ASSESSING THE EFFECT OF POLYPROPYLENE ON THE DURABILITY OF FLEXIBLE PAVEMENTS

DOUGLAS MIVULE

M22B32/023

A DISSERTATION SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

February, 2026

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

ABSTRACT.

One of the primary factors influencing deterioration and failure in flexible pavements is the tensile strength of asphalt mixtures. Therefore, the impacts of reinforcing asphalt mixtures with polypropylene fibres on their engineering performance were examined experimentally in this work.

In order to assess the indirect tensile stiffness modulus, a series of cylindrical asphalt mixture specimens were constructed and put under compression load at various testing temperatures. Tests for fatigue and fracture propagation were also carried out for various asphalt mixtures with and without polypropylene fibres. These fibres' effects on the engineering characteristics of asphalt mixtures were investigated. Tensile, fatigue, and cracking initiation and propagation were all significantly impacted by the reinforced mixes containing polypropylene fibres, according to the laboratory data.

DECLARATION

I, MIVULE DOUGLAS, certify that this is my original work, free of plagiarism, and has not been submitted for any award to any other organization.

.Signature: ……………………………………………... Date…………………………….

APPROVAL

I, Mivule Douglas, have completed and submitted this research and design project report with the university supervisor's approval.

Signed by:..............

Date......................

Dr.Chris Byaruhanga,

Civil and Environmental Engineering Department

ACKNOWLEDGEMENT

I give thanks to the Lord for leading me during the entire research process. I want to express my gratitude to all of the instructors in the Engineering and Environment department for sharing their knowledge and expertise, which have helped me successfully submit this research. I would especially like to thank Dr. Byaruhanga Chris, my supervisor, for her unwavering support and encouragement throughout my research report and project. The support I've received from my parents, friends, and project partner is incomprehensible. May you all continue to be blessed by the Lord.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AC	- Asphalt Concrete
ACV	- Aggregate Crushing Value
AIV	- Aggregate Impact Value
HDPE	- High Density Polyethylene
HMA	- Hot Mix Asphalt
ITSR	- Indirect Tensile Strength Ratio
LAAV	- Los Angeles Abrasion Value
LDPE	- Low Density Polyethylene
PCC	- Portland Cement Concrete
PE	- Polyethylene
PET	- Polyethylene Terephthalate
PP	- Polypropylene
PVA	- Polyvinyl Acetate
PVC	- Polyvinyl Chloride
TFV	- Ten Percent Fines Value
UV	- Ultra-Violet
VFB	- Voids Filled with Bitumen
VIM	- Voids in Mix
VMA	- Voids in Mineral Aggregates
VOC	- Vehicle Operating Costs

CHAPTER ONE: INTRODUCTION

1.0 BACKGROUND

Road pavements are classified into two categories worldwide. There are two types of pavements: stiff and flexible. Roads built using bitumen and asphalt fall under the category of flexible pavements.

The asphalt pavement road network of Uganda is majorly paved with bitumen because bituminous pavements provide a safe, long-lasting and comfortable surface for road users. The performance and durability of flexible pavements is highly influenced on properties of bitumen especially because of its binding properties. However, there has been an increase in premature pavement failures on paved roads. These failures occur due to premature deterioration of bitumen which is evident through cracking, rutting and bleeding of asphalt pavements

The vitality and durability of asphalt pavement is necessary for the efficiency and sustainability of road infrastructure. Though the neat asphalt mixture is universally used, its vulnerability to premature failures such as cracking and rutting majorly due to increase in varying climatic cycles and traffic loads has created a growing need for an alternative or a modification in the general asphalt mixtures to enhance the mechanical properties and durability of asphalt pavements

Among the many approaches to accommodate the growing need above is the incorporation of synthetic polymers. Polypropylene plastic fibers are among the synthetic polymers being researched on. The mechanical properties of polypropylene such as its high tensile strength, resistance to chemical attacks, thermal stability and lightweight nature make it a promising reinforcement for asphalt pavements especially against and moisture damage. (Fini, 2023)

Therefore, this research focuses on to Assessing the effect polypropylene plastic on the durability of asphalt pavements.

1.1 PROBLEM STATEMENT

The Kampala-Masaka Highway is a critical transportation corridor in Uganda linking the capital city to the southwestern region. However, the section of the road that traverses the Lwera swamp area has increasingly shown signs of pavement failure particularly in form of cracking and rutting which greatly compromise the pavement quality and safety.

The Kampala- Masaka Road has repeatedly suffered pavement failures especially around the Lwera Wetland area. The varying climatic conditions consisting of heavy rains and hot temperatures have caused pavement weakening and water logging leading to longitudinal and transverse cracking and rutting. (UNRA, 2024)

The climate of the region characterized by bimodal rainfall patterns and fluctuating temperatures has led to moisture induced weakening and thermal cracking on the Kampala-Masaka Road. Among the sections affected are the Lwera Samp area near Lukaya District, Katonga Bridge section. (Okello, 2024)

Although asphalt pavements modified with plastic have demonstrated enhanced performance, their capability and full potential use in this field of study remains under explored. (Vijayan, 2024)

Therefore, the Aim of this research is to assess the effect of polypropylene plastic on the durability of asphalt pavements. This through the use of the dry process or method where the coarse aggregate is coated with the polypropylene plastic which are then mixed with other components of asphalt in order to form a homogenous asphalt mixture. (Radeef, 2022)

1.2 RESEARCH OBJECTIVES

Main Objective

- To assess the effect of polypropylene plastic as reinforcement on the durability of asphalt pavements.

Specific Objectives

- To determine the effect of polypropylene on the mechanical properties of, aggregates and bitumen.
- To determine the effect of polypropylene plastic on optimum content for polypropylene modified asphalt mixture.
- To assess the effect of polypropylene on the modified asphalt mixture in comparison to the neat asphalt mixture

1.3 RESEARCH QUESTIONS

What are the mechanical properties of polypropylene, aggregates and bitumen?

What is the effect of optimum polypropylene plastic for the polypropylene modified asphalt mixture?

What is the effect on durability of polypropylene modified asphalt mixture in comparison to the neat asphalt mixture?

1.4 JUSTIFICATION

In recent years the section of the Kampala-Masaka Highway that traverses the Lwera swamp area has increasingly shown signs of pavement failure particularly in form of cracking and rutting. Even with continued repairs over the years to extend its life expectancy the problem still persists.

The Kampala-Masaka Road has repeatedly suffered pavement failures especially around the Lwera Swamp Area. The fluctuating climatic conditions consisting of hot temperatures and heavy rains across the Lwera Swamp Area have caused water logging and pavement weakening, leading to cracking and rutting. (Nakiyemba, 2022)

The road being is a swampy area, the bitumen has always been susceptible to aging due to water effects and oxidation especially in the rainy season that leads to stripping of the bitumen from the aggregates. The reduction and consequently loss of adhesion between the bitumen and the aggregates leads to gradual deterioration of the surface layer which majorly affects the durability of the asphalt pavements.

However, polypropylene is a non-biodegradable material hence when added into the asphalt mixture it increases the characteristics or ability of the asphalt to withstand the earlier stated natural elements of the environment that the pavements are continuously exposed to. Polypropylene has special chemical resistance which means it is not attacked by strong bases. In addition to that it is also resistant to gentle oxidants and reducing agents. The physical properties of polypropylene of being robust, sustainable and light weight further give it more validity in its utilization in the asphalt mixture. (Chunnneng, 2025).

These properties of polypropylene make coating the surface of the aggregates with polypropylene increase the resulting asphalt mixture and application in pavements more resistant to the natural elements of the environment.

1.5 GEOGRAPHICAL SCOPE

The identified Scope of study was the Kampala-Masaka Road specifically the section the road that stretches across the Lwera Swamp area which is about 20kms on the road. It generally lies within the coordinates 0.0°N to 0.3°N and 32.5°E to 32.8°E

Figure 1-1 Geographical scope

CHAPTER TWO: LITERATURE REVIEW

2.0 Road Pavements

A road pavement is a structure consisting of superimposed layers of processed materials above the natural soil subgrade with a primary function of distributing the applied loads to the subgrade. (Uganda Road Manual) The most important goal is to ensure the transmitted stresses due to wheel load are sufficiently reduced so as not to surpass the bearing capacity of the subgrade.

