ASSESSING THE EFFECT OF POLYPROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENTS

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ABSTRACT

Flexible pavements are roads comprising of a surfacing layer comprising of bitumen aggregate and filler. The purpose of this report is to present a study conducted to create a resilient asphalt mixture for the durability of asphalt pavements. The significant existence of early pavement failures in the form of cracking and rutting was the major drive for this study. A modified asphalt mixture made using polypropylene plastic was proposed and tested in evaluation against the conventional asphalt mixture. This goal was achieved by conducting mechanical tests on materials that were used that is the aggregates and bitumen and characterisation of the polypropylene plastic. Other tests included the marshal tests and indirect tensile stress tests on both the modified asphalt and conventional asphalt samples to show the improvement caused by incorporating polypropylene plastic. Coating aggregates with polypropylene plastic led to a reduction in the Average Crushing Value from 15.8% to 13.6%. This signified an improvement in mechanical properties of coated aggregates. Marshall Quotient increased by 0.3, Air voids reduced by 0.5% and Indirect Tensile Strength (ITS) ratio increased to 96% from 80%. These tests also identified that 3% polypropylene plastic modification improved the general properties of asphalt especially making the asphalt mixture more resistant to moisture damage, heat and cracking.

However, there is need for more research in the use of other types of plastic in asphalt mixture in order to ascertain the full potential of polymer modified asphalt.

DECLARATION

I ANKUNDA NOBLE RUHINDA, declare that all the information in this research is my own work and that this research has not been presented to any institution of higher learning for any academic award.

Signature: ………………………………

Date: ……………………………………

ACKNOWLEDGEMENTS

Great appreciation is first extended to the Lord almighty for providing and protecting me throughout the whole process of carrying out this research. I am also thankful for tireless work of all the lecturers of the department to impart the skills and knowledge that have enabled me to submit this research fully. Honourable gratitude goes out to my supervisor, DR. Chris Bic Byaruhanga for the continued and steadfast support and encouragement at all the stages of my research project and report and finally a special thanks to my parents and project partner for your support in completing the research successfully may the Lord bless you all.

APPROVAL

This is to confirm that ANKUNDA NOBLE RUHINDA, a fourth year student of Uganda Christian University offering a Bachelor's of Science in Civil Environmental Engineering has done this research and design project under my supervision and has been submitted for examination with my confirmation as the research supervisor.

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

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TABLE OF CONTENTS

ABSTRACT ....

DECLARATION ii

ACKNOWLEDGEMENTS iii

APPROVAL iv

TABLE OF CONTENTS v

LIST OF TABLES..ix

LIST OF FIGURES x

ABBREVIATIONS AND ACRONYMS xi

CHAPTER ONE: INTRODUCTION 1

1.1 BACKGROUND OF STUDY 1

1.2 PROBLEM STATEMENT 2

1.3 OBJECTIVES OF STUDY 3

1.4 RESEARCH QUESTIONS 4

1.5 JUSTIFICATION.. 4

1.6 GEOGRAPHICAL SCOPE 5

CHAPTER TWO: LITERATURE REVIEW 7

2.1 Road Pavements.. 7

2.2 Types of pavements 7

2.3 Rigid pavements.. 7

2.4 Flexible pavements 8
2.4.1 Elements of flexible pavements 8
2.4.2 Materiel mixing and laying in construction of flexible pavements 13
2.4.3 Failures of flexible pavements 14
2.4.4 The factors affecting the asphalt mixture durability 14
2.5 Durability of asphalt pavements 16
2.6 Polypropylene Modified Mixtures 17
2.7 Summary of Literature Review and Research Gap 18
CHAPTER THREE: METHODOLOGY 20
3.1 Introduction 20
3.2 Material selection and sample preparation 20
3.3 Laboratory Tests 21
3.4 To determine the mechanical properties of polypropylene plastic, aggregates and bitumen 21
3.4.1 Tests on aggregates 21
3.4.2 Tests on Bitumen 22
3.5 To determine the optimum polypropylene plastic content for polypropylene modified asphalt mixture 23
3.5.1 Preparation of polypropylene coated aggregates 23
3.5.2 Preparation of asphalt concrete samples 24

3.5.3 Marshall Test 24
3.5.4 Marshall Mix design 25
3.5.5 Bulk density 25
3.5.6 Mixture specific gravity 25
3.5.7 Percentage of Air Voids in Mix 25
3.5.8 Stability and Flow 26
3.6 To determine the durability of polypropylene modified asphalt mixture in comparison to the neat asphalt mixture 26
3.7 Tests on asphalt concrete sample made 26
3.8 Indirect Tensile Strength Test 26
CHAPTER FOUR: DISCUSSION OF RESULTS 27
4.1 Introduction 27
4.2 Mechanical properties of PP coated aggregates in comparison to conventional aggregates 27
4.3 Tests on bitumen 34
4.4 Job Mix Formula Test Results 35
Combined grading for job mixes 35
4.5 Marshall Mix Design to Determine Optimum Bitumen Content 38
4.6 Performance test results 41

4.7 Indirect tensile strength for conventional asphalt and 3% PP modified asphalt 43

4.8 Data Analysis 44

4.9 DESIGN APPLICATION 45

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS 48

5.1 Conclusions 48

5.2 Recommendations 50

REFERENCES 51

APPENDIX 54

LIST OF TABLES

Table 1: Ten Percent Fines Value Test 28

Table 2: Aggregate Crushing Value Test Results 29

Table 3: Aggregate Impact Value Test Results 31

Table 4: Los Angeles Abrasion Test Results 32

Table 5: Penetration Test Results 34

Table 6: Softening Point Test Results 34

Table 7: Specific Gravity Test Results 35

Table 8: Job Mixes for Combined Grading 36

Table 9: Performance of different bitumen percentages durin biyumen batching 39

Table 10: Determines Bitumen Content 40

Table 11: Summary of the Marshall Mix Test Results 41

Table 12: Indirect Tensile Strength Test Results 44

LIST OF FIGURES

Figure 1: Shows a section of the Kamapala-Masaka highway in the Lwera Swamp . 6

Figure 2: Definition of pavement layers (Transport Research Labaoratory 1993)) 9

Figure 3: Relationship between TFV and polypropylene plastic 29

Figure 4: Relationship between ACV and Polypropylene plastic 30

Figure 5: Relationship between AIV and Polypropylene plastic 32

Figure 6: Relationship between LAAV and Polypropylene plastic 33

Figure 7: Combined Gradation Curve 38

Figure 8: Graphs of Bitumen Content against Stability, Density and Air Voids Respectively 40

ABBREVIATIONS AND ACRONYMS

AC – Asphalt Concrete

NEMA - National Environment Agency

PP – Polypropylene Plastic

AIV – aggregate impact value

ACV – AGGREGATE CRUSHING VALUE

HMA – HOT MIX ASPHALT

LAAV – LOS ANGELES ABRASION VALUE

ITSR – INDIRECT TENSILE STRENGTH RATIO

TFV – TEN PERCENT FINE VALUE

VFB - -VOIDS FILLED WITH BITUMEN

VMA - VOIDS IN MINERAL AGGREGATES

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND OF STUDY

Generally, there are two classes of road pavements recognized. These flexible pavements and rigid pavements are made of mainly Portland cement. Asphalt pavements, which are under flexible pavements, are the roads constructed using bitumen and asphalt. (Mallick & El-Korich, 2018).

The asphalt pavement network of Uganda is majorly paved with bitumen because bituminous pavements provide a safe, long-lasting and comfortable surface for road users. The performance of flexible pavements is highly dependent on properties of bitumen especially because of its binding properties that enable even load distribution (Mallick & El-Korich, 2018; Styer *et al.*, 2024). However, in Uganda 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. (MIER Engineering & Research, 2023; Andrew *et al.*, 2024).

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 (Bamber *et al.*, 2014; Georgios *et al.*, 2024). This 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 is 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 *et al.*, 2023; Chunnneng *et al.*, 2025).

Therefore, this research aims to evaluate the effect polypropylene plastic on the durability of asphalt pavements.

1.2 PROBLEM STATEMENT

The Kampala-Masaka Highway is a critical transportation corridor in Uganda linking the capital city to the south-western 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 (UNRA, 2024).

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; Okello *et al.*, 2024; MEIR Engineering & Research, 2023)

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 Swamp area near Lukaya District, Katonga Bridge section. (Okello, 2024; UNRA, 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. Therefore, the purpose of this research is to analyse the effect of polypropylene plastic on the durability of asphalt pavements. This with 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. (Fini *et al.*, 2023; Vijayan *et al.*, 2024; Radeef *et al.*, 2022)

1.3 OBJECTIVES OF STUDY

Main Objective

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

Specific Objectives

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

1.4 RESEARCH QUESTIONS

- What are the mechanical properties of polypropylene plastic, aggregates and bitumen?
- What is the optimum polypropylene plastic for the polypropylene modified asphalt mixture?
- What is the durability of polypropylene modified asphalt mixture in comparison to the neat asphalt mixture?

1.5 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 persists (UNRA, 2024; Nakiyemba, 2022).

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; Okello *et al.*, 2024; MEIR Engineering & Research, 2023).

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 incorporated 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 (Fini *et al.*, 2023; Chunnneng *et al.*, 2025). Polypropylene has excellent chemical resistance, which means strong bases do not attack it and in addition to that, it is resistant to gentle oxidants and reducing agents. The physical properties of polypropylene of being robust, sustainable and lightweight 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 (Vijayan *et al.*, 2024; Radeef *et al.*, 2022).

1.6 GEOGRAPHICAL SCOPE

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: Shows a section of the Kamapala-Masaka highway in the Lwera Swamp

CHAPTER TWO: LITERATURE REVIEW

2.1 Road Pavements

A road pavement is a structure consisting of a layered system of processed materials above the natural soil subgrade with a basic function of spreading the applied loads to the subgrade (Mallick & El-Korchi, 2018). 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 National 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. These factors can be environmental or structural in nature and lead to distresses such as cracking and rutting. (Andrew, 2024; UNRA 2024).

2.2 Types of pavements

2.3 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 (Mallick & El-Korchi, 2018; Styer *et al*., 2024). In other words, these pavements are designed to transfer or distribute loads in both a non-uniform and uniform 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)

2.4 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 because 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. (Bamber *et al*., 2014; Georgios *et al*., 2024)

2.4.1 Elements of flexible pavements

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

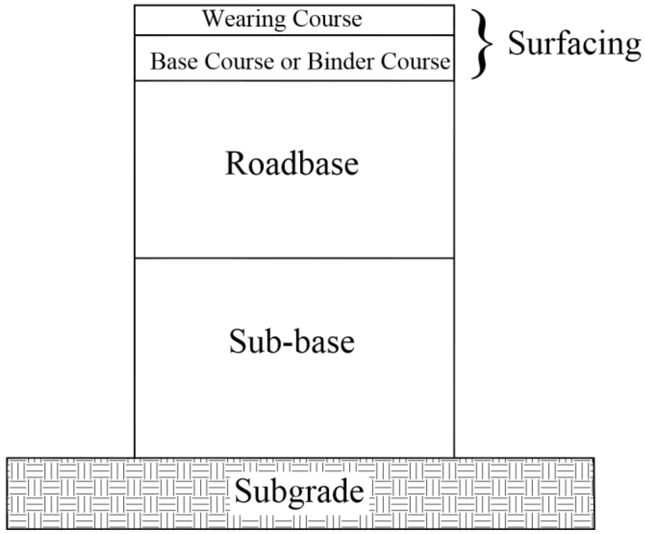


Figure 2: Definition of pavement layers (Transport Research Labaoratory 1993))

Surfacing course: This is the uppermost layer in the road structure. The primary functions of this layer include giving the structure strength, resistance to skidding, and water-tightness. This layer contains a graded skeleton of aggregate bound together with bitumen and works to protect the underlying structure from wear caused by traffic and the environment (Mallick & El-Korchi, 2018; Georgios *et al.*, 2024).

Base and Sub-Base Course: These granular layers contribute additional support towards the structure of the material and help in the distribution of loads towards the subgrade. The properties of this material affect the resistance of the material towards rutting or moisture damage (Bammer *et al.*, 2014; MEIR Engineering & Research, 2023).

Capping layer and subgrade: The subgrade corresponds to the natural formation of the soils under consideration, and the values of the bearing capacity and susceptibility to moisture essentially define the behaviour of the roads. However, in wet areas like Lwera, the high levels of moisture and poor strength imply that the improvement of the subgrade and drainage systems are essential (MEIR Engineering & Research, 2023; Okello *et al.*, 2024).

The bituminous mixture is used as the top portion of a flexible pavement structure to provide a resilient, waterproof, load-distributing medium that protects the base course from detrimental effects of climate conditions and abrasive action of traffic.

Aggregates

There is a classification 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 increasing the interlocking mechanism within the asphalt mixture (Xunhao *et al.*, 2024; Ren & Yin, 2020).

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 & Yin, 2020);

- Aggregates provide the structural skeleton which forms a load bearing framework to transmit the load from the surface down to the subgrade . The mechanical interlock of the aggregate particle's controls strength and rutting resistance.
- They provide skid resistance or surface texture. A section of the aggregate moves slightly above the smooth surface of the asphalt layer providing a texture of surface for the tires to grip thereby improving friction and skid resistance.

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

A paving grade refers to a grade of bitumen with viscosity characteristics appropriate for the type of HMA, the climate and loading conditions where it will be used. (Transport Research Laboratory, 2002; Georgios *et al.*, 2024).

Bitumen is majorly characterised in the following two types of grades:

Viscosity grade

The properties of the bituminous agents are known in terms of viscosity. This classification depends mostly on the scientific test of viscosity carried out under 60°C, and the unit of measurement of viscosity is 'poise'. The viscosity test or classification may be done both in residue samples of asphalt (AR) and in samples of original asphalt (AC).

However, viscosity grading is not commonly practiced in Uganda.

