EVALUATING THE EFFECT OF HYDRATED LIME ON THE WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

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ABSTRACT

This research aimed to evaluate the effectiveness of integrating hydrated lime (HL) as an additive to enhance workability properties of granite stone dust (GSD)-modified asphalt mixes, due to the particle angularity and roughness of GSD and its inability to effectively interact with the binder. The study utilized hydrated lime to substitute GSD at 0%, 1%, 2%, 3%, and 4% by weight of aggregates. A series of laboratory tests—Marshall Stability, Marshall Flow, Bulk density, Air voids, Indirect Tensile Strength (ITS)—were used to evaluate workability properties. Notably, the 3% hydrated lime demonstrated the best performance, denoted by the maximum Marshall Stability of 16.7 kN, best Flow of 3.6 mm, maximum Bulk density of 2.344 g/cm^3, and best moisture resistance with a TSR of 96%. It is evident that the use of 3% hydrated lime improves the workability of GSD asphalt for low-volume road constructions in tropical environments such as Uganda.

DECLARATION

I, Shadrach Ahumuza Ainebyona, hereby declare that this research proposal report was a result of my own work and has not been submitted for any other degree or academic award. Any sources of information not originally my own have been duly acknowledged and referenced.

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

Shadrach Ahumuza Ainebyona

APPROVAL

This is to certify that the above report: "Evaluating the Effect of Hydrated Lime on the Workability of Granite Stone Dust Modified Asphalt Mixture" submitted to the Faculty of Engineering, Design and Technology, Department of Environment and Engineering, at Uganda Christian University, in partial fulfilment of the requirement for the Bachelor of Science in Civil and Environmental Engineering, is researched and approved under my supervision by: Ainebyona Shadrach Ahumuza Reg. No: M22B32/032 and Access No: A97851

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

Dr.Chris Byaruhanga

Supervisor

DEDICATION

I would like to dedicate this Final Year Research and design project to my beloved parents Mr. Baker Wilcky Ainebyona and Mrs. Ruth Komukama Ainebyona for their unwavering love, encouragement, and support. Their sacrifices and encouragement have been a constant source of motivation for me.

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I would like to extend my heartfelt thanks to my parents Mr. Baker Wilcky Ainebyona and Mrs. Ruth Komukama Ainebyona for their unwavering love, encouragement, and support. Their sacrifices and encouragement have been a constant source of motivation for me. I would also like to express my gratitude to Mr. Paul Asiimwe and Mrs. Patricia Asiimwe for their support which has been instrumental to the completion of this Final Year Research and Design Project.

Lastly, I am thankful to the Uganda Christian University for providing me with a conducive learning environment and equipping me with the knowledge and skills necessary to complete my final year research and design project and pursue a career in civil and environmental engineering.

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GSD – Granite Stone Dust

MW- Marble waste

HL – Hydrated Lime

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CHAPTER ONE: INTRODUCTION

1.0 Introduction

1.1 Background

In the Lweeza community, road construction integrated granite stone dust as a filler in asphalt mixtures, which filled the voids in the asphalt, densifying the mixture and reducing moisture infiltration. Because of its high thermal capacity, it was also useful in high temperature conditions as it mitigated rutting (Jwaida et al., 2024). While this approach improved pavement performance, the workability of the granite stone dust was negatively affected. (Ochen, 2024).

1.2 Problem Statement

Roads in the Lweeza community that use GSD-modified asphalt have experienced this premature deterioration, even within the planned design life. Pavement failures such as ravelling, stripping, cracking, and pothole formation negatively affected the durability of the road. Despite proper drainage systems in place, a lack of rutting (indicating heavy traffic loads), and being that it was situated in a residential area where the access road was not in proximity to any swamps (indicating moisture infiltration due to capillary action). While stop-and-go traffic was indeed a source of mechanical wear and tear on the road, it accelerated pavement failure. The road was a low-traffic volume access road, and was still within its design life, implying that it should still be withstanding the traffic loading that it was designed for, for the duration of its design life. These defects are largely attributed to poor compaction and uneven binder coating due to the stiff and segregated nature of granite stone dust-modified mixtures. The resulting lower densities significantly compromised pavement durability and lifespan. The angularity and texture of granite stone dust led to reduced workability, making mixing, compaction, and application more difficult.

The primary issue revolved around the fact that GSD mixes are stiff, segregation-prone, and hardly workable, thus affecting the mixing, laying, and compacting processes, which eventually influenced the observed distress of the pavement. This process translated to lower densities, lower pavement life, and higher maintenance costs.

Although the early failure of the pavement could be attributed to the workmanship, the above consideration ignores the material science constraint imposed by the mixture, causing the inherent workability issues. The granite stone dust caused workability issues due to the high internal friction due to the high angularity, the presence of siliceous material that reduced the affinity for the binder, and the rough texture that reduced the aggregate and binder bond. This required additional compactive force for the creation of a homogenous, pliable, and compact asphalt mixture. That can be applied on the road. The use of the granite stone dust created a ceiling on achievable densities and coating quality, making the best aggregate-binder adhesion and compaction difficult to achieve even with good field practice. Consequently, failures like ravelling and stripping that accelerated pavement failures are the inevitable outcome of using a filler whose properties naturally resist effective mixing and compaction. This study seeks to address the workability challenges of the GSD-modified asphalt in order to retain its benefits as a sustainable construction material with high thermal capacity (preventing rutting) while improving its binder-aggregate adhesion and compact-ability in order to engineer a more workable, durable, water-resistant pavement for reliable, sustainable construction.

Hydrated lime has been studied extensively and proven to be an effective anti-stripping agent. It reduces the plasticity of fine aggregates, and it chemically bonds the binder and the aggregates, enhancing adhesion. The purpose of this research, therefore, was to evaluate the effect of the hydrated lime on the workability of the asphalt. (Han et al, 2019)

However, it's potential to combat the workability issues posed by GSD-modified asphalt—particularly in Uganda's tropical environment was still unexplored. This research, therefore, aims to evaluate the effect of hydrated lime on the workability of GSD-modified asphalt mixtures

1.3 Research Objectives

This study aims to evaluate the effect of hydrated lime on the workability of GSD-modified asphalt mixtures. The specific objectives are:

1. To Determine Physical and chemical Properties of Hydrated Lime in Relation to its Role as a Filler in Asphalt Concrete
2. To determine the optimal content of hydrated lime to be used in granite stone dust modified asphalt mixture
3. To assess the workability of the GSD- asphalt with the integration of hydrated lime and without it
4. To develop a modified mix design specification for the GSD-Hydrated Lime Asphalt mixture

1.4 Research Questions

1. What physical and chemical properties of hydrated lime influence its use as a filler in granite stone dust (GSD)-modified asphalt mixtures?

2. How does varying the proportion of hydrated lime influence the workability of GSD-modified asphalt mixtures?

3. What was the optimum hydrated lime content in GSD-modified asphalt to achieve a balance of workability and structural performance?

4. How does adding hydrated lime affect binder coating, compaction efficiency, and Moisture resistance in granite stone dust asphalt mixtures?

1.5. Scope

This research focuses on:

Geographical Scope: An access road in Lweeza (Lat: N 0°13'25.19184"; Long: E 32°33'17.85636").

Technical Scope: Laboratory-based evaluation of lime-modified GSD asphalt using Marshall Flow, Bulk Density, and Boiling Tests.

1.6 Justification

This study intends to improve road construction by integrating hydrated lime, resulting in reduced construction costs and sustainable construction by utilising a waste product. Hydrated lime increases the workability of asphalt concrete with granite stone dust by changing the fines-binder interactions. This was the first study to investigate the lime-granite stone dust synergy in Uganda's tropical climates, and will provide Uganda's Ministry of Works with evidence-based hydrated lime performance data and dosage guidelines.

Hydrated lime Improves Binder-Aggregate Adhesion by forming strong chemical bonds at the binder-aggregate interface, reducing stripping and Moisture susceptibility (Han et al, 2019). Hydrated lime mitigates this by decreasing the flexibility of particles, increasing the mix's compatibility. It improves the binder's cohesiveness and flow qualities by reducing the stiffening effect caused by angular particles like granite stone dust by lubricating contact points and reducing friction, making the asphalt mix easier to work with and compact during construction. (Little and Epps, 2006) Finally, by neutralizing acids, lime slows the oxidative aging of asphalt, extending pavement life and improving durability.

1.7 Significance of the Study

This study appears important as it tackles an important problem that persists in the road construction industry, particularly for the people of the Lweeza community and the entire country of Uganda, as well as for tropical climates, concerning the early deterioration of roads that was ascribed to the poor workability of granite stone dust (GSD)-modified asphalt mixtures. This study proposes to improve the mixing, compaction, and binding capacity of asphalt to ensure the development of stronger roads. From the study, there are expectations for the development of scientifically based guidelines for the optimal content of GSD-modified asphalt mixtures that contain hydrated lime, ensuring that engineers and policy makers are equipped to improve the nature of the roads, as well as decrease maintenance costs. This study therefore provides support for the development of safe and strong roads for communities, as it would benefit the people and improve the development of the growing community, such as the one experienced by the people of Lweeza. This study scientifically fills the knowledge gap that exists regarding the relationship between GSD and the effect of high temperatures that are experienced in tropical climates, as there are very few scholarly articles and research on such topics. This study improves the comprehension of the influence of the addition of GSD and high temperatures on the nature of the physical and chemical properties of GSD-modified asphalt mixture.

1.8 Conceptual framework

This research investigates the influence of the use of hydrated lime on the workability and longevity of asphalt mixtures modified with granite stone dust (GSD) as used in Uganda. While the use of hydrated lime enhances the binding properties and resistance to damage by water of asphalt mixtures through the chemical component, granite stone dust, which was produced during the granite processing process, consists of jagged, coarse grains that promote the hardening of the asphalt mixture and lower workability. In essence, workability of an asphalt mixture denotes the ease of mixing, transport, spreading, and compaction into the desired, compact surface. This factor, which ascertains the proper coating and compaction of the mixture, stands as the backbone for the longevity of the asphalt. The jagged nature, as well as the grain size, of the GSD particles limits the workability of the GSD-modified asphalts.

Adding hydrated lime to GSD-modified asphalt makes it more workable due to the interaction between the lime and the aggregates and the binder, which makes the particles less stiff and lubricates the contact points. This reduces internal friction, making the material more compactable, which then gives it higher densities and strength without affecting the natural properties of granite stone dust. The study seeks to

1. Characterization of the physical and chemical characteristics of hydrated lime as it applies to asphalt mixtures.

2. To optimize the amount of hydrated lime required for realizing high workability without affecting the strength.

3. Assessment and comparison of the workability and durability of asphalt mixtures with and without the use of hydrated lime in the tropical climate of Uganda. 4. Developing the design for the GSD-hydrated lime asphalt mixture. The general framework offers effective guidelines for the use of hydrated lime to increase the durability and cost-effectiveness of asphalt pavements during the process of their construction for local roads.

CHAPTER TWO: LITERATURE REVIEW

2.0 Literature Review

The aggregate base materials, especially the fillers, play an important role in determining the performance of the asphalt pavements. Nonetheless, granite stone dust, which has acted as the filler material in Uganda based on the availability and performance characteristics, has shown some negative effects regarding the workability of the asphalt mixture. More recent research work has, therefore, focused on the use of additives, such as lime, as one of the alternatives for enhancing the workability and performance. This literature study reviews the available knowledge regarding the use of granite dust as the filler material, as well as the degree to which lime has proved effective.

2.1 Granite Stone Dust in Asphalt

The Granite Stone dust is the by-product of the granite industry. The rut resistance, the rigidity and the water resistance of the road are better with the use of granite stone despite the nature of the stone dust, that is to say the angularity and roughness (De Medeiros et al., 2023; Jwaida et al., 2024; Oesman et al., 2021). Regardless of these advantages, the shape of particles and the high internal interlock of the stone dust in the asphalt composite restrict the mix-ability of the mixture and results in the inherent mixing, compaction and application difficulties. Bessa and others (2015) elaborated that mineral powder and powder content shape affect the compaction and thus usually cause the segregation and variations in density when laying the final surface.

2.2 Granite Stone Dust Workability Challenges

Although GSD offers various benefits, it experiences some workability problems as a result of its angles and rough surface. Workability can be explained as the ease of mixing, transporting, spreading, and compaction of asphalt. For granite dust-modified mixes, the high internal friction and absorption properties of the GSD limit the flexibility of the mixture, making compaction processes more difficult and prone to early failure. The higher absorption properties of GSD compared to the smoothed fillers increase internal friction and deterioration, making it difficult for the mixture to be well compacted, leading to low density and high early failure rates, such as stripping, ravelling, and the development of potholes (Ochen, 2024). Gudimettla, Murali, and Tharaghini (2004) explained that the workability problems can result in the development of an imbalanced binder coating, which enhances segregation and the development of the structure's defect. In addition, the use of GSD experiences drawbacks regarding the design performance. Studies show that no more than 3% of GSD can be well utilized in the design of some asphalt mixtures, compared to 7.5% for cement fillers (Oesman*et al.*, & Benny, 2021)

2.3 Hydrated Lime Effect on Asphalt Mixtures

Hydrated lime has shown enhanced performance characteristics for the asphalt mixture. This was because it promotes aggregate and binder adhesion as a result of the formation of strong chemical bonds with the components of the bitumen, hence calcium soap, which promotes binding and coating (Han et al., 2019). Moreover, it acts as a plastic modifier, softening the particles in the mixture and making it easier to compact, ensuring that the mixture was cohesive (Little & Epps, 2006). Hydrated lime also works as an anti-stripping agent, neutralizing the acidic components of the bitumen, hence enhancing resistance to stripping (ASTM D7173).

There exists research proving the efficacy of the addition of hydrated lime to asphalt mixtures. According to Han et al. (2019), "Lime addition can enhance the polar component of the surface free energy (SFE) of the asphalt binder and improve the wetting and binding interaction between the asphalt binder and aggregates." In regard to reduced compaction efforts, the study by Little and Epps (2006) proved that the addition of lime to the asphalt mixture reduces compaction efforts by 20%, thus allowing for faster and denser compaction. De Medeiros et al. (2023) proved that the use of lime satisfies the complete substitution of the conventional fillers, up to 100%, while maintaining the same levels of mechanical strength but certainly increasing workability and environmental sustainability. In Uganda, the average annual temperature, which varies from 20 – 28°C, intensifies the stiffening effect of the granular material, especially if the material was subjected to dry climatic conditions, thus making the workability process an integral priority for improvement. As a hydrate, lime carries a high lubrication capacity, as it reduces the particles' interaction and thus enhances the process of compaction. According to the research by Denis (2024), "Lubrication reduces compaction resistance and makes compaction easier." In addition, lime helps to overcome the challenge of oxidative aging, thus making the material less reactive and, therefore, less harmful to the environment. As presented in the study by Little and Epps (2006), "Lime reduces the potential for oxidative aging and protects the asphalt binder against reactive acidic compounds, which makes the material especially effective for use and durable performance, especially in hot and tropical climates." Although the lime increases the binding capacity between the binder and aggregate, the effect of the lime on the viscosity of the bitumen requires careful consideration. Several research works (for instance, Han et al. 2019, and

Little & Epps, 2006) suggest that the lime content can increase the binder viscosity through the generation of calcium and organic compounds and absorption of light fractions. This factor can enhance the cohesion of the mixture but limit workability if the lime content becomes excessive. This study, therefore, carries out an elaborate assessment of the workability of the mixture using various lime concentrations to ascertain the optimal content that presents the most benefits without undermining the workability.