The road network of Uganda handles the most dominant mode of transport which is road transport that accounts for over 90% of passenger and cargo movement. The road network of Uganda is about 159,520km constituting of community access roads (79,000km about 50-54% of total), district roads (35,500-38,000km about 25-25%), urban roads (10,100-20,000km) and National roads (20,500-20,010km about 13-14%). (MEIR Engineering and Research, 2023)

The road network of Uganda which is paved to bituminous standards is about 5,500-6,100km that is about 25-29% of the Natonal roads stated above. These bituminous paved pavements are designed to last but, in some cases, do not perform as expected due to several unforeseen factors during their life expectancy which necessitates rehabilitation after a short period of time. These factors can be environmental or structural in nature and lead to distresses such as cracking and rutting. (Andrew, 2024)

2.1 Types of pavements

2.2 Rigid pavements

Rigid pavements are made of a Portland Concrete Cement (PCC) layer with transvers joint at specific intervals thus giving them sufficient flexural stiffness enabling efficient transmission of the wheel load stresses to a wider area of the subgrade. In other words, these pavements are designed to transfer or distribute loads both in a non uniform and unform deflections meaning the deflections are very small and relatively consistent. This pavement layer is directly placed over the prepared or compacted subgrade leaving out the base layer. (Styer, 2024)

2.3 Flexible pavements

Flexible pavements consist of several layers of materials and rely on the combination of these layers to transmit load to the subgrade and as a result of this action, unlike rigid pavements flexible pavements distribute load over a small area of the subgrade. These pavements are flexible in their structural action under loading and are surfaced with bituminous or asphalt materials. (Styler, 2024)

2.3.1 Elements of flexible pavements

A flexible pavement consists of layers namely: surfacing course, road base, subbase, capping layer and subgrade.

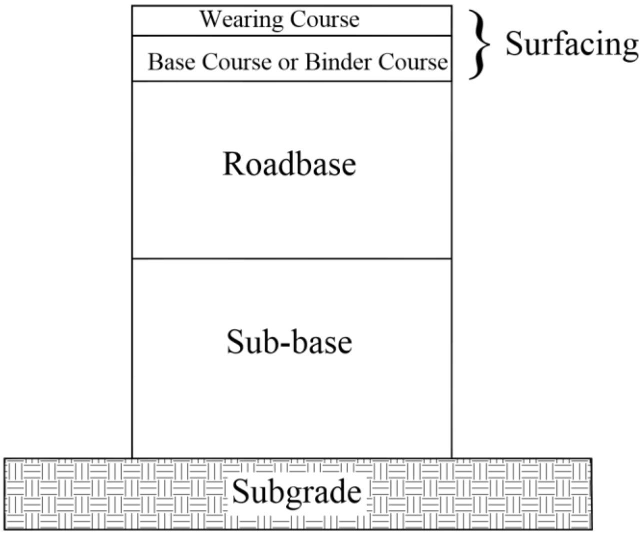

Figure 2-1 Definition of pavement layers Source: (Transport Research Laboratory, 1993

2.3.2 Construction materials used in flexible pavements

As the uppermost part of a flexible pavement construction, the bituminous mixture (surfacing layer) serves as a robust, waterproof, load-distributing medium that shields the base course from the damaging effects of weather and traffic abrasion.

. **Aggregates**

There are different types composition and sizes of aggregates used in asphalt mixtures and these include: coarse aggregates (larger than 2.36mm) and fine aggregates (less than 2.36mm and greater than 0.075mm). These different sizes of aggregates are used for the purpose of increasing the interlocking mechanism within the asphalt mixture. (Xunhao, 2024)

In the bituminous mixtures aggregates usually take up 90% or more in terms of weight of the mixtures which indicates that their properties significantly affect the finished mixture or product. Aggregates have several functions for their use in bituminous mixtures but their basic functions include (Ren, 2020);

- Aggregates provide the structural skeleton which forms a load bearing framework to transmit the load from the surface down to the base course. The mechanical interlock of the aggregate particle's controls strength and rutting resistance.
- They offer surface texture or skid resistance. In order to improve friction and skid resistance, a piece of the aggregate extends slightly above the asphalt layer's usual surface, giving the tires a surface roughness to grip.

Bitumen

Bitumen having good adhesion and cohesion with aggregates is a material commonly used as a binder in pavement construction. Bitumen is a viscoelastic material meaning it behaves similarly to a viscous liquid and partly as an elastic solid. (Georgios, 2024)

Grades of bitumen

Bitumen grade with viscosity properties suitable for the type of HMA, the environment, and the loading circumstances where it will be employed is referred to as a paving grade. (Transport Research Laboratory and Development, 2002) Bitumen is primarily classified into two grades:

a) Viscosity grades

The fluid quality of bituminous materials is referred to as viscosity. This grading is essentially based on a scientific viscosity test with a measuring unit of poise that is carried out at 60°C, which is close to the maximum pavement temperature during the summer. Both original asphalt samples (AC grading) and residue asphalt samples (AR grading) can be graded for viscosity.

However, viscosity grading is not commonly used in Uganda.

b) **Penetration grade**

By measuring the hardness, penetration grade is used to describe the bitumen. The distance in tenths of a millimetre that a standard needle can penetrate vertically into a bituminous material specimen under particular temperature, load, and load duration circumstances is known as the penetration of bituminous material. Bitumen 60/70 is the primary penetration grade that is frequently utilised in the majority of markets. Because there is an empirical correlation between penetration depth and asphalt binder performance, cold regions employ asphalt binders with high penetration values (referred to as soft), whereas warm climates use asphalt binders with low penetration values (referred to as hard).

Filler

A substance with a particle size of smaller than 0.075 mm is called filler. It can come from aggregate fines or be added as cement, lime, or powdered rock. Fillers can be produced, as in the case of lime, cement, ash, or slag, or they can come naturally from the crushing of rocks. Their primary purposes are to improve the cohesiveness of the asphalt binder and the stability of the mixture, as well as to fill the spaces in the aggregate skeleton to produce a denser mixture. Because of this, the asphalt mixture pavement should be impervious to fatigue fractures, low temperature cracks, water and frost, and pavement deformations. Numerous investigations have shown that fillers serve other crucial purposes.

Polypropylene

Polypropylene is one of the most effective polymer additives in bituminous road constructions. Polypropylene has a very good chemical, wear and fatigue resistance. It is a semi crystalline material with a light structure. One of the common types of polypropylene plastic is High Density Polypropylene (HDPP) A substance with a particle size of smaller than 0.075 mm is called filler. It can come from aggregate fines or be added as cement, lime, or powdered rock. Fillers can be produced, as in the case of lime, cement, ash, or slag, or they can come naturally from the crushing of rocks. Their primary purposes are to improve the cohesiveness of the asphalt binder and the stability of the mixture, as well as to fill the spaces in the aggregate skeleton to produce a denser mixture. Because of this, the asphalt mixture pavement should be impervious to fatigue fractures, low temperature cracks, water and frost, and pavement deformations. Numerous investigations have shown that fillers serve other crucial purposes.

2.3.3 Material mixing and laying in construction of flexible pavements

There are two types of mixtures used for road construction known as hot mixes and cold mixes; polypropylene can be used as a modifier under the hot mix. Moreover, waste polypropylene can also be used in road construction

Dry Process

The high-density Polypropylene is thoroughly washed with detergent and rinsed with clean water and then dried and shredded into small particles. The particles are then sieved and those passing the 5mm sieve and retained on the 2.36mm sieve are retained. The aggregates are heated to 170°C. This temperature ensures that the shredded polypropylene to be added melts and bonds with the surface of the aggregates. Maintaining the aggregates at the earlier mentioned temperature the shredded polypropylene retained at the 2.36mm sieve is added in a way that ensures proper coating. The mixture is then added to the bitumen until a uniform mixture is obtained.

Wet Process

In this process the polypropylene is heated and added to the bitumen mixture without adding it to the aggregate first. Therefore, the main difference between the wet process and dry process is the method which the waste polypropylene is added to the mixture prior to get laid on the roads.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

The goal of this chapter is to give a proper state of materials, test methods and experimental standards that were being used and conducted throughout the study. These different tests and methods were used to determine chronologically the different objectives set for the study.

3.1 Material selection and sample preparation

Asphalt mixture components (aggregates, bitumen and polypropylene plastic) required for the study.

Aggregates

Asphalt wearing coarse aggregates of asphalt concrete and nominal size 14 will be used. Grading tests on aggregates to ensure that the nominal size of aggregates is 14 mm with reference to HMA 007-02. Two samples were used to carry out the overall tests, one being the conventional asphalt and the others being the polypropylene modified coated aggregates at different percentages of polypropylene.

Bitumen

Grade 60/70 will be used due to its thermoplastic property which causes the material to soften at high temperatures and harden at low temperatures. It also shows more resistance to traffic loading.

Polypropylene Plastic

The high-density Polypropylene is thoroughly washed with detergent and rinsed with clean water and then dried and shredded into small particles. The particles are then sieved and those passing the 5mm sieve and retained on the 2.36mm sieve are retained for the tests.

3.2 Laboratory Tests To assess the mechanical properties of polypropylene plastic, aggregates and bitumen

3.2.1 Tests on aggregates

Grading or sieve tests

Particle size distribution is a crucial classification test for aggregates, which is why the grading or sieve analysis method was chosen. It displays the proportions of various particle sizes. After that, it is easy to ascertain if the aggregates are primarily composed of gravel, silt, sand, or clay. This test was conducted in compliance with BS 812: Part 130:1985.

Aggregate Crushing Value (ACV)

Because aggregate used in road building must be strong enough to withstand crushing, this method provides a relative assessment of an aggregate's resistance to crushing under gradually added load. In accordance with BS 812: Part 110:1990, this value is determined by the material passing through a designated sieve under a load of 400kN.