Penetration Grade

The penetration test is carried out in order to define the bitumen in terms of penetration grade. The penetration of bituminous material may be defined as the consistency of the bituminous material measured in terms of the distance in tenths of a millimetre that a standard needle penetrates under specified conditions of temperature, pressure, and time. The most commonly marketed bitumen in terms of penetration grade in most markets would be bitumen 60/70. The penetration test result or value of bituminous material is linked with the hardness and softness of bitumen in terms of ‘hard’ and ‘soft’ bitumen respectively. The ‘hard’ bitumen has lower penetration values followed by use in ‘’hot climates’’, whereas ‘’soft’ bitumen’ with ‘’high’’ values are used in ‘’cold climates’’.

Filler

Mineral filler consists of very fine particles (<0.075 mm), either naturally present taken together or added as cement, lime or rock dust. Fillers occupy voids taken together skeleton, increase mixture density and improve binder–aggregate cohesion, thereby enhancing resistance to water damage, permanent deformation

Polypropylene

Polypropylene plastic (PP): Polypropylene is a semi-crystalline thermoplastic polymer with high tensile strength, good fatigue and wear resistance, and excellent chemical stability. High-density polypropylene (HDPP), commonly used in packaging and containers, is particularly attractive due to its high strength-to-density ratio and hydrophobic character (Fini *et al*., 2023; Chunnneng *et al*., 2025). When used as an additive or modifier in asphalt mixtures, PP can enhance stiffness, rutting resistance and moisture resistance, and its high melting point allows it to retain integrity during mixing and compaction (Fini *et al*., 2023; Vijayan *et al*., 2024; Radeef *et al*., 2022).

2.4.2 Materiel 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 (Yadav, 2017; Radeef *et al.*, 2022).

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. (Yadav, 2017; Radeef *et al.*, 2022)

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 waste polypropylene is added to the mixture prior to be laid on the roads. (Yadav, 2017; Vijayan *et al.*, 2024).

Several studies report that both dry and wet processes can improve mechanical properties and durability of asphalt mixtures, but the dry process is particularly attractive for field implementation because it requires less modification of existing asphalt plants and can accommodate relatively high amounts of waste plastic (Vijayan *et al*., 2024; Radeef *et al*., 2022).

2.4.3 Failures of flexible pavements

The durability of asphalt mixtures refers to the capacity of compacted asphalt concrete to preserve its structural integrity over its anticipated service life amid exposure to environmental damage and traffic stresses. (Bamber, 2014)

In flexible pavements, factors affecting its durability are usually the main cause of the pavement failures. These failures include cracking, potholes, rutting and pavement bleeding. Give our scope study the main failures affecting that section of the road were cracking and rutting due to binder aging because of water infiltration and then over heating of the bitumen leading to embrittlement and hardening. (Okello, 2024)

For this study on the durability of asphalt concrete, the findings are associated with loss of adhesion and cohesion bonds between binder and aggregates and moisture damage.

2.4.4 The factors affecting the asphalt mixture durability

Environment

Environmental conditions at the pavement site significantly influence the durability of asphalt concrete. Temperature plays a crucial role in designing flexible pavements and asphalt concrete mixes. It affects the mixture's structural stiffness, resistance to rutting, and ability to resist cracking. Additionally, temperature greatly affects the aging process of asphalt binders and mixtures throughout the pavement's lifespan, with higher temperatures accelerating aging rates. (Amine, 2025)

Moisture is the second key environmental factor affecting asphalt concrete durability. It can cause damage in several ways: (1) weakening the cohesion within the asphalt binder, (2) reducing adhesion between the binder and aggregates, and (3) causing degradation of aggregates, especially when freezing occurs within the mixture. (Amine, 2025)

Drainage

Moisture damage can develop in asphalt mixtures when water enters via interconnected voids and is trapped inside. In flexible pavements, higher moisture levels in aggregate bases and subgrade soils reduce their strength and stiffness. Effective drainage is essential to clear water from the pavement surface and prevent infiltration into the base and foundation layers. (Amine, 2025)

Construction

Construction-related problems often lead to localized issues in asphalt pavements, such as ravelling, faster aging, and moisture-induced damage. Weather conditions during construction impact asphalt mixture longevity, as temperature, moisture, and wind influence cooling rates and compaction time. . (Ramon & Bonaquist, 2016).

Segregation, a frequent construction issue, harms mixture durability by creating spots with uneven aggregate distribution—either too much coarse or fine material—in the final surface. Regions with excess coarse aggregates exhibit reduced binder content, higher air voids, and increased permeability, making them vulnerable to durability failures. . (Ramon & Bonaquist, 2016).

Implementing construction practices to boost compaction and lower air voids, helps mitigate these risks.

Traffic loading

Repeated traffic loads trigger various pavement failures, including rutting and fatigue cracking. Rutting happens when vehicle loads surpass the asphalt mixture's viscos-plastic threshold, causing permanent deformations like wheel-path depressions. This type of rutting decreases with higher traffic speeds and stiffer binders, appearing more often under slow speeds, heavy loads, and elevated temperatures. (Ramon & Bonaquist, 2016).

Fatigue cracking develops as recurring loads gradually weaken the asphalt mixture, forming cracks that start at the bottom and extend upward. In highly aged pavements, top-down cracking emerges when the surface layer becomes brittle, allowing stresses to exceed its strain tolerance. (Ramon & Bonaquist, 2016).

2.5 Durability of asphalt pavements

Durability in asphalt roads can be defined as the capacity of the mixture to maintain its mechanical properties in the presence of traffic loading and environmental factors over time (Bamber *et al*., 2014; Georgios *et al*., 2024). The primary distress type indicative of the issue of lack of durability in roads includes fatigue cracking, thermal cracking, rutting, ravelling, and damage caused by moisture. All these types of distress are mostly caused by incorrect material choices and environmental factors.

Damage caused by moisture in the form of bitumen stripping from the surface of the aggregates is one of the most important factors in areas that receive significant rainfall or where drainage is poor. The action of water in the bitumen layer reduces the adhesive component of the binder and aggregate bond; this causes loss of rigidity and formation of potholes (Bamber *et al.*, 2014). The prolonged saturation of the layers and the subgrade in swamplands further exacerbates this process, as seen in the Lwera Site of the Kampala-Masaka Highway (MEIR Engineering & Research, 2023; Okello *et al.*, 2024).

Durability properties can be evaluated in the laboratory through tests like the Indirect Tensile Strength Test (ITS) and moisture susceptibility tests under various conditioning of water, temperature, or mechanical load. By comparing the values of indirect tensile strength in both the conditioned and unconditioned samples, information regarding the resistance of the mixture samples to moisture damage or loss of cohesion can be gathered (Fini *et al.*, 2023; Radeef *et al.*, 2022).

2.6 Polypropylene Modified Mixtures

The use of polypropylene-modified asphalt mixtures has been investigated in attempts to upgrade the properties of paved surfaces and utilize plastic wastes concurrently. For the dry process, PP functions mostly as a modifier of the aggregate morphology and reinforcing component in the asphalt matrix, compared with the wet process where PP functions in changing the rheological properties of the binder (Yadav *et al.*, 2017; Vijayan *et al.*, 2024).

Laboratory analysis indicates that the addition of PP generally enhances the mixture's rigidity and resistance to permanent deformation, hence improving rutting resistance under high-temperature service conditions (Fini *et al.*, 2023; Amine & Merbouh, 2025). Conversely, the hydrophobic properties of polypropylene may be beneficial in enhancing water resistance through reduced mixture affinity or water absorption and enhanced binder-aggregate bond interface (Radeef *et al.*, 2022). However, high percentages of polypropylene may contribute to reduce compaction density and increased air voids (Fini *et al.*, 2023).

However, the ideal contents of PP in the mixture needs to be identified based upon different material specifications and environmental factors. This has been accomplished through the Marshall Mix design procedure whereby stability parameters, flow properties, bulk density values, and void analyses are taken into consideration in assessing different binder and modifier percentages providing balanced properties (Transport Research Laboratory, 2002; Mallick & El-Korchi, 2018).

2.7 Summary of Literature Review and Research Gap

The literature under review indicates that the most common type of paved roads in Uganda are flexible roads and that they are highly traffic and environmentally sensitive (MEIR Engineering & Research, 2023; Andrew *et al.*, 2024). However, in wet areas such as Lwera Swamp, the major type of distress would be from moisture and rutting in roads like Kampala-Masaka Highway that have repeatedly developed premature failures (UNRA, 2024; Okello *et al.*, 2024).

Research carried out on the use of polymer-modified asphalt products such as polypropylene and other plastic wastes has shown considerable potential in improving the resistance to rutting, stiffness, and resistance to moisture of the asphalt mixture (Fini *et al.*, 2023; Vijayan *et al.*, 2024; Radeef *et al.*, 2022). However, most of this research has been carried out in foreign laboratories outside of Uganda.

However, there are no concrete research studies conducted specifically on the behavior of polypropylene-modified asphalt mixtures applicable in the context of Ugandan material types and environmental factors, and even fewer research studies conducted in critical locations such as the Lwera swampland region of the Kampala-Masaka Highway. This research aims to rectify this problem by designing polypropylene-modified asphalt mixtures applicable in the region based upon the available material types and assessing the relevant properties using ITS-based performance tests.

CHAPTER THREE: METHODOLOGY

3.1 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.

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

3.2 Material selection and sample preparation

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. Triplicate 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 nature, which causes softening at higher temperatures and hardening at lower 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.

3.3 Laboratory Tests

3.4 To determine the mechanical properties of polypropylene plastic, aggregates and bitumen

3.4.1 Tests on aggregates

Grading or sieve tests

The grading or method of sieve analysis was selected because particle size distribution is a necessary classification test for aggregates. It presents the relative portions of different sizes of particles. (**BS 812: Part 130:1985)**It is then possible to determine if the aggregates consist of predominantly gravel, silt, and sand or clay sizes.

Ten Percent Fines Value

This test is performed on aggregates to determine their resistance to a crushing under gradually applied compressive load. It is meant to determine the load in kN required to produce 10% of fines from a sample of aggregate under a specified compression rate (**BS 812: Part 111:112:1990)**.

Aggregate Crushing Value (ACV)

This method gives a relative measure of the resistance of an aggregate to crushing under gradually applied load due to the strength required of aggregate used in road construction to resist crushing **(BS 812: Part 110:1990)** this value is measured by the material passing through a specified sieve under a load of 400kN.

Aggregate Impact Value (AIV)

This test gives the relative measures of the resistance of an aggregate to sudden shock or impact. The test is done in reference to **BS 812: Part 110:1990.**

Los Angeles Abrasion Test

This test evaluates the hardness of relatively coarse aggregates meant for use in the paving process. The procedure can be utilized in the estimation of the deterioration in standard aggregates caused by actions like abrasion, striking, and grinding in the rotating steel drum holding a stipulated number of steel spheres **(AASHTO T96 – 99).**

Specific Gravity of Aggregates

The specific gravity of aggregates is important in the determination of the volumetric properties of an asphalt mix, such as the calculation of air voids, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). The specific gravities of the aggregate size range to be used was determined, and was later used to determine the build specific gravity of total aggregate **(ASTM: C128 – 97).**

3.4.2 Tests on Bitumen

Penetration Test

This test gives a relative measure of the consistency of bituminous material in terms of the distance in tenth of a millimetre that a standard needle penetrates the material under definite conditions of load, time, and temperature. The result of this test gives the measure of softness or hardness of the bitumen **(ASTM D5-86).**

Softening point test

This test provides information about the binder is softening point and hence information about the viscosity of bituminous material. The value of the softening point of material defines the temperature susceptibility of material. This test can be used in the temperature range 30°C-200°C in order to measure the bituminous binder's softening point. The material possessing a higher softening point has more tendency towards flow. The material possessing lower softening point has less tendency towards flow **(ASTM D36-95)**

Specific Gravity of Bitumen

This important index shows the density of bitumen compared with the density of the same quantities of water. The test of specific gravity assumes particular significance regarding the classification of different bitumen, assessing the purity of bitumen, and in connection with the calculation of the necessary quantities of bitumen in the mixture **(ASTM D70-97).**

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

3.5.1 Preparation of polypropylene coated aggregates

The dry process or method was used in coating the aggregates. The aggregates were heated to 170°C this temperature ensures that the shredded polypropylene to be added melts and bonds with the surface of the aggregates (Radeef *et al.*, 2022; Vijayan *et al.*, 2024). 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%, 2%, 3%, 4% and 5%. 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 were then subjected to the same mechanical tests explained earlier to obtain the optimum polypropylene plastic that will later be used in overall modified asphalt mixture.

3.5.2 Preparation of asphalt concrete samples

For each of the two samples that is the 0% PP aggregates as our control to form the conventional asphalt mixture and the 3% PP of polypropylene coated aggregates to form the modified asphalt mixture. With **0% PP sample** as control five trial binder(bitumen) contents are selected from (3.5-6.0) % in increments of 0.5%. The aggregate samples and bitumen were mixed and compacted with 75 blows on each side. The sample preparation is extremely important as directly influences the resulting volumetric properties of the asphalt mixtures.

3.5.3 Marshall Test

This test determines the relative measure of physical properties of asphalt specimens that relate to the plastic deformation properties of asphalt mixes. It provides values, which are used to determine the volumetric properties of asphalt mixtures as well as their performance. It also enables us to determine the optimum bitumen content in the asphalt mixtures. It also determines if the asphalt mixture can handle the load that is to be applied on the pavement without being deformed. In other words, it is to determine whether the asphalt mixture is able to perform the purpose it was designed **(ASTM D1559-98)**

3.5.4 Marshall Mix design

For the mix design in this report, the Marshall Mix procedure has been utilized in calculating the optimum binder dosage relevant for use in trial mixes. This process entails density-voids analysis of samples, stability and flow tests of samples in mix design. The various tests utilized in mix design are discussed in more detail below.