2.4 Optimum content of Granite Stone Dust

In the experiment, the industrial waste obtained from granite stone production, which came as dust, was utilized as filling material present in the AC-WC mixture. The amount of filling material used varies from 3%, 4.5%, 6%, 7.5%, 9%, based on the comparison using cement filler. The experiment involved the use of wheel tracking equipment designed to operate at 60°C, 45°C, and 30°C. Results obtained from the experiment indicate that 3% Granite dust was the best content for the filling mixture of the AC-WC mixture. (Oesman et al., 2021)

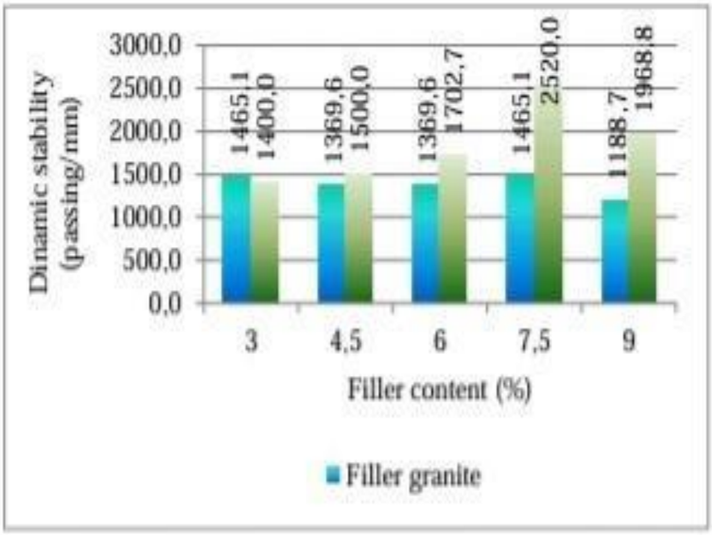


Figure 1: The dynamic stability values of asphalt concrete

The diagram indicates that the link between dynamic stability and filler content was not linear, nor was the type of filler. In general, asphalt concrete with cement filler was more stable than asphalt concrete with granite filler. The use of a 7.5% cement filler results in the maximum dynamic stability rating, 2520.0 passing/mm. Meanwhile, asphalt concrete with 3% granite filler content attained the maximum dynamic stability value, 1465.1 passing/mm, surpassing that of cement filler of the same degree (1400 passing/mm).

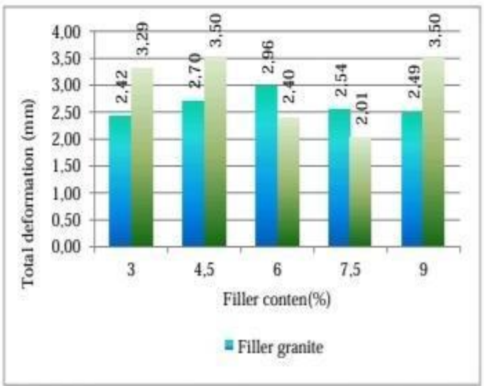


Figure 2: The depth of deformation on the pavement at 60^{0}C.

The graphic indicates that the deformation depth was not proportional to the filler content or kind. The smallest deformation (2.01 mm) in cement-filled pavement occurs at a filler level of 7.5%. On the granite filler pavement, the smallest distortion (2.42 mm) occurs at 3% filler content.

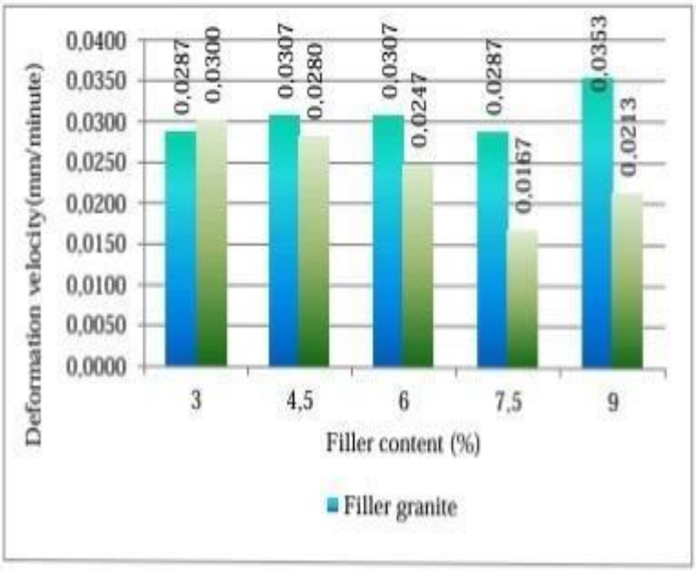


Figure 3: The deformation velocity of asphalt concrete

The diagram indicates that the relationship between deformation velocity and filler content was not linear, nor is the type of filler. The smallest deformation speed (0.0167 min/mm) was seen in asphalt concrete with cement filler with a filler percentage of 7.5%. The asphalt concrete with the granite filler variation had the smallest deformation velocity (0.0287 min/mm) at the 3% filler level. As the speed of deformation decreases, the value of dynamic stability increases, implying that the depth of deformation decreases.

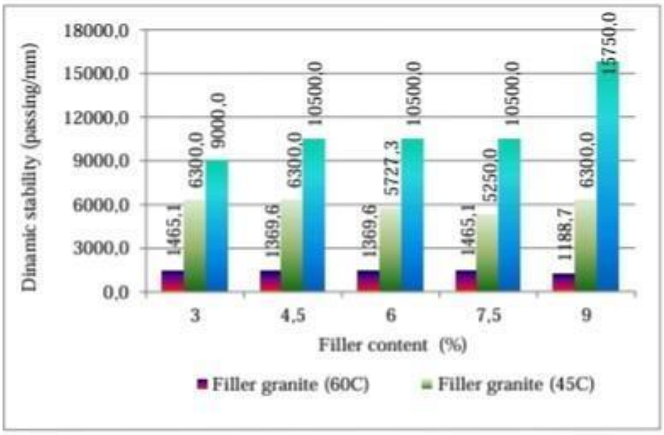


Figure 4: Dynamic stability and granite filling content

The picture indicates that when the temperature rises, the value of dynamic stability on the pavement decreases. The loss in dynamic stability was related to the asphalt's great sensitivity to temperature changes.

(Tiwari, Satyam &Miani, 2022) investigated the integration of MW as a filler at 4.5%, 5.5%, 7%, and 8.5% by weight in hot mix asphalt. The altered mixtures met the requirements for abrasion, moisture damage, and Marshall Stability tests. (Khan et al, 2023) did a similar investigation on the use of MW as a filler in hot mix asphalt, investigating filler amounts ranging from 0 to 6 wt. % of aggregates. The Marshall method (by impact) was used for dosing, which may not adequately reflect field rolling compaction conditions. With the limestone aggregates in the combinations, 4% MW was determined to be the optimal level. However, when the amount of filler (marble powder) in the asphalt mixture grew, the fatigue life decreased. De Medeiros et al. evaluated the feasibility of partially and totally replacing filler in hot asphalt mixtures with waste from the granite and marble industries. The commonly used filler, hydrated lime, was replaced with residue in proportions of 50% and 100% by weight. The results revealed that, as compared to the reference combination (having 0% residue), the asphalt mixture compromising waste marble and granite performed somewhat better mechanically. This was demonstrated by the lower ratio of the Resilient Modulus (RM) and Tensile Strength (TS), as depicted.

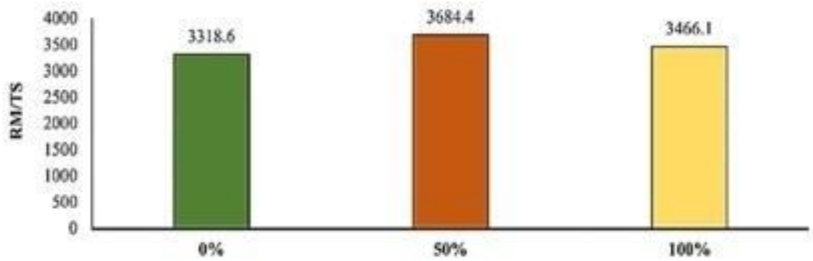


Figure 5: Resilient Modulus and Tensile Strength

2.5 Conclusion

-The higher the temperature on the pavement, will cause the value of dynamic stability to decrease.

- The use of cement filler with 7.5% content reaches the highest dynamic stability value, ie, 2520.0 passing/mm. Meanwhile, asphalt concrete with granite filler with 3% filler content reached 1465.1passing / mm.

- On asphalt concrete with variation of cement filler content, the smallest deformation (2.01 mm) occurs at 7.5% filler level. While on asphalt concrete with a variation of granite filler content, the smallest deformation (2.42 mm) occurred at 3% filler content.

-The smallest deformation speed (0.0167 min/mm) occurs in asphalt concrete with cement filler, at 7.5% filler content. While the asphalt concrete with the granite filler variation of the smallest deformation velocity (0.0287 min/mm) at 3% filler content.

-Where the Marshall method (by impact) was used for dosing, which may not adequately reflect field rolling compaction conditions. With the limestone aggregates in the combinations, 4% MW was determined to be the optimal level.

2.6 Physical and chemical properties of hydrated lime

Property / Test (Method)	**Recommended Value or Range**	**Citation**
Fineness / PSD (ASTM C110; EN 459-1)	≥99% passing 75 µm; ≥94% passing 45 µm; EN limit ≤7% residue on 0.09 mm	EN 459-1:2015; ASTM C110; Mississippi Lime datasheet
Bulk Density (loose/compacted)	≈560 / 670 $kg \cdot m^{-3}$	Mississippi Lime datasheet
Specific Gravity (true density)	≈2.3–2.34	Mississippi Lime datasheet
M Content (EN 459-1)	≤2%	EN 459-1:2015
$Ca(OH)_2$ Purity (Available Lime, EN 459-1; ASTM C25)	≥80% (EN min. for CL 90-S); many asphalt grades ~97%	EN 459-1:2015; ASTM C25
CaO + MgO Total	≥90%	EN 459-1:2015
MgO	≤5% (≤7% if soundness passes)	EN 459-1:2015

Table 1: Physical and Chemical Properties

2.7 Research Gap

Despite considerable global research, local data are scarce on the performance of lime-GSD asphalt mixtures in Uganda and other tropical countries. The majority of empirical studies are from temperate regions, which limits their relevance in East

Africa. There was also a need for practical dose standards that are specific to local materials and construction techniques. Without these, the use of lime-GSD technology in community-level projects remains hampered. Despite, it being more cost-effective and sustainable.

Although granite stone dust can enhance the mechanical behaviour of asphalt, it was prone to make workability difficult owing to its nature. Hydrated lime, on the other hand, offers a practical solution to improve adhesion, reduce plasticity, and enhance resistance to moisture. Several studies have documented how lime can facilitate compaction, enhance the binder coating, and increase the durability of asphalt mixes containing GSD. There are, however, significant gaps in our understanding of the behaviour of this mixture under Ugandan-specific climate and material conditions.

CHAPTER THREE: METHODOLOGY

3.0 Research Methodology

This chapter explores the process and approach that are going to be utilized to investigate the influence of the effect of hydrated lime on the workability of granite stone dust (GSD)-modified asphalt mixtures. The study adopted an experimental approach, involving laboratory testing for the evaluation of the material and the construction of asphalt mixtures, and to examine workability-related characteristics. This method was structured in relation to the objectives of the study, the characterisation of hydrated lime and the search for the most optimal method for producing its dosage, and comparing the workability of asphalt mixtures with and without hydrated lime.

This study adopted the design of comparative laboratory experiments. Two groups of asphalt mixtures were prepared, one using granite stone dust as the only aggregate and the other using a mixture of granite stone dust and progressively greater amounts of hydrated lime. The research was divided into three primary stages:

1. Material characterisation
2. Marshall mix design and hydrated lime content optimization
3. Workability testing and comparative analysis.
4. Development of a usable Marshall Mix Design

3.1 Materials and Equipment

The main materials to be employed in the research are:

1. Asphalt Binder (Penetration Grade 60/70)
2. Granite stone dust (GSD), derived from local quarries
3. Hydrated lime, from Tororo Cement
4. ASTM C33 specified coarse and fine aggregates.

To guarantee compliance with applicable requirements, all materials were air-dried, sieved to the required grade, and tested before use.

3.2 Laboratory Testing

Objective 1: Characterization of Hydrated Lime.

To analyse the physical and chemical properties of hydrated lime relevant to its behaviour as filler, the following experiments were performed:

Physical Properties

1. Fineness (Particle Size Distribution): To determine the particle size distribution the use of a dry sieve analysis method according to ASTM C110. Finer particles of lime promoted the packing density of the asphalt mix and enhanced the interaction of the binder and the aggregates leading to lower air voids and improving the workability.
2. Moisture Content: In order to prevent cracking during storage we determine the moisture content by the means of oven-dry method (ASTM C25), to make sure that the moisture content did not exceed 2%.
3. Bulk Density and Specific Gravity: The density values are crucial for volumetric calculations for the mix design. The standards were required to be 400-600 kg/m3 and 2.2-2.4 respectively.

Chemical Properties

Calcium Hydroxide Content (Ca (OH)2 Purity: The high purity is necessary for the neutralization of the acidic components and enhance better coating at the binder aggregate interface. We used acid-base titration to test for a purity (>90%) as per ASTM C25.

Minor Oxides (MgO and CaO): These two oxides play a crucial role in the asphalt mastic. The MgO influences soundness and the CaO influences Alkalinity. Utilized an XRF (ASTM C 25).

Objective 2: Determine the Optimal Hydrated Lime Content.

The approach for determining the most effective amount of hydrated lime in GSD-modified asphalt was as follows:

1. Marshall Mix Design: Asphalt specimens were created in accordance with ASTM D6926 specifications. Multiple batches were prepared, with 0%, 1%, 2%, 3%, and 4% hydrated lime substituting some of the GSD by weight. The optimum binder content (OBC) was determined for the control mixture using standard Marshall Stability and Flow analysis.
2. The optimum hydrated lime content was determined for each mixture using Marshall Stability and Flow analysis, as well as Bulk Density.
3. Preliminary Workability tests: To evaluate the ease of mixing, compaction, and handling, we performed a Marshall Flow, Stability, and the bulk density (Saturated Surface Dry Method),
4. Selection Criteria: The dosage with the best mix of workability and structural performance (stability, flow, and density) were deemed ideal.

Objective 3: Assessment of Workability.

Asphalt is a composite material; therefore, its workability is a composite property rather than a single measurable characteristic, like specific gravity. Instead, it’s a combination of a number of components that come together to give the asphalt composite its workability. That is to say, workability addressed the components of the composites ‘ease of mix-ability, compact-ability, and applicability. Therefore, a combination of tests was necessary to properly assess each characteristic to collectively assess the workability of the asphalt mixture.

The workability of asphalt mixtures—with and without hydrated lime—were tested using the following standard tests:

1. The Marshall Flow Test (ASTM D6927) measured the deformation of asphalt under load. Higher flow numbers typically suggest improved workability. That is the sample's vertical deformation at the peak load point. It gauged the mix's flexibility or plastic deformation. This was a direct indicator of workability. A mixture with a higher flow value was less stiff and more pliable, making it easier to compact and apply within the field without leading to segregation. The mix was brittle and stiff (poor workability) if the flow was very low. It was too plastic and prone to rutting if the flow was extremely high.
2. The Bulk Density Test (Saturated Surface Dry Method) determined compact-ability by measuring the density of the compacted material. The density of a compacted asphalt sample can be determined with great accuracy using this test. Three conditions are used to weigh the sample: dry, immersed in water, and saturated (surface-dry). We computed its volume and density using these weights. Compact-ability was the outcome of workability, and density was the gold standard for this. Every sample in the lab was compressed with precisely the same amount of energy (75 Marshall Hammer blows). By definition, a mix was more workable if it reached a higher density than another with the same compaction effort.

3.3 Materials and Sample Preparation

1. Asphalt Binder: A penetration grade asphalt binder that was compliant with ASTM D5 (Standard Penetration of Bituminous Materials Test Method)was sourced from the supplier to bring about consistency. The properties of the binder are instrumental in defining mixture behaviour. The binder was placed in temperature-controlled containers that are sealed at about 25 °C, as a precaution to inhibit aging. It was conditioned before the test, correct testing temperature (e.g.,60 °C) according to ASTM D36 (Standard Test Method for Softening Point).

2. Aggregates: Granite Stone Dust (GSD) was collected from the local quarries within Lweeza. It was important that it was representative of the real material that was used in the local pavement layers. The mineral composition and particle size distribution were checked. Standard coarse and finely aggregated materials were sourced with certified suppliers, in line with ASTM C33 (Standard Specification of Concrete Aggregates). Aggregates were dried in an oven at all-time sat a temperature greater than 105°for at least 24 hours to dry off Moisture, which may cause changes in mix properties.(ASTM C127, ASTM C128).

3. Hydrated Lime: Hydrated lime [$Ca(OH)_2$] of commercial grade were obtained at Tororo Cement and made according to the ASTM C110 specifications. The material dried in the oven at 105°C to remove any existing Moisture and then sieved with a .200 sieve (75 um) to assure uniformity of size of the particles. This fine particle size was critical to the successful sealing of pores between aggregates and enhancing mix density.

3.4 Material Characterization

3.4.1 Asphalt Binder Testing

Penetration Test (ASTM D5): The test was used to determine the consistency or the hardness of the Bitumen through the distance that a typical needle goes into a binder vertically sample.

Softening Point Test (ASTM D36): To establish the temperature at which Bitumen has a specific level of softness, which implies that it was vulnerable to temperature changes at which it passes between semi-solid and viscous liquid state.

