ASSESSING THE USE OF ETHYLENE VINYL ACETATE EVA FOR RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENTS

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ABSTRACT

Pothole reoccurrence is generally initiated by water penetration inducing bitumen oxidation and leading to the deterioration of conventional asphalt repair under traffic loading. This research investigated the utilization of Ethylene Vinyl Acetate (EVA) for enhancing the durability of asphalt pavements used in pothole patching. The suitability of the aggregates utilized and the enhanced properties of bitumen with low penetration and high softening point were validated through material characterization tests. The vinyl and acetate compound peaks' high values reflected the high curing and general reactivity of EVA. Between 2% and 8% by weight of bitumen EVA contents were experimented upon and 4% findings presented a reduction in penetration values and an increase in softening point values at elevated levels making it suitable for adhesion with material components. EVA-modified bitumen mix, containing 4% EVA by weight of 60/70 grade bitumen, was manufactured and its performance compared with that of a standard bitumen mix. The EVA-modified asphalt mix exhibited better properties, including higher stability, flow, and indirect tensile strength, and better resistance to moisture damage. The test results show that EVA modification is a good way of creating more durable and longer-lasting pothole patching materials.

DECLARATION

I KUTESA ANDREW declares to the best of my knowledge that this work was done out of my original efforts and it has never been submitted to any institution for any award.

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

KUTESA ANDREW

APPROVAL

This research and design project report has been submitted for examination with my Approval as the university supervisor.

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

ENG. DR BYARUHANGA CHRIS

Department of Engineering and Environment

DEDICATION

This report is in honor of my parents, teachers and mentors, whose encouragement, patience and guidance have helped me become what I am today. Your support has been the driving force behind my academic achievement, and I am forever grateful for your faith in my abilities. This success is as much yours as it is mine.

Thank you for everything.

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ABBREVIATION

AC- Asphalt Concrete

ACV – Aggregate Crushing Value

EVA- Ethylene Vinyl Acetate

HMA- Hot Mix Asphalt

TFV-Ten Percent Fines

ITS-Indirect Tensile Strength

AIV-Aggregate Impact Value

CHAPTER ONE: INTRODUCTION

1.1 Background

Potholes, cracks, disintegration, and surface flaws are only a few of the faults that cause the pavement to continuously deteriorate and lose its serviceability over time (Kanoungo et al., 2021). Potholes are holes in the road surface that vary in size and shape and are caused by a variety of events, including localized pavement material extraction, expansions, and contraction. Since pothole formation has been linked to claims of vehicle damage and accidents the public's worry has grown in recent years due to the ongoing development of potholes on asphalt pavements. Since it is always desire that the roadway provides a safe and smooth driving surface with adequate skid resistance for road users, road agencies strive to carry out repairs in terms of patching to seal the potholes to increase the serviceability of roads (Sainz, 2016).

Potholes are typically caused by insufficient routine, periodic, or preventive maintenance, continuous wet conditions for significant periods of time, and ineffective or no repairs for existing defects (Paige-Green et al.,2010). One of the most intensive maintenance procedures performed by road authorities is patching, which is the process of replacing or covering material in a highly distressed area with extra material to hide or remove the distress (Caltrans Division of Maintenance, 2007). The endurance and resilience of the patches are mostly determined by the material quality of the patching mix, claim Torrenti et al. (2016). Furthermore, the mix properties.

The method employed to repair the potholes has a big impact on how long-lasting and economical the patches end up being (Dong et al., 2014). Falcon Asphalt(2022) states that the most popular repair techniques include filling potholes with patching material without any preparation or compaction before traffic opens (throw-and-go), placing patching material without any preparation or compaction before traffic opens(throw-and-roll) neatly preparing the pothole by removing any inferior material and shaping it before applying patching material that is compacted before traffic opens (Semi-permanent), and filling pressure cleaned potholes with a mixture of aggregates and emulsion using forced air spray-two injection.

The most popular repair material for potholes is hot mix asphalt, of HMA. Due to heat loss during transportation, the ultimate temperature at which the material is laid is often determined by the mode of transportation and the time it takes to get from the production plant to the site. According, using this material at extremely low temperature has an impact on path performance and typically leads to early patch failure (Rahman and Chambwewrlain, 2017). HMA transportation is linked to the formation of temperature differentials and material thermal segregation, which can lead to inadequate compaction, temperature in differences at the interface of contact between the fresh and old asphalt material cause insufficient bonding (Rahman et al., 2013). Bonding between the new material, the existing material, and the lower layer after the HMA is placed into the pothole has a significant impact on the patch's performance and residence to any pressure that may be created. The strength of the bond between the patching material and the original material is determined by the adhesiveness of the substance (Biswas et al.,2016).

Potholes are frequently seen on urban roadways in Uganda, particularly in Kampala, the country's capital. Poor urban drainage infrastructure, higher traffic volumes, and poor road maintenance are all factors in their creation. The KCCA identified 8500 square meters of potholes in Kampala's five divisions in December 2022.

Although KCCA is constrained by budgetary constraints, efforts have been undertaken to address the number of potholes in Kampala by pothole filling (Draku, 2023). Using stone base and human mixtures to patch potholes is one of the comparatively low-cost solutions used. The MOWT Road Maintenance requirements offer asphalt mix requirements for filling potholes and a semi-permanent patching technique, although this is only a temporary fix because the material is washed away during rainy seasons, causing the potholes to reappear. To prevent re-emergence, this repair needs to be done in dry conditions and according to the guidelines. But even after KCCA patched the holes, they kept coming back a few days later (Draku, 2021), which caused more public outcry and financial hardship.

1.2 Problem statement

Potholes continue to be a key difficulty and maintenance component for the highway maintenance industry, and their ongoing development has negative consequences on the general public, including longer travel times and higher vehicle operating expenses (Marasteanu, 2018). When main issue is that pothole patches are not very resilient; as they fail a few weeks after they are applied shown on the Busega-Natete route. The economic loss resulting from repairing the damage using materials of short-term durability necessitates the need for more durable materials to create more resilient pothole patches for longer-term performance (Torrenti and La Torre, 2016).

In this regard, various studies have been made in the utilization of polymers to modify asphalt cement to improve the performance of asphalt mixtures for example the use of Polyethylene Coated Aggregates to improve durability of feasible pavements. This test showed an increase in the tensile strength of the asphalt pavement. The study is therefore aimed to assessing the use of ethylene vinyl acetate (EVA) for resilience of pothole patches in asphalt pavements.

1.3. Research objectives

1.3.1. Main objectives

1. To assess the effect of applying ethylene vinyl acetate for resilience of pothole patches.

1.3.2 Specific Objective

1. To determine the mechanical properties of aggregates, conventional bitumen and ethylene vinyl acetate.
2. To determine the optimum ethylene vinyl acetate content for polymer modified bitumen.
3. To determine indirect tensile strength of the modified bitumen.

1.4 Research Questions

1. what are the mechanical properties of aggregates, conventional bitumen and ethylene vinyl acetate?
2. what is the optimum ethylene vinyl acetate content for polymer modified bitumen?

3. what is the indirect tensile strength of the modified bitumen?

1.5. Justification

Ethylene-vinyl acetate (EVZA) is a polymer that is widely used to modify asphalt binders because of its rigid three-dimensional network structure and unique functional groups (Chi-sa Lim and Dac-sang Jang, 2022). The two key characteristics of eVA are its melting flow index (MFI) and Vinyl acetate (VA) content. Modification with EVA improves the asphalt binders' high- temperature performance by forming chemical bonds between adjacent molecules (Xu and Zing, 2023), this modification can improve cracking resistance, tensile strength, and high-temperature stability. In copolymer blends, the phases of polyethylene (PE) and Eva have high compatibility which results in a strong interfacial interaction between them and finer dispersion of EVA particles (Chi-sa Lim and Dac-Sang Jang, 2022).

It has been shown that adding polymers, such as EVA, to asphalt binders enhances their performance and characteristics, including their ability to withstand thermal cracking at low temperature and persistent deformation at high temperature (Alsolieman et al., 2021).

Additionally, polymers can improve the rheological characteristics of asphalt binders, increasing their resistance to rutting and fatigue cracking. (Gharehveran and Behnood, 2019)

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This chapter reviewed literature on the road pavements, asphalt pavement design, material characteristics for bitumen, aggregates, filler with mechanisms of potholes and action of EVA.

2.1.1. Road pavements

Road pavements are critical components of transportation infrastructure, providing a stable and durable surface for vehicular and pedestrian movement. They are broadly categorized into flexible and rigid pavements. Flexible pavements, typically constructed with asphalt, are designed to distribute loads across multiple layers and flex slightly under traffic, offering resilience to minor ground movements (AASHTO 1993) they consist of a surface course for durability and smoothness, a base course for load distribution, and a sub-base for drainage and stability. Rigid pavements, on the other hand, are constructed with concrete and rely on their rigidity and high strength to withstand loads, requiring minimal maintenance over time. These pavements often have a longer lifespan but higher initial costs compared to flexible pavements.

Materials used in pavement construction include asphalt, concrete, aggregates and sometimes reinforcing steel, chosen based on factors like traffic load, environmental conditions and cost considerations. Proper design, construction, and maintenance are essential for ensuring long- term performance, safety, and sustainability of road pavements.

2.1.1.1 Flexible pavements

Flexible pavement is one that is made up of a bituminous layer with the underlying layers of base, subbase and subgrade. Flexible pavements usually termed as asphalt pavement can be of a hot, warm or cold mix asphalt (Yode, E.J, 1975).

The use of any of these depends on the job mix specified. The bituminous material used also is of different grades depending on the temperatures of the region of application (Huang.H.,2004).

The asphalt pavement is mostly built on a gravel base material and this asphalt pavement allows for significant plastic deformation (NAPA,2015). Asphalt pavement has different classes depending on the traffic load being dealt with for example AC20, AC14 depending on load distribution characteristics. Although this pavement is normally used, it requires routine maintenance and repair to prevent its deterioration over years (Yode, E.J,1975).

Talking about deterioration, a flexible pavement is prone to defects like fatigue cracking, rutting, having and pothole formation among others. Though regular maintenance for example cracks sealing, proper drainage, the flexible pavement lifespan is extended (Roberts, 1996).

2.1.1.2. Rigid pavements

Rigid pavements, consisting primarily of Portland cement concrete (PCC), distribute traffic loads over a relatively broad surface due to their flexural strength and high stiffness (AASTO, 1993). Unlike flexible pavements that employ layer deformation for load dissipation, rigid pavements act as a structural slab, minimizing stress transfer to the subgrade (Huang,2004). This natural rigidity translates to good load-carrying capacity and long life, usually longer than that of flexible pavements under equal traffic. Though usually more expensive in the initial cost based on material cost and construction complexity, rigid pavements require fewer maintenance activities during their lifespan, translating into lower life-cycle costs where there is heavy traffic volume (Yoder & Witczak, 1975). Their tough, unbreakable strength also makes them resistant to rutting and deformation caused by heavy axle loads and heat, providing for a smoother, longer-lasting riding surface. Rigid pavements are susceptible to cracking due to temperature and load stresses, and hence joints need to be provided to control cracking patterns and for movement (AASHTO, 2002). Construction is also likely to be slower than flexible pavements, and it has to be well planned and well-constructed to ensure enough curing and joint position for optimal performance and durability (Kosmatka et al., 2002).

2.1.2. Pothole formation

Potholes are bowl-shaped depressions of localized deterioration that vary in size. Typically found on the surface of flexible pavements, these can be full-depth or partially penetrating depressions (Biswas et al. 2016). Fatigue cracking is the cause of potholes, which are bowl shaped gaps in the pavement surface caused by interconnected cracks that produce tiny pieces of pavement (Asphalt Institute, 2023). Potholes are a result of pavement disintegration under traffic loads, which is frequently accompanied by water (Kanoungo et al., 2021a). Potholes are frequently seen in places with inadequate drainage, and the expansion and contraction of ground water can make them worse. Water expands when it enters the ground beneath the pavement and freezes, it then expands as it erodes the pavement making potholes more likely (B.Alan Brubaker, 2020). Potholes can also develop when water seeps into surface cracks and freezes, widening the gaps and allowing passing cars to push pavement fragments loose.

Pothole growth can be avoided with prompt repairs and maintenance (Kanoungo et al., 2021).

The performance of flexible pavements is greatly impacted by the repetitive action of traffic loads because the load eventually becomes too great, which typically shows up as surface roughening and cracks like fatigue cracking, thermal cracking, and reflective cracking (Kanoungo et al., 2021b). a pothole is created when inadequately supported material breaks a part due to the constant motion of vehicles, finally becoming disconnected and removed from the pavement (Wenchen Ma, 2016). Many potholes have been observed to fail a few days after installation, despite efforts to fix them, and the mechanism behind this is quite broad.