3.5.5 Bulk density

The resulting bulk density was then utilized in the density-voids analysis of the mixture to calculate the unit weight, absorbed asphalt percentage, air void percentage, voids filled with asphalt percentage, and voids in mineral aggregates percentage, all of which indicate the mixture's sensitivity to binder content **(ASTM D2726).**

3.5.6 Mixture specific gravity

The theoretical maximum specific gravity represents the bulk specific gravity of a fully compacted mixture with no air voids. This value is crucial for evaluating the quality and performance of asphalt mixtures throughout the design and construction stages **(ASTM D2726).**

3.5.7 Percentage of Air Voids in Mix

In asphalt mix design, determining the Voids in Mix (VIM) is a vital parameter that affects the mixture's volumetric properties. VIM refers to the void spaces within the compacted asphalt mixture and is essential for evaluating the mix's quality and performance. It is usually calculated by assessing the voids in the mixture, voids in mineral aggregates (VMA), and voids filled with asphalt binder (VFB) **(ASTM D2726).** The VIM value is important because it influences the asphalt's strength, durability, and aging behaviour. Monitoring and measuring VIM during design and construction is crucial to achieving optimal pavement performance. Factors such as asphalt content, aggregate gradation, and compaction methods can cause variations in the VIM value.

3.5.8 Stability and Flow

The Marshall test assesses the load bearing and flow properties of asphalt samples, including those with conventional bitumen and PMB cores. Using the Marshall Mix design approach, engineers can identify the ideal asphalt binder content that satisfies the required stability and flow criteria at the target density **(ASTM D6927).**

3.6 To determine the durability of polypropylene modified asphalt mixture in comparison to the neat asphalt mixture

3.7 Tests on asphalt concrete sample made

3.8 Indirect Tensile Strength Test

ITS tests were carried out on cylindrical specimens to determine tensile strength and to infer resistance to cracking under repeated traffic loads. Both the neat and modified were tested to evaluate moisture susceptibility. The ratio of the neat and modified ITS values was used as a durability or tensile strength ratio indicator **(AASHTO T283).**

CHAPTER FOUR: RESULTS AND DISSCUSSION

4.1 Introduction

This chapter reports the findings from the study's tests. The results are analysed and compared between polypropylene (PP)-coated aggregates and uncoated aggregates to evaluate their mechanical properties.

The Marshall Mix design method was applied to determine the optimal bitumen content for the asphalt mix, given the fixed aggregate gradation and binder type. Volumetric properties of mixes containing coarse PP-coated aggregates were assessed via Marshall testing

Durability characteristics of the asphalt mix, using 3% PP and 4.9% optimum binder content, were evaluated through the Indirect Tensile Strength Test.

As advised by a panel in both my project proposal and progress project presentations all tests were conducted in triplicates as will clearly be seen in this chapter and my appendix. In addition graphs were also advised for better interpretation of my results which have also been included in this chapter.

4.2 Mechanical properties of PP coated aggregates in comparison to conventional aggregates

Ten Percent Fines Value

The specification for TFV test is greater than 75% according **BS 812: Part 111:112:1990.**

Table 1: Ten Percent Fines Value Test

PERCENTAGE OF PLASTIC	SAMPLE		FORCE
	WET	DRY	WET/DRY (%)
0	12.5	10.6	89
2	11.3	10.4	94
3	10.1	9.8	98
4	10.1	10.7	97
5	11.1	12.3	93

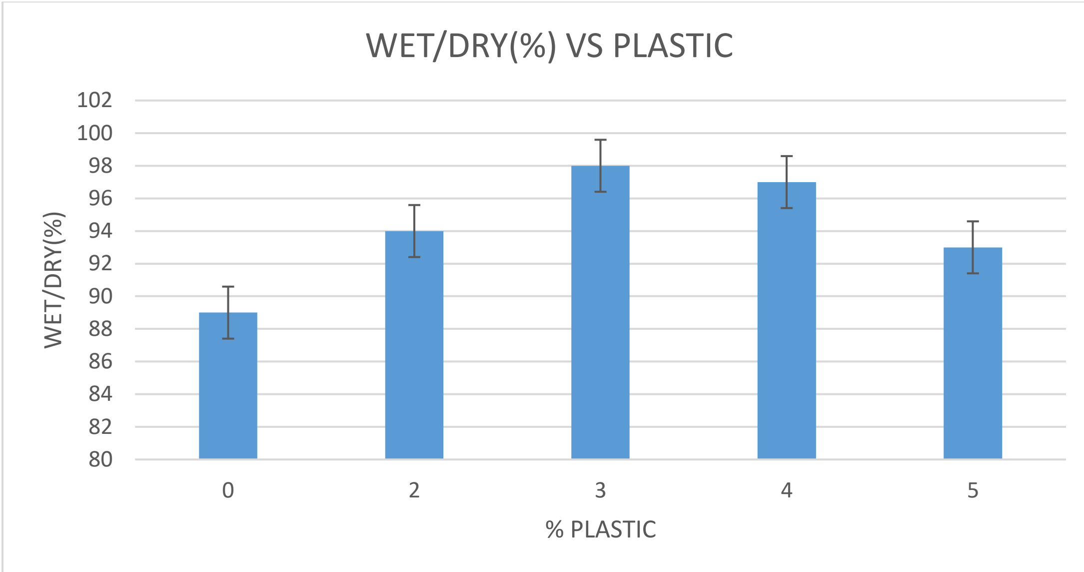


Figure 3: Relationship between TFV and polypropylene plastic

From the figure above it is evident that the PP coating of aggregates leads to consequent increases of the TFV as higher percentage of plastic was added the TFV increased from 89 at 0% to 98 at 3% and then starts to decline beyond 3%. This was also of the factors that informed our choice of 3% PP as our optimum polypropylene content as they require a much heavier load is required to produce 10% fines hence higher resistance to continually applied load.

Aggregate Crushing Value

The specification for ACV test is less than 25% according **BS 812: Part 110:1990.**

Table 2: Aggregate Crushing Value Test Results

PERCENTAGE OF PLASTIC	SAMPLE			AVERAGE ACV (%)
	1	2	3	
0	15.8	15.7	15.8	15.8

2	14.8	15.0	15.0	14.9
3	13.7	13.4	13.7	13.6
4	13.7	14.3	13.5	13.8
5	14.3	14.5	14.0	14.3

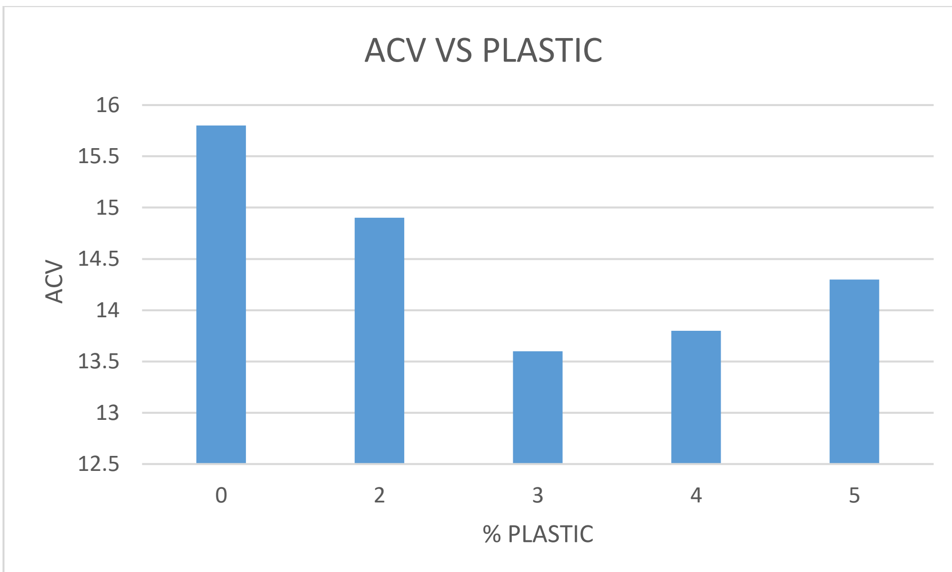


Figure 4: Relationship between ACV and Polypropylene plastic

This demonstrates that with increased coating aggregates with PP plastic decreases the aggregate crushing value but starts to decrease beyond 3% PP. The average ACV dropped from 15.8% at 0% PP to 13.6% at 3% PP

This enhancement means PP-coated aggregates in asphalt mixtures will obviously increase the ability to resist crushing under traffic wheel loads compared to uncoated ones. All tested ACVs remained below 25%, confirming compliance with standard specifications

Aggregate Impact Value

The specification for AIV test is less than 25% according **BS 812: Part 110:1990.**

Table 3: Aggregate Impact Value Test Results

PERCENTAGE OF PLASTIC	SAMPLE			AVERAGE AIV (%)
	1	2	3	
0	14.9	14.9	15.1	15.0
2	14.2	14.3	14.1	14.2
3	13.4	13.2	13.1	13.2
4	13.3	13.4	13.4	13.4
5	13.8	13.5	13.6	13.6

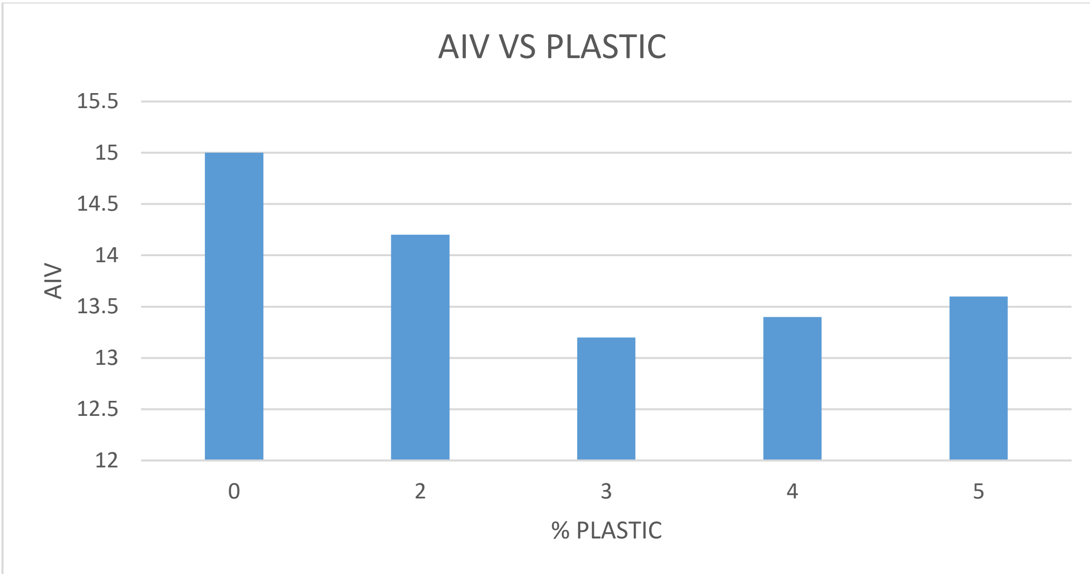


Figure 5: Relationship between AIV and Polypropylene plastic

Figure above illustrates the relationship between Aggregate Impact Value (AIV) and PP plastic percentage. It compares neat aggregates (0% PP) with those coated at varying PP levels, where lower AIV indicates greater aggregate strength. From the figure above it confirms that PP coating reduces AIV, dropping from 15.0% at 0% PP to 13.2% at 3%

This shows 3% PP-coated aggregates exhibit higher strength than uncoated ones informing our choice of 3% pp as our optimum pp content and shows an increased resistance to sudden impact hence increased and enhanced aggregate toughness.

LOS ANGELES ABRASION TEST

The specification for LAAV test is less than 30% according **AASHTO T96 - 99**

Table 4: Los Angeles Abrasion Test Results

	SAMPLE	AVERAGE LAAV (%)

PERCENTAGE OF PLASTIC	1	2	
0	16.9	16.7	16.8
2	16.4	16.4	16.4
3	15.6	15.7	15.6
4	15.6	15.7	15.6
5	15.9	15.8	15.8

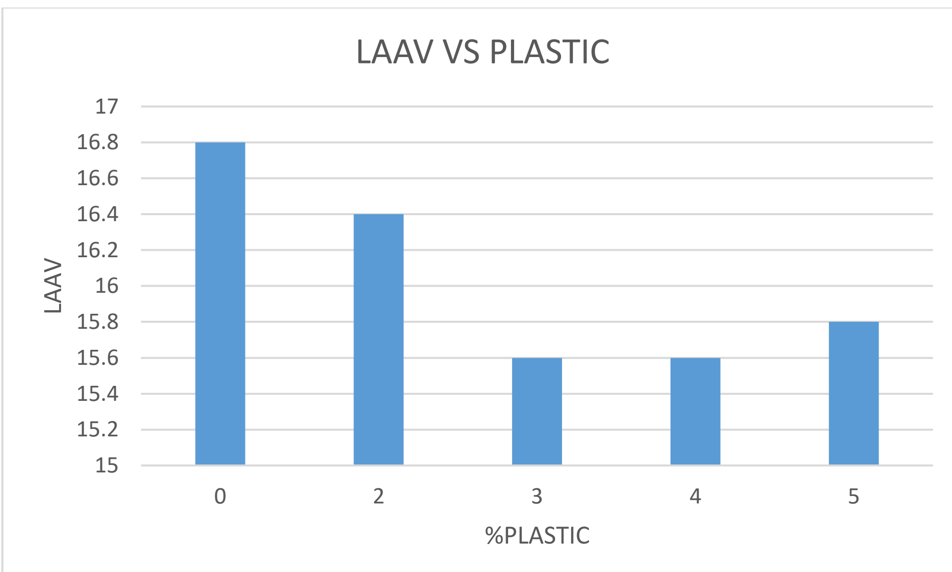


Figure 6: Relationship between LAAV and Polypropylene plastic

This reveals that PP-coated aggregates exhibit greater resistance to wear and abrasion under high loads. The Los Angeles Abrasion Value (LAAV) decreased from 16.8% at 0% PP coating to 15.6% at 3% PP coating, with resistance improving as percentage coating increases then beyond 3% it starts decline beyond 3% PP coating hence informing our choice as 3% PP as our optimum polypropylene content.

