry Density and Optimum Moisture Content also showed good improvement.

These findings prove that shredded sachets can serve as a cheap and effective material for soil stabilization. The method helps improve weak soils used for roads while also reducing environmental pollution caused by plastic waste. Using this waste material promotes cleaner surroundings and supports sustainable development goals.

RECOMMENDATIONS

1. The use of One point proctor for compaction. This is a faster means of compaction and avoids the need for a full curve every time.
2. Reduce landfill load and lower demand for new raw materials by using things like recycled concrete aggregate (RCA), construction and demolition (C&D) waste, ash, or slag as fill or stabilizing agents.

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APPENDIX

APPENDIX A

SPECIFIC GRAVITY TEST

S/N	LOCATION	DEPTH (m)	BN	B+W	B+S+W	B+S	B	Ad. W	WWAS	WS	WOWDS	Gs	AGs
1		100	S6	74.58	95.36	58.13	20.37	54.21	37.28	37..94	16.93	2.24	2.26
			NE	76.70	95.60	55.49	21.82	54.88	40.11	33.67	14.77	2.28	

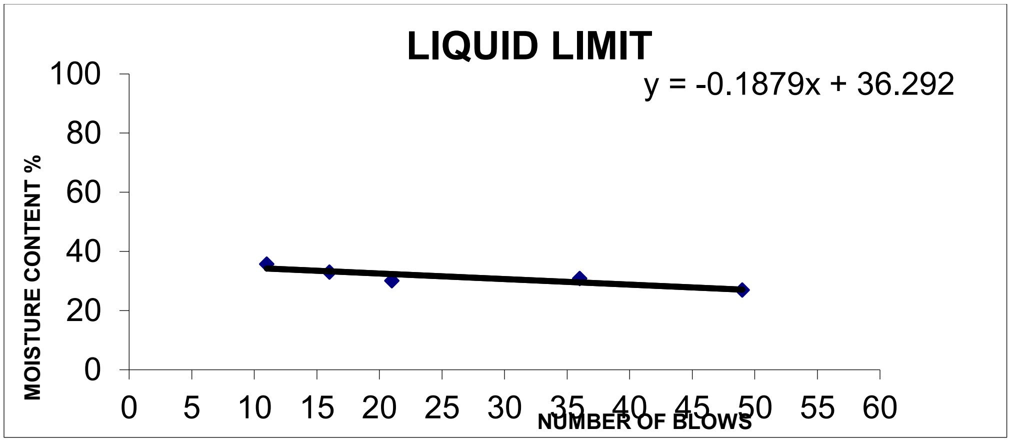
SIEVE ANALYSIS TEST

SIEVE NO.				
APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
⅛	3.35		100	
7	2.36	0.8	99.2	99.2
10	2	1.0	100	98.2
14	1.18	2.5	97.5	97.5
25	0.6	0.2	97.3	97.3
36	0.425	10.0	87.3	87.3
52	0.3	12.5	74.8	74.8
72	0.212	13.6	61.2	61.2
100	0.15	11.1	50.1	50.1
200	0.075	10.5	39.6	39.6