2.1.3. Mechanism of path failure

Factors including aggregate, adhesion and cohesion, bitumen characteristics, stress distribution, and loading pattern on the patch all have a significant impact on patch degradation and failure (Leilei et al., 2023). The asphalt mix loses cohesiveness and adhesion due to moisture penetration, which ultimately results in decreased patching material stiffness, strength, and durability (Sanchez et al.,2015). Patch distresses including edge disintegration and missing patches may arise from the patching material's decreased adherence to the underlying layer or to the existing layer (Dong, Huang, and Zhao, 2014b).

Under the moving vehicle load, points in the asphalt pavement structure experience different stress and strain states, as shown in figure 1. For instance, point B in the asphalt pavement surface layer is in a three-direction stress state. When a wheel is applied at the upper part of point B, point B is subject to tension. However, the direction of the stress changes, the quantity becomes smaller, and some shear stress is produced when the vehicle flips over (Petri Varin, Timo Saarenketo, and Pauli Kolisaga, 2010). Moving traffic loads put road structures under a variety of complicated stresses and strains, including shear forces in the bound and unbound layers, vertical stresses, and horizontal stresses, as well as subgrade soils. With compressive stresses in the bonded layers in front and behind the wheel load, and highly tensile tensions beneath the wheel load, the primary stresses rotate before, under, and after the wheel load. Because irregular bumps can result in impact loads and significantly increase stresses, the smoothness and evenness of the road surface also affects the magnitude of stresses and strains and faster pavement deterioration and path failure (Wenchen Ma, 2016).

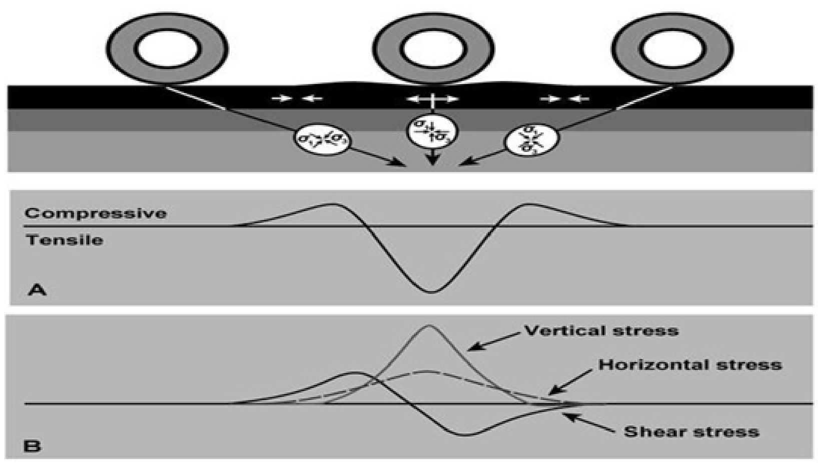


Figure 1: Pavement surface layer's stress state under the wheel.

2.1.4. Pothole Repair

For feasible pavements, pothole patching is a crucial maintenance task. Winter patching and summer patching are the two distinct times of the pothole repair season (Caltrans Division of Maintenance, 2007). Because they experience immediate stress from freeze-thaw cycles, winter patches typically have a shorter survival time. Patching materials and maintenance techniques are the two principal ingredients of pothole patching operations, and there is a unique impact of every combination of these two ingredients on performance and cost (Dong, Onyango, and Huang, 2014).

The overall process for repairing a pothole is to cut the patch line, remove water and debris from the pothole, pour fill material into the pothole, compact the material, and ensure the vertical position and smoothness of the patch (Wilson and Romine, 1999).

2.1.5 Patching Materials

Pothole repair has been the focus of multifaceted research that has focused on patching materials and characterization. The primary materials used in pothole patching include hot-mix asphalt (HMA), cold-mix asphalt, aggregate/asphalt emulsion mixtures, and special patching mixtures (Wang et al., 2023). Bituminous patching mixtures are composites of bituminous binders and aggregates that have distinctive properties needed for pothole filling on pavements. There are numerous types of patching mixtures which are highly varied in terms of price, stability, quality, and application (Garcia and Hansen, 2001) and they can be broadly categorized in one of three classes, based on the type of mixing and the temperature of the mixture during placement. Hot Mix Asphalt (HMA) is widely used most frequently type of asphalt utilized in major paving applications, and it requires hot temperatures (300-350°F) to apply. Such HMAs can exist in various subtypes of varying strengths, like Open-Graded Friction Courses (OGFC), Stone Matrix Asphalt (SMA), and fine- and coarse-graded dense mixes (Garcia and Hansen, 2001). Cold Mix Asphalt (CMA) is the asphalt mix category that is typically employed for temporary patch work as it remains soft and workable at cooler temperatures. Such mixes are typically under open-air warehouses during summer and are not advised to be used on heavy-traffic roads for repair (JICA, 2016). The mixtures have unique characteristics which allow them to be appropriate for various applications (Maher et al., 2001) and choice of the patching mixture depends on traffic volumes, environmental conditions, underlying pavement structure, pavement condition, and preparation (Garcia and Hansen, 2001).

Bitumen

The performance of asphalt mixtures is greatly governed by the asphalt binder and the mastic. Asphalt mastic, comprised of mineral filler and asphalt binder, plays a fundamental role in imparting viscoelasticity and adhesion to the asphalt mixture (Bi et al., 2021). The rheological properties of asphalt mastic essentially derive from the asphalt binder (Bao et al., 2023). The study has shown that the mechanical behavior of the mixture is governed by the asphalt mastic (Diab and Enieb, 2018) and it has been confirmed that the properties of the asphalt binder and mastic can influence the dynamic modulus of the asphalt mixture (bi et al., 2021). Moreover, molecular dynamics simulations were utilized to examine the effects of solutions on asphalt binder and mastic, with findings exhibiting the effect of solution effects on their stability (Li et al., 2022). Thus, both the asphalt binder and mastic are pivotal to the performance and properties of asphalt mixtures

Polymer Modified Bitumen.

Polymers have also been widely utilized to enhance asphalt binder characteristics such as elasticity, stiffness, low-temperature ductility, moisture resistance, and higher temperature performance (Favakeh, Bazgir, Karbasi, Alavi & Abdi 2022). The performance and efficiency of polymer-modified bitumen (PMB) depend on the type and source of polymer utilized. The most commonly utilized polymers belong to two broad groups: plastomers and thermoplastic elastomers (Behnood and Gharehveran, 2019). Thermoplastic elastomers are typically utilized to enhance the low and high service temperatures of the binder. Plastomers, however, are renowned for increasing the high service temperature of the asphalt binder (Alsolieman et al., 2021). These polymers can alter the binder characteristics by increasing the softening point, thereby enhancing the resistance to permanent deformation at high temperatures and thermal cracking at low temperatures and ultimately improving pavement life (Behnood and Gharehveran, 2019).

Ethylene-vinyl acetate (EVA) is a widely used polymer in asphalt binder modification due to its three-dimensional network structure and special functional groups (Chi-sa Lim and Dac-sang Jang, 2022). The two significant characteristics of EVA are melting flow index (MFI) and vinyl acetate (VA) content. EVA modification improves asphalt binder performance at high temperatures due to the formation of chemical bonds between adjacent molecules (Xu and Xing, 2023). High-temperature stability can potentially be enhanced by modification. tensile strength, and resistance to cracking. Polyethylene (PE) phases and EVA in copolymer blends are of high compatibility, leading to a strong interfacial interaction between them and the dispersion of EVA particles at a finer scale (Chi-sa Lim and Dac-sang Jang, 2022). The addition of polymers, like EVA, into asphalt binders has been established to improve their performance and properties, e.g., resistance to permanent deformation under high temperatures and thermal cracking at low temperatures (Alsolieman et al., 2021). The kind of polymer to be added depends on the specific requirements of the pavement, e.g., desired temperature range and the presence of other additives like lime and liquid antistrips (FHWA, 2012). Polymers, like EVA, also have the potential to enhance the rheological behavior of asphalt binders with better fatigue cracking as well as rutting resistance (Behnood and Gharehveran, 2019).

Aggregates

Aggregates make up the majority of asphalt mix (approximately 95%), and they play a very significant role in determining the final mix performance. The amount and quality of aggregates in the mix are extremely crucial in terms of delivering acceptable performance. In order to detect poor-quality mixtures and improve their performance, several procedures and techniques such as technical specifications and quality control are applied to ensure the quality of asphalt mixtures, minimize possible expansion, and mitigate unique characteristics of asphalt mixtures (El-Haggar, 2007). Laboratory rutting and cracking tests are designed to evaluate the quality of asphalt mixtures and identify mixtures with poor rutting susceptibility or cracking resistance. Additionally, volumetric properties of asphalt mix samples are used to control asphalt mixture quality by comparing the reported properties with those of contractors and establishing any discrepancies from laboratory testing (Lee et al., 2019). Successful asphalt content refers to the volume of asphalt not retained by aggregate and is critical in the formation of a bonding film on aggregate surfaces. Finding the effective asphalt content precisely controls asphalt content in the mix. The aggregate's properties, such as the absorptiveness of an aggregate, its surface area, and gradation, are also key considerations for determining asphalt content of a mix. Understanding and controlling these properties in the right way can lead to more stable and durable pavement (FHWA, 2020). Using these procedures and techniques, one can identify poor-quality mixtures and enhance their performance, guaranteeing the durability and longevity of the pavement.

Patching Techniques

Different maintenance agencies use different repair methods depending on the intention of patching and available constraints such as time and resources. Throw-and go method is normally preferred during emergency repairs because of its high rate of production. This method is fast as there is no time wasted on preparing potholes for patching and no compaction after filling the pothole. It is normally applied for temporary patching and the basic steps followed include simply filling the pothole with patching material one after the other with no compaction applied. Throw-and-roll is also a temporary method of patching done in the same way as the throw and go but in this case, the patch material is compacted before opening up to traffic (Marasteanu, 2018). There is no preparation done on the pothole before patching but compaction is done for each patched area. The basic procedure includes filling the pothole with the patching material and then compacting the patch. Semi-permanent patching is a pothole repair technique that requires preparation of the pothole beforehand. The pothole3 is cleaned of water and debris, and the edges of the pothole are cut back to existing pavement material. Patching material is placed in the hole and compacted with vibratory equipment. This method is considered one of the best for repairing potholes, schcort of full- depth removal and replacement (Caltrans Division of Maintenance, 2007).

This method can be done according to some basic steps of removal of all inferior material from the pothole, trimming the edges of the potholes to a definite shape with some extension into the sound pavement, filling the pothole with patching material, and compaction of the patch to ensure bonding. Another patching technique is the spray injection method which is normally used to repair potholes mostly in the winter periods. Spray injection patching offers several advantages over traditional pothole repair methods, such as quick and convenient repairs, cost-effectiveness, durability, and environmental friendliness of cold patching or hot-mix asphalt repair. (Kwon et al, 2018a). the patching process involves cleaning up the pothole of any loose debris to ensure proper bonding. A mixture of aggregates and emulsion asphalt is prepared, and hot tack cost asphalt emulsion is them applied to the pothole and then followed by praying the patching material into the pothole using compressed air until it fills up (Kwon et al., 2018b).

Patch Performance and Durability

The durability and performance of patches are significantly influenced by the quality of the patch mixture, including the material characteristics of the ingredients mixing proportions, and manufacturing processes. The material properties that affect the performance and durability of the patch include elastic module, dying shrinkage, tensile strength, and adhesion between the repair material and the in-field existing material (Czarneki, Gerylo, and Kuczyriski, 2020). Permeability of the repair material is another significant factor that needs to be considered as a low permeability is desired to limit the ingress of moisture that induces deterioration (Hamakareem, 2019). Furthermore, the strength and coefficient of thermal expansion of the underlying material and that of the repair material should nearly be the same to ensure proper stress flow through the composite material and avoid excessive stress build-up due to nonhomogeneous expansion respectively (Eledho and Jones, 2016). Low drying shrinkage is crucial to prevent cracking and maintain patch integrity. For better performance of patches, the mix used for patching must possess improved high-temperature performance, increased Marshall stability and indirect tensile strength values, high early strength gain, improved adhesive and cohesive properties of the mix, increased resistance to rutting and fatigue cracking. Patch durability and performance can be evaluated through laboratory tests and field surveys. Various laboratory tests are carried out to determine mix properties such as coating, stripping resistance, adhesion, cohesion, stability, linear viscoelasticity, permanent deformation, and low temperature thermal cracking potential, which guide to give an impression of the resulting performance of the material (Diaz, 2016). Field performance evaluation is normally done by monitoring trial patches installed with specific material and technique combinations for at least one year (Wilson and Romine, 1999). After the installation of these patches, they are continuously inspected for their survival or failure by checking for the presence of any defects or signs of failure (Dong, Huang, and Zhao, 2014). According to Want et al (2022) some common failure signs and possible causes of failure of patches include dishing, edge disintegration, reveling, cracking, and showing, bleeding and missing patches. These failures are identified to rank the performance of the materials being tested from best to worst.