This occurs because polymer coatings enhance adhesion to aggregate surfaces, smooth out roughness, and thereby minimize surface.

4.3 Tests on bitumen

Penetration test results

Table 5: Penetration Test Results

TEST NUMBER	3	5	2P	AX	AVERAGE
PENETRATION 100gr 5 sec 25°C	66	69	67	68	68
	68	67	68	69	
	68	66	68	69	

From table above, the penetration test gave a penetration of 68 which means the neat bitumen in this study was of penetration grade 60/70.

Softening point

Table 6: Softening Point Test Results

	RING 1	RING 2	AVERAGE

SOFTENING POINT (°C)	53	54	53.5

The softening point value is 53.5°C is within the range of (49-56) °C implying that the bitumen is suitable for mixing into the asphalt since it is not susceptible to flowing with in the average clinic temperatures.

Specific Gravity

Table 7: Specific Gravity Test Results

TEST NUMBER	3	5	2P	AX	UNITS	AVERAGE SPECIFIC GARVITY OF BITUMEN
Specific Gravity of Bitumen	1.027	1.017	1.027	1.030	g/cm^3	1.025

The average bulk specific gravity of the bitumen samples (Gb) measured 1.025 g/cm^3, as shown in table above which falls within the standard range of 1.01–1.06. This confirms the bitumen's suitability for use in testing procedures.

4.4 Job Mix Formula Test Results

Combined grading for job mixes

Table 8: Job Mixes for Combined Grading

Sieve (mm)	Sample 1 Mass retained	Sample 2 Mass retained	Average Mass retained	%Average Mass retained	%Average passing	JMF	
						Upper	Lower
20	0.0	0.0	0.0	0.0	100	100	100
14	42.5	42.0	42.3	3.3	97	100	85
10	124.5	151.9	138.2	10.9	86	94	72
5	431.2	211.6	321.4	25.4	60	72	52
2.36	204.4	272.7	238,6	18.9	41	55	37
1.18	131.5	164.1	147,8	11.7	30	41	26
0.600	114.6	107.1	111.2	8.8	21	28	16

0.300	101.5	69.1	85.3	6.8	14	20	12
0.150	56.2	44.6	50.4	4.0	10	1215	8
0.075	46.7	40.0	43.4	3.4	7	10	4
Total filler	9.6	25.0	17.3				

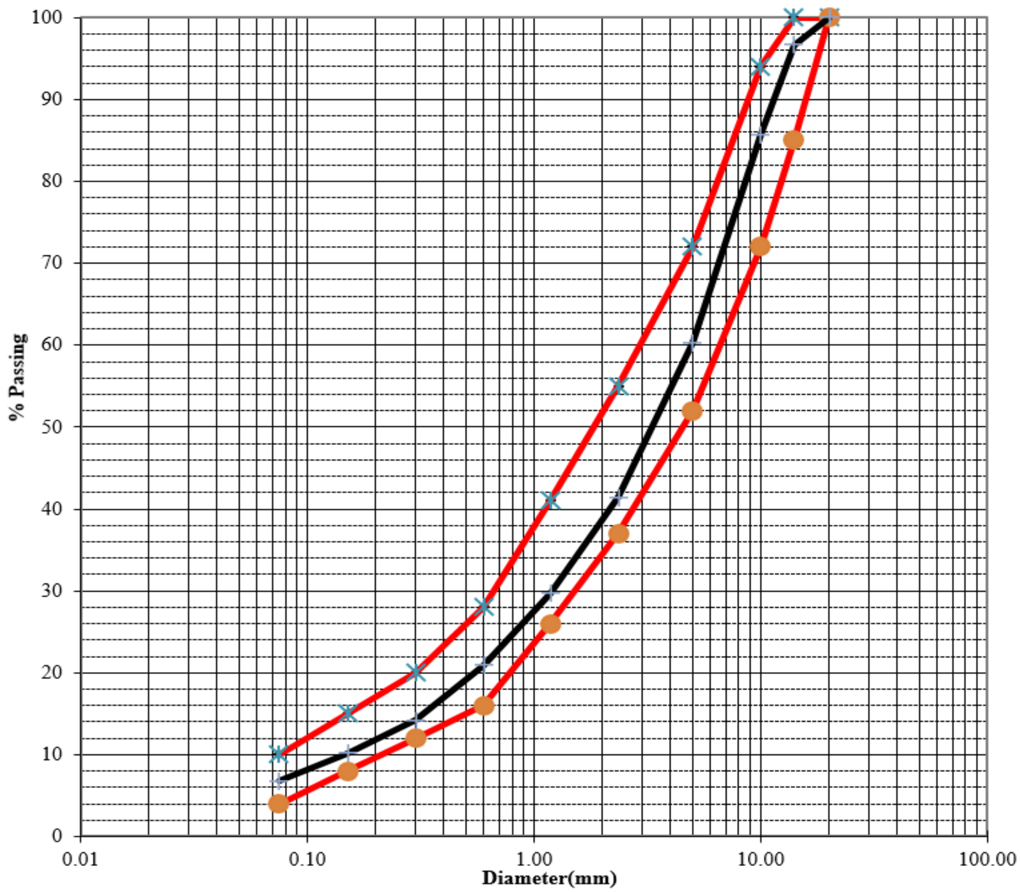


Figure 7: Combined Gradation Curve

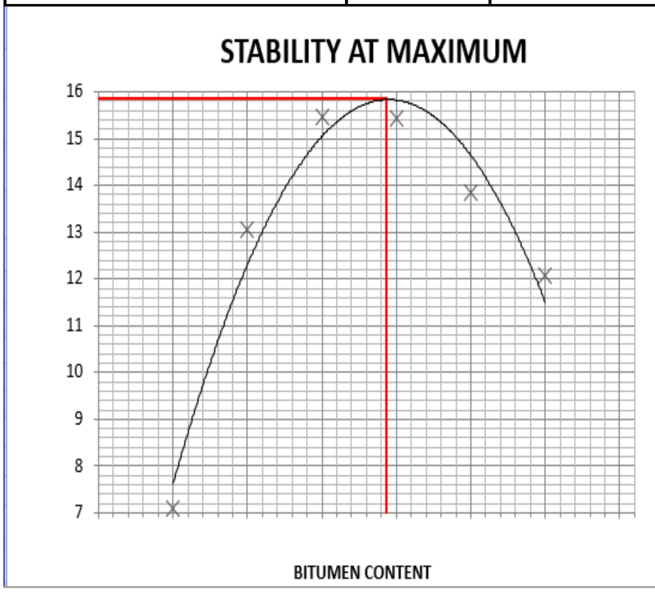
The figure above shows an AC14 combined gradation for asphalt job mixes illustrating the percentage passing versus diameter of particle size. The two outer red boundary curves show the upper and lower limits respectively that are specification requirements based on **ASTM** standards. The black curve at the center represents our actual combined gradation curve corresponding to our results. Given that our actual gradation line has remained within the acceptable rages of the red boundary curves, it means that the selected aggregate blend for the asphalt mix is acceptable.

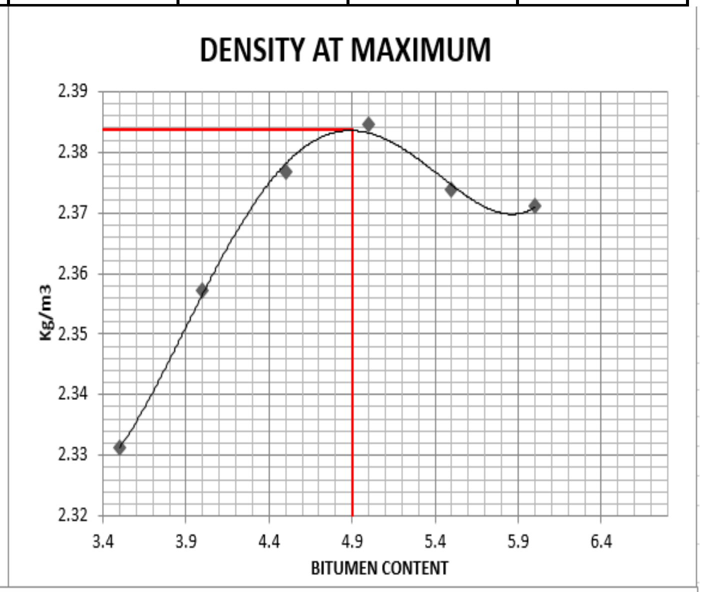
4.5 Marshall Mix Design to Determine Optimum Bitumen Content

The bitumen grade that was used for the mix design was 60/70

Table 9: Performance of different bitumen percentages during bitumen batching

BITUMEN (%)	3.5	4	4.5	5	5.5	6
DENSITY	2.33	2.357	2.377	2.385	2.374	2.371
STABILITY	7.1	13.0	15.5	15.4	13.8	12.1
FLOW	2.63	2.45	2.6	2.8	3.2	3.5
VOIDS	6.8	4.8	4.2	4.4	2.2	1.0





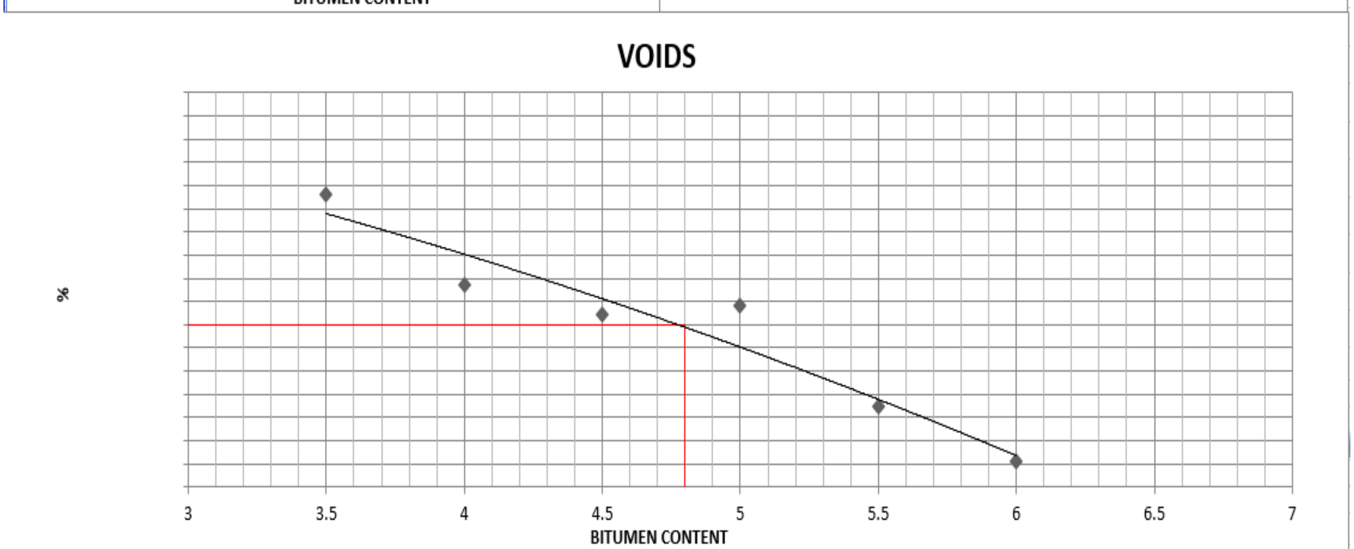


Figure 8: Graphs of Bitumen Content against Stability, Density and Air Voids Respectively

The Marshall Mix Design method determined the optimum bitumen content by evaluating key properties stability, density, and voids with results for varying bitumen percentages detailed in the table below. Graphs plotting these properties against bitumen content pinpointed peak values at 4.9% for Marshall Stability and density and 4.8% for voids. The average of these values, 4.9%, was selected as the optimum bitumen percentage.

Table 10: Determines Bitumen Content

PARAMETERS	VALUES (%)
Stability	**4.9**
Density	**4.9**
Voids	**4.8**
Average	**4.9**

From the results in the table above, the optimum bitumen content for the asphalt mixture was 4.9%, which was attained from calculating the average of the Stability, Density and Voids. This is the percentage considered for bitumen in the research design.

4.6 Performance test results

Marshall Test results

Table 11: Summary of the Marshall Mix Test Results

Marshall Mix Test Results after Mix	Achieved plant production asphalt with neat aggregates	Achieved plant production asphalt with 3% PP aggregates	Specified
Marshall flow	3.0	3.2	2-4mm
Marshall stability 75blows (Newton)	14.2	17.3	>9
Marshall air voids	4.9	4.4	3-7%
Voids in mineral aggregates	15	15	>15%
Voids filled with binder	68	71	65-78%
Bitumen content after extraction	4.9	4.9	±0.3
Ratio (stability/flow)	4.8	5.1	>2

Marshall Flow

The flow is linked to the stability of the asphalt mixture. The flow value indicates the loading flexibility and plasticity resistance of the hot mix asphalt material. The flow value of the conventional asphalt mixture is 3.0mm. The flow value of the asphalt mixture with 3% PP Coated aggregates is greater than that of the conventional asphalt mixture by 0.2mm. This indicates that the asphalt mixture with 3%-coated aggregates has higher plastic resistance.

Marshall Stability

The stability of 3% PP mixture is greater compared to the stability of conventional asphalt mixture. The difference in stability values between conventional asphalt mixture and 3% modified asphaltic concrete observed 3.1 kN. The stability index verifies the functionality of the mixture under loading. The stability values increase due to the use of plastic in the mixture. The increase in stability may be attributed by enhanced bonding between the aggregates and binding material.

Air Voids

The asphalt mixture with 3% PP coated aggregates had air voids of 4.4%, which was less than that of the conventional mixture, which was 4.9%. This implies that with the incorporation of PP, the air voids in an asphalt mixture are reduced. The reduction of air voids implies that the mixture is more resistant to oxidation and moisture, which usually enter the asphalt mixture through the voids. The value of 4.4% lies within the specification limits of 3-7%, which implies that the air voids are sufficient for expansion and contraction of the asphalt mixture without causing cracking of the flexible pavements.