Aggregate Impact Value (AIV)

This test provides relative measurements of an aggregate's resistance to abrupt impact or shock. The test is conducted in accordance with BS 812: Part 112:1990.

Los Angeles Abrasion Test

The hardness of coarse aggregates used in pavement construction is evaluated by this test. It can also be used to gauge how standard aggregates deteriorate as a result of a variety of processes, such as impact, abrasion, and grinding in a revolving steel drum with a predetermined quantity of steel spheres. This test is conducted using ASTM C131-89 as a guide.

Specific Gravity of Aggregates

When calculating the volumetric parameters of an asphalt mix, including air spaces, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA), the specific gravity of the aggregates is crucial. The build specific gravity of the whole aggregate was thereafter calculated using the specific gravities of the aggregate size range to be utilised. This test was conducted in compliance with BS 812: Part 2: 1975.

3.2.2 Tests on bitumen

Penetration Test

The distance in tenths of a millimetre that a standard needle vertically penetrates a sample material under known loading, duration, and temperature conditions is used in this test to determine the relative consistency of bituminous materials. The test's result serves as a gauge for how soft or hard the bitumen is. This test is conducted in compliance with ASTM D5-86.

Softening point test

This test establishes a binder's softening point and, indirectly, the bituminous material's viscosity. A material's susceptibility to warmth is indicated by its softening point value. This test is performed to find the bituminous binder's softening point between 30°C and 200°C. A high softening point indicates a greater propensity to flow, whereas a low softening point indicates a reduced propensity. This test is conducted using ASTM D36-95 as a guide

Specific Gravity of Bitumen

One important characteristic that shows the bitumen's density in relation to an equivalent volume of water is its specific gravity. The specific gravity test is crucial for categorizing different types of bitumen, finding impurities to control quality, and figuring out the ideal bitumen volume required for asphalt mixes. This test was conducted in compliance with ASTM D70-97.

3.3 To determine the optimum polypropylene plastic content for polypropylene modified asphalt mixture

3.4 Preparation of polypropylene coated aggregates

The dry process or method will be used in coating the aggregates. The aggregates are heated to 170°C. This temperature ensures that the shredded polypropylene to be added melts and bonds with the surface of the aggregates. Maintaining the aggregates at the earlier mentioned temperature the shredded polypropylene retained at the 2.36mm sieve is added. The shredded polypropylene is added to the aggregates by weight of mix at 0%, 0.1%, 0.3%, 0.5% and 0.6%. These separated into different sample according to the respective percentages mentioned. This coating aims to improve the overall mechanical properties the asphalt mixture.

The coated aggregates are later mixed with bitumen to form testing samples for the Marshal test at a temperature of 170°C this temperature of the bitumen doesn't affect the polypropylene coating hence maintaining its properties and the same temperature is above the temperature 155°C below which the bitumen is not effective in an asphalt mix.

3.5 Preparation of asphalt concrete samples

For each of the five samples of polypropylene cotted aggregates with **0% PP sample** as control five trial binder(bitumen) contents are selected from (4.0-6.0) % in increments of 0.5%. The aggregate samples and bitumen were mixed at a temperature of 170°C for 5 minutes and compacted with 75 blows on each side at the same temperature. The sample preparation is extremely important as directly influences the resulting volumetric properties of the asphalt mixtures.

3.6 Marshall Test

This test establishes the relationship between the plastic deformation properties of asphalt mixes and the relative measure of the physical characteristics of asphalt specimens. It offers values that are used to assess the performance and volumetric characteristics of asphalt mixtures. Additionally, it allows us to ascertain the ideal bitumen content for the asphalt mixtures. Additionally, testing establishes if the asphalt mixture can support the load that will be placed on the surface without deforming. To put it another way, the goal is to ascertain whether the asphalt mixture can fulfil its intended function. This test is conducted using ASTM D1559-98 as a guide.

3.5.1 Marshall mix design

The ideal binder content for the experimental mixes was found using the Marshall Mix design process. It included stability and flow testing, as well as density-voids examination of the samples. The following highlights the particular mix design testing and analysis.

3.5.2 Bulk Density

The ASTM D2726-96 rules were followed in determining the samples' bulk densities. In order to determine the unity weight, percentage of absorbed asphalt, percentage of air voids, percentage of voids filled with asphalt, and percentage of voids in mineral aggregates that demonstrate the mixture's sensitivity to binder content, the bulk density was utilised in the density-voids analysis of the mixture.

3.5.3 Mixture specific gravity

The theoretical maximum specific gravity is the build specific gravity of a compacted mixture with zero air voids, and it is determined using standardized test methods like ASTM D2041/D2041M-19. Tis value plays a key role in assessing the quality and performance of asphalt mixtures during design and construction processes.

3.5.4 Percentage of air Voids in Mix (VIM)

In asphalt mix design, the determination of Voids in Mix (VIM) is a crucial parameter that influences the volumetric properties of the asphalt mixture. VIM represents the void space with in the compacted asphalt mixture and is a key factor in assessing the quality and performance of the mix. The VIM value is typically obtained by measuring the voids in the mixture, voids in mineral aggregates (VIM), and voids filled with asphalt binder (VFB). The VIM value is significant as it affects the strength, durability, and aging characteristics of the asphalt mixture. It is essential to measure and monitor VIM during the design and construction processes to ensure optimal performance of the asphalt pavement. The VIM value can vary based on factors such as asphalt content, aggregate gradation, and compaction methods used during the mix design process.

3.5.5 Voids in Mineral Aggregates (VMA)

Finding the bulk specific gravity of the total aggregates (Gsb) and the percentage of aggregate content by mix weight (Ps) are the first steps in determining Voids in Mineral Aggregate (VMA) in an asphalt mix. The effective volume of aggregates Vagg was then computed using the volume V of each asphalt specimen core and the sample density. The next step is to calculate the Voids Filled with Asphalt Binder (VFB), which is a measure of the bitumen's volume in the mixture.

3.5.6 Stability and Flow

Both conventional bitumen and PMB asphalt cores were tested using the Marshall test, which assesses the load and flow properties of asphalt samples. This test was conducted in compliance with ASTM D1559-89. Engineers can find the ideal asphalt binder content that satisfies the required stability and flow criteria at a desired density by using the Marshall Mix design approach.

Tests to determine the effect of polypropylene modified asphalt mixture in comparison to the neat asphalt mixture

Indirect Tensile Strength Test

This test is performed to ascertain the bituminous mixes' tensile stress characteristics, which show the asphalt mixture's resistance to water and moisture susceptibility. The test results can be used to estimate the likelihood of cracking and to assess the relative quality of asphalt mixtures. This test is conducted using ASTM D6331-17 as a guide.

Four Point Beam Test or Fatigue Test

The values of this test are essential in determining the number of cycles the asphalt mix can withstand before failure under flexural loading. This test is carried out in reference AASHTO T321

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0 Ten Percent Fines Value (TFV)

High TFV results are desired as they indicate a high resistance of the aggregates to crushing, which is a contributor to the quality, durability, and performance of the asphalt mix. The results of both the dry and soaked TFV are shown below