ATTERBERG LIMITS TEST

Plastic and liquid limits at 0% Table

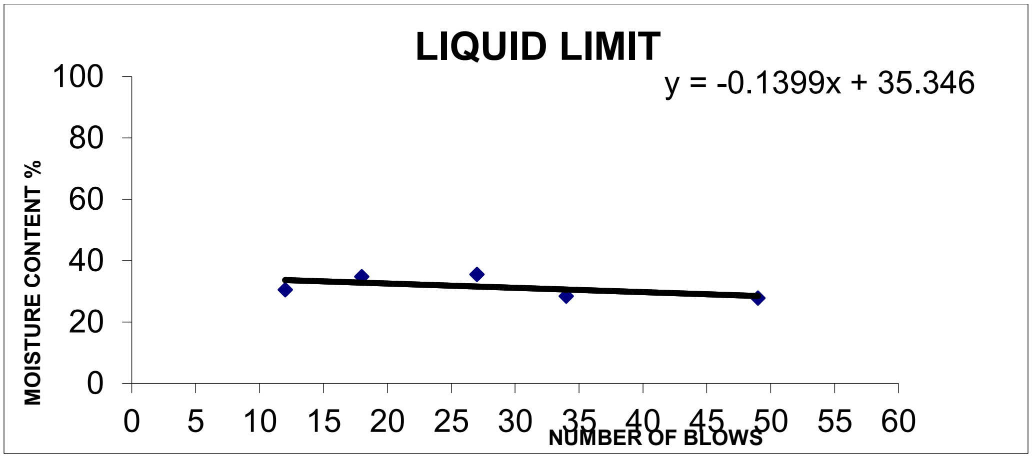
Type of Test	**LL**		**LL**		**LL**		**LL**	**LL**
No. of Blows/shrinkage %	49.00		36.00		21.00		16.00	11.00
Container No.	EK		TO		ST		PA	NP
Wt of wet soil & container (g)	47.50		54.10		43.70		49.60	55.10
Wt of dried soil & container (g)	41.80		46.80		38.80		42.80	46.10
Wt of container (g)	20.60		23.10		22.50		22.20	20.90
Wt of dry soil (Wd) (g)	21.20		23.70		16.30		20.60	25.20
Wt of moisture (Wm) (g)	5.70		7.30		4.90		6.80	9.00
Moisture content 100 (Wm/Wd)	26.89		30.80		30.06		33.01	35.71
Type of Test		**PL**		**PL**		**PL**		
No. of Blows/shrinkage %								
Container No.		JA		EN		RT		
Wt of wet soil & container (g)		30.20		27.20		28.70		
Wt of dried soil & container (g)		28.90		26.10		27.50		
Wt of container (g)		21.70		21.20		21.20		
Wt of dry soil (Wd) (g)		7.20		4.90		6.30		
Wt of moisture (Wm) (g)		1.30		1.10		1.20		
Moisture content 100 (Wm/Wd)		18.06		22.45		19.05		



Liquid limit graph at 0%

Plastic and liquid limits at 2% Table

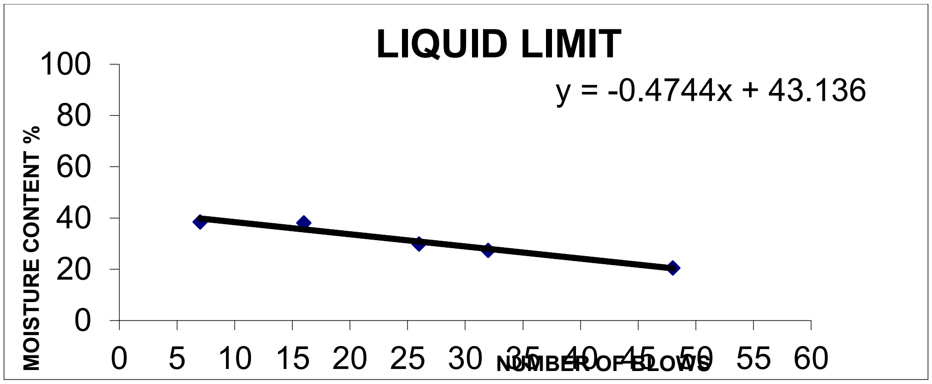
Type of Test	**LL**		**LL**		**LL**		**LL**	**LL**
No. of Blows/shrinkage %	49.00		34.00		27.00		18.00	12.00
Container No.	GR		RX4		0.15		PA	NO
Wt of wet soil & container (g)	41.60		66.10		65.60		67.10	48.60
Wt of dried soil & container (g)	37.40		56.50		54.80		55.20	42.10
Wt of container (g)	22.30		22.80		24.40		21.00	20.80
Wt of dry soil (Wd) (g)	15.10		33.70		30.40		34.20	21.30
Wt of moisture (Wm) (g)	4.20		9.60		10.80		11.90	6.50
Moisture content 100 (Wm/Wd)	27.81		28.49		35.53		34.80	30.52
Type of Test		**PL**		**PL**		**PL**		
No. of Blows/shrinkage %								
Container No.		C		SUE		RT		
Wt of wet soil & container (g)		27.10		26.30		30.80		
Wt of dried soil & container (g)		26.50		25.70		30.00		
Wt of container (g)		21.30		22.20		25.80		
Wt of dry soil (Wd) (g)		5.20		3.50		4.20		
Wt of moisture (Wm) (g)		0.60		0.60		0.80		
Moisture content100 (Wm/Wd)		11.54		17.14		19.05		