Marshall Quotient

The asphalt mix with 3% PP has a higher Marshall Quotient of 5.1 than the asphalt mixtures with neat aggregates with a Marshall Quotient of 4.8. This value of 5.1 indicates a higher stiffness mix with a greater ability to spread the applied load.

Voids filled with binder (VFB)

Voids Filled with Bitumen percentage are expected around 65-75% but because of the reduction in voids by coating the aggregates with polyethylene, there is an observed decrease in the VFB values.

4.7 Indirect tensile strength for conventional asphalt and 3% PP modified asphalt

The indirect tensile strength results of three samples in dry and wet conditions of neat and 3% PP modified asphalt are presented in the table below. The data obtained indicates improvements in water resistance of the PP coated aggregate asphalt mixtures compared to conventional neat mixtures. The values of Tensile Strength Ratio of neat and 3% PP modified asphalt mixtures are higher compared to the minimum recommended level based on the specifications of 80%.

Table 12: Indirect Tensile Strength Test Results

Percentage of PP coating	Average tensile strength, Kpa		Tensile strength ratio (wet/dry)%
	Wet condition	Dry condition	
0 (neat asphalt)	879.5	762	87
3 (modified asphalt)	1238.2	1192	96

The tensile strength ratios for the asphalt mixture containing 3% PP were higher than 80%. This indicates that coating the aggregates with polypropylene does not cause the mixture to weaken when exposed to moisture and heat.

The samples with 3% PP coated aggregates and neat aggregates were subjected to extreme temperatures of $0℃, 29℃\ and\ 110℃$ and the rate of water absorption for all the samples was attained as seen in APPENDIX. The results show that asphalt mixtures with 3% PP coating had a lower value for water absorption than the mix with neat aggregates. This implies that with the incorporation of 3% PP modification, the asphalt mixture becomes more resistant to moisture, which attributes to roads that are more durable.

4.8 Data Analysis

Test results were summarised using descriptive statistics such as means and standard deviations. Graphs and tables were prepared to compare the behaviour of control and polypropylene-modified mixtures in terms of Marshall Properties, ITS and moisture susceptibility. Trends were interpreted in light of the literature on polymer-modified asphalt mixtures, with particular attention to identifying an optimum PP content that provides enhanced durability without compromising workability or other essential performance characteristics.

4.9 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 $\mathbf{a_1}$ due to the modification of the asphalt mix with 3% PP modification, $\mathbf{a_1=0.36}$

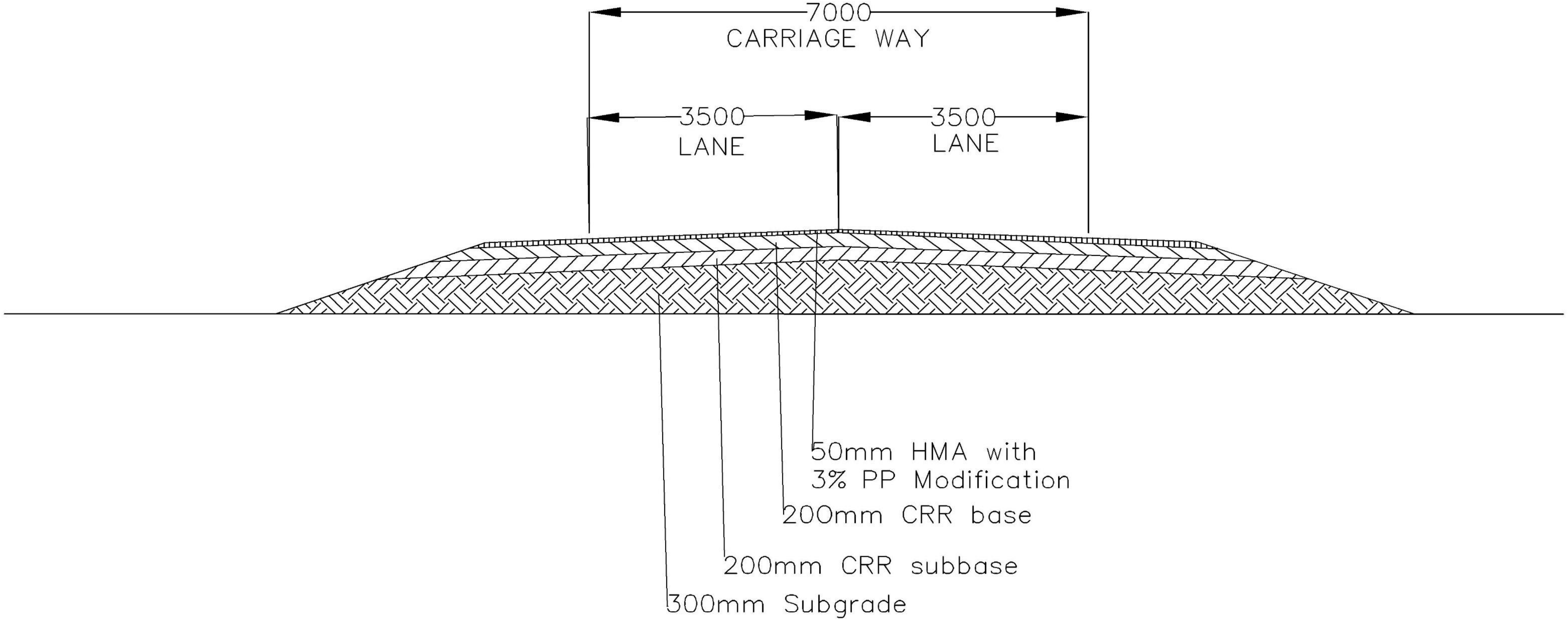
Calculating the new thickness for the 3% PP Modified asphalt mix material

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

$$\mathbf{D_1 = 48.61mm \approx 50mm}$$

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



TYPICAL CROSS SECTION
SCALE 1:50

TYPICAL CROSS SECTION	
PROJECT TITLE	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTIC ON THE DURABILITY OF ASPHALT PAVEMENTS
AUTHOR	ANKUNDA NOBLE RUHINDA
REG NUMBER	S21B32/048
SCALE	1:50 A3

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study focused on the use of polypropylene coated aggregates to enhance the durability of flexible pavements.

The prime aim of this research work was to investigate the dirability of asphalt roads influenced by polypropylene plastic. This aim was met by using the following methods;

- Conducting of the Ten Percent Fines (TFV), Aggregate Crushing Value (ACV) test, Aggregate Impact Value (AIV) test, Los Angeles Abrasion Value (LAAV) test and bitumen tests that include: penetration test and softening point test. In addition to that, material characterization was done for the polypropylene plastic. These test enabled in gaining information regarding the mechanical properties aggregates and our choice in penetration grade of bitumen. This is what enabled us to achieve our first objective, which was to determine the mechanical properties of aggregates, bitumen and polypropylene.
- For our next objective, which was to determine the optimum plastic content for the polypropylene, modified asphalt. Conducting of test on polypropylene coated aggregates and neat aggregates. The tests showed great improvement in these mechanical properties but showed the most effective aggregates as the 3% PP coated aggregates in comparison to the neat aggregates. Improvements were as follows; TFV-(89-98)% , ACV-(15.8-13.6)% , AIV-(15-13.2)% , LAAV-(16.8-18.6). Next was the Marshall Mix Design. The Marshall Mix Design was followed by the Marshall Test in gaining information regarding the volumetric properties of polypropylene-coated versus uncoated asphalt mixes. The polymer modified

asphalt mix gives a more durable material in the construction of flexible pavement because the mixture indicates that the Marshall Quotient of the asphalt mix with 3% PP is higher by 5.1 compared to the neat asphalt mix Marshall Quotient of 4.8. The Marshall Quotient of 5.1 indicates that the mixture exhibits high stiffness properties in terms of load spreading capacity. This indicates that the resistance to permanent deformation of the 3% PP modified mixture pavements is higher. The test continues to show a positive change in the volumetric properties of the asphalt mixture with the use of PP. The process of coating the aggregate with plastic minimized the Void in Mineral Aggregates (VMA) and air voids in the mixture. This resulted in the increase in the Void Filled with Binder (VFB). This is because the process of coating the aggregate with plastic enhanced the process of adhesion between the aggregate hence perfect bonding, meaning that the Hot Mix Asphalt mixture is likely to endure or last longer if the aggregate is coated with PP. The air voids reduced, indicating that the process of modifying the asphalt with polypropylene decreases the porosity and absorption of moisture and oxygen in the asphalt mixture. This provides a remedy or gives further answers to our selection the 3% PP modified asphalt and also reasons behind the durability in terms of environmental factors.

- Given my third objective is to determine the durability of polypropylene modified asphalt to that of the neat asphalt mixture, the performance test of the Indirect Tensile Strength test proved that the asphalt sample modified with 3% of polypropylene improved the performance of the bituminous mixture by improving the Tensile Strength ratio by 9%. Comparing the two mixtures showed that deformation resistance was highest for bituminous mixtures with 3% polypropylene.

5.2 Recommendations

- There is need for increased studies and reseach 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

- Nakiyemba, (2022), Uganda National Roads Authority, Journal of Civil and Environmental Research
- 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
- Uganda National Roads Authority (UNRA). (2024) Pavement Condition Survey Report Kampala – Masaka Road. Kampala: UNRA Publications
- Okello, B., *et al*. (2024). Climatic Impact Assessment on Road Infrastructure in Uganda: Case Study Kampala – Masaka Road. Uganda Journal of Environmental Engineering
- 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
- 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
- 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
- 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.
- 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.
- Styer, J., Tunstall, L., Landis, A., Grenfell, J., (2024). Innovations in Pavement Design and Engineering: A 2023 sustainability review, Volume 10, Issue 13, e33602.
- 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.
- 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
- 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
- Bamber, R., Shuang Cui, Blackman, Anthony, J. (2014). Durability of asphalt mixtures: Effect of aggregate type and adhesion promoters, International Journal of Adhesion and Adhesives, Volume 54, pp, 100-111

- Amine Bekhedda, Merbouh, M. (2025). Effects of thermal cycles on modified and unmodified asphalt mixtures with plastic waste of PET, Construction and Building Materials, Volume 493, pp. 143-235
- Yadav, Y. (2017). Construction of Plastic Roads:An effective way to utilize wastes. International Research Journal of Engineering and Technology (IRJET), pp. 650-652.
- Al-Khateeb, G., *et al*. (2020). *Asphalt Binder Aging and Distress Mechanisms*. Journal of Materials in Civil Engineering.

APPENDIX

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 [illegible] P.O. BOX [illegible] KAMPALA (U)

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

DETERMINATION OF AGGRGATE'S 10% FINES VALUE DRY AND SOAKED
(BS 812PART 111:112:1990)

MATERIAL SOURCE:	STIRLING YARD	OPERATOR	LAB TEAM
		DATE SAMPLED	02 November 2025
MATERIAL DESCRIPTION	5% POLYPROPYLENE PLASTICS WITH AGGREGATES	DATE TESTED	03 November 2025

10% FINE VALUE DRY

TEST NO	1	2	3
CRUSHING FORCE (KN)	294	294	294
WT. OF AGGREG (gm)after crushing (M1)	2853.4	2828.8	2,852.1
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2537.9	2505.9	2542.5
WT AGGREG (gm) PASSING SIEVE 2.36 mm (M2)	315.5	322.9	309.5
TEN % FINE VALUE (M=M2/M1*100)	11.1	11.4	10.9
AVERAGE RESULTS % (M)		11.1	
AVERAGE CRUSHING FORCE (F)		294.3	

$F = \left[\frac{14\ f}{M + 4}\right]$ 272.7 DRY 272.7 KN

10% FINE VALUE SOAKED

TEST NO	1	2	3
CRUSHING FORCE (KN)	294	294	294
WT. OF AGGREG (gm)after crushing (M1)	2854.6	2834.9	2803.5
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2497.9	2488.7	2461
WT AGGREG (gm) PASSING SIEVE 2.36 mm (M2)	356.7	346.2	342.6
TEN % FINE VALUE (M=M2/M1*100)	12.5	12.2	12.2
AVERAGE RESULTS % (M)		12.3	
AVERAGE CRUSHING FORCE (F)		294.3	

$F = \left[\frac{14\ f}{M + 4}\right]$ 252.5 SOAKED WET/DRY (%)= 93

SPEC >110 SPEC >75%

f= Maximum force (KN)

M= % of material passing the 2.36mm sieve at maximum force

SPEC ... 7.5% ... (BS 812 111) ...

STIRLING CIVIL ENGINEERING LTD

P. O. BOX 755, KAMPALA (U)

FOR STIRLING

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

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

MATERIAL SOURCE:	STIRLING YARD	Oparator	LAB TEAM
MATERIAL DESCRIPTION:	5% POLYPROPYLENE PLASTICS WITH AGGREGATES	Date	3/Nov/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2842.5	2798.9	2835.5
(B) WT AFTER CRUSHING (gm)	2841.7	2798.5	2835
(C) WT RETAINED AFTER CRUSHING (gm)	2434.1	2391.4	2437.6
(D) WT PASSING SIEVE 2.36 mm	407.6	407.1	397.4
A.C.V(%) (D/B)*100	14.3	14.5	14.0
AVERAGE RESULTS %		14.3	

NB more than B by 10gms repeat the test

A.I.V

(A) WT BEFORE TEST (gm)	373.6	384	376.3
(B) WT AFTER TEST (gm)	373.3	383.6	376.1
(C) WT RETAINED AFTER TEST (gm)	321.9	332	325.1
(D) WT PASSING SIEVE 2.36 mm	51.4	51.6	51.0
A.I.V(%) (D/B)*100	13.8	13.5	13.6
AVERAGE RESULTS %		13.6	

NB If c+d is more than B by 1gms repeat the test

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

FOR STIRLING

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

PROJECT	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE

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

		OPERATOR	LAB TEAM
MATERIAL SOURCE:	STIRLING YARD	TOTAL BY DRY WT. OF THE SAMPLE 1	4,999.3
		TOTAL BY DRY WT. OF THE SAMPLE 2	5,000.6
MATERIAL:	5% POLYPROPYLENE PLASTICS WITH AGGR	DATE SAMPLED:	2/Nov/2025
SPECIFICATION...		DATE TESTED:	3/Nov/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	4,926.1
GRADING USED FOR TEST:	SAMPLE: 1	SAMPLE: 2	Wt after crushing:	4,942.6
Wt of Mat. Retained on 1.7mm sieve : gm	4,206.7	4,210.0		
Wt of fine material _ gm	792.6	790.6	Average %	15.8
Percentage of Wear %	15.9	15.8	Spec Req	≤30%

STIRLING CIVIL ENGINEERING LTD

P. O. BOX 723, KAMPALA (U)

FOR STIRLING

INSTITUTION	STUDENTS	TESTING LAB
IDA 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.......................		