Specific Gravity (ASTM D70): This will measure the density of the Bitumen, in comparison with water.

3.5 Aggregate Testing

1. Gradation Analysis: Sieve analysis in accordance with ASTM C136
2. Flakiness Index (FI): The shape and the elongation of the aggregate affects compaction. We Measured according to ASTM C136.
3. Specific gravity via ASTM C127.
4. Water absorption via ASTM C128, which was significant in assessing the Moisture-related durability issues.

3.6 Mixture Design and Preparation

The asphalt mix was designed based on the Marshall method (ASTM D1559) to establishing optimum binder content. We had a control mix and Modified mix. The control mix had no GSD and the Modified mix had hydrated lime of changing percentages.

Specimen Preparation

1. Heating: Blend the constituents at the right temperatures in order to guarantee proper coating and workability.

2. Mixing: Combination of hydrated lime and GSD were mixed with aggregate materials on a dry basis with the addition of binder to provide the uniform distribution.
3. Compaction: Marshal Compactor should be used to form target air voids and specimens density as per specification to ASTM D1559.
4. Curing: Room temperature (~25 C) conditioning of cooled specimens will take place at room temperature hours before testing in order to ascertain performance.

3.7 Testing Procedures

Workability Assessment

1. Flow and Consistency: The value of the flow that is realized in the process of compaction measured in millimetres was used as a measure of workability. The lower and higher flow values are the differences in the plasticity of the mixture and the ease with which it can be compacted (Asthana et al., 2015)

2. Compaction Effort: The number of blows to achieve the desired density in making the specimen was taken as an indirect measure of workability.

3.8 Quality Control and Validation

1. Each experiment was done thrice according to ASTM E691.
2. The equipment was also calibrated on a regular basis.
3. There were detailed records of processes, observations and variations during the experiment.

3.9 Work Plan/ Timeline

The study took approximately 8 months and was split into the following significant stages; proposal defence, material collection, mix design and lab testing, analysis of data, and report writing. The initial month was used to construct the research hypothesis, carry out review of literature, and writing the proposal to be approved. This was preceded by the purchase and manufacture of materials like the dust of granite stones, hydrated lime, and bitumen. Testing took a few weeks and it involved physical and chemical characterization of hydrated lime, Marshall Mix design formulation, and test of workability. These procedures were conducted according to ASTM and AASHTO standards, which guaranteed validity. The data gathered during the experimental stage were analysed, interpreted, and presented.

Budget

Activity	Cost, UGX
Materials Collection	400,000
Sample Preparation	150,000
Laboratory Fees	800,000
Transport	200,000
Documentation and Printing	100,000
Data Analysis Tools	100,000
Unforeseen costs	150,000
Total	1,900,000

Figure 7: Budget

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0 Results and Discussions

4.1 Introduction

This chapter introduces, explains as well as interprets the results of the preliminary material characterisation phase that are necessary in exploring the inherent aspects of the raw materials used in this paper. The physical properties, elemental composition and morphology of Granite Stone Dust (GSD) had been explored along with the chemical and physical properties of Hydrated Lime (HL) in the test certificate issued by the lab. These results form a good basis in analysing the behaviour of Granite Stone Dust modified asphalt mixes with a partial substitution of the substitute filler material with hydrated lime during subsequent stages of the experiment.

4.2 Characterisation of Hydrated Lime.

The hydrated lime (HL) used as the modifying agent in this study was acquired from Tororo Cement and was taken through the tests to establish its quality at the Central Materials Laboratory- Kireka.

In this section, the secondary data, as in the test certificate (Ref: CML: 012/26/08/25), was utilised to verify the quality of the material and also to gain deeper insight on the effect of the substance on the workability of the GSD modified asphalt mixtures because of the nature of its physical and chemical properties that have the potential to counter the shortcoming of the GSD nature.

Parameter	Achieved	Required (BS-EN 459-1: 2015
Calcium & Magnesium Oxides (%)	95	90
Availability Lime as Ca(OH)2	82	80
Total CaO content (%)	60.0	-
Total MgO content (%)	3.1	5
Free Water Content	0.5	2
Density (kgm-3)	874	-
Volume (m3)	3.43×10^{-4}	-
Specific Gravity	2.45	-

Table 2; Source: Secondary data from CML KirekaLab Test on Tororo Road lime

4.2.1 The physical and chemical properties of Hydrated lime

The test findings demonstrated that the procured hydrated lime was of good quality and met the required international construction lime standard, BS EN 459-1: 2015. Its physical and chemical properties had a great many positive implications on the workability challenge experienced by GSD-modified asphalt.

- Calcium and Magnesium oxides & Available lime: The combined Calcium and Magnesium Oxides content of 95% and Available Lime (as $Ca(OH)_2$) concentration of 82% exceeded the standard's minimum standards. This high purity was important to the material's reactivity. Lime (Ca(OH)2) that was available in asphalt mixes reacted with polar constituents in bitumen to form calcium soaps (Little and Epps 2006).

- Free water content: This test was done to determine the quantity of water in the hydrated lime. The amount of moisture in lime when its too high will cause foaming and release steam till it interacts with hot binder lime at (150-160°C) Moisture Water Content of 0.5% was extremely low which was a most desirable property. This adversely impacts the integrity of the mixture that might leave voids and weaken the structure of the mixture (Han et al., 2019). This lime had a low Moisture content which facilitated enhanced binder aggregate coating and compaction.
- Specific Gravity: The specific Gravity is necessary for volumetric calculations to facilitate carrying out of the Marshall mix design. This test identified the density of the hydrated lime in comparison with water. Specific Gravity of 2.45 calculated was found to be within normal range of hydrated lime (2.2 -2.4) as stated in literature and in the project proposal. The objective was to ensure the best balance of density and air voids is achieved.

The hydrated lime proved to possess adequate chemical and physical properties to facilitate the experimentation to understand the effect on the workability of the synergy between the GSD and hydrated lime mixture.

4.2.2 Particle Size Distribution

Percentage Passing (%)	Sieve Sizes
100	14
100	10
100	5
90	2
80	0.85
64	0.6
59	0.59
50	0.425
35	0.18
22	0.09
20	0.075
16	0.065
13	<0.065

Table 3; Source: Secondary Data from Lab analysis on Hydrated Lime

The particle size distribution of hydrated lime as determined by dry sieve analysis in accordance with BS EN 459-2:2021.

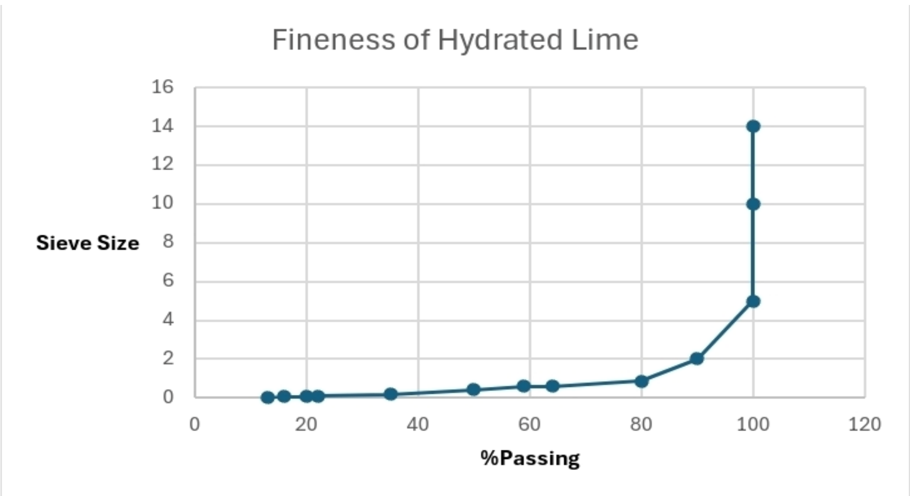


Figure 8: Fineness of Hydrated Lime

This test is very important, as it gave a measure of the fineness of the lime, which is a determining factor in its efficiency when mixed with the asphalt. The test revealed that the hydrated lime is very fine, having 100% of it pass through the 5.00 mm sieve and 20% of it pass through the 0.075 mm sieve, which is the No. 200 sieve. Its high fineness is important in the project due to the following reasons:

- Improved Reactivity and Filler Effectiveness: The higher surface area of the finer particles led to more points of contact between the particles and the asphalt binder to which chemical reactions could be enhanced. This led to more beneficial calcium soap formation at the asphalt binder and aggregate interface, which is basically how finer hydrated lime increased adhesion and reduced Moisture Susceptibility (Little and Epps, 2006). A finer lime is, therefore, a more reactive lime.
- Improved Workability and Lubrication. The small, spherical, smooth particles of hydrated lime worked as a physical lubricant when mixed with the angular and rough texture of the Granite Stone Dust (GSD). These particles filled up the spaces between the large, angular particles of GSD and aggregate. As a result, the friction between the particles decreased. Consequently, the interlocking of particles, which made the mix of GSD stiff and difficult to compact, and the workability issue plaguing this study were significantly reduced.

Therefore it can be concluded that the PSD proved that the hydrated lime possessed the necessary physical properties (fineness) to perform effectively either as a chemical modifier and adhesion enhancer, and/or a physical lubricant to take advantage of the workability provided by the stiff GSD-modified asphalt.

4.3 Granite stone dust: physical and chemical profile

In this study, we closely examined the granite stone dust (GSD), which is the primary filler to be used by utilised for experimentation. It is essential to understand the physical and chemical properties. To establish the composition of the granite stone dust, we conducted X-ray Fluorescence (XRF), and to evaluate the shape and surfaces, we conducted a scanning electron microscope (SEM) test, which provided important information to explain the workability problems associated with GSD-modified asphalt.

4.3.1. XRF Results for Granite Stone Dust

Table 4.1 shows the elemental composition of the GSD sample analyzed by XRF, expressed as oxide percentage, following the Government Analytical Laboratory

Summary of Granite stone dust properties		
XRF Analysis Results	Achieved (%m/m)	Required (%m/m)
Loss on Ignition	0.38	>5
Silicon Dioxide	72.301	>60
Aluminum oxide	14.653	Not Specified
Potassium oxide	4.447	Not Specified
Sodium oxide	3.121	Not Specified
Calcium oxide	1.863	Not Specified
Iron (III) oxide	1.732	Not Specified
Titanium oxide	1.1	Not Specified
Magnesium (II) oxide	0.474	<5
Phosphorus Pent Oxide	0.279	Not Specified

procedure (Job Desc: DFD 357/2025).

Table 4; Source: Primary Data from Analytical Lab

- Silicon Dioxide (SiO_2): The significant constituent is the high percentage of SiO_2, which is 72.30%. SiO_2 is a chief ingredient of quartz, which is very hard and often has very sharp edges after it has been crushed. These sharp edges are the reasons why mixes with the GSD were more frictional and stiffer (Oesman et al. 2021), which directly relates to workability.

- Aluminosilicate framework: The presence of high amounts of Aluminium Oxide (Al_2O_3), Potassium Oxide (K_2O), and Na_2O suggests the presence of feldspar minerals common in granitic rocks. The aluminosilicate component is another factor adding to the inert and stable composition of the mixture within the asphalt. Unlike cement and hydrated lime, which react and can work to improve cohesiveness, GSD does not take part in any pozzolanic reaction.
- Loss on Ignition (LOI):The low value of LOI, which is 0.38%, shows little presence of moisture, carbonates, and organics. It is an advantageous filler property because it translates to low volatility when mixed hot, which could result in voids and compromise the asphalt integrity.
- Calcium Oxide (CaO): CaO is merely 1.86%, which is substantially less than the CaO present in hydrated lime (60% total CaO content). This reflects a total inability on the part of GSD to show any chemical reactivity, which could otherwise act as a binding agent between the aggregate and binder.

4.3.2 Scanning Electron Microscopy (SEM)

SEM analysis gave information on the texture and shape of the particles of GSD. Refer to Figure 4.1, which is the SEM photograph, to supplement the information on the chemical workability.

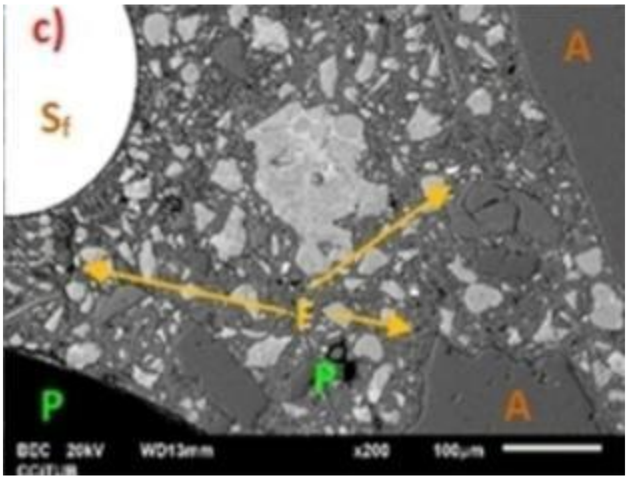


Figure 9; Source: Secondary data of the SEM imaging of Granite stone dust

- Particle shape and angularity: The particle shape and angularity of GSD are clearly angular, with sharp and broken edges. These are due to the fracturing of granite, which is a hard rock.
- Surface Texture: The particles are observed to have a rough, irregular structure under the microscope, which further increases the friction between the particles, thereby increasing the strength of the mixture.

Taking into consideration the above points, it could be said that the observations show that the GSD used was locally extracted siliceous filler, which is chemically inert and has very angular and rough particles.

4.3.2 Link to the workability

The primary particle regime-related factor behind the decreased workability associated with asphalt mixtures modified by the addition of GSD is the presence of angular and rough particles. During the mixture and compaction phases, such particles are reluctant to slide against each other and the aggregate, which is more difficult and also tends to generate inconsistencies associated with separation (Gudimettla et al., 2004). This is associated with decreased density and increased susceptibility to elevated pavement defects such as ravelling and cracking.

4.4 Marshall Properties of Asphalt Mixture with varying Lime content

The main objective of the experimental part of this research compromised batching and evaluating asphalt mixtures with varied percentages of Hydrated Lime (0%,1%,2%,3%,4%) partially replacing part of the Granite Stone Dust (GSD) filler. The table below compiles the Marshall Mix design results for every blend.

Lime Content (%)	Stabilty (KN)	Flow (mm)	ITS (kPa)	TSR (kPa)	Bulk density (kg/m^3)	Air voids(%)
0	13.3	3.3	1092	88	2.334	4.6
1	16.1	3.5	1146	90	2.34	4.6
2	14.7	3.4	1198	93	2.335	4.5
3	16.7	3.6	1288	96	2.344	4.3
4	12.8	4.2	1767	72	2.316	5.6

Table 5: Summary of Marshall Properties

4.4.1 Analysis of Marshall Properties

1. Marshall Flow: The sample's vertical deformation at the peak load point. It gauged the mix's flexibility or plastic deformation. This was a direct indicator of workability. A mixture with a higher flow value was less stiff and more pliable, making it easier to compact and apply with in the field without leading to segregation. The mix was brittle and stiff (poor workability) if the flow was very low. It was too plastic and prone to rutting if the flow was extremely high. The ease of particle rearrangement under stress can be directly measured in a lab setting using the Marshall Flow value. The Flow value was a strong and direct indicator of workability and

compact-ability since compaction in the field was the process of pushing particle rearrangement for densification. It was evident from our raising flow values with lime concentration that we are lowering internal friction and improving the mixture's workability.

In order to demonstrate that we had produced a workable but stable mix, we determined the lime concentration that provided us with a flow value within the ideal specification range (2-4mm). While a very high flow value can indicate a mix that was too plastic and prone to rutting, our optimal flow value of 3.6 mm for the 3% lime mix was a direct indicator of superior compact-ability. This was not about making construction easier for workers; it's about building a more durable road.

A workable mix ensures we can achieve the target density in the field. There are fewer and smaller interconnecting air voids in a mix that has better compact-ability. This was because the internal resistance caused by the interlocking of the GSD, was mitigated by the HL, making the mixture easier to mix and compact, therefore achieving a higher density. As a result, water was kept out by a homogeneous layer that was almost impermeable. This directly stopped the ravelling, stripping, and potholes we observed on the Lweeza road because water seeps into the already weakly bonded aggregates and binder, the main source of the stripping damage. This improvement was demonstrated by our ITS test, which showed that the 3% lime mix maintained its strength even when wet with a 96% TSR. An increase in the flow value from our control at 3.3 mm to 3.6 mm at 3%, improved the durability significantly of the asphalt mixture for the 15-25 year design life that it’s supposed to serve for.