Styrene-butadiene Rubber (SBR)

SBR is a latex rubber material mainly from waste tires that disperses uniformly within when mixed with bitumen. Its mix with bitumen formed cross link matrix network allowing asphalt resistance to external deformation and also demonstrated heightened affinity in alkaline aggregates (Zhang, H, 2018). The hydrophobic nature of SBR modified bitumen and Van der Waals interact with the aggregates interface where these amplify interfacial bonding (F. Zhang et al, 2010).

Despite all these properties, different percentage blends were conducted using SBR and it was proven that beyond 30% blend, SBR molecules caused aggregation. This effect led to phase separation between aggregates and the modified bitumen (Yildirim, Y. 2007).

Ethylene Vinyl Acetate (EVA)

EVA is a principle plastomers and a copolymer made of Ethylene and Vinyle Acetate. This material was used in some parts of Europe and Asia where temperatures vary on a wide margin and its properties showed improvement.

When this copolymer is blended with bitumen, it forms a stable cross link matrix improving workability, deformation resistance thermal stability and elasticity of the asphalt (Anil Kumar, 2022). The tests from Rolling Thin Oven Test showed that EVA reduces the aging effects by reducing the aging index of complex modulus (Sudhakar Reddy, K., 2002).

Polyethylene Terephthalate (PET).

PE is a thermoplastic polymer used commonly in plastic and packaging which is added to asphalt to improve its strength and durability. When added to bitumen, increases its stiffness by reducing flow at high temperatures. A review on using waste plastics as asphalt modifiers for hot mix asphalt was performed and indicated that waste PET modified asphalt has a better resistance to rutting and fatigue cracking ((Zhang et al., 2019). The results also showed that a comprehensive addition of PET could lead to segregation of asphalt composition enhancing bleeding ((Chen et al., 2020; Wang et al., 2019).

CHAPTER THREE: METHODOLOGY

3.1 Introduction

In this chapter, we seek to clearly state the materials, experimental standards, and test methods that we used and carried out throughout the study. These various methods and tests aimed at determining the engineering properties of the aggregate, bitumen (both conventional and EVA modified), conventional patching mix. These were tested using various test methods such as Ten Percent fines Value (TFV), penetration test, softening point test, particle size distribution, and Marshall stability Test.

3.2 Material acquisition and sample preparation

Asphalt components required for the research such as fine aggregate, coarse aggregates were attained or sourced from Stirling Engineering limited.

a. Aggregates

Aggregates that were used in the study was obtained from Stirling Construction Company Limited quarry located in Mbalala-Mukono. Sampling was done from random points of the aggregate stockpiles of different sieve size ranges of 0mm-6mm, 6mm-10mm, 10mm-14mm, and 14mm-20mm. various tests were conducted on the aggregates to understand their suitability and strength for the study. The tests include sieve analysis sing sieve sizes ranging from 0.075 to 20mm, aggregate Ten percent fines Value (TFV), and Aggregate impact Value (AIV).

b. Bitumen

Bitumen was also obtained from Stirling in Mbalala in Mukono. The bitumen grade selected was 60/70 which was the same bitumen used on Nateete-Busega road. This grade has thermoplastic properties which cause the material to soften at high temperate and harden at lower temperatures.

c. **EVA**

This material was obtained from Stirling in Mbalala in Mukono. The bitumen Desbro(U) Ltd-Kampala Industrial Area. This was in granular form.

3.3. Laboratory Tests

Determining the mechanical properties of aggregates and conventional bitumen in comparison with polymer modified bitumen.

3.3.1. Tests on aggregates

Grading or Sieve Tests (BS 812-P103-1)

The purpose of sieve analysis was to determine the particle size distribution and check the compliance of the mix aggregates with the design, production control requirements, and specifications referred to in the design. The experiment was performed in accordance with BS 1377: Part 2: Clause 9:1990. The results of this test were used in aggregate blending to come up with appropriate aggregate proportions per sieve range to proportions per sieve range to produce a well-graded blend to be used in the mix design.

Ten percent fine value test. BS 812: Part 110:1990

The Ten Percent Fines Value (TFV) Test was conducted in accordance with BS 812 (1990) to determine the load required to produce ten percent of fine material when subjected to a gradually applied compressive load. This test is used to assess the strength of coarse aggregates used in construction, and it is recommended for both strong and weak aggregates. The relationship between the aggregate crushing value

(ACV) and the TFV has been established through regression modeling, allowing for the estimation of ACV values for weaker aggregates. This relationship can be useful in saving time and cost on construction sites by estimating one variable when another is known.

Specific Gravity of Aggregates Bs 812: Part 2:1975

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). In accordance with BS 812: Part 2:1975, the specific gravities of all the aggregate size ranges to be used were determined, and these were later used to determine the build specific gravity of total aggregate.

$$Gsb = (P1 + P2 + \cdots \cdot + Pn) / (P1 / G1 + P2 / G2 + \cdots \cdots + Pn / Gn)$$

Gsb = bulk (dry) specific gravity of the aggregate

P1, P2…Pn = percentages by weight of aggregates 1, 2, through to n

G1, G2…Gn = bulk (dry) specific gravity of aggregates 1, 2, through to n

Aggregate Crushing Value (ACV)

The Aggregate Crushing Value (ACV) was opted for as it provides a relative indication of an aggregate's ability to withstand crushing when a weight is applied gradually. The material that passes through a particular sieve after being crushed under a 400KB stress is measured to find the ACV.

Aggregate Impact Value: BS 812: Part 112:1990

The Aggregate Impact Value (AIV) Test was carried out to determine the strength of the aggregates on impact. The test was carried out in accordance with BS 812: Part 112:1990. The AIV gives the relative measure of aggregate resistance to impact loading. The impact value is one of the mechanical properties of coarse aggregate resistance to impact loading. The impact value is one of the mechanical properties of coarse aggregates that are measured to evaluate their quality. It indicates the ability of the aggregate to resist impact loads and is an important factor in determining the durability and strength of the aggregate. By conducting the impact the impact value test, it can be determined whether the coarse aggregate meets the required specifications for road-based construction.

To determine the optimum bitumen content for the polymer modified bitumen.

3.4 Modified and non-modified bitumen sample preparation

3.4.1. Preparing a neat bitumen sample

The bitumen grade 60/70 was prepared in compliance with ASTM D5. A measured quantity of bitumen was cooked to a flowing state in the oven.

3.4.2. Preparation of modified bitumen

Penetration Test

This test was carried out on both the conventional and EVA modified bitumen in accordance with ASTM D5-86. The penetration value obtained from the test is an in indicator of the softness or hardness of the bitumen, hence providing an insight on the consistency of the bitumen. In addition, the penetration value obtained is relevant to determine the performance grade of the bitumen.

Softening Point Test

The softening point of asphalt binders was determined using the ring and ball test method as specified in ASTM D36-70. This test assesses the suitability of bitumen for road construction in given climactic conditions. Asphalt mixtures made with high softening point binders exhibit good resistance to deformation at high temperatures. When bitumen reaches exceeds the pavement temperature; it indicates that the asphalt mixtures can effectively withstand permanent deformations. This test was conducted on both conventional bitumen and PMB with Ethylene Vinyl Acetate (EVA).

Specific Gravity of Bitumen

Specific gravity is a crucial property that indicates the density of the bitumen relative to that of an equal volume of water. The specific gravity test is essential for classifying bitumen types, controlling quality by identifying impurities, and relevant in determining the optimal volume of bitumen needed for asphalt mixes. This test was done for both conventional and EVA modified bitumen and done in accordance with ASTM D70-97.

To determine the durability properties of bituminous mixtures with polymer modified bitumen.

3.5. Preparation of asphalt concrete samples

The aggregates to be used in the mix design were batched using the “total Fractionation of all aggregate materials” method, five trial binder contents were selected ranging from 3-5-5.5% in increments of 0.5% for each of the two types of bitumen. The aggregates and bitumen were mixed at a temperature of 165^{o}C for 5 minutes and compacted with 75 blows on each side at the same temperature. The sample preparation is quite crucial as it directly affects the resulting volumetric properties of the asphalt mixtures and, hence, the selection of an appropriate binder content.

3.5.1 Marshall Mix Design

The Marshall Mix design method was used to determine the optimum binder content for use in the trial mixes. It involved density-voids analysis of the samples, stability and flow tests on the samples. The specific tests and analyses of the mix design are highlighted below.

Bulk Density

The bulk densities of the samples were determined following the ASTM D2726-96 guidelines. The bulk density obtained was used in the density-voids analysis of the mixture to obtain the unity weight, percentage of absorbed asphalt, percentage of air voids, percentage of voids filled with asphalt, and percentage of voids in mineral aggregates which show sensitivity of the mixture to binder content.

Theoretical maximum specific Gravity

Theoretical maximum specific gravity refers to the construct specific gravity of a compacted mixture with zero air voids and is measured using standardized tests such as ASTM D2041/D2041M-19. This value plays a vital role in considering the quality and service properties of asphalt mixtures during design and construction phases.

Percentage of air voids in the mix (VIM)

In the design of asphalt mix, the Voids in Mix (VIM) is a crucial parameter that impacts the volumetric properties of the asphalt mixture. VIM is the void area within the compacted asphalt mix and is one of the critical factors in the assessment of mix quality and performance. The VIM value is typically quantified by calculating the voids in the mixture, voids in mineral aggregates (VIM), and voids in asphalt binder (VFB). The VIM value has significance as it affects the strength, durability, and aging characteristics of the asphalt mixture. VIM measurement and monitoring are required at design and construction phases to attain maximum performance of the asphalt pavement. The VIM value is reversible based on asphalt content, aggregate gradation, and compaction methods used in the mix design process.

Voids in mineral Aggregates (VMA) and Voids filled with bitumen (VFB)

The Voids in Mineral Aggregate (VMA) calculation in the asphalt mix began with the determination of the bulk specific gravity of the total aggregates (Gsb) and the percent of aggregate content by weight of the mix (Ps). The volume V, of each of the asphalt specimen cores was then established together with the density of the sample for the calculation of the effective volume of aggregates Vagg. Followed by calculating the Voids Filled with Asphalt Binder (VFB), that is, the space occupied by the bitumen in the mixture.

$VMA = 100 - Vagg$

$Vagg = Ps \times (Gmb/Gsb)$

$VFB = ((VMA - VIM)/VMA) \times 100$

Stability and Flow

The Marshall test evaluates the load and flow characteristics of asphalt samples, which were examined for both conventional bitumen and PMB asphalt cores. This test was carried out in accordance with ASTM D1559-89. Through the Marshall Mix design method, engineers can determine the optimal asphalt binder content that meets the specified stability and flow requirements at a desired density.

3.6 Tests on asphalt concrete mixtures

3.6.1 Indirect Tensile Strength

The indirect tensile strength (ITS) test is a crucial method for evaluating the performance and durability of asphalt mixes, particularly in terms of their resistance to fatigue cracking and rutting. The test is essential for understanding the pavement's behavior under various loads as it measures the tensile strength of a bituminous mixture under loading. The test was carried out in accordance with AASHTO T28. The test started with determining the appropriate number of blows that produce asphalt with air voids within the range of (6-8) prevent air voids but most preferably (7+0.5) percent air voids. The obtained number of blows was used to prepare test specimens three for dry and three for testing after conditioning to obtain the ITS for either condition. The test was done for both PMB and conventional bitumen.