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

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**

DETERMINATION OF AGGRGATE'S 10% FINES VALUE DRY AND SOAKED
(BS 812PART 111:112:1990)

MATERIAL SOURCE:	STIRLING YARD	OPERATOR	LAB TEAM
		DATE SAMPLED	02 November 2025
MATERIAL DESCRIPTION:	4% POLYPROPYLENE PLASTICS WITH AGGREGATES	DATE TESTED	03 November 2025

10% FINE VALUE DRY

TEST NO	1	2	3
CRUSHING FORCE (KN)	299	299	299
WT. OF AGGREG (gm)after crushing (M1)	2836.7	2870.4	2,798.9
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2549	2580.8	2507
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	287.7	289.8	291.9
TEN % FINE VALUE (M=M2/M1*100)	10.1	10.1	10.4
AVERAGE RESULTS % (M)		10.2	
AVERAGE CRUSHING FORCE (F)		299.4	

$F = \frac{14F}{M+4}$ 294.8 DRY 294.8 KN

10% FINE VALUE SOAKED

TEST NO	1	2	3
CRUSHING FORCE (KN)	299	299	299
WT. OF AGGREG (gm)after crushing (M1)	2819.2	2824.4	2754.0
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2520.7	2524	2455.1
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	298.5	300.4	298.9
TEN % FINE VALUE (M=M2/M1*100)	10.6	10.6	10.9
AVERAGE RESULTS % (M)		10.7	
AVERAGE CRUSHING FORCE (F)		299.4	

$F = \frac{14f}{M+4}$ 285.3 SOACKED WET/DRY(%)= 97

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 ...)> discard

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

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

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

MATERIAL SOURCE:	STIRLING YARD	Oparator	LAB TEAM
MATERIAL DESCRIPTION:	4% POLYPROPYLENE PLASTICS WITH AGGREGATES	Date	3/Nov/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2851.8	2804	2891
(B) WT AFTER CRUSHING (gm)	2851.6	2804	2890.5
(C) WT RETAINED AFTER CRUSHING (gm)	2460.3	2402.7	2501.6
(D) WT PASSING SIEVE 2.36 mm	391.3	401.3	388.9
A.C.V(%) (D/B)*100	13.7	14.3	13.5
AVERAGE RESULTS %	13.8		

NB more than B by 10gms repeat the test

A.I.V

(A) WT BEFORE TEST (gm)	368.4	367.5	356.5
(B) WT AFTER TEST (gm)	368.3	367.2	355.3
(C) WT RETAINED AFTER TEST (gm)	319.5	318	307.6
(D) WT PASSING SIEVE 2.36 mm	48.8	49.2	47.7
A.I.V(%) (D/B)*100	13.3	13.4	13.4
AVERAGE RESULTS %	13.4		

NB If c+d is more than B by 1gms repeat the test

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

STIRLING CIVIL ENGINEERING LTD

P. O. BOX [illegible], KAMPALA (U)

FOR STIRLING

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

PROJECT	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE

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

		OPERATOR	LAB TEAM
MATERIAL SOURCE:	STIRLING YARD	TOTAL BY DRY WT. OF THE SAMPLE 1	5,000.5
		TOTAL BY DRY WT. OF THE SAMPLE 2	4,995.6
MATERIAL:	4% POLYPROPYLENE PLASTICS WITH AGGR	DATE SAMPLED:	2/Nov/2025
SPECIFICATION...		DATE TESTED:	3/Nov/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

	SAMPLE: 1	SAMPLE: 2		
GRADING USED FOR TEST:			Wt after crushing:	4,958.9
			Wt after crushing :	4,964.5
Wt of Mat. Retained on 1.7mm sieve : gm	4,221.8	4,210.0		
Wt of fine material _ gm	778.7	785.6	Average: %	15.6
Percentage of wear _ %	15.6	15.7	Spec Req	≤30%

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 733, KAMPALA (U)

FOR STIRLING

INSTITUTION	STUDENTS	TESTING LAB
IDA 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 3% POLYROPYLENE PLASTICS

TYPE OF TEST	ACHIEVED	SPECIFICATION
TEN % FINE VALUE	307.0	> 110
TEN % FINE VALUE WET/DRY(%)	98	> 75
ACV	13.6	< 28
AIV	13.2	< 25
LAA	15.6	< 30
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 DURABILITY OF ASPHALT PAVEMENT

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

(BS 812PART 111-112:1990)

MATERIAL SOURCE:	STIRLING YARD	OPERATOR	LAB TEAM
		DATE SAMPLED	02 November 2025
MATERIAL DESCRIPTION:	[illegible]% POLYPROPYLENE PLASTICS WITH AGGREGATES	DATE TESTED	03 November 2025

10% FINE VALUE DRY

TEST NO	1	2	3
CRUSHING FORCE (KN)	302	302	302
WT. OF AGGREG (gm)after crushing (M1)	2810.7	2817.5	2,834.1
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2523.9	2559.5	255.1
WT.AGGREG (gm) PASSING SIEVE 2.36 mm (M2)	286.8	257.0	273.1
TEN % FINE VALUE (M=M2/M1*100)	10.2	9.9	9.5
AVERAGE RESULTS % (M)	9.8		
AVERAGE CRUSHING FORCE (F)	302.0		

$F = \left[\frac{14 \quad F}{M \quad + \quad 4}\right]$ 307.0 DRY 307.0 KN

10% FINE VALUE SOAKED

TEST NO	1	2	3
CRUSHING FORCE (KN)	302	302	302
WT. OF AGGREG (gm)after crushing (M1)	2792.2	2795.0	2792.0
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2502.1	2516.6	2434
WT.AGGREG (gm) PASSING SIEVE 2.36 mm (M2)	290.1	279.4	258.0
TEN % FINE VALUE (M=M2/M1*100)	10.4	10.0	9.9
AVERAGE RESULTS % (M)	10.1		
AVERAGE CRUSHING FORCE (F)	302.0		

$F = \left[\frac{14 \quad F}{M \quad + \quad 4}\right]$ 300.1 SOAKED WET/DRY(%)= 98

SPEC >110 SPEC >75%

F= Maximum force (KN)

M= [illegible] of material passing the [illegible] sieve at maximum force

SPEC REQUIREMENT 7.5% - 12.5% (BS 812: 111) of [illegible]

STIRLING CIVIL ENGINEERING LTD

FOR STIRLING

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

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

MATERIAL SOURCE:	STIRLING YARD	Oparator	LAB TEAM
MATERIAL DESCRIPTION:	3% POLYPROPYLENE PLASTICS WITH AGGREGATES	Date	3/Nov/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2824.3	2830.8	2828.7
(B) WT AFTER CRUSHING (gm)	2824	2830	2828.7
(C) WT RETAINED AFTER CRUSHING (gm)	2438.3	2450.8	2441.2
(D) WT PASSING SIEVE 2.36 mm	385.7	379.2	387.5
A.C.V(%) (D/B)*100	13.7	13.4	13.7
AVERAGE RESULTS %	13.6		

NB more than B by 10gms repeat the test

A.I.V

(A) WT BEFORE TEST (gm)	360.3	332.5	357.5
(B) WT AFTER TEST (gm)	360	332.3	357.2
(C) WT RETAINED AFTER TEST (gm)	311.7	288.4	310.4
(D) WT PASSING SIEVE 2.36 mm	48.3	43.9	46.8
A.I.V(%) (D/B)*100	13.4	13.2	13.1
AVERAGE RESULTS %	13.2		

NB If c+d is more than B by 1gms repeat the test

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

STIRLING CIVIL ENGINEERING LTD

FOR STIRLING

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

PROJECT	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE

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

		OPERATOR	LAB TEAM
MATERIAL SOURCE:	STIRLING YARD	TOTAL BY DRY WT. OF THE SAMPLE:1	5,000.5
		TOTAL BY DRY WT. OF THE SAMPLE:2	4,995.6
MATERIAL:	3% POLYPROPYLENE PLASTICS WITH AGGR	DATE SAMPLED:	2/Nov/2025
SPECIFICATION...		DATE TESTED:	3/Nov/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:	4,958.9
GRADING USED FOR TEST.	SAMPLE: 1	SAMPLE: 2	Wt after crushing :	4,964.5
Wt of Mat. Retained on 1.7mm sieve gm	4,221.8	4,210.0		
Wt of fine material _ gm	778.7	785.6	Average: %	15.6
Percentage of wear %	15.6	15.7	Spec Req	≤30%

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 7?3, KAMPALA (U)

FOR STIRLING

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...........................		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 75 KAMPALA

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

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

(BS 812PART 111:112:1990)

MATERIAL SOURCE:	STIRLING YARD	OPERATOR	LAB TEAM
		DATE SAMPLED	02 November 2025
MATERIAL DESCRIPTION:	2% POLYPROPYLENE PLASTICS WITH AGGREGATES	DATE TESTED	03 November 2025

10% FINE VALUE DRY

TEST NO	1	2	3
CRUSHING FORCE (KN)	282	282	282
WT. OF AGGREG (gm)after crushing (M1)	2767.2	2806 9	2,788 0
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2476.8	2526	2490
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	290 4	280 9	298 0
TEN % FINE VALUE (M=M2/M1*100)	10.5	10.0	10.7
AVERAGE RESULTS % (M)		10.4	
AVERAGE CRUSHING FORCE (F)		281 8	

$F = \frac{14F}{M+4}$ 274 0 DRY 274.0 KN

10% FINE VALUE SOAKED

TEST NO	1	2	3
CRUSHING FORCE (KN)	281.8	282	
WT. OF AGGREG (gm)after crushing (M1)	2791 9	2806.7	2757.3
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2473.6	2493.2	2447
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	318 3	313.5	310 3
TEN % FINE VALUE (M=M2/M1*100)	11.4	11.2	11 3
AVERAGE RESULTS % (M)		11.3	
AVERAGE CRUSHING FORCE (F)		281.8	

$F = \frac{14F}{M+4}$ 258.3 SOACKED WET/DRY(%)= 94

SPEC >110 SPEC >75%

f= Maximum force (KN)

of material passing the 2.36mm [illegible] at the maximum force

SPEC [illegible]ENT:7 5%-12.5% (BS 812-111) (if <or> discard

STIRLING CIVIL ENGINEERING LTD
P.O. BOX [illegible] KAMPALA (U)

FOR STIRLING

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

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

MATERIAL SOURCE:	STIRLING YARD	Oparator	LAB TEAM
MATERIAL DESCRIPTION:	2% POLYPROPYLENE PLASTICS WITH AGGREGATES	Date	3/Nov/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2746.2	2698	2733
(B) WT AFTER CRUSHING (gm)	2745.9	2697.8	2732.4
(C) WT RETAINED AFTER CRUSHING (gm)	2338.9	2294	2323.1
(D) WT PASSING SIEVE 2.36 mm	407	403.8	409.3
A.C.V(%) (D/B)*100	14.8	15.0	15.0
AVERAGE RESULTS %		14.9	

NB more than B by 10gms repeat the test

A.I.V

(A) WT BEFORE TEST (gm)	354.6	358.8	358.2
(B) WT AFTER TEST (gm)	354.2	358.8	357.7
(C) WT RETAINED AFTER TEST (gm)	304	307.4	307.3
(D) WT PASSING SIEVE 2.36 mm	50.2	51.4	50.4
A.I.V(%) (D/B)*100	14.2	14 3	14.1
AVERAGE RESULTS %		14 2	

NB If c+d is more than B by 1gms repeat the test

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

STIRLING CIVIL ENGINEERING LTD P.O. BOX 150, KAMPALA (U)

FOR STIRLING

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

PROJECT	ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE

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

		OPERATOR	LAB TEAM
MATERIAL SOURCE:	STIRLING YARD	TOTAL BY DRY WT. OF THE SAMPLE:1	5,000.0
		TOTAL BY DRY WT. OF THE SAMPLE:2	5,000.0
MATERIAL:	2% POLYPROPYLENE PLASTICS WITH AGGR	DATE SAMPLED:	2/Nov/2025
SPECIFICATION..		DATE TESTED:	3/Nov/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

	SAMPLE: 1	SAMPLE: 2		
GRADING USED FOR TEST:			Wt after crushing:	4,981.5
Wt of Mat. Retained on 1.7mm sieve gm	4,179.4	4,180.1	Wt after crushing :	4,972.3
Wt of fine material gm	820.6	819.9	Average: %	16.4
Percentage of wear %	16.4	16.4	Spec Req	≤30%

STIRLING CIVIL ENGINEERING LTD

FOR STIRLING

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:	LGD	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	

Fo = [illegible] 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	

Fo = [illegible] 226.9 SOAKED WET/DRY(%)= 89

SPEC >110 SPEC >75%

F= Maximum force (KN)

= material passing the 2.36mm sieve at the maximum force

SPEC REQUIREMENT [illegible] is non- deduct

LAB

Materials Engineer

STIRLING CIVIL ENGINEERING LTD

P.O. BOX [illegible], KAMPALA (U)

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

A.C.V LABORATORY TEST RESULT FORM

(BS 812PART 110:1999)

LOCATION:	MUKONO SITE		Operator	5/Sep/25
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT		Date	5/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)	2315		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)	295.2		286.6
(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		