Liquid limit graph at 2%

Plastic and liquid limits at 4%

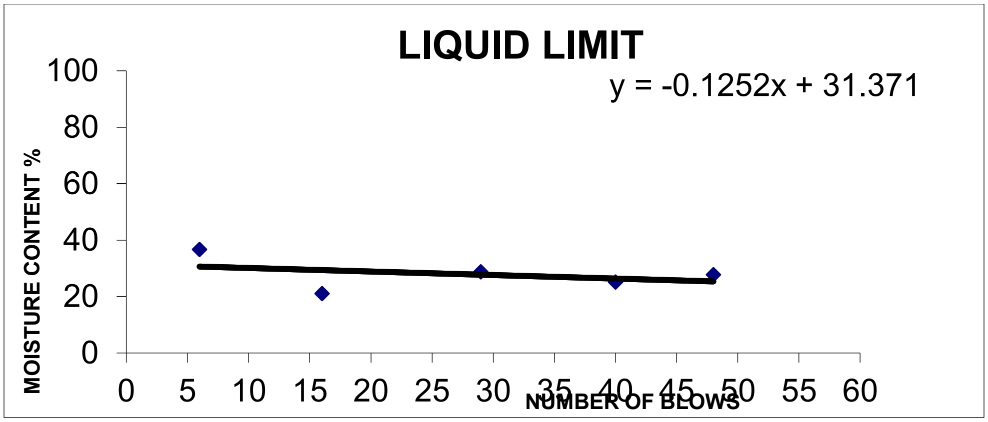
Type of Test	**LL**		**LL**		**LL**		**LL**		**LL**
No. of Blows/shrinkage %	48.00		32.00		26.00		16.00		7.00
Container No.	EK		TO		ST		PA		NP
Wt of wet soil & container (g)	65.80		75.70		68.70		76.10		61.50
Wt of dried soil & container (g)	58.41		66.77		60.12		63.79		51.18
Wt of container (g)	22.45		34.19		31.43		31.49		24.38
Wt of dry soil (Wd) (g)	35.96		32.58		28.69		32.30		26.80
Wt of moisture (Wm) (g)	7.39		8.93		8.58		12.31		10.32
Moisture content100 (Wm/Wd)	20.55		27.41		29.91		38.11		38.51
Type of Test		**PL**		**PL**		**PL**			
No. of Blows/shrinkage %									
Container No.		JA		EN		RT			
Wt of wet soil & container (g)		21.70		32.22		28.99			
Wt of dried soil & container (g)		20.81		30.84		28.13			
Wt of container (g)		16.56		23.06		23.43			
Wt of dry soil (Wd) (g)		4.25		7.78		4.70			
Wt of moisture (Wm) (g)		0.89		1.38		0.86			
Moisture content 100 (Wm/Wd)		20.94		17.74		18.30			



Liquid Limit graph at 4%

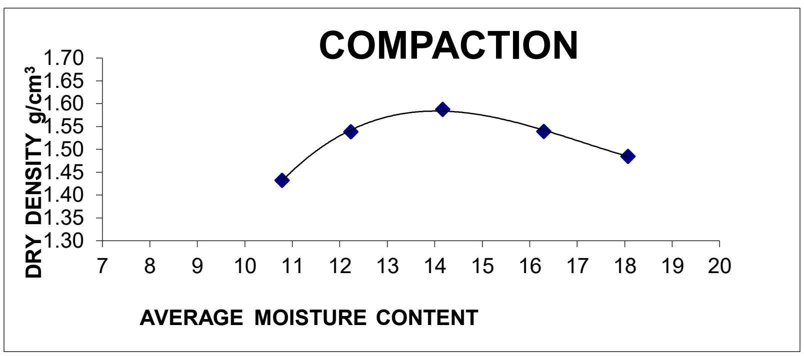
Plastic and Liquid limits at 6%

Type of Test	**LL**		**LL**		**LL**		**LL**		**LL**	
No. of Blows/shrinkage %	48.00		40.00		29.00		16.00		6.00	
Container No.	ZJ		UB		ST		PA		NP	
Wt of wet soil & container (g)	76.19		71.85		62.71		68.36		79.59	
Wt of dried soil & container (g)	66.80		63.90		56.28		62.45		67.50	
Wt of container (g)	33.00		32.22		33.96		34.42		34.55	
Wt of dry soil (Wd) (g)	33.80		31.68		22.32		28.03		32.95	
Wt of moisture (Wm) (g)	9.39		7.95		6.43		5.91		12.09	
Moisture content 100 (Wm/Wd)	27.78		25.09		28.81		21.08		36.69	
Type of Test		**PL**		**PL**		**PL**				
No. of Blows/shrinkage %										
Container No.		JA		EN		RT				
Wt of wet soil & container (g)		37.51		37.68		35.05				
Wt of dried soil & container (g)		36.76		37.07		34.41				
Wt of container (g)		33.20		33.76		31.11				
Wt of dry soil (Wd) (g)		3.56		3.31		3.30				
Wt of moisture (Wm) (g)		0.75		0.61		0.64				
Moisture content 100 (Wm/Wd)		21.07		18.43		19.39				