Essentially, we are enhancing more than simply constructability by increasing workability (as indicated by the higher flow number). We are directly ensuring the development of a more uniform, denser, impermeable pavement structure that was intrinsically more resilient.

2. Marshall Stability: The Peak load that the sample can bear before failing. It gauged the mixture's shear strength to ensure we weren't creating a weak, mushy mix by increasing workability. We demonstrated that the lime-modified mixture was genuinely more robust and resilient to shoving and rutting under vehicles. When HL was added, Marshall Stability rose by up to 3%. With a peak stability of 16.7 kN, the 3% HL mix significantly outperformed the control mix by (13.3 kN). But at 4% HL, the stability fell to 12.8 kN, which was less than the performance of the control mix. Lime modification significantly increased stability, with the 3% lime mix showing the peak strength (16.7 kN)

   It's a frequent misconception that a more workable blend has to be weaker. Our findings clearly disprove this trade-off. Not only did the 3% lime mixture become easier to deal with, but it also became stronger and more cohesive by nature. In addition to being brittle, weaker, and unworkable, the control mix (0% lime) had the lowest stability. Internal friction and particle interlock created a weak, brittle form of strength that causes cracking, at the points of its stiffness.

   We replaced the brittle, frictional strength with cohesive, ductile strength by adding hydrated lime. Two things were done by the lime; it improved workability and decreased the detrimental internal friction by physically lubricating the angular GSD particles. It strengthened the binder-aggregate link chemically.

The end product was a mixture that was easier to compact and stronger under load. Not only was the 3% lime combination easier to use, but it also performs better overall. It possessed the structural strength to withstand rutting and deformation under traffic for many years to come, as well as the workability to be compacted into a dense, impermeable layer in the field.

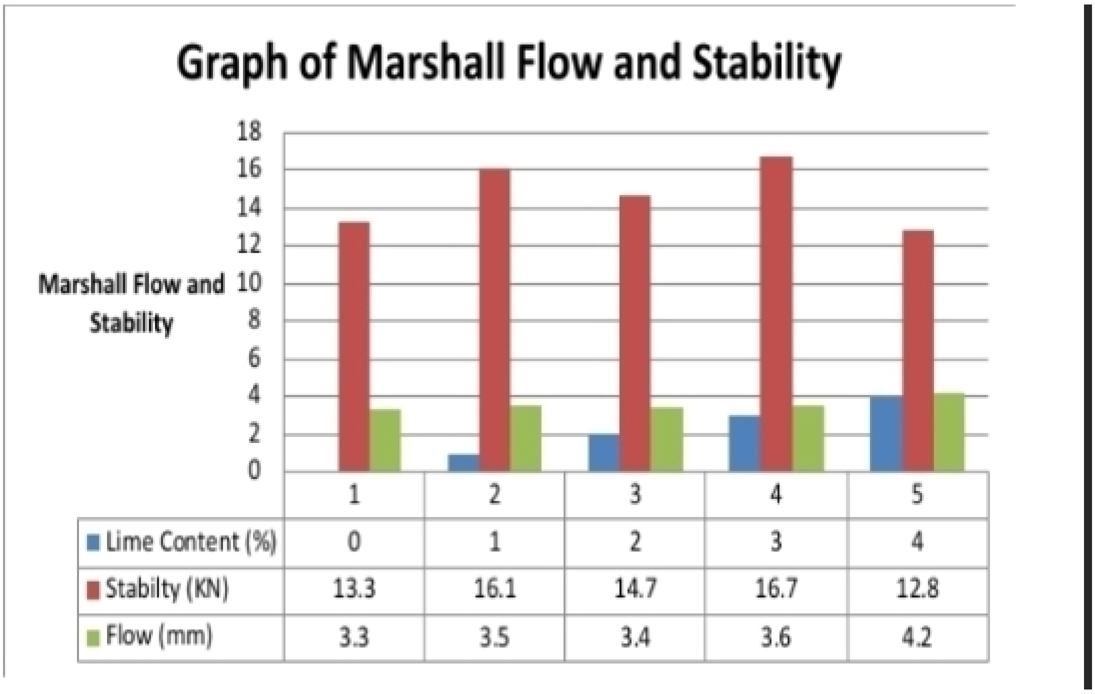


Figure 10: Graph of Marshall Flow and Stability

3. Density: This test can be used to measure density of compacted asphalt sample with a lot of accuracy. The sample is weighed in three conditions, namely, dry, in water, and saturated (surface-dry). With these weights we determined its volume and density. Determination of density is the gold standard for testing compact-ability. All samples in the laboratory are subjected to the same pressure (75 Marshall Hammer blows). Since mixes become more readily workable as their density increases, a higher density

achieved in one mix compared to another at the same compaction effort resulted in a more workable mix. The observation that our 3% lime mixture achieved the greatest specific gravity was sufficient testimony that it was the easiest to ram. The lime mix achieved a density of 2.344 kg/m3, the maximum compact-ability.

Density and durability are synonymous in asphalt construction. Increasing the workability does not only make the work of construction workers easier, but it also helped directly in achieving a construction material which was more resistant to failure.

4. Voids: The density achieved in the previous test and the theoretical maximum density of the mix facilitated the calculation of the percentage of small air gaps that were enclosed between the components. The air voids are vital to performance. Should it have been excessively low, this would have caused the asphalt to bleeding. The pavement will however become too permeable when the air voids are excessive. Moisture damage (stripping) can be induced by air and water intrusion through the voids and cause rapid binder aging. The huge air pores in the 0 % lime (control) mixture was a sign that it was hard to compress and was not easily workable. The 3 % lime mix achieved the optimal air voids about 4 %, which meant that we had the denser, optimised, and more workable mixture.

   The aim of this was a layer with semi-impermeability and possessing optimum voids. It is not so porous that the binder will ooze to the surface in hot climates, and it should also not be too impermeable so as to exclude most of the water and air, which will cause stripping and ageing. A pavement with optimal air voids experience wear and tear at a significantly slower rate. Attainment of the optimal air voids basically was the final and conclusive evidence that we had turned around the difficult to mix asphalt to a more workable and durable mixture.

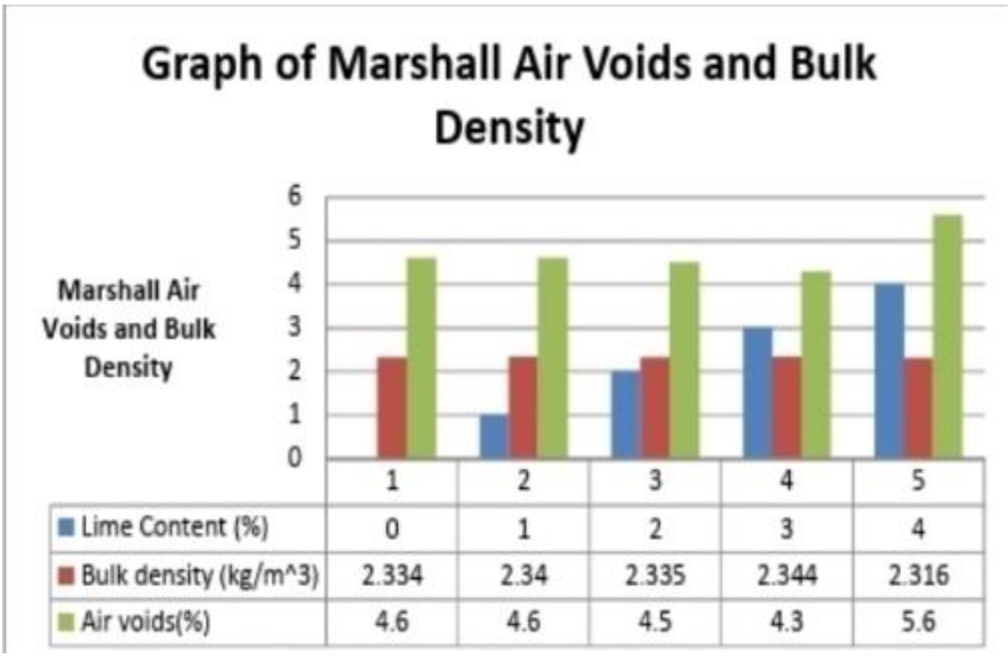


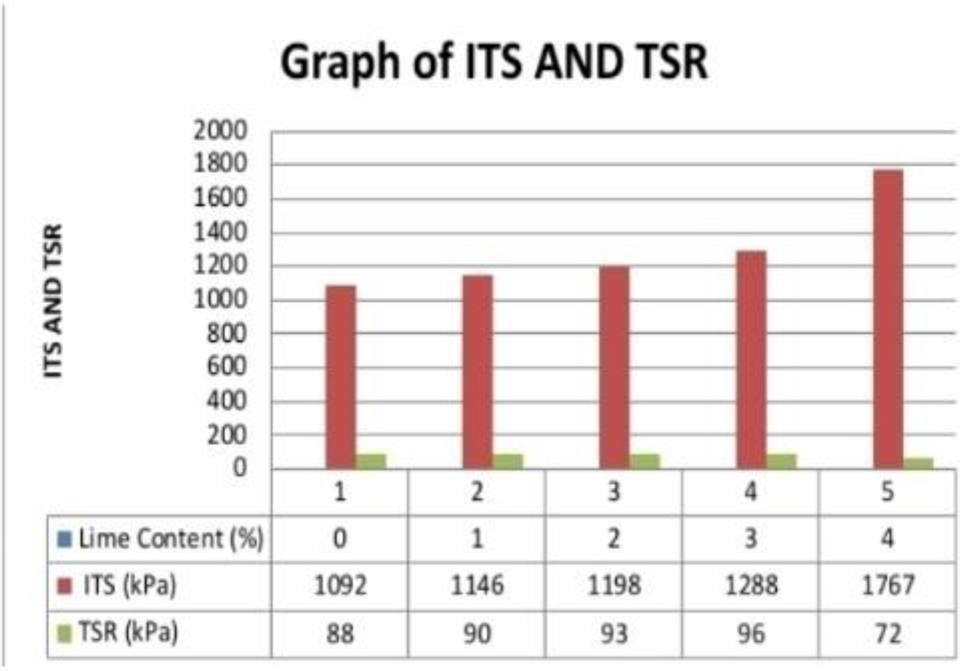
Figure 11: Graph of Marshall Air Voids and Bulk Density

5. Moisture Susceptibility: This test determined the level of resistance of the asphalt mixture to cracking. The compressed sample was loaded along its vertical diameter; the sample was subjected to a stress condition and was pulled horizontally until it did part. This is done by under two conditions:

   i. Dry Condition: The inherent tensile strength of the sample was tested
   ii. Wet Condition: Samples were investigated in vacuum-saturated condition and then conditioned in a water bath. This was done to test the durability of the sample when exposed to water for extended periods.

Our major failure mode in the Lweeza road was Moisture damage, which affected the weakly bonded aggregates and binder. The Tensile Strength Ratio (TSR) calculation formula was (Wet ITS/ Dry ITS) x 100%. The large TSR (specifications require it to have >80), indicated that the mixture was very resistant to shedding as it did not weaken under wet conditions.

All of the lime mixes passed, and the 3% mix achieved a TSR of 96%. This was strong evidence that hydrated lime chemically shielded the binder-aggregate link from water, thus resolving the underlying cause of the field failures.



	1	2	3	4	5
Lime Content (%)	0	1	2	3	4
ITS (kPa)	1092	1146	1198	1288	1767
TSR (kPa)	88	90	93	96	72

Figure 12: Graph of ITS and TSR

4.5 Summary

The findings showed that the characteristics of GSD-modified asphalt are greatly impacted by the addition of HL. While Flow has an increasing pattern up to 3% HL before a dramatic decrease at 4% HL, Marshall Stability first rises with HL content, culminating at 3% HL. According to TSR, the Moisture resistance steadily increases up to 3% HL but sharply declines at 4%

HL. Additionally, the 4% HL mix does not satisfy the requirements for ITS, VFB, Air Voids, and Stability. The 3% Hydrated Lime mix delivers the best overall performance, offering superior stability, excellent workability, optimal density, and the highest Moisture resistance.

4.6 The Mix Design

4.6.1 Aggregate Grading

Sieve (mm)	Smp1 Mass retained	Smp2 Mass retained	Av. Mass retained	% Av. Retained	% Av. passing	JMF	
						Lower	Upper
20	0.0	0.0	0.0	0.0	100	100	100
14	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				

Figure 13: Aggregate Blending

4.6.2 Aggregate Grading Curve

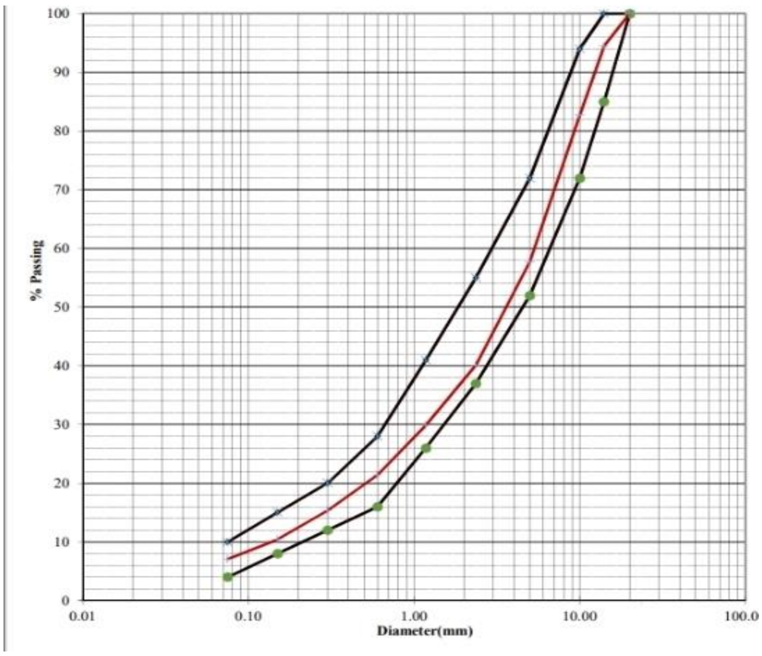


Figure 14: Aggregate Blending Curve

4.6.2 Aggregate Properties

Tests	Achieved	Specified
Water Absorption	0.3	<2%
TFV Dry	239.8	>110kN
TFV Soaked Wet/ Dry Ratio	99%	>75%
Flakiness Index	19.5%	<25%
LAA	16.9%	<30%
ACV	10.7%	<30%
AIV	16.4%	<30%

Table 6: Summary of Aggregate Properties

4.6.3 Bitumen Properties

Tests	Achieved	Specified
Penetration	65	60-70
Softening Point	49.3	49-56
Specific Gravity	1.012	1.01-1.06

Table 7: Summary of Bitumen Properties

4.6.4 Aggregate Blend at Optimum Hydrated Lime Content

Component	Proportion (% by Weight of Total Mix)	Specific Gravity	Water Absorption
14-20	4.8	2.623	0.2
10-14	6.7	2.618	0.3
6-10	17.1	2.614	0.3
0-6	62.5	2.621	0.3
Filler : GSD	2	2.635	
Filler : HL	3		
Bitumen Content	4.9	1.012	

Table 8: Mix Design proportions and Volumetric Properties

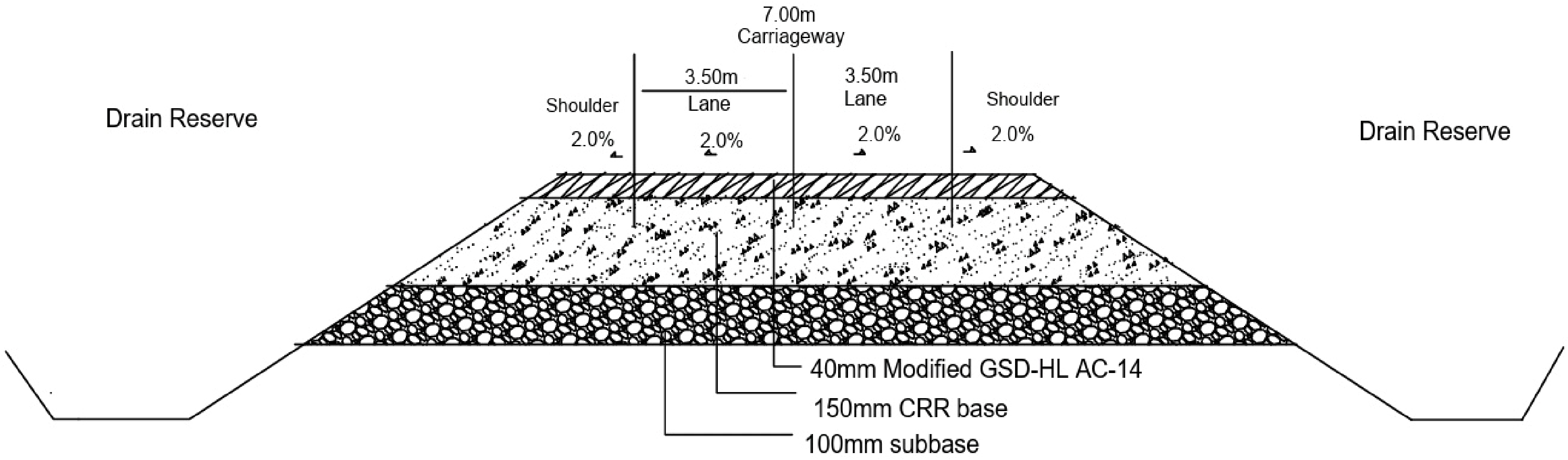
4.6.5 Volumetric Properties at Optimum Hydrated Lime Content

Properties	Acheived	Specified
Marshall Flow	3.6	2-4
Marshall Stability	16.7	9-18
Air Voids	4.3	3-5
Voids in Mineral Aggregates	15.5	>15%
Voids filled with Binder	72.0	65-75%
Indirect Tensile Strength @25C	1288	>800kpa
Tensile Strength Ratio	96	>80% of dry

Table 9: Volumetric Properties at Optimum Lime Content

Our Mix design was based on the Marshall Method. We first determined the Aggregate properties, performed tests to determine their Aggregate Impact Value, Aggregate Crushing Value, Ten Percent Fines Value, Flakiness Index, Las Angeles Abrasion and water absorption. We then determined the appropriate aggregate blend as per the AC-14 Gradation curve Specification for the different Aggregate sizes in our mix design. We then proceeded to determine the optimum Bitumen Content for our control with just the GSD, preparing 15 specimens for 3 samples at 5 different binder percentages, ultimately achieving our OBC at 4.9%.