SPECIFICATIONS IN ACCORDANCE WITH TYPE OF MATERIAL

CONTRACTOR

Lab Technician

Materials Engineer

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

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

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

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 752, KAMPALA (U)

FOR CONTRACTOR

LAB TECHNICIAN

MATERIALS ENGINEER

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 ..., 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
MIX	AGGREGATES COATED WITH 3% POLYPROPYLENE PLASTICS

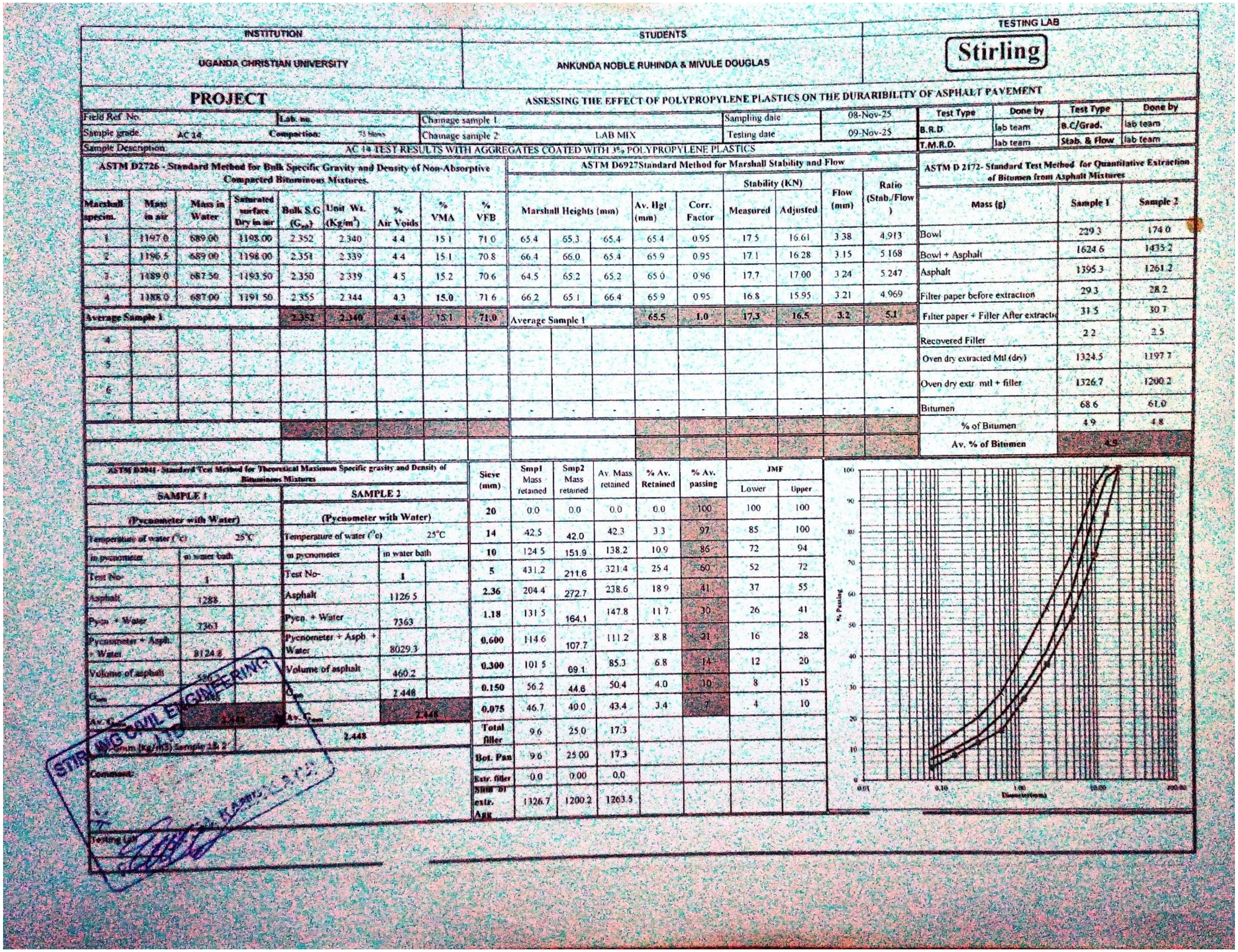
Date Sampled:	8-Nov-25	Date Tested:	9-Nov-25

SUMMARY OF A/C 14 TEST RESULTS WITH AGGREGATES COATED WITH 3% POLYPROPYLENE PLASTICS

MARSHALL MIX TEST RESULTS AFTER MIX		ACHIEVED PLANT PRODUCTION	SPECIFIED
MARSHALL FLOW		3.2	2—4
MARSHALL STABILITY 75BLOWS (NEWTON)		17.3	>9
MARSHALL AIR VOIDS 75BLOWS		4.4	3—7
VOIDS IN MINERAL AGGREGATES		15	>15%
VOIDS FILLED WITH BINDER		71	65—78%
BITUMEN CONTENT AFTER EXTRACTION		4.9	±0.3
RATIO (Stab./Flow)		5.1	>2
ITS DRY		1238.2	>800kpa
ITS WET/DRY		96	>80

FOR LAB

STIRLING CIVIL ENGINEERING LTD



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

Field Ref No.		Lab. no.		Chainage sample 1	Sampling date	08-Nov-25
Sample grade:	AC 14	Compaction:	75 blows	Chainage sample 2: LAB MIX	Testing date	09-Nov-25
Sample Description	AC 14 TEST RESULTS WITH AGGREGATES COATED WITH 3% POLYPROPYLENE PLASTICS					

Test Type	Done by	Test Type	Done by
B.R.D	lab team	B.C/Grad.	lab team
T.M.R.D.	lab team	Stab. & Flow	lab team

ASTM D2726 - Standard Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures. / **ASTM D6927Standard Method for Marshall Stability and Flow**

Marshall specim.	Mass in air	Mass in Water	Saturated surface Dry in air	Bulk S.G (G_{mb})	Unit Wt. (Kg/m³)	% Air Voids	% VMA	% VFB	Marshall Heights (mm)			Av. Hgt (mm)	Corr. Factor	Stability (KN) Measured	Stability (KN) Adjusted	Flow (mm)	Ratio (Stab./Flow)
1	1197.0	689.00	1198.00	2.352	2.340	4.4	15.1	71.0	65.4	65.3	65.4	65.4	0.95	17.5	16.61	3.38	4.913
2	1196.5	689.00	1198.00	2.351	2.339	4.4	15.1	70.8	66.4	66.0	65.4	65.9	0.95	17.1	16.28	3.15	5.168
3	1189.0	687.50	1193.50	2.350	2.339	4.5	15.2	70.6	64.5	65.2	65.2	65.0	0.96	17.7	17.00	3.24	5.247
4	1188.0	687.00	1191.50	2.355	2.344	4.3	15.0	71.6	66.2	65.1	66.4	65.9	0.95	16.8	15.95	3.21	4.969
Average Sample 1				2.352	2.340	4.4	15.1	71.0	Average Sample 1			65.5	1.0	17.3	16.5	3.2	5.1
4																	
5																	
6																	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	229.3	174.0
Bowl + Asphalt	1624.6	1435.2
Asphalt	1395.3	1261.2
Filter paper before extraction	29.3	28.2
Filter paper + Filler After extractio	31.5	30.7
Recovered Filler	2.2	2.5
Oven dry extracted Mtl (dry)	1324.5	1197.7
Oven dry extr. mtl + filler	1326.7	1200.2
Bitumen	68.6	61.0
% of Bitumen	4.9	4.8
Av. % of Bitumen	4.9	

ASTM D2041 - Standard Test Method for Theoretical Maximum Specific gravity and Density of Bituminous Mixtures

SAMPLE 1 (Pycnometer with Water)		SAMPLE 2 (Pycnometer with Water)	
Temperature of water (°c)	25°C	Temperature of water (°c)	25°C
in pycnometer	in water bath	in pycnometer	in water bath
Test No-	1	Test No-	1
Asphalt	1288	Asphalt	1126.5
Pycn. + Water	7363	Pycn. + Water	7363
Pycnometer + Asph. + Water	8124.8	Pycnometer + Asph. + Water	8029.3
Volume of asphalt	[illegible]	Volume of asphalt	460.2
G_{mm}	[illegible]	G_{mm}	2.448
Av. G_{mm}	[illegible]	Av. G_{mm}	2.448
Av. Gmm (kg/m3) Sample 1& 2	2.448		

Comment:

Testing Lab

Sieve (mm)	Smp1 Mass retained	Smp2 Mass retained	Av. Mass retained	% Av. Retained	% Av. passing	JMF Lower	JMF Upper
20	0.0	0.0	0.0	0.0	100	100	100
14	42.5	42.0	42.3	3.3	97	85	100
10	124.5	151.9	138.2	10.9	86	72	94
5	431.2	211.6	321.4	25.4	60	52	72
2.36	204.4	272.7	238.6	18.9	41	37	55
1.18	131.5	164.1	147.8	11.7	30	26	41
0.600	114.6	107.7	111.2	8.8	21	16	28
0.300	101.5	69.1	85.3	6.8	14	12	20
0.150	56.2	44.6	50.4	4.0	10	8	15
0.075	46.7	40.0	43.4	3.4	7	4	10
Total filler	9.6	25.0	17.3				
Bot. Pan	9.6	25.00	17.3				
Extr. filler	0.0	0.00	0.0				
Sum of extr. Agg	1326.7	1200.2	1263.5				

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

INDIRECT TENSILE STRENGTH AASHTO T283

BITUMINOUS MIXTURE SAMPLED ON: 08/11/2025 | 102 | GMM: 2.459 | Bit.content,%: 4.9 | NO OF BLOWS: 49

Compacted material parameters

SAMPLE NO.	HEIGHT 1 (mm)	HEIGHT 2 (mm)	HEIGHT 3 (mm)	Av. Thickness (mm)	Weight of Core in Air (g) A	Weight of Core in Water (g) B	Weight of Core in SSD condition (g) C	Volume of Core (cc) D=(C-B)	Bulk Density (g/cm³) E=(A/D)	GMM (maximum theoretical density) (g/cm³) F	VOLUME OF AIR	SATURATED SPECIMEN	VOLUME OF WATER	DEGREE OF SATURATION	VIM - AIR voids (%) [illegible]
MIX	ITS TEST RESULTS WITH AGGREGATES COATED WITH 3% POLYPROPYLENE PLASTICS														
WET															
1	65.8	65.7	66.4	66.0	1192.5	680.0	1196.1	516.1	2.287	2.459	36.070	1219.0	26.500	73.468	7.0
4	68.1	67.6	67.8	67.8	1187.5	681.0	1195.1	514.1	2.287	2.459	36.083	1216.5	29.000	80.370	7.0
3	68.3	68.0	68.0	68.1	1182.0	683.5	1197.5	514.0	2.277	2.459	36.197	1211.5	29.500	77.231	7.4
DRY															
2	67.3	66.8	67.0	67.0	1194.0	689.0	1205.5	516.5	2.289	2.459	35.866				6.9
5	68.1	68.1	68.5	68.2	1187.0	683.9	1199.5	515.6	2.279	2.459	37.784				7.3
6	69.5	68.1	69.3	69.0	1188.5	683.5	1199.0	515.5	2.282	2.459	37.080				7.2

INDIRECT TENSILE STRENGTH

DRY

SPECIMEN No.	GAUGE READING (div)	LOAD RING FACTOR (kN/div)	MAXIMUM LOAD P (kN)	SINGLE TENSILE STRENGTH S_t (kPa)	AVERAGE TENSILE STRENGTH S_t
2	[illegible]	0.024	[illegible]	1,348.1	1,238.2
3	[illegible]	0.024	[illegible]	1,228.1	
6	[illegible]	0.024	[illegible]	1,138.4	

WET

SPECIMEN No.	GAUGE READING (div)	LOAD RING FACTOR (kN/div)	MAXIMUM LOAD P (kN)	SINGLE TENSILE STRENGTH S_t (kPa)	AVERAGE TENSILE STRENGTH S_t (kPa)	[illegible]	RETAINED (spec. 80%)
1	505	0.024	12.2	1,155.6	1,192	[illegible]	96
4	555	0.024	13.4	1,336.1			
3	534	0.024	12.8	1,083.9			

STIRLING CIVIL ENGINEERING LTD

Lab Technician

KAMPALA (U)

Materials Engineer

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
% WET/DRY		87	>80

FOR LAB:

STIRLING CIVIL ENGINEERING LTD

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

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

JOB ASPHALT MIX DESIGN

LOCATION MUKONO LAB

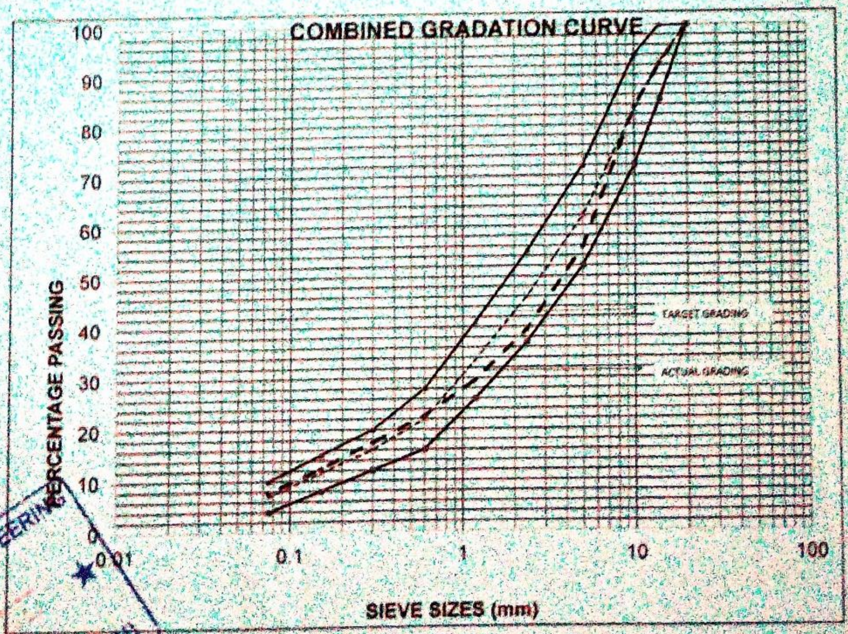
JOB MIX GRADING COMPOSITION

SUPPLIER HOTBIN

DATE 06/11/2025

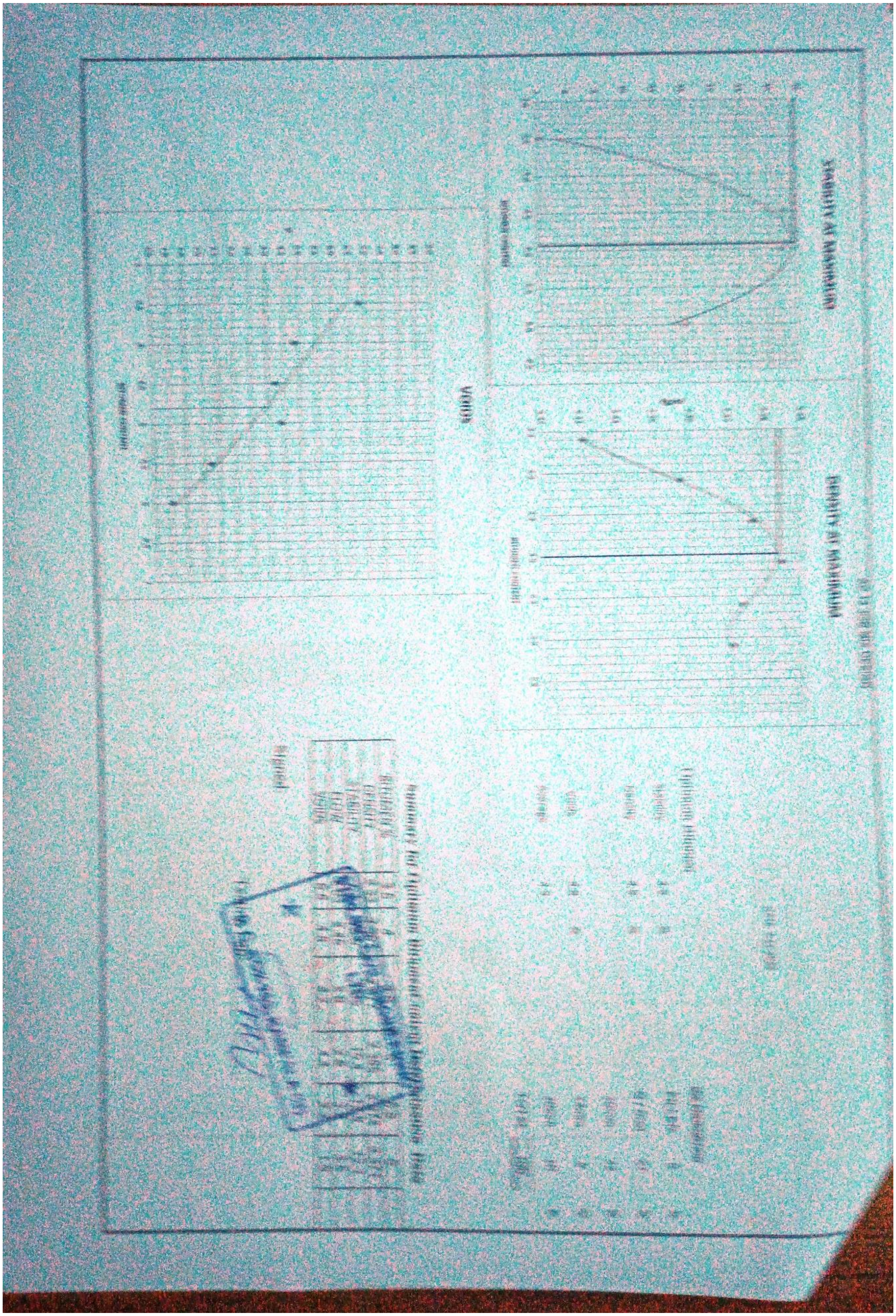
MATERIAL AC 14 INDIVIDUAL GRADATION

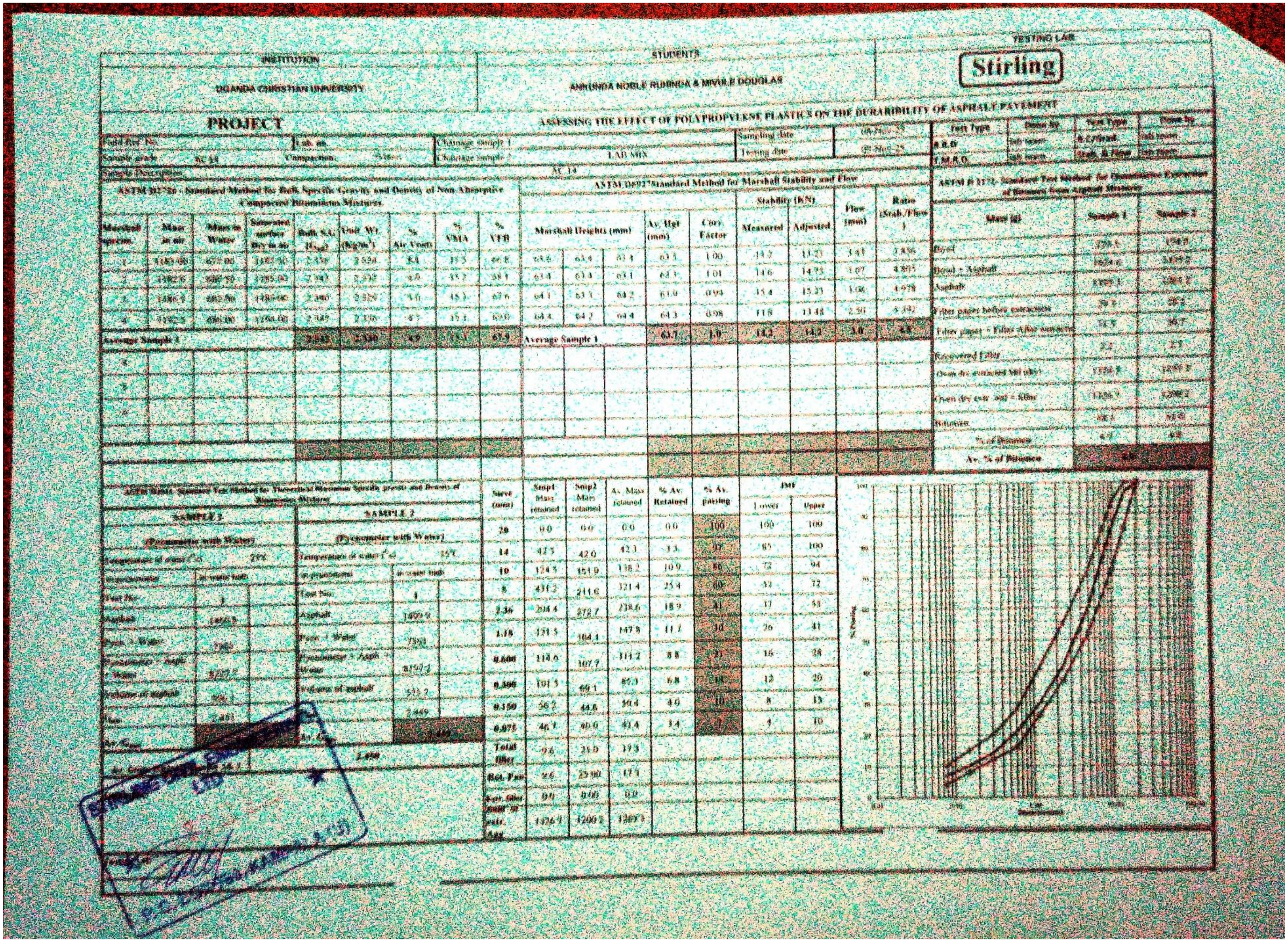
	14/20MM		10/14MM		6/10MM		0/6MM		FILLER		actual	TARGET GRADING	SPEC
		10.0		6.0		22.0		57.0		5.0	100.0		
20	90.2	9.9	100.0	6.0	100.0	22.0	100.0	57.0	100.0	5.0	100	100	100
14	24.6	2.5	95.6	5.7	99.9	22.0	100.0	57.0	100.0	5.0	92	93	85—100
10	1.9	0.2	26.3	1.6	89.9	19.8	100.0	57.0	100.0	5.0	84	83	72—94
5	0.8	0.1	2.1	0.1	4.5	1.0	87.1	49.6	100.0	5.0	56	62	52—72
2.36	0.7	0.1	1.6	0.1	2.2	0.5	59.5	33.9	100.0	5.0	40	46	37—55
1.18	0.7	0.1	1.7	0.1	1.7	0.4	42.3	24.1	99.9	5.0	30	34	26—41
0.6	0.7	0.1	1.5	0.1	1.4	0.3	30.4	17.3	98.4	4.9	23	22	16—28
0.3	0.7	0.1	1.4	0.1	1.2	0.3	22.1	12.6	89.2	4.5	17	16	12—20
0.15	0.6	0.1	1.2	0.1	1.0	0.2	15.1	8.6	69.8	3.4	12	12	8—16
0.075	0.5	0.0	0.8	0.0	0.7	0.1	9.2	5.2	50.7	2.3	8	7	4—10



STIRLING CIVIL ENGINEERING LTD
P.O. BOX [illegible], KAMPALA (U)

FOR LAB


STABILITY AT MAXIMUM
DENSITY AT MAXIMUM
VOIDS



INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AHNUNDA NOBLE RUBINDA & MIVULE DOUGLAS	Stirling

PROJECT — ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE DURABILITY OF ASPHALT PAVEMENT

Field Ref. No.		Lab. no.		Chainage sample 1		Sampling date	[illegible]
Sample grade	AC 14	Compaction	[illegible]	Chainage sample 2	LAB MIX	Testing date	[illegible]
Sample Description				AC 14			

Test Type	Done by	Test Type	Done by
B.R.D	lab team	B.C/Bind.	lab team
T.M.R.D	lab team	Stab. & Flow	lab team

ASTM D2726 - Standard Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures

Marshall specimen	Mass in air	Mass in Water	Saturated surface Dry in air	Bulk S.G.	Unit Wt (kg/m³)	% Air Voids	% VMA	% VFB
1	1183.00	677.00	1183.30	2.338	2.324	5.1	15.3	66.8
2	1182.6	680.70	1185.00	2.343	2.332	4.6	15.2	69.1
3	1186.7	682.80	1185.00	2.340	2.329	5.0	15.3	67.6
4	1192.3	686.00	1194.02	2.345	2.336	4.7	15.1	69.0
Average Sample 1				2.342	2.330	4.9	15.3	67.9
5								
6								
7								

ASTM D6927 Standard Method for Marshall Stability and Flow

Marshall Heights (mm)			Av. Hgt (mm)	Corr Factor	Stability (KN) Measured	Stability (KN) Adjusted	Flow (mm)	Ratio (Stab./Flow)
63.6	63.4	63.4	63.5	1.00	14.2	14.21	3.41	3.856
63.4	63.4	63.1	63.3	1.01	14.6	14.75	3.07	4.805
64.1	63.3	64.2	63.9	0.99	15.4	15.23	3.06	4.978
64.4	64.2	64.4	64.3	0.98	11.8	11.48	2.50	5.392
Average Sample 1			63.7	1.0	14.2	14.2	3.0	4.8

ASTM D 2172 - Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	[illegible]	[illegible]
Bowl + Asphalt	[illegible]	[illegible]
Asphalt	[illegible]	[illegible]
Filter paper before extraction	[illegible]	[illegible]
Filter paper + Filler After extraction	[illegible]	[illegible]
Recovered Filler	2.2	2.1
Oven dry extracted Mat (dry)	[illegible]	[illegible]
Oven dry extr. mat + filler	[illegible]	[illegible]
Bitumen	[illegible]	[illegible]
% of Bitumen	4.7	4.9
Av. % of Bitumen	4.8	

ASTM D2041 Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Mixtures

SAMPLE 1 (Pycnometer with Water)		SAMPLE 2 (Pycnometer with Water)	
Temperature of water (°C)	25°C	Temperature of water (°C)	25°C
Test No.	1	Test No.	1
Asphalt	[illegible]	Asphalt	[illegible]
Pycn. + Water	[illegible]	Pycn. + Water	[illegible]
Pycnometer + Asph. + Water	[illegible]	Pycnometer + Asph. + Water	[illegible]
Volume of asphalt	[illegible]	Volume of asphalt	[illegible]
Gmm	[illegible]	Gmm	2.469
Av. Gmm	2.458		

Sieve (mm)	Smpl Mass retained	Smp2 Mass retained	Av. Mass retained	% Av. Retained	% Av. passing	JMF Lower	JMF Upper
20	0.0	0.0	0.0	0.0	100	100	100
14	42.5	42.0	42.3	3.3	97	85	100
10	124.5	151.9	138.2	10.9	86	72	94
8	431.2	211.6	321.4	25.4	60	51	72
2.36	204.4	272.7	238.6	18.9	41	37	53
1.18	171.5	104.1	147.8	11.7	30	26	41
0.600	114.6	107.7	111.2	8.8	21	16	28
0.300	101.5	69.1	85.3	6.8	14	12	20
0.150	56.2	44.6	50.4	4.0	10	8	15
0.075	46.1	40.6	43.4	3.4	7	4	10
Total filler	9.6	25.0	17.3				
Bot. Pan	9.6	25.00	17.3				
Extr. filler	0.0	0.00	0.0				
Sum of extr. Agg	1326.7	1200.2	1263.5				

INSTITUTION

STUDENTS

ASSESSING THE EFFECT OF POLYPROPYLENE PLASTICS ON THE DURABILITY OF ASPHALT PAVEMENT

[illegible]

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