CHAPTER FOUR: DISCUSSION OF RESULTS

4.1. Tests on aggregates

Gradation of aggregates

The gradation of aggregates carried out on the independent aggregate ranges 20/14, 14/10, 10/6, 6/0, and filler was manipulated to obtain an aggregate blend with different proportions of aggregates within the gradation limits specified by the general specifications for roads and bridgeworks series 4000. The blend proportions from each sieve size were calculated using the following equation:

$P = (A \times a) + (B \times b) + (C \times c) + \cdots$

Where P = the blended percent passing for a given sieve

A, B, C = the percent passing a sieve for an individual stockpile

a, b, c = proportion of stockpile to be added in the blend, where total = 1.00

The resulting aggregate proportions are shown in Table1 and the trial blend gradation curve shown in Figure 1. A proper aggregate gradation is crucial for the performance of the resulting asphalt mix. A variety of the properties of the produced asphalt concrete, such as durability, workability, and strength, are affected by the gradation of the aggregates used in the mix.

sieves	14/20MM		10/14MM		6/10MM		0/6MM		FILLER		Theoretical actual	TARGET GRADING	SPEC
		25.0		12.0		8.0		53.0		2.0	100.0		
28	100.0	25.0	100.0	12.0	100.0	8.0	100.0	53.0	100.0	2.0	100	100	100
20	98.6	24.7	99.4	11.9	100.0	8.0	100.0	53.0	100.0	2.0	100	90	80–100
14	18.7	4.7	70.3	8.4	99.4	8.0	100.0	53.0	100.0	2.0	76	70	60–80
10	1.6	0.4	18.7	2.2	93.9	7.5	100.0	53.0	100.0	2.0	65	60	50–70
5	0.4	0.1	1.3	0.2	6.6	0.5	83.0	44.0	100.0	2.0	47	46	36–56
2.36	0.4	0.1	0.9	0.1	5.1	0.4	53.7	28.5	100.0	2.0	31	36	28–44
1.18	0.4	0.1	0.8	0.1	4.3	0.3	37.4	19.8	100.0	2.0	22	27	20–34
0.6	0.4	0.1	0.7	0.1	3.6	0.3	27.3	14.4	99.8	2.0	17	21	15–27
0.3	0.4	0.1	0.6	0.1	3.0	0.2	19.1	10.1	95.8	1.9	12	15	10–20
0.15	0.4	0.1	0.5	0.1	2.5	0.2	12.0	6.3	79.7	1.6	8	9	5–13
0.075	0.4	0.1	0.4	0.0	2.2	0.2	6.5	3.4	58.4	1.2	5	4	2–6

Table 1: Aggregate Blending

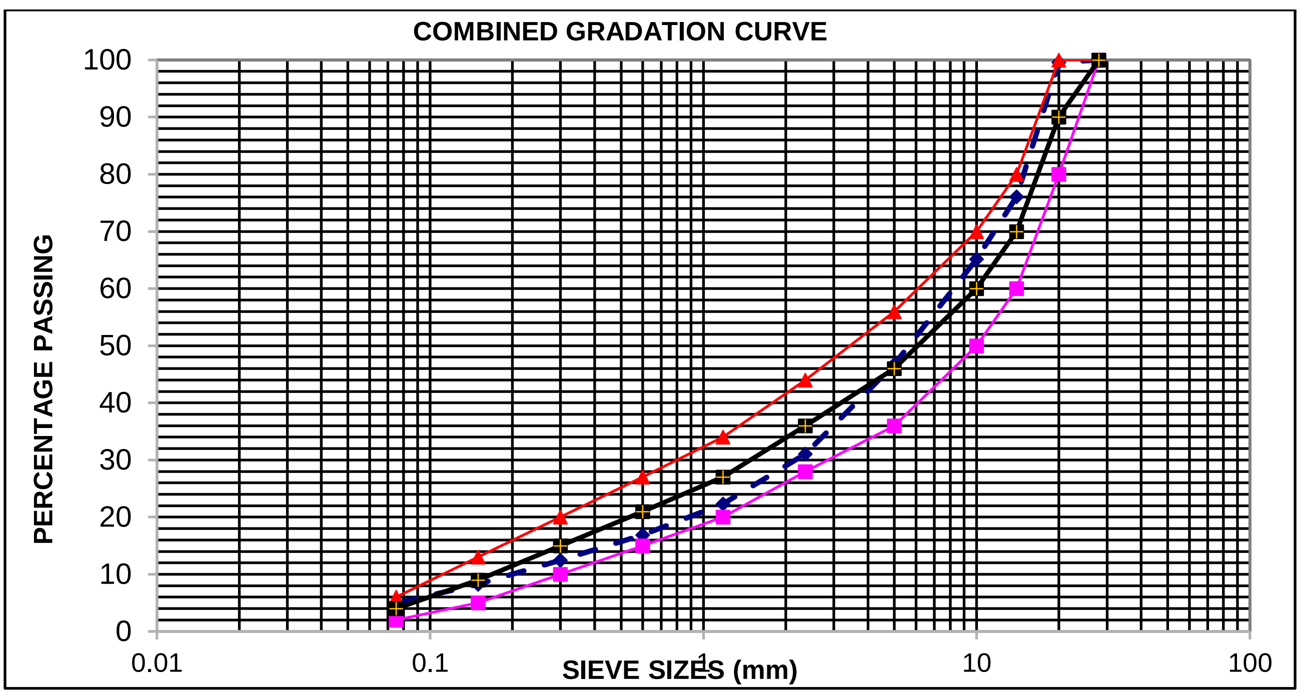


Figure 2: Aggregate Blend Gradation curves

Aggregate Impact Value (AIV)

The result of the AIV test is an indicator of the resistance of an aggregate to sudden shock or impact. A lower AIV value indicates stronger aggregates that can sufficiently resist impact loads. The AIV obtained from the testing is shown in Table 2 and as the value is between 17% - 21%, the aggregates are classified as very strong. Toughness is a crucial material property for aggregates to be used in road construction as there is a need to resist impact from the pounding effect of traffic loads that may cause fracture of the asphalt concrete. The aggregate impact value was found to be 19.3% which lies within the recommended range of 17% - 21% for granite aggregates and thus the aggregates are fit for use in the proposed mixtures for patching (Adebola Jethro et al., 2014).

Table 2: shows AIV results.

AIV		
sample	1	2
(A) WT BEFORE TEST (gm)	373	371.5
(B) WT AFTER TEST (gm)	372.5	371
(C) WT RETAINED AFTER TEST (gm)	327.5	323.5
(D) WT PASSING SIEVE 2.36 mm	45	47.5
A.I.V(%) (D/B) *100	12.1	12.8
AVERAGE RESULTS %	12.4	

Aggregate crushing value (ACV) test results

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

Table 3: shows ACV results.

ACV		
sample	1	2
(A) WT BEFORE CRUSHING (gm)	2807	2825.5
(B) WT AFTER CRUSHING (gm)	2807	2825
(C) WT RETAINED AFTER CRUSHING (gm)	2360	2358.5
(D) WT PASSING SIEVE 2.36 mm	447	466.5
A.C.V(%) (D/B) *100	15.9	16.5
AVERAGE RESULTS %	16.2	

Ten Percent Fines Value (TFV)

High TFV results are desired as they indicate a high resistance of the aggregates to crushing, which is a contributor to the quality, durability, and performance of the asphalt mix. The results of both the dry and soaked TFV are shown in Tables 3 and 4 respectively.

Table 4: shows Dry TFV results

TEST NO	1	2	
CRUSHING FORCE (KN)	321.5	321.5	
WT. OF AGGREG (gm)after crushing (M1)	2850.5	2797	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm(M3)	2499	2455	
WT.AGG. (gm) PASSING SIEVE 2.36 mm (M2)	351.5	342.0	
TEN % FINE VALUE (M=M2/M1*100)	12.3	12.2	
AVERAGE RESULTS % (M)	12.3		
AVERAGE CRUSHING FORCE (F)	321.5		
F DRY = 276.5 KN			

Table 5: shows Soaked TFV results

10% FINE VALUE SOAKED			
TEST NO	1	2	
CRUSHING FORCE (KN)	321.5	321.5	
WT. OF AGGREG (gm)after crushing (M1)	2845.5	2849.0	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm(M3)	2456	2462	
WT.AGG. (gm) PASSING SIEVE 2.36 mm (M2)	389.5	387.0	
TEN % FINE VALUE (M=M2/M1*100)	13.7	13.6	
AVERAGE RESULTS % (M)	13.6		
AVERAGE CRUSHING FORCE (F)	321.5		
F wet = 255.2 KN			

The values for both the dry and wet conditions are seen to be greater than 110kN, which is the least recommended ten percent fine value for asphalt concrete surfacing. Table 5 shows the wet/dry strength ratio is as well above the minimum acceptable limit of 75% thus the aggregates are good enough to withstand load under crushing (MoWHC, 2005).

Table 6: shows Wet/Dry strength ratio

Sample	Dry	Wet	Wet/Dry (%)
Force	276.5	255.2	92

Specific Gravity of Aggregates

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

The absorption values indicate the amount of water that can be absorbed from the binder by the aggregates. Generally, high absorption values are undesirable as they will affect the performance of the mix. According to 2005, the water absorption values should not exceed 2% by mass of the aggregates for use in asphalt concrete surfacing. Thus, the tested aggregates are fit for use based on both the specific gravity and water absorption criteria.

Table 7: Summary of combined aggregate specific gravities and water absorption

Aggregate size:	20-14	14-10	10-6.0	6.0-0	FILLER
GS bulk:	2.620	18.313	2.597	2.616	2.546
PROPORTIONS:	25	12	8	53	2
COMBINED SG:	2.914				
WATER ABSOPTION	0.4	0.6	0.7	0.1	
COMBINED WATER ABSOPTION	0.2				

Aggregates for use in road surfacing are recommended to have specific gravity lying within the 2.5 – 3.0 range and the water absorption not to exceed 2% of by mass of the aggregates used. As seen in table 11, the combined specific gravity falls within the range indicating that the mix with have less voids hence preventing defects like moisture penetration.

4.2. Tests on bitumen.
Softening Point of Bitumen

The softening point is an indicator of the performance and durability characteristics of bitumen in different climates. It shows the temperature at which the bitumen attains specific softness and starts to show deformation and fluidity properties. The softening point of bitumen was obtained by calculating the average of the temperatures at which the three bitumen samples touched the lower plate in the water bath. A higher softening point is, therefore, desirable as it indicates better resistance to deformation at elevated temperatures. Figure 2 shows that EVA-modified bitumen has a higher softening point than conventional bitumen, therefore, its patching mixture will exhibit better field performance.

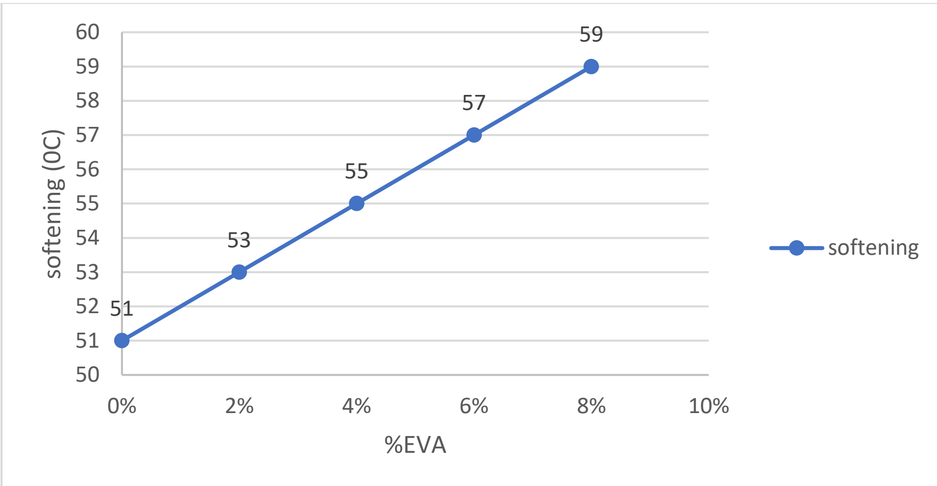


Figure 3: Softening Point Result

The percentages 2 and 4 lie within the allowable range of 49 – 56 0C (CMLT, 2000) which means that the bitumen would not liquefy until the surface temperature was above 53 and 55 degrees when used road Construction. Considering that maximum road temperature in tropical regions is about 36^0C, the Bitumen modified with 2% and 4% EVA is suitable to make Asphalt Concrete for Road construction in the Tropical Climates.

Penetration of bitumen

Results from this test give an indication of the softness or hardness of the bitumen with smaller values signifying a harder bitumen and larger values signifying a softer bitumen. From the test results, it was observed that the EVAMB was harder than the conventional bitumen as seen from the low penetration values as shown in figure 3 below. The low penetration produced by the EVA-modified bitumen is attributed to the additives used to modify it which make it harder than the conventional bitumen and therefore has better temperature susceptibility leading to increased aging resistance (Kaya Özdemir, 2021).