To perform the partial Replacement of the GSD with the Hydrated Lime we kept the total Aggregate blend constant and only varied the composition of the filler which we was 4% supported by studies that found optimal hydrated lime content to be between 1-3%,(Ogundipe and Sukanmi, 2016) beyond which the benefits of the hydrated lime are negated. We partially replaced our filler content of 5% GSD in our control mix with hydrated lime at 1%, 2%, 3%, and 4% maintaining the filler content at 5% and partially replacing with lime at the different percentages. The optimal hydrated lime content is at 3%.



Layer	Thickness	Material Specification
Wearing Course (surface layer)	40mm	Granite stone dust modified AC-14 with 3% Hydrated Lime
base Course	150mm	150mm of crushed stone base (CRR coarse type min 102% of BS-heavy compaction according to BS1377: Part 4)
Subbase Course	100mm	100mm of natural gravel or crushed rock (Min 98% of BS-heavy compaction according to BS:1377:Part 4)

TYPICAL CROSS SECTION	
PROJECT TITLE	EVALUATING THE EFFECT OF HYDRATED LIME ON THE WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURES
AUTHOR	AINEBYONA SHADRACH AHUMUZA
REG NUMBER	M22B32/032
SCALE	1:50 (A3)

4.7 Design Application

The laboratory experiment results that showed optimal performance of 3 % hydrated lime content were applied into a proposed pavement design to apply in the Lweeza community and other low-volume roads nationwide. Figure 8, the proposed cross-section integrating our GSD-HL Asphalt design, integrates a combination of the optimized granite stone dust modified asphalt with the hydrated lime to the pavement structure, which will be based on the general principles and standards of pavement design and the results of the given research.

The 40 mm wearing course makes use of the AC-14 graded asphalt mixture and the granite stone dust filler has been partially substituted with hydrated lime 3%. This is the minimum thickness required by Ugandan road design manual of surface courses on residential and access roads (Ministry of Works and Transport, 2018). This is directly applied to the overall material composition where 3% HL has 3.6mm Marshall Flow and 16.7 kN Marshall Stability which is greater than the 9 minimum set by UNRA and offers 96 % moisture resistance; essential in the tropical climates.

Under it, the base course of 150 mm crushed stone has primary structural capacity for effective load distribution. The material complies with Standard Materials Tests of crushed rock base with CBR equal to or higher than 80%, Los Angeles Abrasion equal to or less than 30 %, compacted to 102 % BS heavy compaction. This is combined with a 100 mm granular subbase acting as both a capillary break and construction platform using a thickness which is optimized according to the TRL Overseas Road Note 31 (2004) recommendations for tropical areas where moisture control is the key factor.

The cross-section geometry integrates a 2% cross-fall across the 7.00 m carriageway and that satisfies the minimum required on the surface to aid drainage as per Ugandan Road Design Manuals.

The proposed cross-section has been designed to match laboratory data to field-implementable specifications, giving contractors and the Ministry of Works and Transport for implementing sustainable GSD-HL asphalt in local infrastructure projects.

4.8 Discussion of results

4.8.1 Introduction

This chapter provides an in-depth discussion and interpretation of the results from our experimentation in chapter 4. The findings were analysed relative to our research objectives and the literature review done in chapter 2. This section discusses the observed effects of the hydrated lime on the workability, mechanical properties, volumetric characteristics and the overall durability of Granite stone dust modified asphalt mixtures.

4.8.2 Material Characterization

1. **Granite Stone dust**

   Granite Stone Dust (GSD): The XRF analysis indicated high silica content (72.30% SiO_2) and the SEM images demonstrated very angular, rough-textured particles scientifically explain the field observations. Siliceous aggregates are known to have poor physicochemical affinity for asphalt binders, leading to weak adhesion. Also, the angularity and roughness created high levels of internal particle-to-particle friction, which was directly proportionate to high mixture stiffness and resistance to rearranging the particles during compaction. This inherent material property sets an upper limit to potential field density no matter how much effort was put in the workmanship.

2. **Hydrated Lime**

   Hydrated Lime (HL): The test certificate showed that the lime purchased was of high purity (82% Available Lime, Ca(OH)2) and fineness (20% below 0.075 mm). The purity was high and offered strong chemical interaction with the bitumen, and the small size of the particles was suitable in two important roles,

   1) As a physical lubricant between large GSD particles, and

   2) Provided a high surface area to reaction with chemicals. The low moisture level (0.5) was needed to reduce the foaming and steam formation during the heat mixing to maintain the integrity of the mix.

3. **Workability**

   Marshall Flow: The value of the Marshall Flow increased with the lime content; this was in confirmation of a high workability. The 4% lime mix has however gone above specification limit (4.2 mm was the upper limit on specification) and it can be seen to be too soft. The hydrated lime addition caused a steady rise in the values of Marshall Flow. This affirmed that lime was effective in resolving the brittleness of the granite stone dust mix that was stiff and difficult to work with. The optimal dosage was found to be the 3 % hydrated lime mixture. It provided the greatest Marshall Stability (16.7 kN), great workability (Flow = 3.6 mm), the maximum bulk density, and high level of resistance to Moisture damage.

The Density and Air Voids: Density was the most direct laboratory gauging of workability created through compaction. The HL acceleration with 3% mixing reached the highest bulk density (2.344 g/cm3) and the lowest air voids (4.3 %). This portrays clearly high compact-ability. The fine HL particles under the same conditions of 75-blows of the Marshall compaction were shown to efficiently lubricate the angular GSD, reducing inter-particle friction of the substance and allowing aggregates to efficiently restructure to a denser form. Conversely, HL mix (4% HL) exhibited low density and high air voids (5.6%), which was an indicator of hard combination (harsh) and over-filled mixture that was not easy to compact.

4. **Moisture Susceptibility**

The 4% lime mix shows the highest tensile strength (1767 kPa) and the control mix (0% lime) had the lowest Moisture resistance. All lime-modified mixes passed (TSR > 80%). Hydrated lime significantly improves moisture resistance, reducing the potential for stripping. This was a performance indicator that showed how the hydrated lime improved the workability of the asphalt mixture, and henceforth improved the performance of the mixture.

5. **Optimal Hydrated Lime Content**

The most efficient dosage that was shown to be the most effective in terms of balance was the 3% HL dose, which demonstrated peak stability (16.7 kN), good balance of density and air voids, proper flow value by specification being able to deliver good working strength without involving an insufficient degree of flexibility, and the best resistance to Moisture. This would be in accordance with results provided by Ogundipe and Sukanmi

(2016), who noted that the benefits of HL are the most significant in an interval of 1-3%.

6. Addressing the Research Objectives and Problem

This research successfully addressed all four objectives:

1. Characterize HL: HL had been established as a fine, high purity and chemically suitable modifier.

2. Identify the Ideal HL Content: The optimum HL content was identified as 3% of the total aggregate by weight.

3. Determine Workability: The 3% HL mix exhibited excellent capacities to compactness (maximum density), excellent stability and a flow value indicative of a workable non-brittle mix.

4. Design a Mix: Combinations of Job Mix Formula (JMF) and performance requirements have been established to be used with 3% HL-modified GSD asphalt (Section 4.6).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.0 Conclusion and recommendation

5.1 Conclusion

The hydrated lime was added, which then resulted in a steady rise in the values of Marshall Flow. This proves that lime was a very good solution to the stiffness and hard-to-work granite dust mix which makes it more compact in construction. The mixed dosage of the 3% hydrated lime was found to be the best. It provided the maximum Marshall Stability (16.7 kN), high workability (Flow = 3.6 mm), the maximum bulk density, and the great resistance to the damage by Moisture. The 80% TSR specification was reached in all mixes that were lime-modified with ease. The 3 percent lime mixture recorded a TSR of 96 percent, which confirmed lime as a good anti-stripping agent even in the tropical climates. This research was effective in showing that substitution of granite stone dust with hydrated lime in a partial state by 3% offers an asphalt mixture which was so much easier to work with and stronger, more stable and very resistant to water damages. Hence, reduce the premature failure and enhance the durability of the pavements.

5.2 Recommendation

1. We suggest that the Ministry of Works and Transport (MowT) and local contractors should use 3% hydrated lime content, which was a standard when using the granite stone dust as filler in asphalt on low-volume roads.

2. Investigate the long-term field performance and aging characteristics of the optimized lime-GSD mix under actual Ugandan traffic and environmental conditions.
3. The use of granite stone dust (an industrial by-product) combined with a small amount of lime presents a cost-effective and sustainable solution for road construction.
4. The results of the present study must be included in the national paving specifications and guidelines to enhance the durability and the performance of road pavements in Uganda.

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APPENDICES

Appendix 1: Marshall Flow and Stability Testing

Appendix 2: Mixing of Bitumen and aggregates for Marshall Compaction

THE REPUBLIC OF UGANDA

MINISTRY OF WORKS AND TRANSPORT
MATERIALS TESTING AND RESEARCH DIVISION
CENTRAL MATERIALS LABORATORY- KIREKA
P.O Box 7174, Kampala-Uganda Tel 256-414-387132, Email: cml@works.go.ug

TEST CERTIFICATE FOR SAMPLE OF LIME FOR SOIL STABILIZATION

CLIENT : M/S EGISS ENGINEERING CONTRACTORS LTD

PROJECT : CONSTRUCTION OF TRADING COMPLEX AT NATIONAL FARMERS LEADERSHIP CENTRE-MPIGI DISTRICT

DATE : 05 SEPTEMBER 2025

Test Standards and Methods: BS EN 459-2:2021 and BS EN 459-1: 2015

Material Description/ Source: Tororo Road lime

Job ref: CML: 012/26/08/25

A. Physical properties

Norminal aperture Size of sieves (mm)	Sample label		Specifications		
	Percentage retained (%)	Percentage passing (%)	BS EN 459-1:2015 (%)	US 288:2001 (%)	AASHTO M216 (2002) (%)
14.00	0	100	-	-	
10.00	0	100	100	-	
5.00	0	100	95 minimum passing	-	
2.00	10	90	-	-	
0.850	10	80	-		
0.600	16	64	-	2.5 maximum retained	3 maximum
0.590	5	59	-	-	
0.425	9	50	-	-	
0.180	15	35	-	-	
0.090	13	22	-	-	
0.075	2	20	-	35 maximum retained	25 maximum retained
0.065	4	16	-	-	
< 0.065	3	13	-	-	

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CHIEF MATERIALS ENGINEER

THE REPUBLIC OF UGANDA

MINISTRY OF WORKS AND TRANSPORT
MATERIALS TESTING AND RESEARCH DIVISION
CENTRAL MATERIALS LABORATORY- KIREKA
P.O. Box 7174, Kampala-Uganda, Tel: 256-414-287132, Email: cml@works.go.ug

TEST CERTIFICATE FOR SAMPLE OF LIME FOR SOIL STABILIZATION

CLIENT : M/S EGISS ENGINEERING CONTRACTORS LTD

PROJECT : CONSTRUCTION OF TRADING COMPLEX AT NATIONAL FARMERS LEADERSHIP CENTRE-MPIGI DISTRICT

DATE : 05 SEPTEMBER 2025
Test Standards and Methods: BS EN 459-2:2021 and BS EN 459-1: 2015
Material Description/ Source: Tororo Road lime
Job ref: CML: 012/26/08/25

B. Chemical properties

Parameter	Result (%)	Specifications		
		BS EN 459-1:2015 (%)	US 288:2001 (%)	AASHTO M216 (2002) (%)
Calcium and Magnesium Oxides CaO +MgO,(on loi free basis)	95	90 minimum	75 minimum	90 minimum
Available lime as Ca(OH)2 (%)	82	80 minimum	60 minimum	
Total CaO content (%)	60.0	-	-	
Total MgO Content (%)	3.1	5 maximum	-	
Free water content (%)	0.5	2 maximum	3 maximum	5 maximum
Density (kg/m^3)	874	-	-	-
Volume (m^3)	3.43×10^{-4}	-	-	-
Specific Gravity	2.45	-	-	-

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CHIEF MATERIALS ENGINEER

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

FOR GOD AND MY COUNTRY
THE REPUBLIC OF UGANDA

MINISTRY OF INTERNAL AFFAIRS
DEPARTMENT OF GOVERNMENT ANALYTICAL LABORATORY
Plot No. 2 - 4 Lourdel Road
Wandegeya,
P.O.Box 105639
Kampala - Uganda

DFD 357/2025
24th September 2025

MR. AHUMUZA SHADRACH AND MR. UWIMANA MBONYE DICKSON
REG NO. M22B32/032 & S20B32/025
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4, MUKONO-UGANDA
Tel: 256-709-146275

REPORT OF ANALYSIS

Description of the Samples

One sample in black polythene bag containing Granite stone dust sample was submitted by Mr. Ahumuza Shadrach, on 17th September 2025, and analysed on 22nd September 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Granite stone dust packed in a black polythene bag.	01	Sample "A" DFD 357/2025

Analysis Requested

Elemental analysis

Method of Analysis

Elemental analysis was done using the XRF Method

Results of Analysis

The above sample has been analyzed with the following results as below,

Parameter	Units	DFD 357/2025 Granite Powder
Loss on Ignition	% m/m	0.38
Elemental Composition		
Silicon dioxide	% m/m	72.301
Aluminium oxide	% m/m	14.653
Potassium Oxide	% m/m	4.447
Sodium Oxide	% m/m	3.121
Calcium oxide	% m/m	1.863
Iron (III) Oxide	% m/m	1.732
Titanium dioxide	% m/m	1.100
Magnesium (II)Oxide	% m/m	0.474
Phosphorous pent oxide	% m/m	0.297

Remarks

1. Results relate to sample analyzed and are reported as on received basis.

24/09/25
Semalago Fredrick
Government Analyst

"Go Scientific for a Safe and Just Society"

Page 1 of 1

|

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	
TRUCK No.	0 FROM STOCKPILE	TESTED DATE. 01-Oct-25

Delivered date	1-Oct-25	OPERATOR	Lab team
SUPPLIER			
TEST METHOD: EN 12591-2000		CONTAINER NO.	0
	1-Oct-25		
BITUMEN TYPE		TRUCK NO	0

BITUMEN TESTS

TEST NO	18'		6		18	R7	NG	CX	AVERAGE	TEST METHODS	REMARKS
PENETRATION 100gr 5 sec 25 C	63 65 64		66 65 65		65 65 64	63 66 67	65 65 63	65 65 67	65	ASTM D5	60-70
SOFTENING POINT (°C)		49.0		49.5					49.3	ASTM D36	(48-56)°C
BITUMEN AFFINITY									>95		>95
SUPECIFIC GRAVITY	1.013		1.017		1.014	1.014	1.006	1.009	1.012	ASTM D70	1.01-1.06