Figure 4-1 Relationship between TFV and Polypropylene

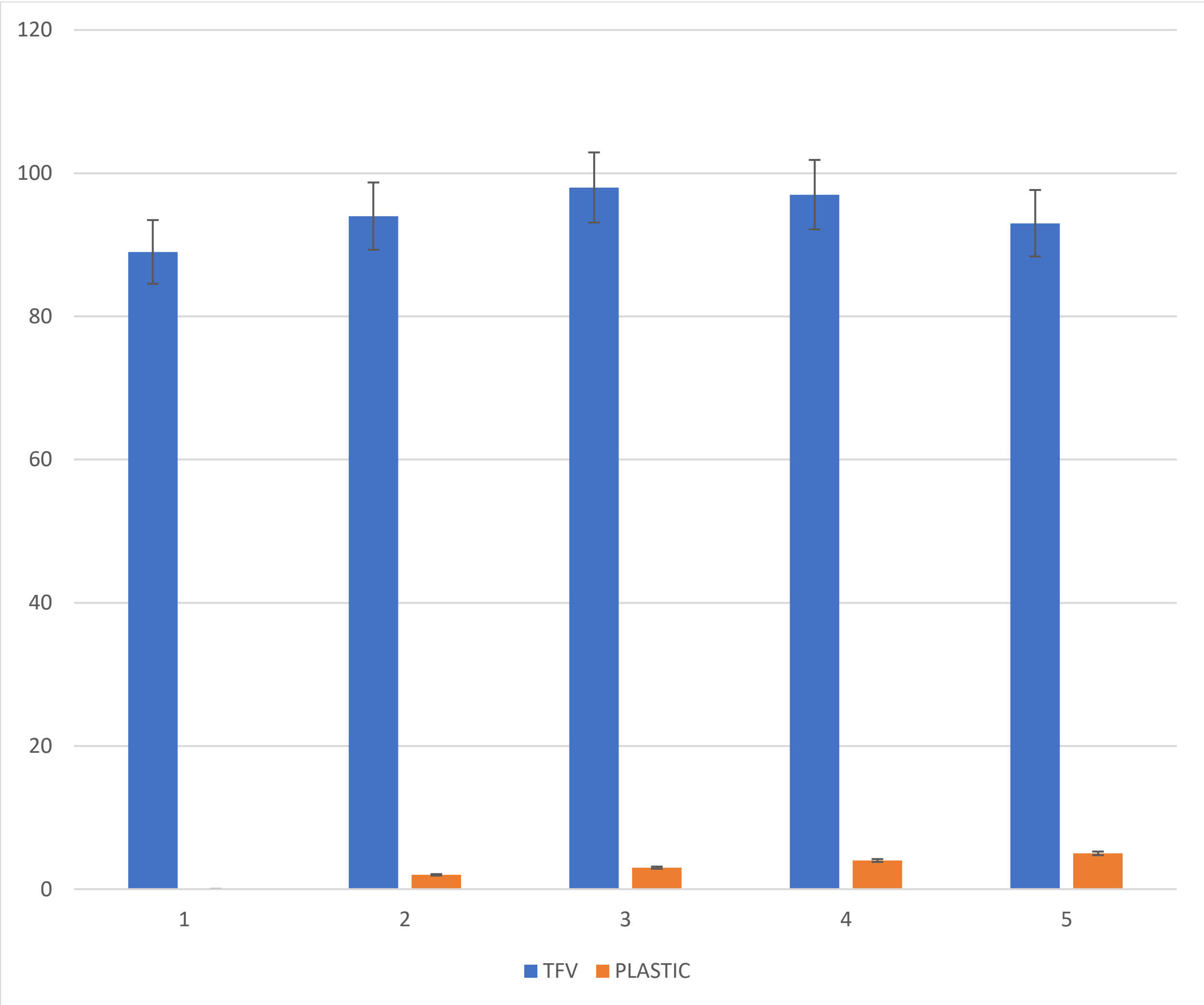

Figure 4-2 RESULTS of Relationship between TFV & Polypropylenen

TFV			
TEST NO	1	2	
CRUSHING FORCE (KN)	267	267	
WT. OF AGGREG (gm)after crushing (M1)	2746	2754.2	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm(M3)	2455	2463	
WT.AGG. (gm) PASSING SIEVE 2.36 mm (M2)	293.0	291.2	
TEN % FINE VALUE (M=M2/M1*100)	10.7	10.6	
AVERAGE RESULTS % (M)	10.6		
AVERAGE CRUSHING FORCE (F)	266.9		
F-DRY= 255.6 kN			

Figure 4-3 RESULTS of Relationship between TFV & Polypropylenen

10% FINE VALUE SOAKED			
TEST NO	1	2	
CRUSHING FORCE (KN)	267	267	
WT. OF AGGREG (gm)after crushing (M1)	2792.2	2770.6	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm(M3)	2443	2425	
WT.AGG. (gm) PASSING SIEVE 2.36 mm (M2)	349.2	345.6	
TEN % FINE VALUE (M=M2/M1*100)	12.5	12.5	
AVERAGE RESULTS % (M)	12.5		
AVERAGE CRUSHING FORCE (F)	266.9		
F wet = 226.6 KN			

4.1 Aggregate Crushing Value

The aggregate crushing value serves as a numerical indicator of the strength of aggregates utilized in construction. It assesses an aggregate's capacity to withstand crushing under a gradually applied compressive load. The ACV is calculated by subjecting an aggregate sample to a prescribed load, crushing it, and subsequently measuring the fines generated from the crushed material, following the procedure outlined in **BS 812 Part 111: 1990**

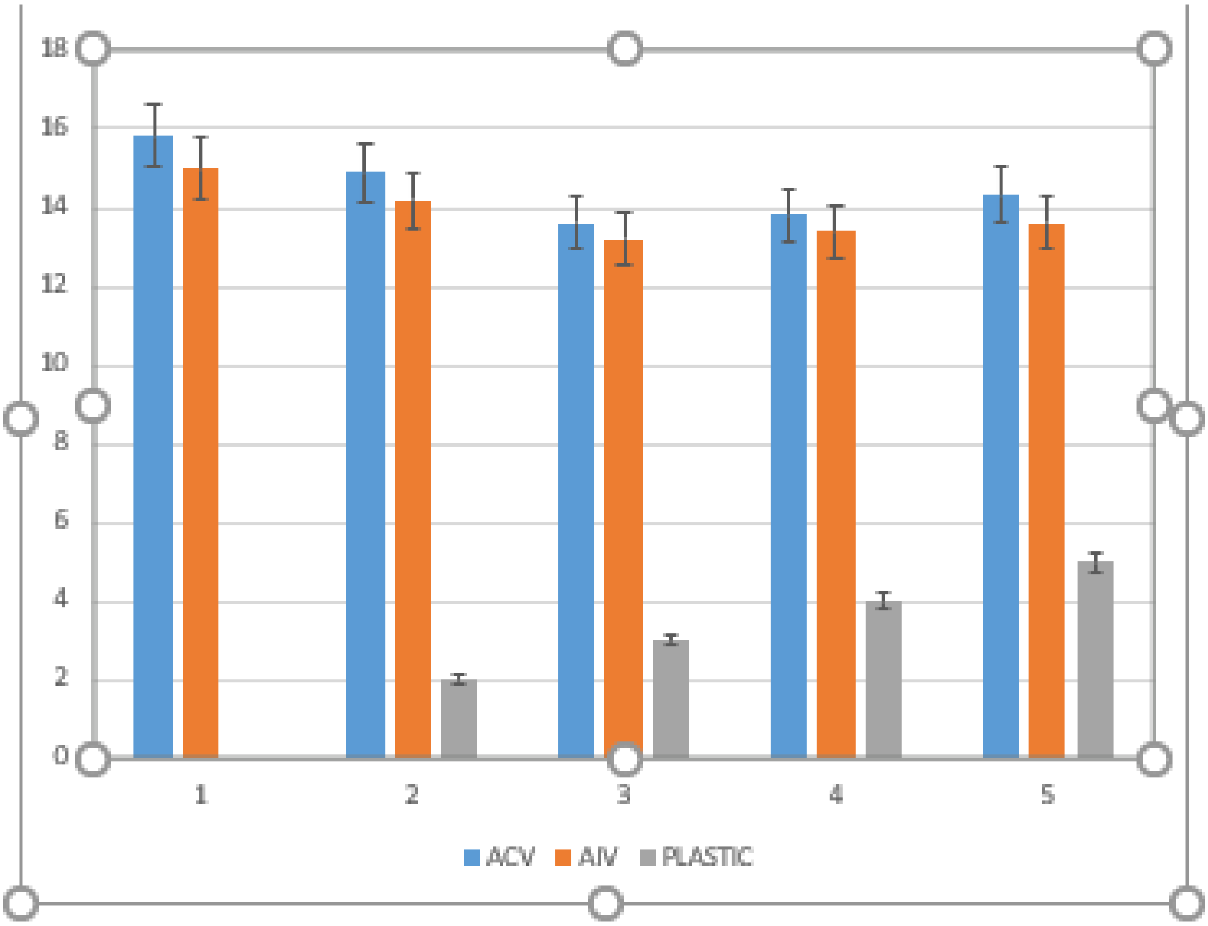

Figure 4-4 Relationship between ACV and Polypropylene.

Figure 4-5 ACV RESULTS of Relationship between ACV and Polypropylene.

ACV		
sample	1	2
(A) WT BEFORE CRUSHING (gm)	2751.1	2753.2
(B) WT AFTER CRUSHING (gm)	2751	2752.4
(C) WT RETAINED AFTER CRUSHING (gm)	2316	2318.9
(D) WT PASSING SIEVE 2.36 mm	435.1	434.3
A.C.V(%) (D/B) *100	15.8	15.8
AVERAGE RESULTS %	15.8	

4.2 Aggregate Impact Value

The result of the AIV test is an indicator of the resistance of an aggregate to sudden shock or impact. A lower AIV value indicates stronger aggregates that can sufficiently resist impact loads. The AIV obtained from the testing is shown in table below and as the value is less than 25%, the aggregates are classified as very strong. Toughness is a crucial material property for aggregates to be used in road construction as there is a need to resist impact from the pounding effect of traffic loads that may cause fracture of the asphalt concrete. The aggregate impact value was found to be 15.0% which lies within the recommended values of less than 25% for granite aggregates and thus the aggregates are fit for use in the proposed mixtures for patching.