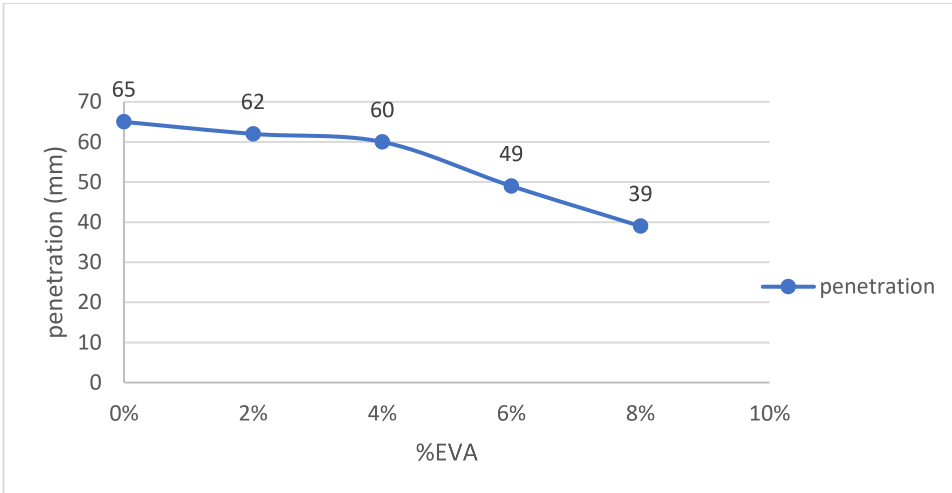


Figure 4: showing the penetration value against EVA percentage

The percentages 2 and 4 lie within the allowable range as seen in Figure 3.

Where the allowable bitumen Grade is 60 – 70 (CMLT, 2000). This implies that the bitumen can withstand the environmental conditions experienced in tropical regions which makes it suitable for Asphalt Concrete use.

Specific Gravity of bitumen.

The specific gravity of bitumen is directly related to the quality and density of the bitumen. It is relevant in mix design to determine the proportion of bitumen for use. The specific gravity results for the two binder types are shown in figure 4 below. From the results, it was seen that the conventional bitumen was heavier than the EVA-modified bitumen therefore producing a more dense and stable asphalt patching mixture.

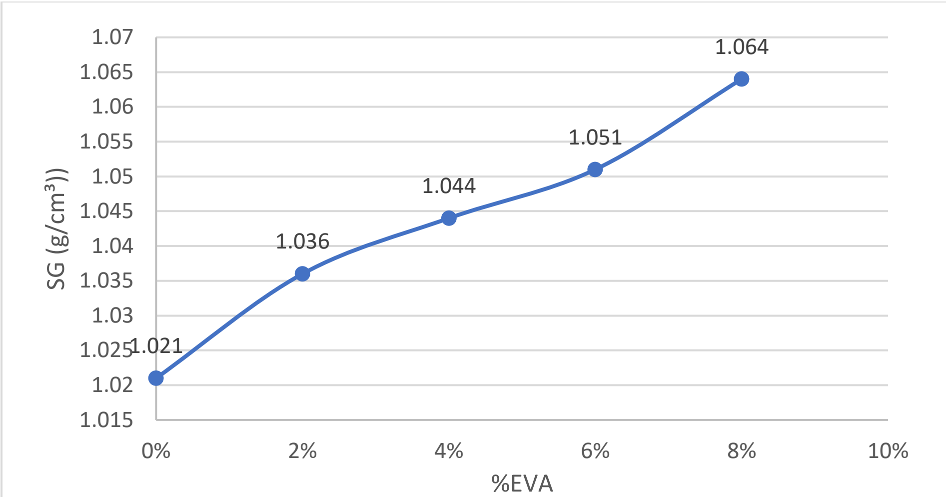


Figure 5: Specific Gravity of Bitumen Result.

Bitumen Specific Gravity of 2%, 4% and 6% as shown in figure 4 lie with in recommended range of 1.01 – 1.06 hence making it adequately coat the Aggregates in the Asphalt Mix (TRL, 2002). This would reduce the air voids with in the mix which in turn reduces moisture sensitivity hence getting rid of problems like moisture damage hence yielding formation of high-quality Asphalt Pavement.

Ductility Test of bitumen

Ductility test is the ability of the bitumen to stretch under a standard condition. inadequate ductility of bitumen grade could make the surface of the asphalt pavement exposed. However, high ductility could make the bitumen more stretching resulting into a non-uniform shape causing problems like bleeding. Low ductility could also have an effect of cracking of the pavement hence the ductility must be within the specified ranges of a given grade. Increase in EVA content in the mix lead to ductility of the modified binder decreasing.

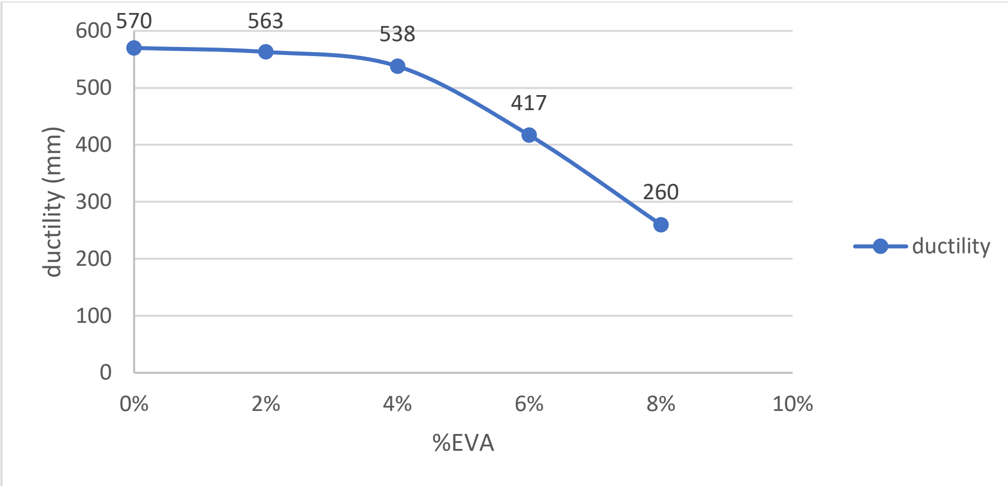


Figure 6: Ductility values against EVA percentages.

The ductility of 2%, 4% and 6% as shown in figure 5 lie with in

recommended range of >500mm hence making g resistance to moisture damage over time (ASTM D113). This would give the bitumen for flexibility hence over coming challenges of alligator cracks caused by loading effect of the cars.

Viscosity of bitumen

Results give an indication of the flowing ability of the bitumen with smaller values signifying less resistant to flow of bitumen because of less time taken for the bitumen and larger values signifying high resistance to flow because of more time it requires for bitumen to flow. From the test results, it was observed that the EVAMB was harder than the conventional bitumen as it takes more time to flow than the conventional one as shown in figure 6 below. The high softening produced by the EVA-modified bitumen is attributed to the additives used to modify it which make it harder than the conventional bitumen (Kaya Özdemir, 2021).

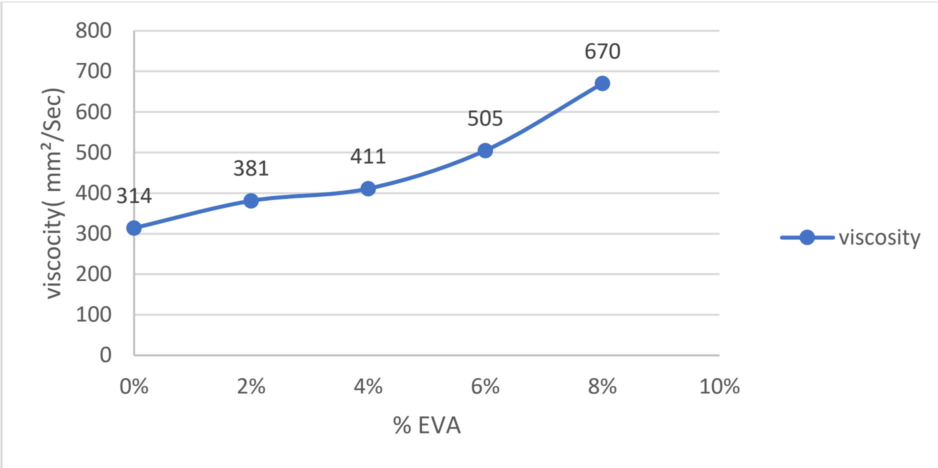


Figure 7: Viscosity values against EVA percentages.

Viscosity increases from 314 ±5 mm/sec with increase in %EVA because of a high molecular weight of EVA which reduces flow. All the percentages fall within the specified range of 295(mm^2/Sec). This implies that the bitumen has the required workability to blend with the aggregates hence reducing on the bleeding defect of the asphalt pavement.

4.3. Marshall Mix Design

Optimum Bitumen Content

Table 8 shows the Marshall property values on which optimum bitumen content values were within the range specifications. The specifications; stability (8-18) KN, air voids (3-6) %, flow (2-4) mm, VMA (min 14%), VFB (65-78) %. Accordingly, they are within the ranges of asphalt specifications of Uganda. The value of stability increases with increasing bitumen content up to a point beyond which the stability decreases. The flow value increases to maximum at 4.5% bitumen content then reduced gradually. The density value increases with increase in bitumen content up to a point beyond which the density decreases. The ratio of air voids reduces upon bitumen increase.

Table 8: showing marshal property results

BITUMEN %	3.5	4	4.5	5	5.5
DENSITY (g/cm^3)	2.333	2.354	2.369	2.363	2.350
STABILITY(KN)	12.5	13.5	13.8	13.2	12.5
FLOW (mm)	2.5	2.5	3.3	2.0	2.3
VOIDS (%)	6.3	4.7	3.5	3.2	3.3

The obtained results were plotted and the optimum bitumen content was deduced from the range that meets the common range. The table above shows the different parameters obtained from the Marshall Tests. The optimum bitumen content was determined by calculating the average of 4.5 and 5.5. OBC was 5 %

4.4. TEST RESULT ON ASPHALT CONCRETE FOR UNMODIFIED AND MODIFIED BITUMEN.

Marshall Stability

The Marshall stability was determined by crushing the asphalt cores in the Marshall stability tester and the values were recorded. The obtained values were then corrected by multiplying through with a correction factor. Correction factors were selected regarding the volume of the asphalt cores. It was observed that the PMB had higher stability compared to the conventional bitumen. Stability gradually increased with an increase in the percentage EVA up to a maximum value and then gradually decreased as EVA content increased

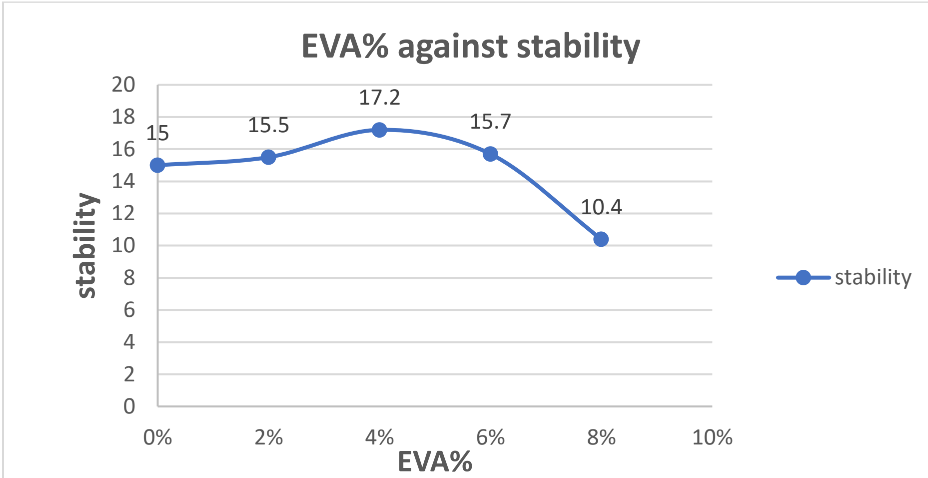


Figure 8; shows Stability values against EVA percentages

Low proportion of EVA enhances the load deformation resistance, which is highly critical in resisting pothole repair rutting. Initial resistance is contributed by EVA reinforcing binder internal friction and cohesion strength. Increased percentage EVA, however, is likely to over-stiffen the mix, rendering it vulnerable to crack and become brittle, thus lose its stability and durability. Optimal content of EVA to peak stability ensures pothole patch is resistant to traffic loading, avoiding early rutting and extending the time before repair.