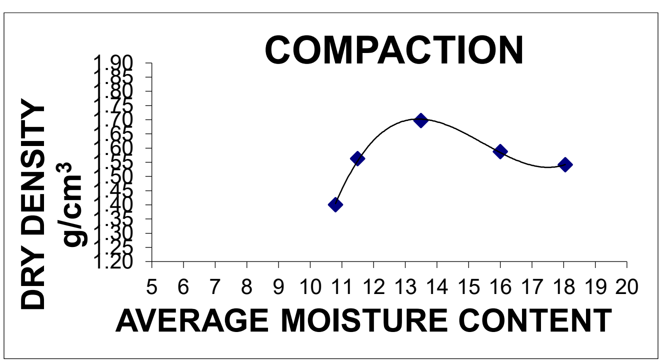


Liquid limit graph at 6%

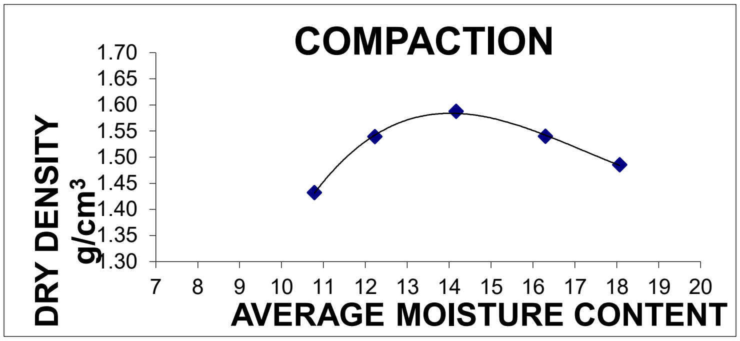
COMPACTION TEST ANALYSIS



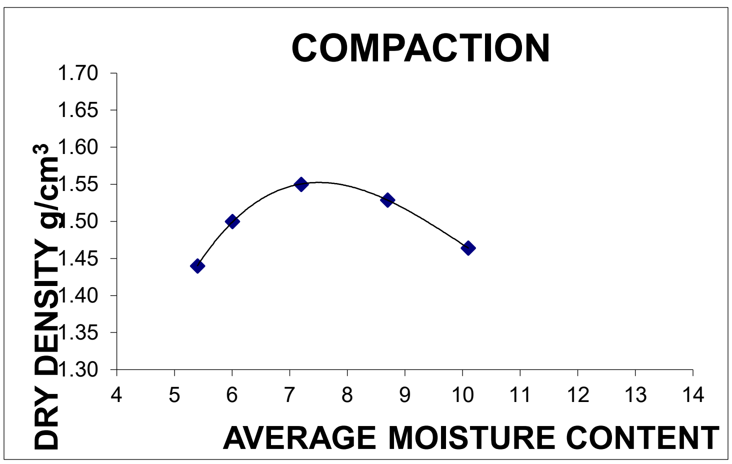
compaction at 0%



Compaction 2%



Compaction at 4%



Compaction at 6%

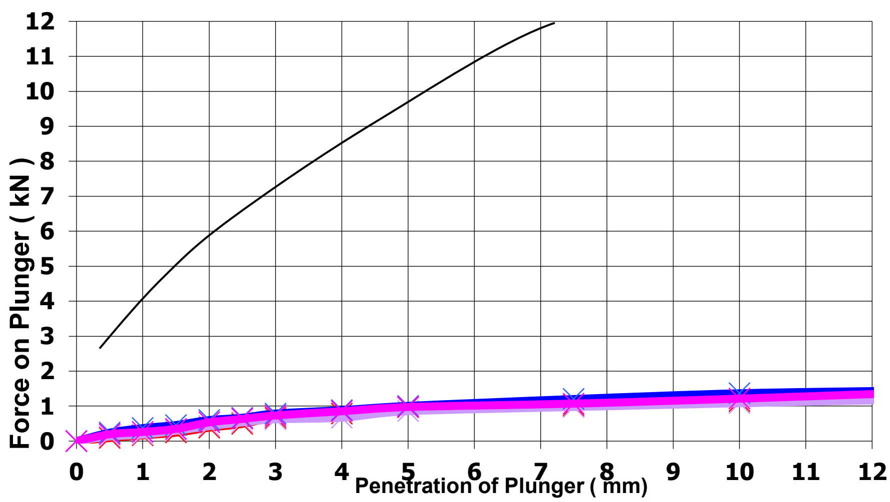
Compaction analysis

SPWS	0%	2%	4%	6%
MOISTURE CONTENT	15.73	13.45	14.55	10.10
DRY DENSITY	1.65	1.70	1.48	1.55

CALIFORNIA BEARING RATIO ANALYSIS

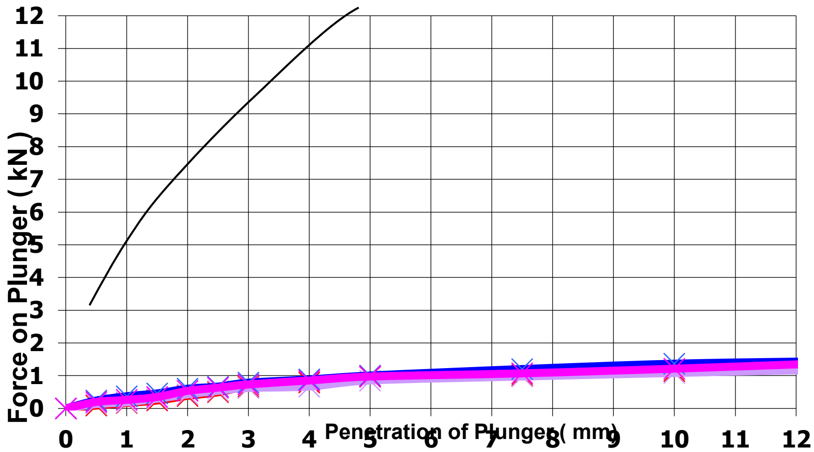
At 0%

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	3.716	4.822	5.038	5.042
TOP	4.047	4.274	4.790	4.877



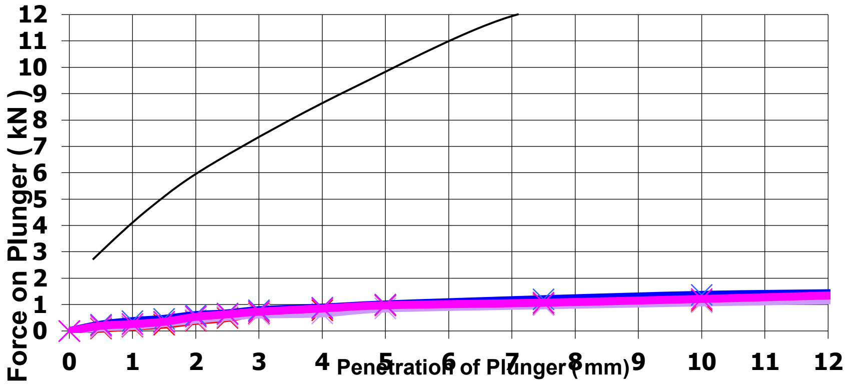