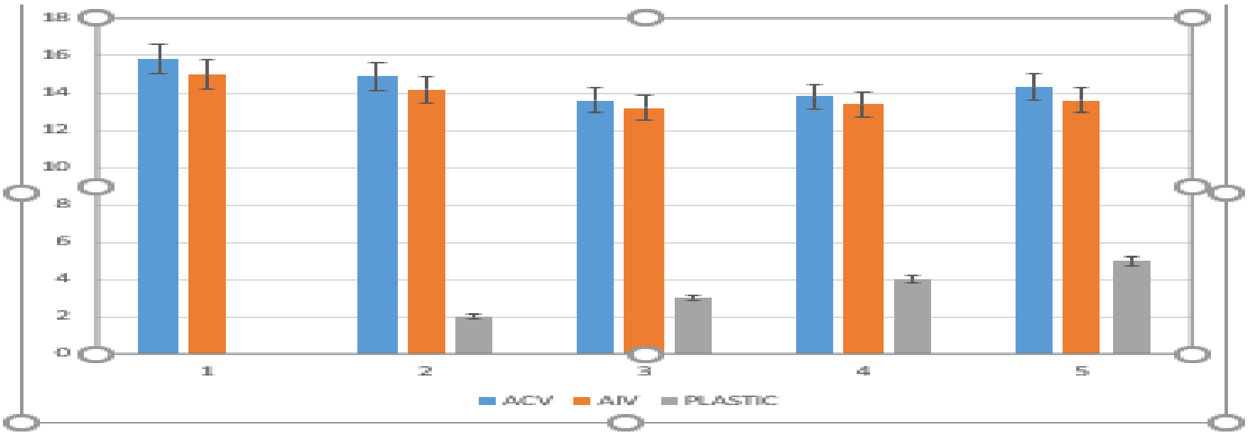

Figure 4-6 Relationship between AIV and Polypropylene

AIV		
sample	1	2
(A) WT BEFORE TEST (gm)	347.5	337.7
(B) WT AFTER TEST (gm)	344.5	337.5
(C) WT RETAINED AFTER TEST (gm)	296.2	286.8
(D) WT PASSING SIEVE 2.36 mm	51.3	50.9
A.I.V(%) (D/B) *100	14.9	15.1
AVERAGE RESULTS %	15.0	

The values for both the dry and wet conditions are seen to be greater than 110kN, which is the least recommended ten percent fine value for asphalt concrete surfacing. Table below shows the wet/dry strength ratio is as well above the minimum acceptable limit of 75% thus the aggregates are good enough to withstand load under crushing

Sample	Dry	Wet	Wet/Dry (%)
Force	255.6	226.6	89

Figure 4-7 Relationship Between dry and Wet samples

4.3 Specific Gravity of Aggregates

The specific gravity of aggregates is crucial in determining the volumetric properties of an asphalt mix, such as voids in mineral aggregates (VMA) and voids filled by asphalt (VFA), which greatly affect the resistance to moisture damage, fatigue cracking, and general durability (Gardete et al., 2022). The specific gravities of the tested aggregates are all found to lie within the recommended range of 2.5 – 3.0 for aggregates in asphalt mixes.

The absorption values indicate the amount of water that can be absorbed from the binder by the aggregates. Generally, high absorption values are undesirable as they will affect the performance of the mix. Thus, the tested aggregates are fit for use based on both the specific gravity and water absorption criteria.

Figure 4-8 Volumetric Properties of samples

Aggregate size:	20-14	14-10	10-6.0	6.0-0	FILLER
Bulk SG:	2.621	2.632	2.633	2.632	
Bulk SG on Saturated Dry Basis	2.627	2.643	2.646	2.646	
Apparent SG:	2.638	2.663	2.666	2.677	2.653
WATER ABSOPTION	0.2	0.4	0.5	0.6	

Aggregates for use in road surfacing are recommended to have specific gravity lying within the 2.5 – 3.0 range and the water absorption not to exceed 2% of by mass of the aggregates used. As seen in table above, the combined specific gravity falls within the range indicating that the mix with have less voids hence preventing defects like moisture penetration.

4.4 BITUMEN TESTS

Figure 4-9 Bitumen tests

TEST NO	**3**		**5**		**2P**	**AX**	**AVERAGE**	**REMARKS**
PENETRATION 100gr 5 sec 25˚C	**66**		**69**		**67**	**68**	**68**	**60-70**
	68		**67**		**68**	**69**		
	68		**66**		**68**	**69**		
SOFTENING POINT		**53**		**54**			**53.5**	**49-56**
SPECIFIC GRAVITY	**1.027**		**1.017**		**1.027**	**1.030**	**1.025**	

4.5 Penetration Test

Results from this test give an indication of the softness or hardness of the bitumen with smaller values signifying a harder bitumen and larger values signifying a softer bitumen.

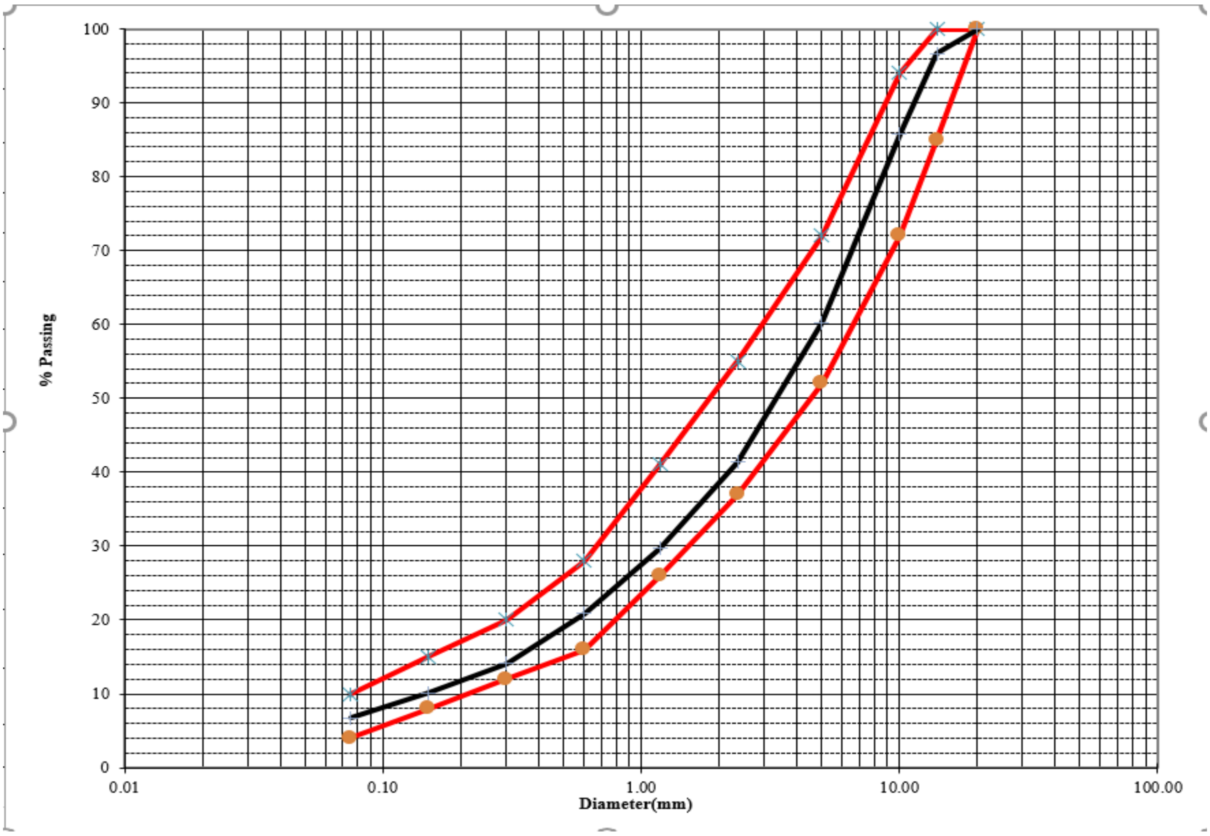

Figure 4-10 Graph showing the Optimum bitumen content.

4.6 Softening Point

The softening point is a measure of bitumen's durability and performance in various climates. It displays the temperature at which the bitumen begins to exhibit fluidity and deformation characteristics and reaches a particular softness. The average of the temperatures at which the three bitumen samples made contact with the lower plate in the water bath was used to determine the bitumen's softening point. Therefore, a higher softening point is preferred since it shows improved resistance to deformation at high temperatures.

4.7 Specific Gravity

The specific gravity of bitumen is directly related to the quality and density of the bitumen. It is relevant in mix design to determine the proportion of bitumen for use.