Marshall Flow

First the graph reflects a decline in flow with increasing EVA content. Flow is a reflection of the workability of the asphalt mix during placement. The more flow, the more workable the mix is, and the more likely it is that it is easy to place and compact. The decline is a reflection that with increased EVA content, the mix is stiffer and less workable. A degree of stiffness is desirable for stability, but excessive stiffness in the mix will interfere with good compaction in pothole patching. Poor compaction creates more air voids, which lead the patch to be susceptible to water infiltration and early deterioration. EVA content is, therefore, important in order to provide adequate flow in order to allow good compaction and long-term repair performance for potholes.

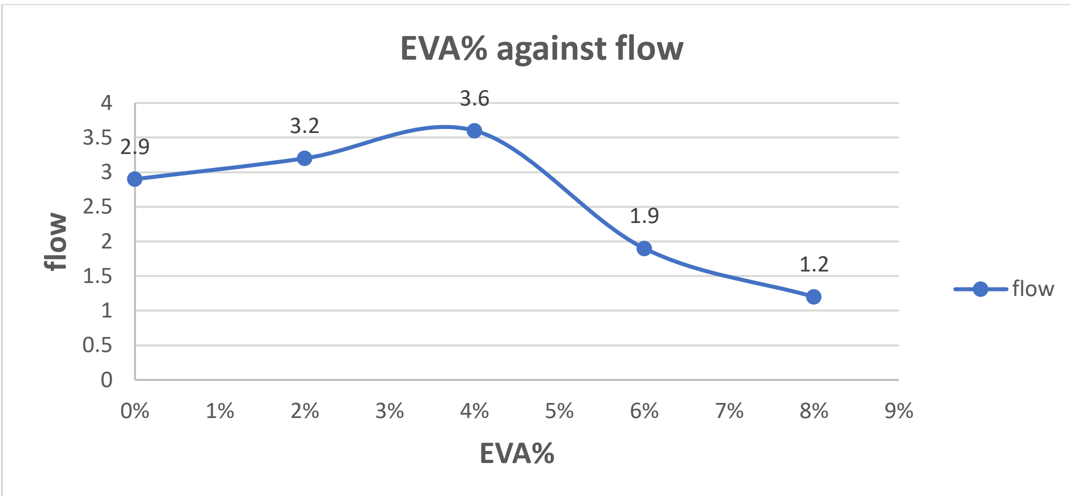


Figure 9; shows flow values against EVA percentages.

4.5 Volumetric Properties of the asphalt concrete

Percentage of Air Voids (VIM)

Air voids consist of tiny areas of air in the asphalt mix. The acceptable voids in the mix (VIM) should be between 3% and 6%. The air voids in the mix were observed to decrease with an increase in bitumen content for PMB and then increase.

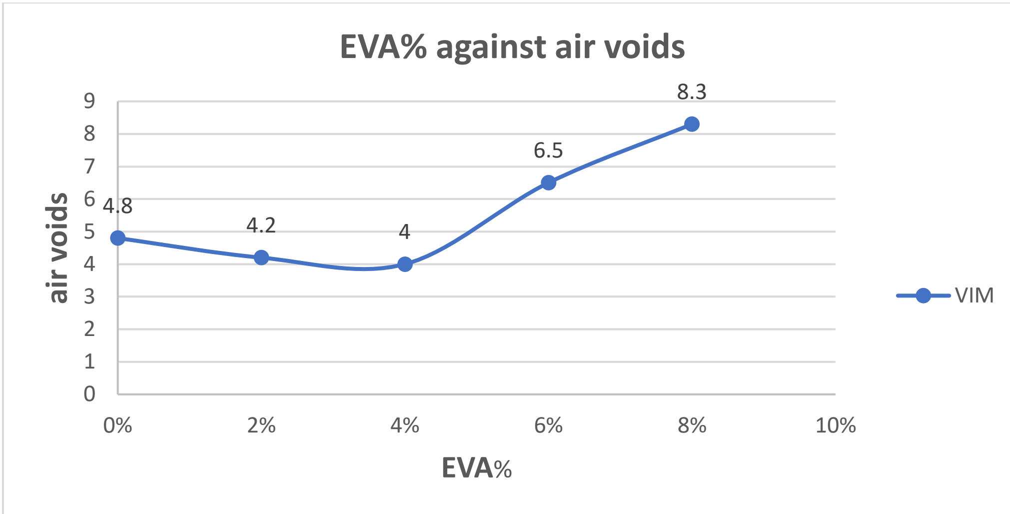


Figure 10; shows Air void values against EVA percentages

The graph shows reduction in air voids with increased EVA content, up to maximum and then increases. Air void content is undesirable in the mix, as it creates a route for water and air to enter the patch and induce oxidation, freeze-thaw, and eventual pothole regrowth. The downward trend is most likely due to EVA adding compact ability to the mix. But if the mix is made too rigid (as indicated in the flow plot) with excessive EVA, compaction can be destabilized and air voids increased. Optimum EVA content that reduces air voids is key to forming a dense, impermeable pothole repair that is less susceptible to environmental degradation and more long lasting.

Voids in Mineral Aggregates (VMA)

The VMA was calculated from;

$$VMA = 100 - Vagg$$

$$Vagg = Ps \times \frac{Gmb}{Gsb}$$

$$VFB = \left(\frac{VMA - VIM}{VMA}\right) \times 100$$

VMA is the volume of voids within the aggregate in an asphalt mixture, and it includes the volume of the space occupied by the asphalt binder. For effective coating of the aggregate and expansion of the asphalt in the binder, adequate room or space in VMA is necessary.

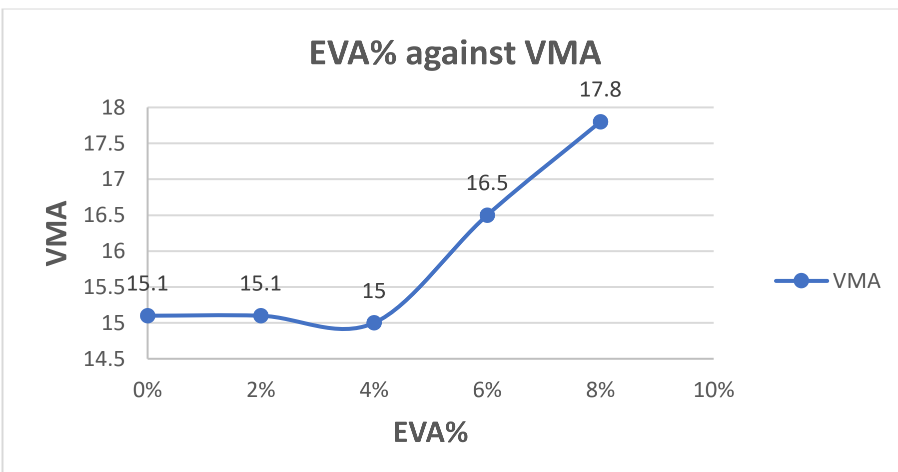


Figure 11; shows VMA values against EVA percentages

The graph suggests that VMA's value decreases and then increases when EVA content is higher. An increase in EVA accompanied by a decrease in VMA indicates that the binder is occupying a greater proportion of the void space. On the other hand, if VMA is too low, it leads to durability issues due to insufficient binder being able to coat the aggregate adequately. Proper Binder content is crucial, and preventing premature distress on pot-hole repairs due to an imbalance in EVA and sufficient VMA to ensure adequate binder is key

Voids Filled with Bitumen (VFB)

The EVA percentage correlating with VFB demonstrates that as EVA content increases, VFB also tends to rise. VFB refers to the volume percentage of VMA, which is Volume of the Mix A, filled with asphalt binder. A higher VFB tends to express a richer mix that is richer in binder. In the initial stages, VFB is increasing, and this increase can be helpful in increasing the durability of the mix and its resistance to cracking. On the other hand, If VFB is too high, the mix may become unstable due to rutting and bleeding. The right amount of EVA should achieve a suitable VFB that has enough binder to ensure durability, but not too much to make the mix unstable. This is essential in the prolonging of the repair of the pothole.

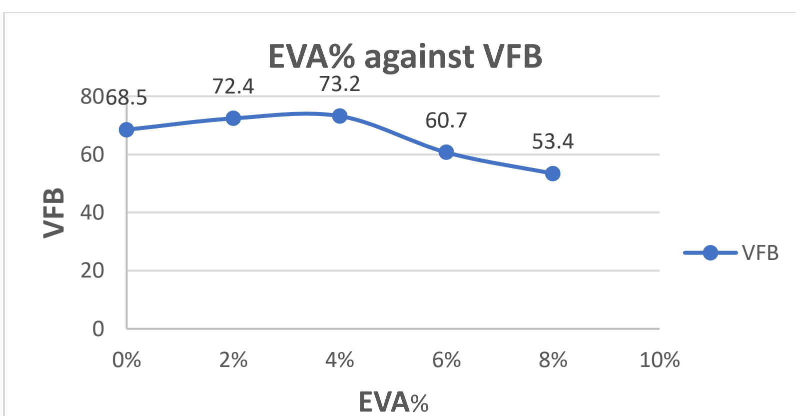


Figure 12; shows VFB values against EVA percentages

Indirect Tensile Strength Test

Results from this test are relevant in evaluating the resistance of asphalt to fatigue cracking which is a crucial parameter in evaluating the performance of a mixture. The test was done on wet and dry samples for EVA-modified bitumen as shown in Table. The PMB showed better resistance to fatigue cracking, it was further noticed that asphalt concrete with PMB had better resistance from moisture-induced damage.

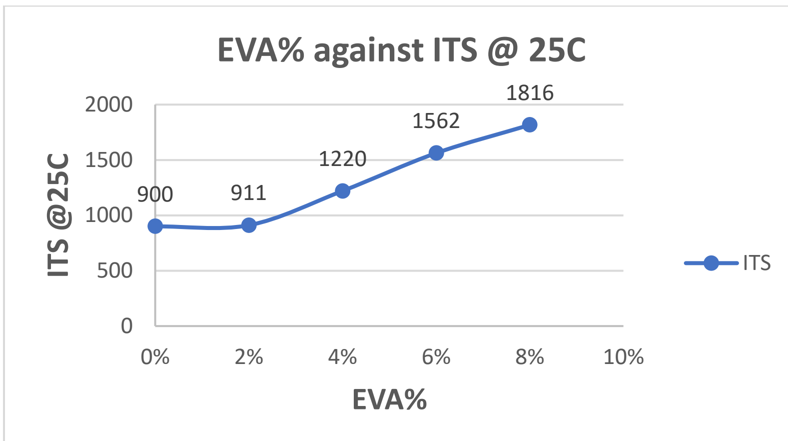


Figure 13; shows ITS values against EVA percentages

The graph illustrates that ITS increases initially with EVA content, then declines. The ITS represents the tensile strength of the asphalt mix, which explains how well the material will crack. The initial increase indicates that EVA is helping the mix withstand tensile stresses which is necessary for the mitigation of crack propagation during pothole repairs. Yet, overuse of EVA can result in a modification of the mix that is too stiff and brittle which will crack under certain conditions. In order to develop repairs that do not crack and lose integrity over time, EVA content should be optimized to ITS.