Observation

Testing Lab

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

INSTITUTION	STUDENTS	TESTING LABORATORY
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

SOFTENING POINT

SAMPLE REF	0	TECHNICIANS	
BITUMEN TYPE		SAMPLING DATE	1-Oct-25
SUPPLIER		TESTING DATE	1-Oct-25
LOCATION OF SAMPLING			
TEMPERATURE		BATH FLUID	

TIME (MINUTES)	TEMP °C	TEMP RISE °C		TIME (MINUTES)	TEMP °C	TEMP RISE °C
0	11.0	11.0		0	11.0	11
1	13.0	2.0		1	13.0	2
2	15.0	2.0		2	15.0	2
3	18.0	3.0		3	18.0	3
4	21.5	3.5		4	21.5	3.5
5	25.0	3.5		5	25.0	3.5
6	29.0	4.0		6	29.0	4
7	33.0	4.0		7	33.0	4
8	36.0	3.0		8	36.0	3
9	40.0	4.0		9	40.0	4
9	44.0	4.0		10	44.0	4
9	49.0	5.0		11	49.0	5
				12	49.5	0.5

	RING 1		RING 2		AVERAGE
SOFTENING POIT(°C)	49.0		49.5		49.3

REMARKS

STIRLING CIVIL ENGINEERING LTD
23 NOV 2025
P.O. BOX 70... KAMPALA (U)
...Lab

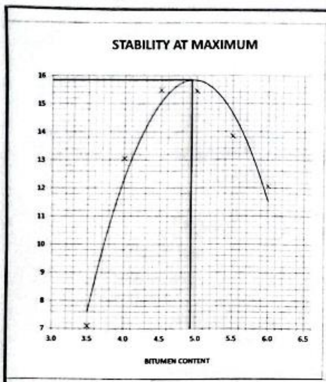
INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	NEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON M	Stirling

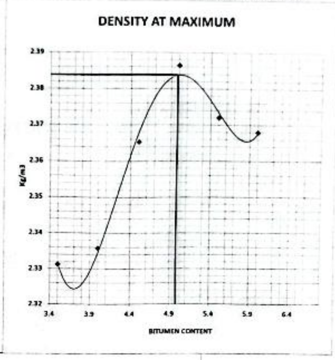
PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

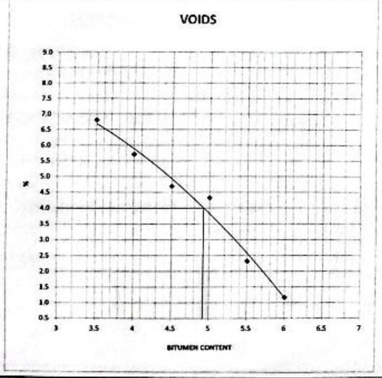
TEST	BULK SPECIFIC GRAVITY OF BITUMEN					
Test Reference No.:						
Sample no:			Technician :	Lab team		
Grade			Sampling date:	1-Oct-25		
Source of the sample	FROM STOCKPILE		Testing date:	1-Oct-25		
Temperature of the Test:	.					
Cup No.		18'	6	18	R7	NG	CX
Weight of cup in air	A	111.88	111.87	112.03	111.90	112.10	111.94
Weight of cup filled with water	B	191.07	191.33	190.82	191.28	191.57	191.48
Weight of cup partially filled with bitumen in air	C	176.58	177.27	178.46	176.27	176.72	176.25
Weight of cup filled with bitumen & water	D	191.88	192.44	191.71	192.14	191.96	192.05
Volume of the cup	B-A	79.2	79.5	78.8	79.4	79.5	79.5
Weight of bitumen	C-A	64.700	65.400	66.430	64.370	64.620	64.310
Volume of the water above bitumen level.	D-C	15.300	15.170	13.250	15.870	15.240	15.800
Volume of the bitumen	((B-A)-(D-C))	63.890	64.290	65.540	63.510	64.230	63.740
Bulk specific gravity of bitume (Gb)	(C-A)/((B-A)-(D-C))	1.013	1.017	1.014	1.014	1.006	1.009
Average Bulk specific gravity of bitumen (Gb)		1.012					
		TESTING LAB					

STIRLING CIVIL ENGINEERING LTD
NOV 2025
P. O. BOX [illegible], KAMPALA (U)

AC 14 JOB MIX DESIGN







DATE: 02-10-2025

Optimum Bitumen

Stability	4.9	%
Density	5.0	%
Voids	4.9	%
Average	4.9	

MIX PROPORTION

FILLER	5	%
Q / Dust	68	%
10mm	15	%
14mm	7	%
20mm	5	%
TOTAL	100	

Summary for Optimum BitumenContent Determination Data

BITUMEN %	3.5	4	4.5	5	5.5	6	
DENSITY	2.33	2.336	2.365	2.386	2.372	2.368	
STABILITY	7.1	13.0	15.5	15.4	13.8	12.1	
FLOW	2.63	2.45	2.6	2.8	[illegible]	3.5	
VOIDS	6.8	5.7	4.7	4.3	[illegible]	1.2	

Signed:

Contractor:__________

STIRLING CIVIL ENGINEERING LTD
23 NOV 2025
P. O. BOX 793, KAMPALA (U)

CONSULTANT	CLIENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

INDIRECT TENSILE STRENGTH

BITUMINOUS MIXTURE SAMPLED ON 11/10/2025 102 GMM 2.454 Bit.content,% 4.9 NO OF BLOWS 54

SAMPLE NO.	THICKNESS				Compacted material parameters										
	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 (%) =100*(F-E)/F spec min 3.0% G
MIX	4% HYDRATED LIME AS PART OF FILLER														
WET															
1	63.7	64.0	63.9	63.9	1201.2	682.0	1208.4	526.4	2.259	2.454	41.860	1220.7	19.500	46.583	8.0
2	64.2	63.8	64.0	64.0	1210.2	692.5	1219.4	526.9	2.274	2.454	38.730	1228.0	17.800	45.959	7.4
DRY															
3	63.2	63.1	63.7	63.3	1194.2	682.0	1202.6	520.6	2.271	2.454	38.884				7.5
4	62.7	63.1	62.8	62.9	1193.6	683.0	1205.9	522.9	2.260	2.454	41.426				7.9

INDIRECT TENSILE STRENGTH

DRY						WET							
SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH,S_t	AVERAGE TENSILE STRENGTH,S_t	SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH,S_t	AVERAGE TENSILE STRENGTH,S_t		WET/DRY
	div	kn/div	kn	spec min 800 kPa			div	kn/div	kn	kPa	kPa	S_t =2P/∏tD where P= maximum load(N) t=specimen thickness(mm) D=specim	spec 80%
3	48	0.2312	11.1	1,084.1	1,058.3	1	33	0.2312	7.6	745.3	767		72
4	45	0.2312	10.4	1,032.5		2	35	0.2312	8.1	788.8			

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
23 NOV 2025
P.O. BOX 750, KAMPALA (U)

CONSULTANT	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref. No.		Lab. no.	MIX	4% HYDRATED LIME AS PART OF FILLER	Sampling date	11-Oct-25	Test Type	Done by	Test Type	Done by
Sample grade	AC 14	Compaction: 75 blows			Testing date	12-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description			AC 14				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/m^3)	% Air Voids	% VMA	% VFB	Marshall Heights (mm)			Av. Hgt (mm)	Corr. Factor	Stability (KN) Measured	Stability (KN) Adjusted	Flow (mm)	Ratio (Stab./Flow)
1	1203.0	690.00	1206.70	2.328	2.317	5.6	15.6	64.2	63.2	62.8	63.2	63.1	1.01	12.0	12.14	4.12	2.947
2	1207.0	690.20	1209.70	2.323	2.312	5.8	15.8	63.3	64.0	63.7	63.8	63.8	0.99	12.7	12.59	4.34	2.901
3	1198.1	685.40	1200.80	2.325	2.313	5.7	15.7	63.6	63.7	63.4	63.8	63.6	1.00	12.5	12.48	4.46	2.799
4	1209.7	692.30	1210.50	2.334	2.323	5.3	15.4	65.3	63.5	63.4	63.3	63.4	1.00	14.1	14.10	3.75	3.761
Average Sample 1				2.328	2.316	5.6	15.6	64.1	Average Sample 1			63.5	1.0	12.8	12.8	4.2	3.1
-				-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Sample 2									Average Sample 2								
Average Sample 1 & 2				2.328	2.316	5.6	15.6	64.1	Average Sample 1 & 2								

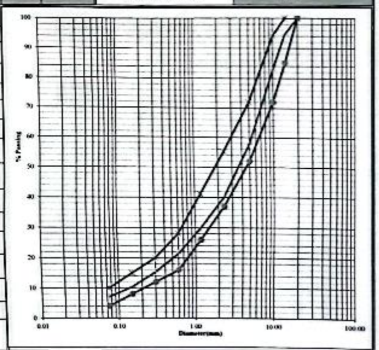
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractio	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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

SAMPLE 1			SAMPLE 2		
(Pycnometer with Water)			(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	2	Test No-	1	2
Asphalt	1162.1		Asphalt	1110.1	-
Pycn. + Water	8553.5		Pycn. + Water	8553.5	-
Pycnometer + Asph. + Water	9242.5		Pycnometer + Asph. + Water	9210.9	-
Volume of asphalt	473.1	-	Volume of asphalt	452.7	-
G_{mm}	2.456	-	G_{mm}	2.452	-
Av. G_{mm}	2.456		Av. G_{mm}	2.452	
Av. Gmm (Kg/m3) Sample 1& 2			2.454		

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



Comment:

FOR TESTING LAB

Materials Engineer

STIRLING CIVIL ENGINEERING LTD

2 3 NOV 2025

..., KAMPALA (U)

CONSULTANT	CLIENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

INDIRECT TENSILE STRENGTH

BITUMINOUS MIXTURE SAMPLED ON 20/10/2025 | 102 | GMM 2.445 | Bit.content,% 4.9 | NO OF BLOWS 54

SAMPLE NO.	THICKNESS: HEIGHT 1 (mm)	HEIGHT 2 (mm)	HEIGHT 3 (mm)	Av. Thickness (mm)	Compacted material parameters: 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 (%) =100*(F-E)/F spec min 3.0% G
MIX	2% HYDRATED LIME AS PART OF FILLER														
	WET														
1	64.1	63.7	64.1	64.0	1195.0	683.0	1197.5	514.5	2.299	2.445	30.677	1217.3	22.300	72.693	6.0
2	63.5	63.8	63.7	63.7	1201.1	688.0	1202.5	514.5	2.311	2.445	28.207	1217.9	16.800	59.559	5.5
	DRY														
3	64.2	64.0	64.2	64.1	1189.0	679.0	1194.0	515.0	2.286	2.445	33.606				6.5
4	63.7	63.1	6300.0	2142.3	1179.5	675.0	1184.0	509.0	2.294	2.445	31.453				6.2

INDIRECT TENSILE STRENGTH

DRY: SPECIMEN No	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH,S_t	AVERAGE TENSILE STRENGTH,S_t	WET: SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH,S_t	AVERAGE TENSILE STRENGTH,S_t		WET/DRY
	div	kn/div	kn	spec min 800 kPa			div	kn/div	kn	kPa	kPa	S_t =2P/∏tD where P= maximum load(N) t=specimen thickness(mm) D=specim	spec 80%
3	62	0.2312	14.3	1,398.1	1,288.1	1	54	0.2312	12.5	1,217.7	1,198		93
4	52	0.2312	12.0	1,178.1		2	52	0.2312	12.0	1,178.1			

FOR TESTING LAB

CONSULTANT	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref. No	Lab. no.	MIX	2% HYDRATED LIME AS PART OF FILLER	Sampling date:	20-Oct-25	
Sample grade AC 14	Compaction: 75 blows			Testing date:	21-Oct-25	
Sample Description		AC 14				

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.

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
1	1193.4	685.00	1194.30	2.343	2.332	4.6	15.3	69.7
2	1171.5	675.30	1173.50	2.351	2.340	4.3	15.0	71.3
3	1186.6	684.30	1189.90	2.347	2.336	4.5	15.1	70.4
4	1192.0	685.40	1193.90	2.344	2.333	4.6	15.2	69.9
Average Sample 1				2.346	2.335	4.5	15.2	70.3
-				-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2				2.346	2.335	4.5	15.2	70.3

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)
62.6	62.7	63.0	62.8	1.02	15.2	15.49	3.27	4.737
61.7	61.9	61.7	61.8	1.04	15.6	16.22	3.64	4.456
62.5	62.8	62.7	62.7	1.02	14.4	14.65	3.59	4.081
62.9	63.2	62.7	62.9	1.02	13.5	13.81	3.36	4.111
Average Sample 1			62.5	1.0	14.7	15.0	3.5	4.3
-	-	-	-	-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2								

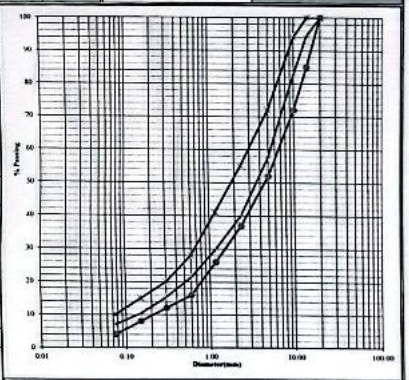
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractio	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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

SAMPLE 1			SAMPLE 2		
(Pycnometer with Water)			(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	2	Test No-	1	2
Asphalt	1207.2		Asphalt	1180.3	-
Pycn. + Water	8553.5		Pycn. + Water	8553.5	-
Pycnometer + Asph. + Water	9266.9		Pycnometer + Asph. + Water	9251.2	-
Volume of asphalt	493.8	-	Volume of asphalt	482.6	-
G_{mm}	2.445	-	G_{mm}	2.446	-
Av. G_{mm}	2.445		Av. G_{mm}	2.446	
Av. Gmm (Kg/m3) Sample 1& 2	2.445				

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



Comment:

FOR TESTING LAB

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
2 NOV 2025
P.O. BOX 790, KAMPALA (U)

CONSULTANT	CLIENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

INDIRECT TENSILE STRENGTH

BITUMINOUS MIXTURE SAMPLED ON	22/10/2025	102	GMM	2.451	Bit.content,%	4.9	NO OF BLOWS	54

SAMPLE NO.	THICKNESS				Compacted material parameters										
	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 (%) =100*(F-E)/F spec min 3.0% G
MIX	3% HYDRATED LIME AS PART OF FILLER														
WET															
1	63.3	63.7	63.8	63.6	1194.0	679.9	1199.0	519.1	2.277	2.451	36.737	1222.7	28.700	78.122	7.1
2	64.0	64.0	64.2	64.1	1198.5	681.9	1203.6	521.7	2.274	2.451	37.519	1222.6	24.100	64.233	7.2
DRY															
3	63.5	63.9	63.8	63.7	1206.0	685.2	1211.0	525.8	2.271	2.451	38.589				7.3
4	65.2	64.8	64.9	65.0	1200.8	683.9	1205.1	521.2	2.281	2.451	36.090				6.9

INDIRECT TENSILE STRENGTH

DRY						WET							WET/DRY
SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH,S_t	AVERAGE TENSILE STRENGTH,S_t	SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH,S_t	AVERAGE TENSILE STRENGTH,S_t		
	div	kn/div	kn	spec min 800 kPa			div	kn/div	kn	kPa	kPa	S_t =2P/∏tD where P= maximum load(N) t=specimen thickness(mm) D=specim	spec 80%
3	60	0.2312	13.9	1,360.8	1,335.4	1	56	0.2312	12.9	1,270.1	1,288		96
4	59	0.2312	13.6	1,309.9		2	58	0.2312	13.4	1,305.8			