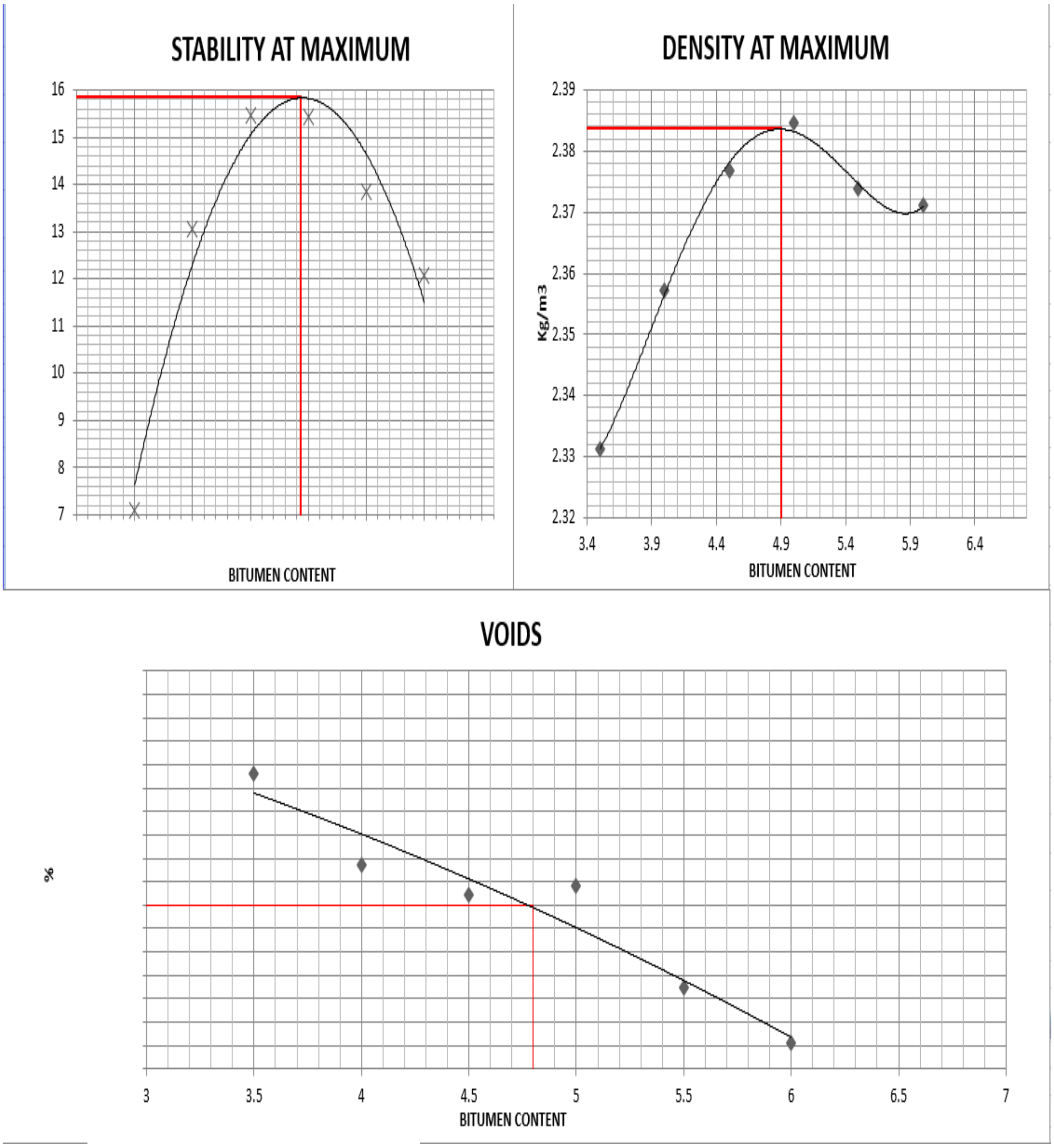

Figure 4-11 Results of Specific Gravity Tests

4.8 DESIGN APPLICATION

Design using AASHTO method design:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

Original Pavement Design

- 50mm Hot Mix Asphalt
- 200mm CRR Base
- 200mm CRR Subbase

Coefficients for each layer based on materials used

a_1=0.35, and a_2=0.14 and a_3=0.12

Assuming drainage conditions of water being removed within 1 week and the pavement structure is exposed to moisture levels approaching saturation for a time greater than 25%, drainage coefficients for the subbase and base layer can be taken as m2 = m3 = 0.8

Hence the structural number can be obtained from

$$SN = (0.35 \times 50) + (0.14 \times 200 \times 0.8) + (0.12 \times 200 \times 0.8)$$

$$SN = 59.1$$

Using the **AASHTO** nomographs the new coefficient for **a_1** due to the modification of the asphalt mix with 3% PP modification, **a_1=0.36**

Calculating the new thickness for the 3% PP Modified asphalt mix material

$$59.1 = (0.36 \times D_1) + (0.12 \times 200 \times 0.8) + (0.12 \times 200 \times 0.8)$$

$$D_1 = 48.61mm \approx 50mm$$

Therefore, the new pavement design with the 3% PP modification will remain the same thickness of layers

- 50mm Hot Mix Asphalt
- 200mm CRR Base
- 200mm CRR Subbase

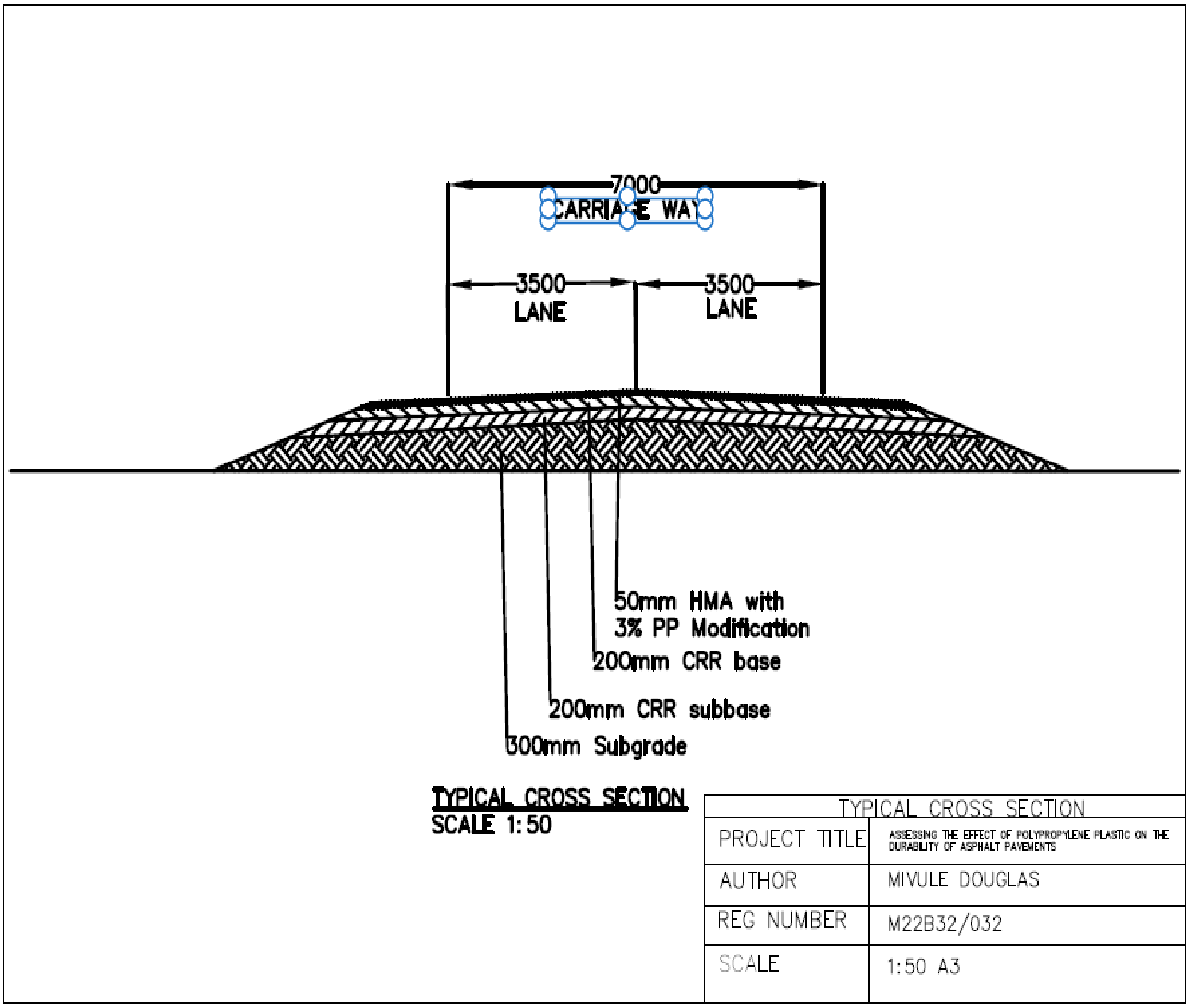

Figure 4-12Typical Pavement structure

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main objectives of this research were to study the mechanical performance of polypropylene modified asphalt concrete mixtures. The additions of modifier to the pure bitumen improve the properties of bitumen. Mechanistic and simulative tests were conducted in modified and unmodified asphalt concrete mixtures, Indirect Tensile Strength and Compressive test and Marshall Stiffness test After conducting laboratory tests on bitumen and mixtures with polymers content and after analyzing the data and comparing the results, the following conclusions have been drawn: •

The polymer modification has enhanced physical properties of bitumen mixture. • Adding (P.P) content showed increases the stability and the flow decreases up to 5% P.P content. • The effect of additive no increasing the indirect tensile strength value of mixture is more influential in the conditioned state due to the improved adhesion property. •

The value of Compressive strength for 7 % modified asphalt concrete mixtures with (P. P) has the heights value comparing with the value of Compressive strength for 0 % and 5 % asphalt concrete mixtures.