4.6. DESIGN

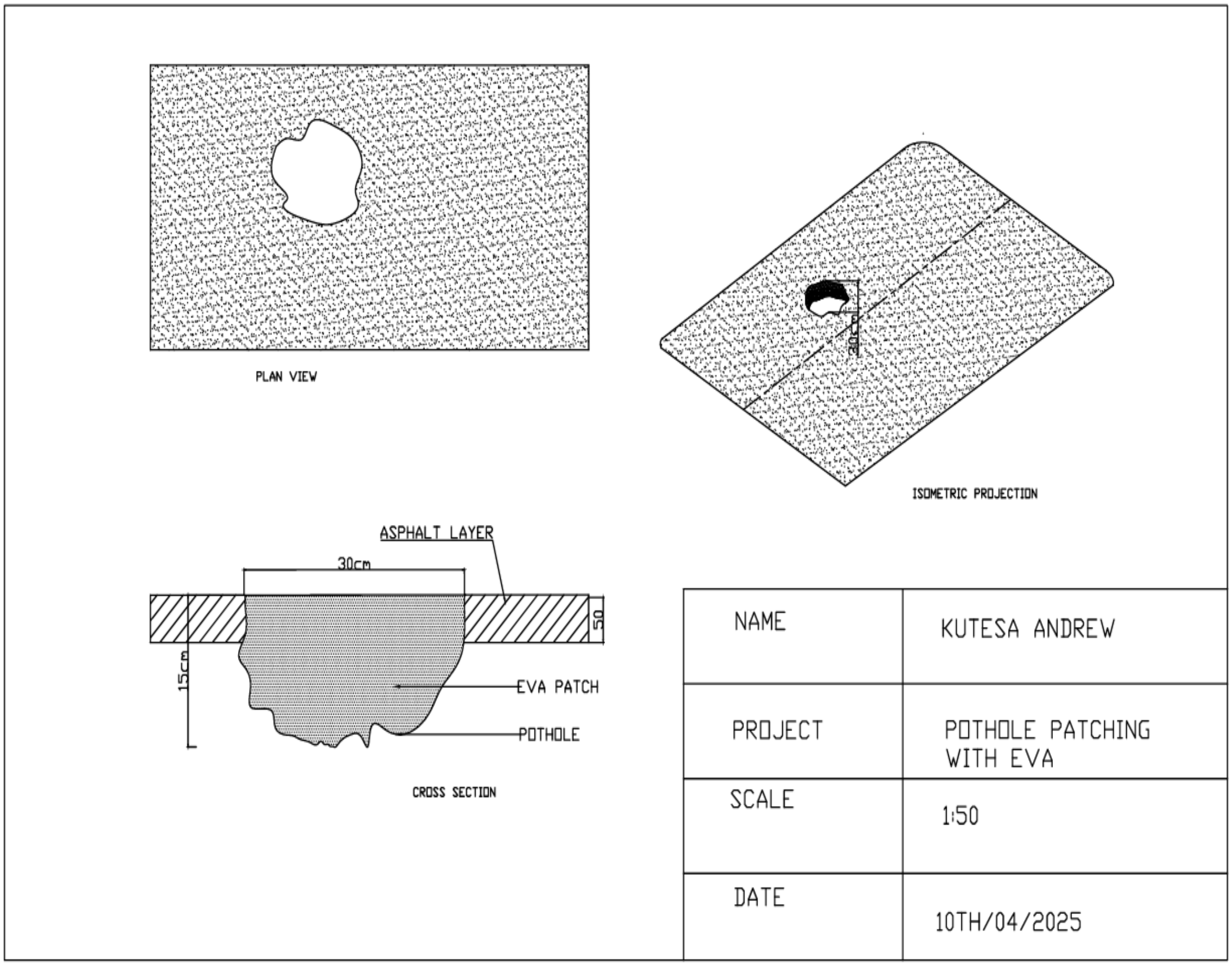
Percentage batch calculation for the design.

Bitumen content for the mix 4.4% amounting to 4.4/96×3500=160.4g

EVA content in the mix 4% of the bitumen content4/100×45.8=6.416g

Aggregate size	Proportional mixes before bitumen (%)	Percentages in the asphalt mix (%)	Mass in the mix (g)
14/20	25.0	23.9	860.4
10/14	12.0	11.5	419.3
6/10	8.0	7.5	273.4
0/6	53.0	50.7	1848.4
filler	2.0	1.9	69.27
total	100	100	3470.8

Pothole Design.



CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This chapter includes the conclusions and suggestions drawn from the research findings, which resulted from the pursuit of this study's objectives. It provides a concise overview of the critical insights gained from assessing the behavior of PMB and traditional bitumen asphalt mixtures used for pothole patching.

5.1 Conclusions

The materials used in the formulation of the mixes were found to be acceptable for use in road works per the general specifications. The aggregates exhibited desirable properties such as good resistance to crushing, impact, and specific gravity which all contribute to the resulting stability, deformation resistance, and durability of the asphalt mixtures. The EVA-modified bitumen was found to be superior to the conventional bitumen as it exhibited better material properties such as lower penetration and higher softening point. It can therefore be concluded that the EVA-modified bitumen is stiffer than the conventional one and is expected to have better performance under load and pavement service temperature.

The asphalt mixture made using EVA modified showed higher stability, flow, indirect tensile strength, and better resistance to moisture-induced damage compared to the conventional bitumen mixture. This can be linked to enhanced elasticity and flexibility of the bitumen resulting from polymer modification which increases resistance to rutting and cracking resulting in higher stability and flow values. These enhanced properties make PMB a superior binder option for use in making resilient patching mixtures.

From the results of monitoring the trial patches, it can be concluded that the patches made using EVA-modified bitumen mixture performed well and therefore were resilient as there were no observed defects during the monitoring period. However, a few of the patches made using the conventional bitumen mixture experienced mild defects during the monitoring period and hence are less resilient than the proposed mixture.

5.2. Recommendations

There is a need to incorporate other parameters and tests such as, adhesion and cohesion properties, and moisture sensitivity based on another test method to better understand the performance of the two different bitumen types.

The aging test can also be used to evaluate the changes in the rheological properties after aging to assess the resistance to rutting and hardening for either type of bitumen.

The trial patching should be carried out on different roads to obtain representative samples of the performance under different urban traffic situations.

The research should be carried out with a longer monitoring period to adequately observe the performance parameters of the pothole patches.

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APPENDIX

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In any Correspondence on
this subject please
quote No..............................

THE REPUBLIC OF UGANDA

MINISTRY OF INTERNAL AFFAIRS
DIRECTORATE OF GOVERNMENT
ANALYTICAL LABORATORY
Plot No. 2 Lourdel Road
Wandegeya,
P.O. Box 105639
Kampala - Uganda

DFD 034/2025
07th February 2025

MR. KUTEESA ANDREW
REG NO. S21B32/038
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-705-025012

REPORT OF ANALYSIS

Description of the Samples
One sample in black polythene bag containing Ethylene/Vinyl Acetate (EVA)sample was submitted by MR. Kuteesa Andrew, on 24th January 2025, and analysed on 30th January 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Colorless plastic pellets packed in a black polythene bag	1	**SAMPLE A DFD 034/2025**

Analysis Requested
Identification by FTIR.

Method of Analysis
Analysis of the sample done using the FTIR scanning method.

Results of Analysis
The mean analysis values are as below,

Sample/Lab No	Test/Parameter	Results
SAMPLE A DFD 034/2025	FTIR SCREENING	Ethylene/Vinyl Acetate (EVA) Copolymer (Vinyl Acetate content 25%) Ethylene-vinyl acetate Film, Poly (Vinyl Stearate), Candelilla Wax

Remarks
Results relate to samples analyzed and are reported as on received basis.

07/02/25

Semalago Fredrick
Government Analyst

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KUTESA ANDREW, Reg No. S21B32/038	Stirling STIRLING
PROJECT :	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT	

A/C 20 ASPHALT MIX DESIGN

SUMMARY OF A/C 20 JOB MIX TEST RESULTS

			BITUMEN CONTENT		#REF!
AGGREGATE TESTS	**ACHIEVED**	**SPECIFIED**	**MARSHALL MIX TEST RESULTS AFTER MIX**	**ACHIEVED**	**SPECIFIED**
Coating and Stripping	>95	>95%	MARSHALL FLOW	2.9	2—4
Sodium Soundness	2.1	<12%	MARSHALL STABILITY 75BLOWS	15.0	8-18
Water Absorption	0.2	< 2%	MARSHALL AIR VOIDS 75BLOWS	4.6	3—5
TFV Dry	276.5	>110kN	VOIDS IN MINERAL AGGREGATES	15.3	>14%
TFV Soaked Wet/Dry ratio	92%	>75%	VOIDS FILLED WITH BINDER	69.9	65—75%
Flakness Index	19.4	< 25%	INDIRECT TENSILE STRENGTH @ 25C	900	>800kpa
			INDIRECT TENSILE WET STRENGTH	82	>80% of dry
Sand Equivalent	—	< 45	AIR VOIDS AT REFUSAL DENSITY (PRD)	3.1	>3%
LAA	19.9		BITUMEN CONTENT AFTER EXTRACTION	4.6	±0.3
ACV	16.2				
AIV	12.4				

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10 MAR 2025
...95, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	KUTESA ANDREW, Reg No. S21B32/038	Stirling
PROJECT	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT	

JOB ASPHALT MIX DESIGN

LOCATION MUKONO LAB

22-Jan-25

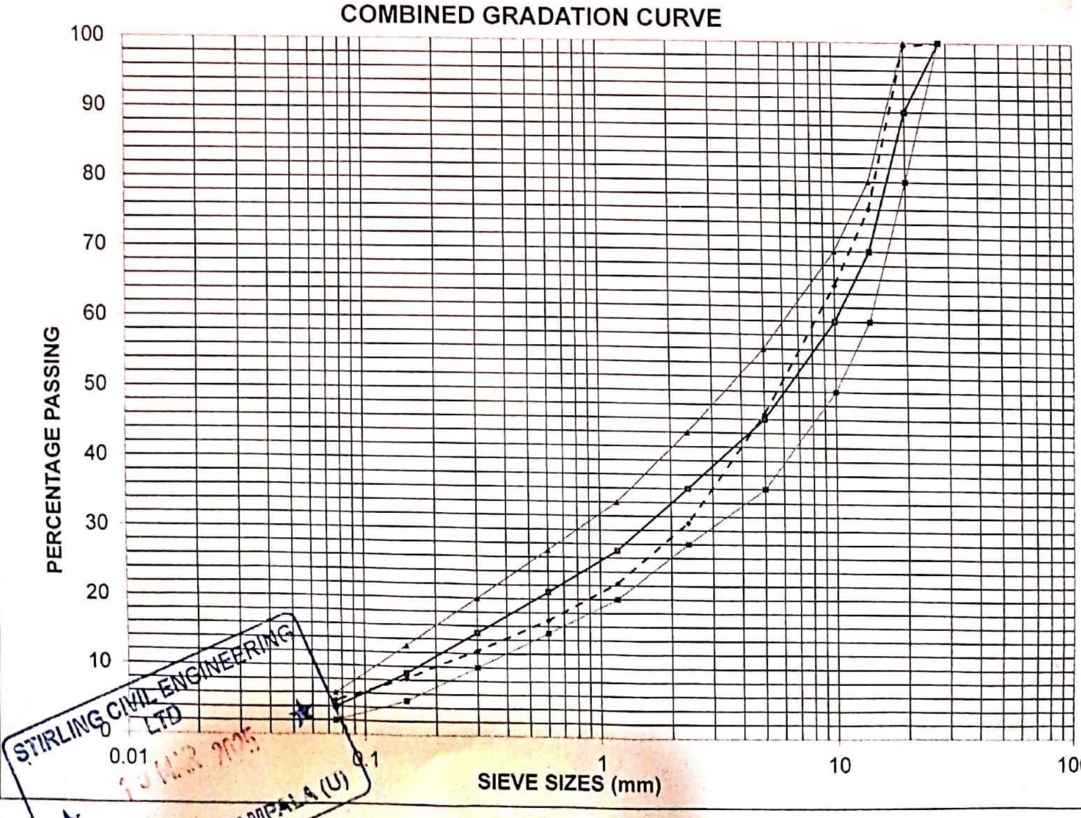
SUPPLIER HOTBIN No1

SAMPLE No

MATERIAL AC 20 INDIVIDUAL GRADATION

	14/20MM		10/14MM		6/10MM		0/6MM		FILLER		actual	TARGET GRADING	SPEC
		25.0		12.0		8.0		53.0		2.0	100.0		
28	100.0	25.0	100.0	12.0	100.0	8.0	100.0	53.0	100.0	2.0	100	100	100
20	98.6	24.7	99.4	11.9	100.0	8.0	100.0	53.0	100.0	2.0	100	90	80—100
14	18.7	4.7	70.3	8.4	99.4	8.0	100.0	53.0	100.0	2.0	76	70	60—80
10	1.6	0.4	18.7	2.2	93.9	7.5	100.0	53.0	100.0	2.0	65	60	50—70
5	0.4	0.1	1.3	0.2	6.6	0.5	83.0	44.0	100.0	2.0	47	46	36—56
2.36	0.4	0.1	0.9	0.1	5.1	0.4	53.7	28.5	100.0	2.0	31	36	28—44
1.18	0.4	0.1	0.8	0.1	4.3	0.3	37.4	19.8	100.0	2.0	22	27	20—34
0.6	0.4	0.1	0.7	0.1	3.6	0.3	27.3	14.4	99.8	2.0	17	21	15—27
0.3	0.4	0.1	0.6	0.1	3.0	0.2	19.1	10.1	95.8	1.9	12	15	10—20
0.15	0.4	0.1	0.5	0.1	2.5	0.2	12.0	6.3	79.7	1.6	8	9	5—13
0.075	0.4	0.1	0.4	0.0	2.2	0.2	6.5	3.4	58.4	1.2	5	4	2—6

COMBINED GRADATION CURVE



FOR TESTING LAB

FOR STUDENTS

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UGANDA CHRISTIAN UNIVERSITY	KUTESA ANDREW, Reg No. S21B32/038	Stirling

PROJECT: ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT

OPERATOR: Lab team

LOCATION

SUPPLIER

CONTAINER/DELIVERY NO

BITUMEN TESTS

20-Jan-25

DESTINATION

MATERIAL TYPE: 60/70

TEST NO	J		K		2	P	ER	ST	AVERAGE	REMARKS
PENETRATION 100gr 5 sec 25 C	65 65 63		65 67 66		63 66 64	65 64 64	65 65 63	68 67 68	65	60-70
SOFTENING POINT (°C)		50		51					51	(49-56)°C
BITUMEN AFFINITY										>95
SUPECIFIC GRAVITY	1.051		1.038		1.035	1.022	1.045	1.024	1.036	1.01-1.06

Materials Engineer.