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD

23 NOV 2025

P. O. BOX 793, KAMPALA (U)

CONSULTANT	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref. No.		Lab. no.	MIX	3% HYDRATED LIME AS PART OF FILLER	Sampling date	22-Oct-25	Test Type	Done by	Test Type	Done by
Sample grade	AC 14	Compaction: 75 blows			Testing date	23-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description			AC 14				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/m^3)	% Air Voids	% VMA	% VFB	Marshall Heights (mm)			Av. Hgt (mm)	Corr. Factor	Stability (KN) Measured	Stability (KN) Adjusted	Flow (mm)	Ratio (Stab./Flow)
1	1204.9	694.30	1205.50	2.357	2.346	4.3	15.4	72.2	63.0	63.0	62.8	62.9	1.02	17.3	17.69	3.59	4.927
2	1208.5	693.80	1208.90	2.346	2.335	4.7	15.8	70.1	62.3	62.5	62.5	62.4	1.03	16.9	17.38	3.25	5.349
3	1200.8	693.50	1201.50	2.364	2.352	4.0	15.2	73.6	62.6	62.7	63.0	62.8	1.02	16.0	16.27	3.24	5.022
4	1205.2	695.60	1207.30	2.355	2.344	4.3	15.5	71.9	64.7	64.5	64.8	64.7	0.97	16.6	16.15	2.50	6.459
Average Sample 1				2.356	2.344	4.3	15.5	72.0	Average Sample 1			63.2	1.0	16.7	16.9	3.1	5.4
-				-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Sample 2									Average Sample 2								
Average Sample 1 & 2				2.356	2.344	4.3	15.5	72.0	Average Sample 1 & 2								

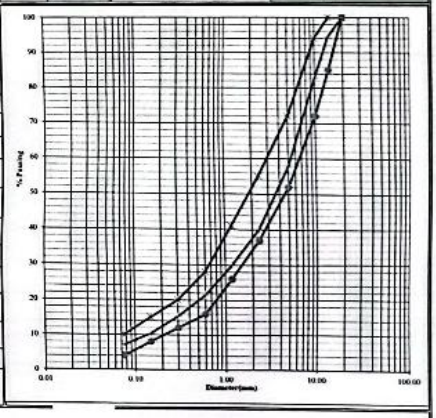
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extraction	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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	2	Test No-	1	2
Asphalt	1200.6		Asphalt	1198.5	-
Pycn. + Water	8553.5		Pycn. + Water	8553.5	-
Pycnometer + Asph. + Water	9264		Pycnometer + Asph. + Water	9263.1	-
Volume of asphalt	490.1	-	Volume of asphalt	488.9	-
G_{mm}	2.450	-	G_{mm}	2.451	-
Av. G_{mm}	2.450		Av. G_{mm}	2.451	
Av. Gmm (Kg/m3) Sample 1& 2	2.451				

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



Comment:

TESTING LAB

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
26 NOV 2025
P.O. BOX 793, KAMPALA (U)

INSTITUTION	CLIENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref No		Lab. no.		Chainage sample 1		Sampling date	20-Oct-25	Test Type	Done by	Test Type	Done by
Sample grade	AC 14	Compaction:	75 blows	Chainage sample 2	CONTROL	Testing date	21-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description	AC 14							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/m^3)	% Air Voids	% VMA	% VFB	Marshall Heights (mm)			Av. Hgt (mm)	Corr. Factor	Stability (KN) Measured	Stability (KN) Adjusted	Flow (mm)	Ratio (Stab./Flow)
1	1195.0	687.00	1196.50	2.345	2.334	4.6	15.0	69.4	65.4	65.3	65.4	65.4	0.95	13.6	12.96	3.97	3.264
2	1194.5	686.00	1196.00	2.342	2.331	4.7	15.1	68.7	66.4	66.0	65.4	65.9	0.95	12.7	12.08	3.55	3.403
3	1189.0	688.00	1194.50	2.347	2.336	4.5	14.9	69.8	64.5	65.2	65.2	65.0	0.96	13.9	13.32	3.91	3.406
4	1188.0	685.00	1191.50	2.346	2.334	4.6	15.0	69.4	66.2	65.1	66.4	65.9	0.95	12.9	12.30	3.68	3.342
Average Sample 1				2.345	2.334	4.6	15.0	69.3	Average Sample 1			65.5	1.0	13.3	12.7	3.8	3.4
-				-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Sample 2									Average Sample 2								
Average Sample 1 & 2				2.345	2.334	4.6	15.0	69.3	Average Sample 1 & 2								

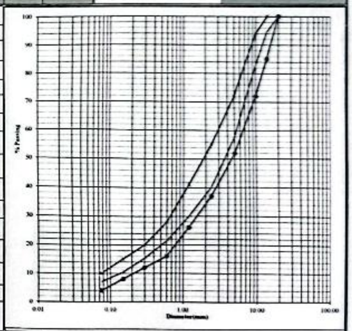
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractio	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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

SAMPLE 1			SAMPLE 2		
(Pycnometer with Water)			(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	2	Test No-	1	2
Asphalt	1288		Asphalt	1126.5	-
Pycn. + Water	7363		Pycn. + Water	7363	-
Pycnometer + Asph. + Water	8124.8		Pycnometer + Asph. + Water	8028.8	-
Volume of asphalt	526.2	-	Volume of asphalt	460.7	-
G_{mm}	2.448	-	G_{mm}	2.445	-
Av. G_{mm}	2.448		Av. G_{mm}	2.445	
Av. Gmm (Kg/m3) Sample 1& 2	2.446				

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of Extr. Agg	1619.6	1614.1	1616.9				



Comment:

FOR LAB

STIRLING CIVIL ENGINEERING LTD
2 3 NOV 2025
BOX 793, KAMPALA (U)

CONSULTANT	CLIENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	MUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

INDIRECT TENSILE STRENGTH

BITUMINOUS MIXTURE SAMPLED ON 20/10/2025 102 GMM 2.446 Bit.content,% 4.9 NO OF BLOWS 50

SAMPLE NO.	THICKNESS				Compacted material parameters										
	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 (%) =100*(F-E)/F spec min 3.0% G
LOCATION :															
WET															
1	66.1	66.0	65.7	65.9	1191.5	679.0	1199.5	520.5	2.266	2.446	38.341	1212.5	21.000	54.772	7.4
4	64.3	65.4	65.0	64.9	1188.5	680.5	1198.5	518.0	2.271	2.446	37.055	1216.5	28.000	75.563	7.2
3	65.7	65.8	66.1	65.9	1192.0	675.0	1195.9	520.9	2.265	2.446	38.539	1215.5	23.500	60.978	7.4
DRY															
2	65.2	65.6	66.2	65.7	1189.0	678.0	1197.0	519.0	2.268	2.446	37.853				7.3
5	65.2	65.4	66.1	65.6	1179.5	670.0	1184.0	514.0	2.272	2.446	36.697				7.1
6	65.3	65.3	66.1	65.6	1187.5	678.0	1195.0	517.0	2.274	2.446	36.460				7.1

INDIRECT TENSILE STRENGTH

DRY						WET							WET/DRY
SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH S_t	AVERAGE TENSILE STRENGTH S_t	SPECIMEN No.	GAUGE READING	LOAD RING FACTOR	MAXIMUM LOAD,P	SINGLE TENSILE STRENGTH S_t	AVERAGE TENSILE STRENGTH S_t		
	div	kn/div	kn	spec min 800 kPa			div	kn/div	kn	kPa	kPa		spec 80%
2	56	0.231	12.7	1,303.2	1,237.1	1	49	0.231	11.3	1,072.0	1,092	S_t =2P/(πtD) where P= maximum load(N) t=specimen thickness(mm) D=specimen diameter(mm)	88
5	59	0.231	13.6	1,298.0		4	47	0.231	10.9	1,044.6			
6	55	0.231	12.7	1,210.0		3	53	0.231	12.3	1,160.7			

LAB

PP

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
26 NOV 2025
P. O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT: EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

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

(BS 812PART 111:112:1990)

LOCATION:	Lab	OPERATOR	
		DATE SAMPLED	20 October 2025
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT	DATE TESTED	21 October 2025

10% FINE VALUE DRY

TEST NO	1		2
CRUSHING FORCE (KN)	243		243
WT. OF AGGREG (gm)after crushing (M1)	2825.0		2820.2
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2535.6		2532.9
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	289.4		287.3
TEN % FINE VALUE (M=M2/M1*100)	10.2		10.2
AVERAGE RESULTS % (M)	10.2		
AVERAGE CRUSHING FORCE (F)	243.5		

F= $\boxed{\dfrac{14F}{M+4}}$ 239.8 DRY 239.8 KN

10% FINE VALUE SOAKED

TEST NO	1		2
CRUSHING FORCE (KN)	243		243
WT. OF AGGREG (gm)after crushing (M1)	2831.7		2855.2
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2539.9		2560.4
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	291.8		294.8
TEN % FINE VALUE (M=M2/M1*100)	10.3		10.3
AVERAGE RESULTS % (M)	10.3		
AVERAGE CRUSHING FORCE (F)	243.5		

F= $\boxed{\dfrac{14F}{M+4}}$ 238.1 SOACKED WET/DRY(%)= 99

SPEC >110 SPEC >75%

f= Maximum force (KN)

f material passing the 2.36mm sieve at the maximum force

SPEC REQUIREMENT 7.5%-12.5% (BS 812-111) (if [illegible] discard

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
23 NOV 2025
P.O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT: EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

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

(BS 812PART 111:112:1990)

LOCATION:	Lab	OPERATOR	
		DATE SAMPLED	20 October 2025
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT	DATE TESTED	21 October 2025

10% FINE VALUE DRY

TEST NO	1		2
CRUSHING FORCE (KN)	243		243
WT. OF AGGREG (gm)after crushing (M1)	2825.0		2820.2
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2535.6		2532.9
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	289.4		287.3
TEN % FINE VALUE (M=M2/M1*100)	10.2		10.2
AVERAGE RESULTS % (M)	10.2		
AVERAGE CRUSHING FORCE (F)	243.5		

$$F=\frac{14\ F}{M\ +\ 4}$$ 239.8 DRY 239.8 KN

10% FINE VALUE SOAKED

TEST NO	1		2
CRUSHING FORCE (KN)	243		243
WT. OF AGGREG (gm)after crushing (M1)	2831.7		2855.2
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2539.9		2560.4
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	291.8		294.8
TEN % FINE VALUE (M=M2/M1*100)	10.3		10.3
AVERAGE RESULTS % (M)	10.3		
AVERAGE CRUSHING FORCE (F)	243.5		

$$F=\frac{14\ F}{M\ +\ 4}$$ 238.1 SOACKED WET/DRY(%)= 99

SPEC >110 SPEC >75%

f= Maximum force (KN)

of material passing the 2.36mm sieve at the maximum force

SPEC REQUIREMENT:7.5%-12.5% (BS 812-111) (if <or> d[illegible]

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
23 NOV 2025
P.O. BOX [illegible], KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

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	5,002.6
SUPPLIER:	STIRLING	TOTAL BY DRY WT. OF THE SAMPLE:2	4,998.6
MATERIAL:	AGGREGATES FOR ASPHALT	DATE SAMPLED:	20/Oct/2025
SPECIFICATION...		DATE TESTED:	21/Oct/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:	4,975.4
GRADING USED FOR TEST:	SAMPLE: 1	SAMPLE: 2	Wt after crushing :	4,966.8
Wt of Mat. Retained on 1.7mm sieve :	4,145.6	4,160.6		
Wt of fine material _ gm	857.0	838.0	Average: %	16.9
Percentage of wear_ %	17.1	16.8	Spec Req	40%

FOR TESTING LAB

LAB TECHNICIAN

MATERIALS ENGINEER

STIRLING CIVIL ENGINEERING LTD
2 5 NOV 2025
P.O. BOX 753, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	SAMPLE DATE: 20/10/2025
TYPE: 14-20 mm	TESTING DATE: 22/10/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	2427.1		2184.8
[B] wt. of saturated surface dry sample in air	(gm)	2431.0		2188.5
[C] wt of saturated sample in water	(gm)	1506.9		1354.6
Bulk Specific Gravity on oven dry basis	A / (B-C)	2.626		2.620
Bulk Specific Gravity on saturated surface dry basis	B / B-C	2.631		2.624
Apparent Specific Gravity	A / A-C	2.638		2.632
Water Absorption(%)=	100(B-A) / A	0.2		0.2

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.623
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.628
APPARENT SPECIFIC GRAVITY	2.635
WATER ABSORPTION	0.2

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
20 NOV 2025
P.O. BOX 753, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	SAMPLE DATE: 20/10/2025
TYPE: 14-10 mm	TESTING DATE: 22/10/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	2021.4		2014.0
[B] wt. of saturated surface dry sample in air	(gm)	2026.6		2019.7
[C] wt of saturated sample in water	(gm)	1254.6		1250.3
Bulk Specific Gravity on oven dry basis	$\frac{A}{(B-C)}$	2.618		2.618
Bulk Specific Gravity on saturated surface dry basis	$\frac{B}{B-C}$	2.625		2.625
Apparent Specific Gravity	$\frac{A}{A-C}$	2.636		2.637
Water Absorption(%)=	$\frac{100(B-A)}{A}$	0.3		0.3

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.618
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.625
APPARENT SPECIFIC GRAVITY	2.637
WATER ABSORPTION	0.3

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
20 NOV 2025
P.O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION:	Mukono Quarry	OPERATOR:	
SAMPLE No		SAMPLE DATE:	20/10/2025
TYPE:	10 - 6 mm	TESTING DATE:	22/10/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	2088.4		2033.8
[B] wt. of saturated surface dry sample in air	(gm)	2094.2		2041.8
[C] wt of saturated sample in water	(gm)	1296.1		1262.8
Bulk Specific Gravity on oven dry basis	A / (B-C)	2.617		2.611
Bulk Specific Gravity on saturated surface dry basis	B / B-C	2.624		2.621
Apparent Specific Gravity	A / A-C	2.636		2.638
Water Absorption(%)=	100(B-A) / A	0.3		0.4

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.614
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.623
APPARENT SPECIFIC GRAVITY	2.637
WATER ABSORPTION	0.3

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
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P.O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	

SPECIFIC GRAVITY & WATER ABSORPTION FINE AGGREGATES

(AASHTO ; T84—00)
ASTM DESIGNATION ; C128—97

LOCATION:	OPERATOR:
SAMPLE No	SAMPLE DATE: 20/10/2025
TYPE: QUARRY DUST (O/6 mm)	TESTING DATE: 22/10/2025

TEST NO		1		K
[A] wt. of oven dry sample in air	(gm)	568.54		547.12
[B] wt. of pycnometer filled with water	(gm)	1803.71		1771.19
[C] wt. of pycnometer with specimen and water	(gm)	2157.22		2110.82
[S] wt of saturated surface dry sample	(gm)	569.44		549.28
Bulk Specific Gravity on oven dry basis	(B-C) / (B+S-C)	2.633		2.610
Bulk Specific Gravity on saturated surface dry basis	S / (B+S-C)	2.637		2.620
Apparent Specific Gravity	A / 100(B-A)	2.644		2.637
Water Absorption(%)=	A / A	0.2		0.4

BULK SPECIFIC GRAVITY	2.621
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.629
APPARENT SPECIFIC GRAVITY	2.640
WATER ABSORPTION	0.3

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
23 NOV 2025
P.O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT:	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	

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

LOCATION: Mukono Lab	OPERATOR:
SAMPLE No	SAMPLE DATE: 20/10/2025
TYPE: Filler	TESTING DATE: 22/10/2025

	Beaker K		Beaker 1
[A) Wt. OVEN dry sample (gm	490.43		483.28
[B) Wt. of Pycnometer containing water alone (gm	1805.95		1768.7
[C] Wt of Pyconometer containing Sample and water (	2109.49		2069.36
SPECIFIC GRAVITY OF FILLER $\frac{A}{A+(B-C)}$	2.624		2.646
AVERAGE	2.635		

FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
2 3 NOV 2025
P.O. BOX 753, KAMPALA (U)

INSTITUTION	CLIENT	TESTING LAB
GANDA CHRISTIAN UNIVERSIT	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE
TEST	**SPECIFIC GRAVITY**
TEST METHOD	**ASTM:C128-97**

Sample Ref:	**AC 14 MM**	Technician :	
SOURCE:	**Mukono Stirling quarry**	Sampling date:	20/10/2025
Aggregate size :	**COMBINED**	Testing date:	22/10/2025
Description of aggregates:	**HOT BINS**		

Aggregate size :	**20-14**	**14-10**	**10-6.0**	**6.0-0**	**FILLER**
GS bulk :	2.623	2.618	2.614	2.621	2.635
PROPORTIONS:	5	7	18	66	4
COMBINED SG :	2.620				
WATER ABSOPTION	0.2	0.3	0.3	0.3	
COMBINED WATER ABSOPTION	0.3				

REMARKS

FOR TESTNG LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
2 3 NOV 2025
P.O. BOX 790, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT :	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