5.2 RECOMMENDATION

- There is need for increased studies and research into polymer modification in asphalt mixtures with other different types of plastic for example polyvinyl chloride (PVC), Polyvinyl Acetate (PVA), polyethylene (PE) and Polyethylene Terephthalate (PET). This is because different types of plastic have different properties.
- Further studies can be carried out to assess the viability of application of this 3% polypropylene modification in the field for both short-term and long-term aging rates of asphalt mixtures by carrying out simulated aging tests.

REFERENCES

Andrew, M., Lawrence, M., Chris Byaruhanga, B., (2024). Investigating the cost of mechanised unpaved road maintenance operations in Uganda, Transport Research Interdisciplinary Perspectives, Volume 25, pp. 101-135.

Chunnneng, Y., Yi Luo, Da Mei, (2025), Mechanical Properties of polypropylene fibre reinforced geopolymer-based reef limestone aggregate concrete, Construction and Building Materials, Vol.483, pp. 141-739

Fini, E. H., Zhang, X., You, Z. (2023). Sustainable Fiber Reinforced Asphalt Mixtures: Advances, Challenges and Future Directions. Resources Conservation and Recycling, Vol.189, pp. 106-709

Georois, P., Anand, S., Johannes, M., Amit, B. (2024). Engineering bitumen for future asphalt pavements: A review of chemistry, structure and rhenology, Materials and Design, Volume 244, pp. 113-157

International Standards: American Society for Testing and Materials (ASTM), British Standards (BS), American Association of State Highway and Transportation Officials (AASHTO)

MEIR Engineering and Research Limited, (2023). Final Data Compilation Report: Data Collection for Climate Change Mitigation Potential Analysis and Scenario Development in Uganda’s Transport Sector.

Nakiyemba, (2022), Uganda National Roads Authority, Journal of Civil and Environmental Research

Okello, B., et al. (2024). Climatic Impact Assessment on Road Infrastructure in Uganda: Case Study Kampala – Masaka Road. Uganda Journal of Environmental Engineering

Radeef, H., Hassan, N., Katman, H., (2022), The mechanical response of dry process polymer wastes under asphalt aging and moisture damage, Case studies in construction materials, Vol.16, pp. E00913

Ren, J., Yin, C. (2020). Investigating mechanical characteristics of aggregate structure for road materials. International Journal of Pavement Engineering, Volume 23(2), pp. 372-386

Styer, J., Tunstall, L., Landis, A., Grenfell, J., (2024). Innovations in Pavement Design and Engineering: A 2023 sustainability review, Volume 10, Issue 13, e33602.

Uganda National Roads Authority (UNRA). (2024) Pavement Condition Survey Report Kampala – Masaka Road. Kampala: UNRA Publications

Vijayan, V., Manthos, E., Mantalovos, K., (2024), multi-recyclability of asphalt mixtures modified with recycled plastic: Towards a circular economy, Results in Engineering, Vol.23, pp. 102-523

Xunhao, D., Fengteng, L., Tao Ma, Baitong, X., (2024). Effects of coarse aggregate morphology on Asphalt mixture's flowability: Parametric and prediction study, Case Studies in Construction Materials, Volume 21, e03735.

APPENDIX

INSTITUTION	STUDENT	TESTING LAB
GANDA CHRISTIAN UNIVERSIT	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling

PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT

SOFTENING POINT

SAMPLE REF		TECHNICIANS	
BITUMEN TYPE	60-70	SAMPLING DATE	5-Sep-25
SUPPLIER		TESTING DATE	5-Sep-25
LOCATION OF SAMPLING			
TEMPERATURE		BATH FLUID	

TIME (MINUTES)	TEMP °C	TEMP RISE °C	TIME (MINUTES)	TEMP °C	TEMP RISE °C
0	2.0	2.0	0	2.0	2
1	7.0	5.0	1	7.0	5
2	11.0	4.0	2	11.0	4
3	15.0	4.0	3	15.0	4
4	20.0	5.0	4	20.0	5
5	24.0	4.0	5	24.0	4
6	29.0	5.0	6	29.0	5
7	34.0	5.0	7	34.0	5
8	38.0	4.0	8	38.0	4
9	44.0	6.0	9	44.0	6
10	49.0	5.0	10	49.0	5
11	50.0	1.0	11	50.0	1
12	53.0	3.0	12	54.0	4

	RING 1	RING 2	AVERAGE
SOFTENING POIT(°C)	49.1	49.2	49

TESTING LAB

APPENDIX 1 SOFTENING TEST REPORT

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling

PROJECT: ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

LOCATION:	MUKONO SITE	Oparator	5/Sep/25
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT	Date	6/Sep/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2751.1		2753.2
(B) WT AFTER CRUSHING (gm)	2751		2752.4
(C) WT RETAINED AFTER CRUSHING (gm)	2316		2318.9
(D) WT PASSING SIEVE 2.36 mm	435.1		434.3
A.C.V(%) (D/B)*100	15.8		15.8
AVERAGE RESULTS %	15.8		
NB	more than B by 10gms repeat the test		

A.I.V

(A) WT BEFORE TEST (gm)	347.5		337.7
(B) WT AFTER TEST (gm)	344.5		337.5
(C) WT RETAINED AFTER TEST (gm)	296.2		286.8
(D) WT PASSING SIEVE 2.36 mm	51.3		50.9
A.I.V(%) (D/B)*100	14.9		15.1
AVERAGE RESULTS %	15.0		
NB	If c+d is more than B by 1gms repeat the test		

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

FOR CONTRACTOR		

Lab Technician

Materials Engineer

APPENDIX 2 ACV LABARATORY TESTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling

PROJECT: ASSESSING THE EFFECT OF POLYPROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT

DETERMINATION OF AGGRGATE'S 10% FINES VALUE DRY AND SOAKED

(BS 812PART 111:112:1990)

LOCATION:	Lab	OPERATOR	
		DATE SAMPLED	05 September 2025
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT	DATE TESTED	06 September 2025

10% FINE VALUE DRY

TEST NO	1	2	3
CRUSHING FORCE (KN)	267	267	
WT. OF AGGREG (gm)after crushing (M1)	2748	2754.2	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2455	2463	
WT AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	293.0	291.2	
TEN % FINE VALUE (M=M2/M1*100)	10.7	10.6	
AVERAGE RESULTS % (M)		10.6	
AVERAGE CRUSHING FORCE (F)		266.9	

$F = \frac{14F}{M+4}$ 255.6 DRY 255.6 KN

10% FINE VALUE SOAKED

TEST NO	1	2	3
CRUSHING FORCE (KN)	267	267	
WT. OF AGGREG (gm)after crushing (M1)	2792.2	2770.6	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2443	2425	
WT AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	349.2	345.6	
TEN % FINE VALUE (M=M2/M1*100)	12.5	12.5	
AVERAGE RESULTS % (M)		12.5	
AVERAGE CRUSHING FORCE (F)		266.9	

$F = \frac{14F}{M+4}$ 226.6 SOACKED WET/DRY(%)= 89

SPEC >110 SPEC >75%

f= Maximum force (KN)

of material passing the 2.36mm sieve at the maximum force

SPEC REQUIREMENT 7.5%-12.5% (BS 812-111) (if <or> discard

LAB		

Materials Engineer

APPENDIX 3 TFV TEST RESULTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS**	**Stirling**

PROJECT	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT

RESISTANCE TO DEGRADATION BY ABRASION AND IMPACT TO LOS ANGELES MACHINE (AASHTO T96 - 99)

JOB:	MUKONO SITE	OPERATOR	
LOCATION :	MUKONO CRUSHER	TOTAL BY DRY WT. OF THE SAMPLE:1	5,000.0
SUPPLIER:	STIRLING	TOTAL BY DRY WT. OF THE SAMPLE:2	5,000.0
MATERIAL:	AGGREGATES FOR ASPHALT	DATE SAMPLED:	5/Sep/2025
SPECIFICATION...		DATE TESTED:	6/Sep/2025

Test 1 Grading of Test Samples

SIEVE SIZE		Mass of indicated Sizes,g			Grading
Passing	Retained on	A 12 balls	B 11balls	C 8 balls	D 6balls
mm 20	10				
37.5 (1 1/2in)	25.0 (1 in)	1250 ± 25	......	......	......
25.0 (1 in)	19.0 (3/4 in)	1250 ± 25	......	......	......
19.0 (3/4 in)	12.5 (1/2 in)	1250 ± 10	2500 ± 10	......	......
12.5 (1/2 in)	9.5 (3/8 in)	1250 ± 10	2500 ± 10	......	......
9.5 (3/8 in)	6.3 (3/4 in)	.....	.....	2500 ± 10	......
6.3 (3/4 in)	4.75 (No. 4)	.....	.....	2501 ± 10	......
4.75 (No. 4)	2.36 (No. 8)	.....	.....	......	5000 ± 10
TOTAL:......................		5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10

Speed of Rotation: 33Rev/min. Max. 500 Rev.