AT 2%

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	5.863	6.905	4.212	4.932
TOP	6.607	7.782	4.707	5.535



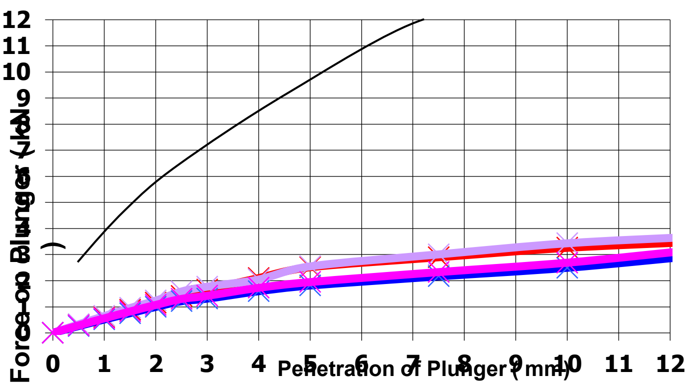
At 4%

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	8.671	10.248	6.772	8.001
TOP	7.102	8.439	7.350	8.658



At 6%

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	10.653	12.604	9.167	9.097
TOP	11.975	12.768	9.827	9.754



APPENDIX B

WEIGHING SAMPLE. **Carrying out compaction test**

PERFORMING ATTERBERG TEST. **CBR APPARATUS**

Sieved laterite sample **Shredded pure water sachets**

Soil and SPWS mix and compaction apparatus **Can for sieve analysis**