2% HYDRATED LIME AS PART OF FILLER

SUMMARY OF A/C 14 JOB MIX TEST RESULTS

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED PLANT PRODUCTION	SPECIFIED
BITUMEN CONTENT		4.9
MARSHALL FLOW	3.4	2—4
MARSHALL STABILITY 75BLOWS	14.7	9-18
MARSHALL AIR VOIDS 75BLOWS	4.5	3—5
VOIDS IN MINERAL AGGREGATES	15.2	>15%
VOIDS FILLED WITH BINDER	70.3	65—75%
INDIRECT TENSILE STRENGTH @ 25C	1,198	>800kpa
INDIRECT TENSILE WET STRENGTH	93	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	5.0	±0.3
RATIO STABILITY/FLOW	4.5	>2.5

TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD ... 798, KAMPALA (U)

Scanned with CamScanner

UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT — EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref. No.:		Lab. no.		MIX	2% HYDRATED LIME AS PART OF FILLER	Sampling date:	20-Oct-25	Test Type	Done by	Test Type	Done I
Sample grade:	AC 14	Compaction:	75 blows			Testing date:	21-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description:				AC 14				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 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
1	1193.4	685.00	1194.30	2.343	2.332	4.6	15.3	69.7
2	1171.5	675.30	1173.50	2.351	2.340	4.3	15.0	71.3
3	1186.6	684.30	1189.90	2.347	2.336	4.5	15.1	70.4
4	1192.0	685.40	1193.90	2.344	2.333	4.6	15.2	69.9
Average Sample 1				2.346	2.335	4.5	15.2	70.3
-				-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2				2.346	2.335	4.5	15.2	70.3

ASTM D6927Standard 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)
62.6	62.7	63.0	62.8	1.02	15.2	15.49	3.27	4.737
61.7	61.9	61.7	61.8	1.04	15.6	16.22	3.44	4.715
62.5	62.8	62.7	62.7	1.02	14.4	14.65	3.39	4.322
62.9	63.2	62.7	62.9	1.02	13.5	13.81	3.36	4.111
Average Sample 1			62.5	1.0	14.7	15.0	3.4	4.5
-	-	-	-	-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2								

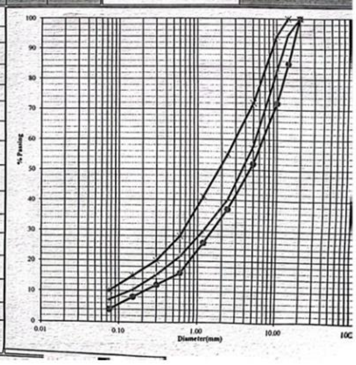
ASTM D 2172- Standard Test Method for Quantitative Extr of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sampl
Bowl	232.3	167.
Bowl + Asphalt	1937.5	1869
Asphalt	1705.2	1701
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractic	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.
Oven dry extr. mtl + filler	1621.1	1615.
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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	2	Test No-	1	2
Asphalt	1207.2		Asphalt	1180.3	-
Pycn. + Water	8553.5		Pycn. + Water	8553.5	-
Pycnometer + Asph. + Water	9266.9		Pycnometer + Asph. + Water	9251.2	-
Volume of asphalt	493.8	-	Volume of asphalt	482.6	-
G_{mm}	2.445	-	G_{mm}	2.446	-
Av. G_{mm}	2.445		Av. G_{mm}	2.446	
Av. Gmm (Kg/m3) Sample 1& 2			2.445		
Comment:					

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



STIRLING CIVIL ENGINEERING LTD

FOR TESTING

UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling
PROJECT :	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE	

A/C 14 ASPHALT NET RESULTS

SUMMARY OF A/C 14 RESULTS FOR NEAT

			BITUMEN CONTENT		4.9
AGGREGATE TESTS	**ACHIEVED**	**SPECIFIED**	**MARSHALL MIX TEST RESULTS AFTER MIX**	**ACHIEVED RESULTS**	**SPECIFIED**
			MARSHALL FLOW	3.3	2—4
			MARSHALL STABILITY 75BLOWS	13.3	9-18
Water Absorption	0.3	< 2%	MARSHALL AIR VOIDS 75BLOWS	4.6	3—5
TFV Dry	239.8	>110kN	VOIDS IN MINERAL AGGREGATES	15.0	>14%
TFV Soaked Wet/Dry ratio	99%	>75%	VOIDS FILLED WITH BINDER	69.3	65—75%
Flakness Index	19.5	< 25%	INDIRECT TENSILE STRENGTH @ 25C	1,092	>800kpa
Plastic Index	N/P	< 4%	INDIRECT TENSILE WET STRENGTH	88	>80% of dry
LAA	16.9		BITUMEN CONTENT AFTER EXTRACTION	5.0	±0.3
ACV	10.7		RATIO STABILITY/FLOW	3.8	>2.5
AIV	16.4				
TEST ON MATERIAL	**ACHIEVED**	**SPECFIED**		**WITH OUT BITUMEN %**	**WITH BITUMEN %**
BITUMEN TESTS			**14/20**	**5**	**4.8**
PENETRATION	**65**	**60-70**	**10/14**	**7**	**6.7**
SOFTENING POINT	**49.3**	**49-56**	**6/10**	**18**	**17.1**
SPECIFIC GRAVITY OF BITUMEN	**1.012**	**1.01--1.06**	**0/6**	**66**	**62.7**
SPECIFIC GRAVITY OF AGGREGATES	**2.592**		**FILLER**	**4**	**3.8**
			BITUMEN CONTENT		**4.9**

STIRLING CIVIL ENGINEERING LTD
KAMPALA (U)

For CONTRACTOR

Lab technician

Materials Engineer

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INSTITUTION	CLIENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref. No.:		Lab. no.		Chainage sample 1:		Sampling date:	20-Oct-25	Test Type	Done by	Test Type	Done by
Sample grade:	AC 14	Compaction:	75 blows	Chainage sample 2:	CONTROL	Testing date:	21-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description:				AC 14				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 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
1	1195.0	687.00	1196.50	2.345	2.334	4.6	15.0	69.4
2	1194.5	686.00	1196.00	2.342	2.331	4.7	15.1	68.7
3	1189.0	688.00	1194.50	2.347	2.336	4.5	14.9	69.8
4	1188.0	685.00	1191.50	2.346	2.334	4.6	15.0	69.4
Average Sample 1				2.345	2.334	4.6	15.0	69.3
-				-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2				2.345	2.334	4.6	15.0	69.3

ASTM D6927Standard 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)
65.4	65.3	65.4	65.4	0.95	13.6	12.96	3.30	3.927
66.4	66.0	65.4	65.9	0.95	12.7	12.08	3.55	3.403
64.5	65.2	65.2	65.0	0.96	13.9	13.32	3.36	3.963
66.2	65.1	66.4	65.9	0.95	12.9	12.30	3.10	3.968
Average Sample 1			65.5	1.0	13.3	12.7	3.3	3.8
-	-	-	-	-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2								

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

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractio	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

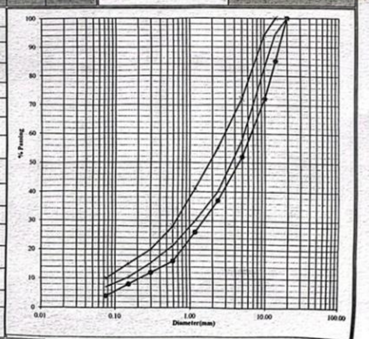
ASTM D2041- Standard Test Method for Theoretical Maximum Specific gravity and Density of Bituminous Mixtures

SAMPLE 1			SAMPLE 2		
(Pycnometer with Water)			(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	2	Test No-	1	2
Asphalt	1288		Asphalt	1126.5	-
Pycn. + Water	7363		Pycn. + Water	7363	-
Pycnometer + Asph. + Water	8124.8		Pycnometer + Asph. + Water	8028.8	-
Volume of asphalt	[illegible]	-	Volume of asphalt	460.7	-
G_{mm}	2.448	-	G_{mm}	2.445	-
Av. G_{mm}	2.448		Av. G_{mm}	2.445	
[illegible] (Kg/m3) Sample 1& 2			2.446		

Comment:

FOR 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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



CIVIL ENGINEERING LTD
BOX 793, KAMPALA (U)

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INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT :	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

3% HYDRATED LIME AS PART OF FILLER

SUMMARY OF A/C 14 JOB MIX TEST RESULTS

BITUMEN CONTENT		4.9
MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED PLANT PRODUCTION	SPECIFIED
MARSHALL FLOW	3.6	2—4
MARSHALL STABILITY 75BLOWS	16.7	9-18
MARSHALL AIR VOIDS 75BLOWS	4.3	3—5
VOIDS IN MINERAL AGGREGATES	15.5	>15%
VOIDS FILLED WITH BINDER	72.0	65—75%
INDIRECT TENSILE STRENGTH @ 25C	1,288	>800kpa
INDIRECT TENSILE WET STRENGTH	96	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	5.0	±0.3
RATIO STABILITY/FLOW	4.7	>2.5

TESTING LAB

Lab technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX 78 KAMPALA (U)

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CONSULTANT	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT: EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref. No.:	Lab. no.	MIX	3% HYDRATED LIME AS PART OF FILLER	Sampling date:	22-Oct-25	Test Type	Done by	Test Type	Done by
Sample grade: AC 14	Compaction: 75 blows			Testing date:	23-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description:		AC 14				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	1204.9	694.30	1205.50	2.357	2.346	4.3	15.4	72.2	63.0	63.0	62.8	62.9	1.02	17.3	17.69	3.59	4.927
2	1208.5	693.80	1208.90	2.346	2.335	4.7	15.8	70.1	62.3	62.5	62.5	62.4	1.03	16.9	17.38	3.75	4.636
3	1200.8	693.50	1201.50	2.364	2.352	4.0	15.2	73.6	62.6	62.7	63.0	62.8	1.02	16.0	16.27	3.54	4.597
4	1205.2	695.60	1207.30	2.355	2.344	4.3	15.5	71.9	64.7	64.5	64.8	64.7	0.97	16.6	16.15	3.60	4.485
Average Sample 1				2.356	2.344	4.3	15.5	72.0	Average Sample 1			63.2	1.0	16.7	16.9	3.6	4.7
-				-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Sample 2									Average Sample 2								
Average Sample 1 & 2				2.356	2.344	4.3	15.5	72.0	Average Sample 1 & 2								

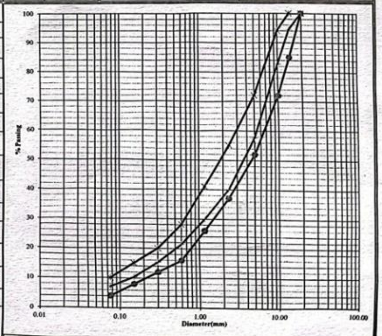
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractic	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mtl (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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	2	Test No-	1	2
Asphalt	1200.6		Asphalt	1198.5	-
Pycn. + Water	8553.5		Pycn. + Water	8553.5	-
Pycnometer + Asph. + Water	9264		Pycnometer + Asph. + Water	9263.1	-
Volume of asphalt	490.1	-	Volume of asphalt	488.9	-
G_{mm}	2.450	-	G_{mm}	2.451	-
Av. G_{mm}	2.450		Av. G_{mm}	2.451	
Av. Gmm (Kg/m3) Sample 1&			2.451		
Comment:					

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



STIRLING CIVIL ENGINEERING LTD

FOR TESTING LAB

CONSULTANT	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

Field Ref No.:		Lab. no.		MIX	1% HYDRATED LIME AS PART OF FILLER	Sampling date:	10-Oct-25	Test Type	Done by	Test Type	Done by
Sample grade:	AC 14	Compaction:	75 blows			Testing date:	11-Oct-25	B.R.D	lab team	B.C/Grad.	lab team
Sample Description:				AC 14				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 specim.	Mass in air	Mass in Water	Saturated surface Dry in air	Bulk S.G (G_{mb})	Unit Wt. (Kg/m^3)	% Air Voids	% VMA	% VFB
1	1190.0	685.60	1191.70	2.351	2.340	4.6	15.1	69.6
2	1182.9	680.60	1183.40	2.353	2.341	4.5	15.0	69.9
3	1187.4	683.90	1189.50	2.348	2.337	4.7	15.2	69.1
4	1196.4	688.80	1197.20	2.353	2.342	4.5	15.0	70.0
Average Sample 1				2.351	2.340	4.6	15.1	69.6
-				-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2				2.351	2.340	4.6	15.1	69.6

ASTM D6927Standard Method for Marshall Stability and Flow

Marshall Heights (mm)			Av. Hgt (mm)	Corr. Factor	Stability (KN) Measured	Adjusted	Flow (mm)	Ratio (Stab./Flow)
62.2	62.7	63.1	62.7	1.02	15.6	15.91	3.61	4.406
61.1	61.4	61.7	61.4	1.06	16.4	17.40	3.50	4.972
62.0	62.7	62.5	62.4	1.03	16.6	17.12	3.53	4.850
61.3	61.7	61.8	61.6	1.05	15.8	16.59	3.39	4.894
Average Sample 1			62.0	1.0	16.1	16.8	3.5	4.8
-	-	-	-	-	-	-	-	-
Average Sample 2								
Average Sample 1 & 2								

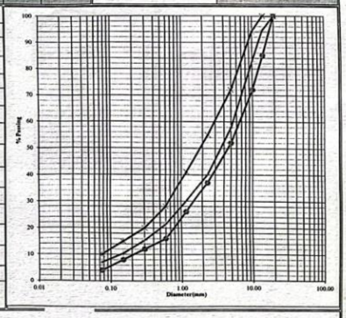
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	232.3	167.8
Bowl + Asphalt	1937.5	1869.0
Asphalt	1705.2	1701.2
Filter paper before extraction	29.3	31.8
Filter paper + Filler After extractic	30.8	33.1
Recovered Filler	1.5	1.3
Oven dry extracted Mil (dry)	1619.6	1614.1
Oven dry extr. mtl + filler	1621.1	1615.4
Bitumen	84.1	85.8
% of Bitumen	4.9	5.0
Av. % of Bitumen	5.0	

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	2	Test No-	1	2
Asphalt	1166.5		Asphalt	1178.2	-
Pycn. + Water	8553.5		Pycn. + Water	8553.5	-
Pycnometer + Asph. + Water	9244		Pycnometer + Asph. + Water	9251.6	-
Volume of asphalt	476	-	Volume of asphalt	480.1	-
G_{mm}	2.451	-	G_{mm}	2.454	-
Av. G_{mm}	2.451		Av. G_{mm}	2.454	
Av. Gmm (Kg/m3) Sample 1&2			2.452		

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	97.9	80.4	89.2	5.5	94	85	100
10	185.0	196.7	190.9	11.8	83	72	94
5	388.0	420.0	404.0	25.0	58	52	72
2.36	287.9	282.1	285.0	17.6	40	37	55
1.18	170.0	160.2	165.1	10.2	30	26	41
0.600	146.4	127.2	136.8	8.5	21	16	28
0.300	106.8	89.8	98.3	6.1	15	12	20
0.150	76.0	83.2	79.6	4.9	10	8	15
0.075	55.0	52.4	53.7	3.3	7	4	10
Total filler	102.1	115.8	109.0				
Bot. Pan	3.0	5.00	4.0				
Extr. filler	1.5	1.30	1.4				
Sum of extr. Agg	1619.6	1614.1	1616.9				



Comment:

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 793, KAMPALA (U)

FOR TESTING LAB

Materials Engineer

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	SHADRACH AHUMUZA AINEBYONA (REG NO. M22B32/032) & UWIMANA DICKSON MBONYE (REG S20B32/025)	Stirling

PROJECT :	EVALUATING THE EFFECT OF HYDRATED LIME ON WORKABILITY OF GRANITE STONE DUST MODIFIED ASPHALT MIXTURE

1% HYDRATED LIME AS PART OF FILLER

SUMMARY OF A/C 14 JOB MIX TEST RESULTS

BITUMEN CONTENT		4.9
MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED PLANT PRODUCTION	SPECIFIED
MARSHALL FLOW	3.5	2—4
MARSHALL STABILITY 75BLOWS	16.1	9-18
MARSHALL AIR VOIDS 75BLOWS	4.6	3—5
VOIDS IN MINERAL AGGREGATES	15.1	>15%
VOIDS FILLED WITH BINDER	69.6	65—75%
INDIRECT TENSILE STRENGTH @ 25C	1,146	>800kpa
INDIRECT TENSILE WET STRENGTH	90	>80% of dry
BITUMEN CONTENT AFTER EXTRACTION	5.0	±0.3
RATIO STABILITY/FLOW	4.8	>2.5

TESTING LAB

Lab technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 795, KAMPALA (U)

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