Max.Duration 15 min			Wt after crushing:	4,968.2
GRADING USED FOR TEST:	SAMPLE: 1	SAMPLE: 2	Wt after crushing :	4,946.1
Wt of Mat. Retained on 1.7mm sieve :	4,155.0	4,165.0		
Wt of fine material _ gm	845.0	835.0	Average: %	16.8
Percentage of wear_ %	16.9	16.7	Spec Req	40%

FOR CONTRACTOR

LAB TECHNICIAN

MATERIALS ENGINEER

APPENDIX 4 ABRASISON AND IMPACT TEST

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT	

SPECIFIC GRAVITY & WATER ABSORPTION FINE AGGREGATES

(AASHTO ; T84—00)

ASTM DESIGNATION ; C128—97

LOCATION:		OPERATOR:	
SAMPLE No		SAMPLE DATE:	5-Sep-25
TYPE:	QUARRY DUST (O/6 mm)	TESTING DATE:	6-Sep-25

TEST NO		1		K
[A] wt. of oven dry sample in air	(gm)	836		873.5
[B] wt. of pycnometer filled with water	(gm)	1800		1786
[C] wt. of pycnometer with specimen and water	(gm)	2324		2333
[S] wt of saturated surface dry sample	(gm)	842		878.5
Bulk Specific Gravity on oven dry basis	(B-C) / (B+S-C)	2.629		2.635
Bulk Specific Gravity on saturated surface dry basis	S / (B+S-C)	2.648		2.650
Apparent Specific Gravity	A / 100(B-A)	2.679		2.675
Water Absorption(%)=	A / A	0.7		0.6

BULK SPECIFIC GRAVITY	2.632
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.649
APPARENT SPECIFIC GRAVITY	2.677
WATER ABSORPTION	0.6

FOR TESTING LAB

APPENDIX 5 SPECIFIC GRAVITY TESTS

INSTITUTION	STUDENT	SUPPLIER
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling

PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT

BITUMEN TESTS

LOCATION	
SUPPLIER	
DATE TESTED:	5-9-2025
MATERIAL TYPE	60/70
OPERATOR	Lab team
CONTAINER/DELIVERY NO	
DESTINATION	

TEST NO	3		5		2P		AX		AVERAGE	REMARKS
PENETRATION 100gr 5 sec 25 C	66 68 68		69 67 66		67 68 68		68 69 69		68	60-70
SOFTENING POINT (°C)	53		54						53.5	(49-56)°C
BITUMEN AFFINITY									>95	>95
SUPECIFIC GRAVITY									1.025	

FOR TESTING LAB

4

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS**	**Stirling**

PROJECT:	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT

SPECIFIC GRAVITY FILLER (AASHTO T100-95 (1995))

LOCATION: Mukono Lab	OPERATOR:
SAMPLE No	SAMPLE DATE: 5-Sep-25
TYPE: Filler	TESTING DATE: 6-Sep-25

	Beaker K		Beaker 1
[A) Wt. OVEN dry sample (gm)	406.74		440.22
[B) Wt. of Pycnometer containing water alone (gm)	1807.69		1770.88
[C] Wt of Pyconometer containing Sample and water (gm)	2061.4		2044.87
SPECIFIC GRAVITY OF FILLER $\frac{A}{A + (B - C)}$	2.658		2.648
AVERAGE	2.653		

FOR TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION:	Mukono Quarry	OPERATOR:	
SAMPLE No		SAMPLE DATE:	5-Sep-25
TYPE:	14-20 mm	TESTING DATE:	6-Sep-25

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	2076.3		2286.2
[B] wt. of saturated surface dry sample in air	(gm)	2081.4		2291.6
[C] wt of saturated sample in water	(gm)	1289.0		1419.6
Bulk Specific Gravity on oven dry basis	A / (B-C)	2.620		2.622
Bulk Specific Gravity on saturated surface dry basis	B / B-C	2.627		2.628
Apparent Specific Gravity	A / A-C	2.637		2.638
Water Absorption(%)=	100(B-A) / A	0.2		0.2

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.621
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.627
APPARENT SPECIFIC GRAVITY	2.638
WATER ABSORPTION	0.2

FOR TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	SAMPLE DATE: 5-Sep-25
TYPE: 14-10 mm	TESTING DATE: 6-Sep-25

TEST NO			A	B	C
[A] wt. of oven dry sample in air	(gm)		1461.8		1456.4
[B] wt. of saturated surface dry sample in air	(gm)		1469.6		1461.6
[C] wt of saturated sample in water	(gm)		913.5		908.8
Bulk Specific Gravity on oven dry basis		A / (B-C)	2.629		2.635
Bulk Specific Gravity on saturated surface dry basis		B / B-C	2.643		2.644
Apparent Specific Gravity		A / A-C	2.666		2.660
Water Absorption(%)=		100(B-A) / A	0.5		0.4

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.632
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.643
APPARENT SPECIFIC GRAVITY	2.663
WATER ABSORPTION	0.4

FOR TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	SAMPLE DATE: 5-Sep-25
TYPE: 10 - 6 mm	TESTING DATE: 6-Sep-25

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	2291.3		2127.6
[B] wt. of saturated surface dry sample in air	(gm)	2301.9		2137.5
[C] wt of saturated sample in water	(gm)	1431.9		1329.5
Bulk Specific Gravity on oven dry basis	A / (B-C)	2.634		2.633
Bulk Specific Gravity on saturated surface dry basis	B / B-C	2.646		2.645
Apparent Specific Gravity	A / A-C	2.666		2.666
Water Absorption(%)=	100(B-A) / A	0.5		0.5

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.633
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.646
APPARENT SPECIFIC GRAVITY	2.666
WATER ABSORPTION	0.5

FOR TESTING LAB

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE DURARIBILITY OF ASPHALT PAVEMENT		
SUMMARY FOR AGGREGATE TESTS WITH 5% POLYROPYLENE PLASTICS		
TYPE OF TEST	ACHIEVED	SPECIFICATION
TEN % FINE VALUE	272.7	> 110
TEN % FINE VALUE WET/DRY(%)	93	> 75
ACV	14.3	< 28
AIV	13.6	< 25
LAA	15.8	< 30
FOR TESTING LAB....................................		

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 753 KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
NDA CHRISTIAN UNIVE	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE DURARIBILITY OF ASPHALT PAVEMENT		
SUMMARY FOR AGGREGATE TESTS WITH 4% POLYROPYLENE PLASTICS		
TYPE OF TEST	ACHIEVED	SPECIFICATION
TEN % FINE VALUE	294.8	> 110
TEN % FINE VALUE WET/DRY(%)	97	> 75
ACV	13.8	< 28
AIV	13.4	< 25
LAA	15.6	< 30
FOR TESTING LAB..............................		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling
ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE DURARIBILITY OF ASPHALT PAVEMENT		
SUMMARY FOR AGGREGATE TESTS WITH 2% POLYROPYLENE PLASTICS		
TYPE OF TEST	ACHIEVED	SPECIFICATION
TEN % FINE VALUE	274.0	> 110
TEN % FINE VALUE WET/DRY(%)	94	> 75
ACV	14.9	< 28
AIV	14.2	< 25
LAA	16.4	< 30
FOR TESTING LAB........................		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling

PROJECT	ASSESSING THE EFFECT OF POLYROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENT
TEST	SPECIFIC GRAVITY
TEST METHOD	ASTM:C128-97

Sample Ref:	AC 14 MM	Technician :	
SOURCE:	Mukono Stirling quarry	Sampling date:	5-Sep-25
Aggregate size :	COMBINED	Testing date:	6-Sep-25
Description of aggregates:	HOT BINS		

Aggregate size :	20-14	14-10	10-6.0	6.0-0	FILLER
GS bulk :	2.621	2.632	2.633	2.632	2.653
PROPORTIONS:	7	15	17	58	3
COMBINED SG :	2.632				
WATER ABSOPTION	0.2	0.4	0.5	0.6	
COMBINED WATER ABSOPTION	0.5				

REMARKS

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 104, KAMPALA (U)

FOR TESTING LAB

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	ANKUNDA NOBLE RUHINDA & MIVULE DOUGLAS	Stirling

PROJECT:	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE DURARIBILITY OF ASPHALT PAVEMENT
Location:	NEAT

Date Sampled:	8-Nov-25	Date Tested	9-Nov-25

SUMMARY OF A/C 14 TEST RESULTS

MARSHALL MIX TEST RESULTS AFTER MIX		ACHIEVED PLANT PRODUCTION	SPECIFIED
MARSHALL FLOW		3.0	2—4
MARSHALL STABILITY 75BLOWS (NEWTON)		14.2	>9
MARSHALL AIR VOIDS 75BLOWS		4.9	3—7
VOIDS IN MINERAL AGGREGATES		15	>15%
VOIDS FILLED WITH BINDER		68	65—78%
BITUMEN CONTENT AFTER EXTRACTION		4.9	±0.3
RATIO (Stab./Flow)		4.8	>2
ITS DRY		879.5	>800kpa
ITS WET/DRY		87	>80

FOR LAB

STIRLING CIVIL ENGINEERING LTD