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PROJECT	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT

MODIFIED WITH 2% EVA

BITUMEN TESTS

LOCATION	OPERATOR Lab team
SUPPLIER	CONTAINER/DELIVERY NO
21-Jan-25	DESTINATION
MATERIAL TYPE 60/70	

TEST NO	H		Y		O				AVERAGE	REMARKS
PENETRATION 100gr 5 sec 25 C	58 60 62		62 64 60		62 63 64				62	60-70
SOFTENING POINT (°C)		52		53					53	(49-56)°C
BITUMEN AFFINITY										>95
SUPECIFIC GRAVITY	1.033		1.027		1.030				1.030	1.01-1.06

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Materials Engineer.__________

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PROJECT	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT

MODIFIED WITH 4% EVA

LOCATION

SUPPLIER

21-Jan-25

MATERIAL TYPE 60/70

BITUMEN TESTS

OPERATOR Lab team

CONTAINER/DELIVERY NO

DESTINATION

TEST NO	YT		PP		DE				AVERAGE	REMARKS
PENETRATION 100gr 5 sec 25 C	60 61 60		59 60 57		59 60 61				60	60-70
SOFTENING POINT (°C)		54		55					55	(49-56)°C
BITUMEN AFFINITY										>95
SUPECIFIC GRAVITY	1.029		1.020		1.029				1.026	1.01-1.06

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PROJECT	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT

MODIFIED WITH 6% EVA

LOCATION	**BITUMEN TESTS**	OPERATOR Lab team
SUPPLIER		CONTAINER/DELIVERY NO
21-Jan-25		DESTINATION
MATERIAL TYPE 60/70		

TEST NO	D		9		6				AVERAGE	REMARKS
PENETRATION 100gr 5 sec 25 C	49 50 52		44 46 52		53 50 48				49	60-70
SOFTENING POINT (°C)		56		57					57	(49-56)°C
BITUMEN AFFINITY										>95
SUPECIFIC GRAVITY	0.995		1.025		1.008				1.009	1.01-1.06

Materials Engineer

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UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	KUTESA ANDREW, Reg No. S21B32/038	Stirling

PROJECT	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT

MODIFIED WITH 8% EVE

LOCATION	BITUMEN TESTS	OPERATOR Lab team
SUPPLIER		CONTAINER/DELIVERY NO
21-Jan-25		DESTINATION
MATERIAL TYPE 60/70		

TEST NO	D		9		6					AVERAGE	REMARKS
PENETRATION 100gr 5 sec 25 C	38 40 42		41 39 40		38 37 35					39	60-70
SOFTENING POINT (°C)		60		59.5						60	(49-56)°C
BITUMEN AFFINITY											>95
SUPECIFIC GRAVITY	0.965		0.988		0.998					0.984	1.01-1.06

Materials Engineer.

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INSTITUTION	STUDENT'S NAME	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	KUTESA ANDREW, Reg No. S21B32/038	Stirling

PROJECT	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT
LOCATION	
MATERIAL TYPE	BITUMEN
OPERATOR	Lab team
DESTINATION	

DUCTILITY BITUMEN TEST

TESTING DATE: 21/01/2025	NEAT BITUMEN				AVERAGE	REMARKS (mm)	Testing method
Mould No.	1	2	3		1570	>1000	ASTM D113
Time poured	10:20Am	10:20Am	10:20Am				
Time place in water bath	10:20Am	10:20Am	10:20Am				
Distance elongated (mm)	1605	1555	1550				

TEST NO	2% EVA				AVERAGE	REMARKS (mm)	Testing method
Mould No.					563	>500	DIN 52013 (For modified bitumen)
Time poured	9:00am	9:00am	9:00am				
Time place in water bath	10:00am	10:00am	10:00am				
Distance elongated (mm)	588	542	560				

TEST NO	4%EVA				AVERAGE	REMARKS (mm)	Testing method
Mould No.					538	>500	DIN 52013 (For modified bitumen)
Time poured	12:20pm	12:20pm	12:20pm				
Time place in water bath	1:20pm	1:20pm	1:20pm				
Distance elongated (mm)	540	548	526				

TEST NO	6% LLDPE				AVERAGE	REMARKS (mm)	Testing method
Mould No.					417	>500	DIN 52013 (For modified bitumen)
Time poured	11:05am	11:05am	11:05am				
Time place in water bath	12:05Pm	12:05Pm	12:05Pm				
Distance elongated (mm)	430	415	405				

TEST NO	8% LLDPE				AVERAGE	REMARKS (mm)	Testing method
Mould No.					260	>500	DIN 52013 (For modified bitumen)
Time poured	1:00pm	1:00pm	1:00pm				
Time place in water bath	2:00pm	2:00pm	2:00pm				
Distance elongated (mm)	252	275	253				

For Stirling

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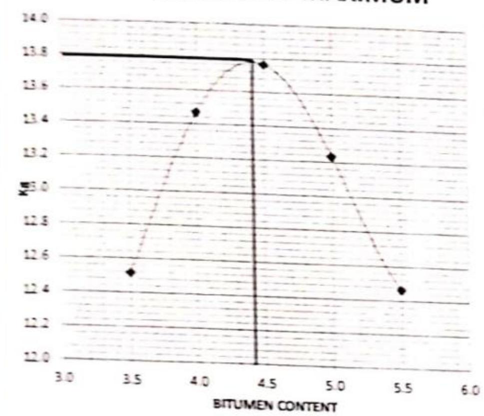
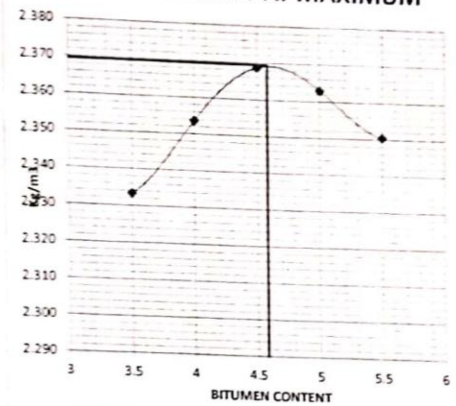
P.O. BOX 783, KAMPALA (U)

AC 20 JOB MIX DESIGN

STABILITY AT MAXIMUM



DENSITY AT MAXIMUM



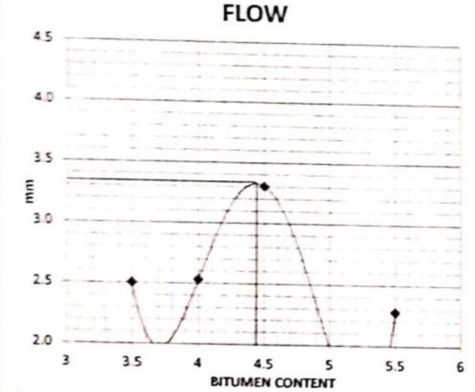
DATE: 20/01/2025

Stability	4.4	%	FILLER	2	%
Density	4.6	%	Q / Dust	53	%
Flow	4.4	%	10mm	8	%
Voids	4.3	%	14mm	12	%
Average	4.4		20mm	25	%
			TOTAL	100	

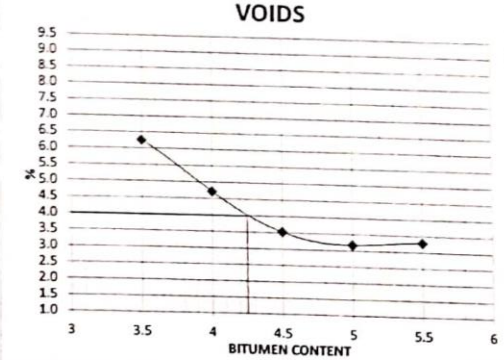
MIX PROPORTION

3

FLOW



VOIDS



BITUMEN %	3.5	4	4.5	5	5.5
DENSITY	2.333	2.354	2.369	2.363	2.350
STABILITY	12.5	13.5	13.8	13.2	12.5
FLOW	2.5	2.5	3.3	2.0	2.3
VOIDS	6.3	4.7	3.5	3.2	3.3

STIRLING CIVIL ENGINEERING LTD
1 3 MAR 2025
P.C. BOX 796, KAMPALA (U)

Signatures:

For Testing Lab ____________

For Students ____________

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KUTESA ANDREW, Reg No. S21B32/038	Stirling STIRLING
PROJECT :	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT	

SUMMARY OF A/C 20 MODIFIED ASPHALT WITH 2% EVA

ASPHALT WITH BITUMEN MODIFIED WITH 2% EVA

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
MARSHALL FLOW	3.2	2—4
MARSHALL STABILITY 75BLOWS	15.5	8-18
MARSHALL AIR VOIDS 75BLOWS	4.2	3—5
VOIDS IN MINERAL AGGREGATES	15.1	>14%
VOIDS FILLED WITH BINDER	72.4	65—75%
INDIRECT TENSILE STRENGTH @ 25C	911	>800kpa
INDIRECT TENSILE WET STRENGTH	77	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	4.6	±0.3

STIRLING CIVIL ENGINEERING LTD, P.O. BOX 736, KAMPALA (U)

SIGNED TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KUTESA ANDREW, Reg No. S21B32/038	Stirling STIRLING
PROJECT :	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT	

SUMMARY OF A/C 20 MODIFIED ASPHALT WITH 4% EVA

ASPHALT WITH BITUMEN MODIFIED WITH 4% EVA

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
MARSHALL FLOW	3.6	2—4
MARSHALL STABILITY 75BLOWS	17.2	8-18
MARSHALL AIR VOIDS 75BLOWS	4.0	3—5
VOIDS IN MINERAL AGGREGATES	15.0	>14%
VOIDS FILLED WITH BINDER	73.2	65—75%
INDIRECT TENSILE STRENGTH @ 25C	1,220	>800kpa
INDIRECT TENSILE WET STRENGTH	84	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	4.6	±0.3

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 86, KAMPALA (U)

SIGNED TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KUTESA ANDREW, Reg No. S21B32/038	Stirling STIRLING
PROJECT :	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT	

SUMMARY OF A/C 20 MODIFIED ASPHALT WITH 6% EVA

ASPHALT WITH BITUMEN MODIFIED WITH 6% EVA

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
MARSHALL FLOW	1.9	2—4
MARSHALL STABILITY 75BLOWS	15.7	8-18
MARSHALL AIR VOIDS 75BLOWS	6.5	3—5
VOIDS IN MINERAL AGGREGATES	16.5	>14%
VOIDS FILLED WITH BINDER	60.7	65—75%
INDIRECT TENSILE STRENGTH @ 25C	1,562	>800kpa
INDIRECT TENSILE WET STRENGTH	73	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	4.6	±0.3

STIRLING CIVIL ENGINEERING P. O. BOX 796, KAMPALA (U)

SIGNED TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KUTESA ANDREW, Reg No. S21B32/038	Stirling STIRLING
PROJECT :	ASSESSING THE USE OF ETHYLENE VINYL ACETATE(EVA) FOR THE RESILIENCE OF POTHOLE PATCHES IN ASPHALT PAVEMENT	

SUMMARY OF A/C 20 MODIFIED ASPHALT WITH 8% EVA

ASPHALT WITH BITUMEN MODIFIED WITH 8% EVA

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
MARSHALL FLOW	1.2	2—4
MARSHALL STABILITY 75BLOWS	12.4	8-18
MARSHALL AIR VOIDS 75BLOWS	8.3	3—5
VOIDS IN MINERAL AGGREGATES	17.8	>14%
VOIDS FILLED WITH BINDER	53.4	65—75%
INDIRECT TENSILE STRENGTH @ 25C	1,816	>800kpa
INDIRECT TENSILE WET STRENGTH	67	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	4.6	±0.3

STIRLING CIVIL ENGINEERING LTD P.O. BOX 736, KAMPALA (U)

SIGNED TESTING LAB