ACCESSING THE USE OF CALCINED QUARTZITE DUST AS A FILLER TO ENHANCE RUT RESISTANCE IN ASPHALT CONCRETE

MOISE LOKORTO AMULE

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ABSTRACT

Worldwide flexible pavements are mainly constructed with aggregates, bitumen and filler. This study aims to assess the use of Calcined quarzite dust (CQD) to enhance rut resistance in the asphalt concrete. The methods used were mechanical,physical, chemical to determine the engineering properties of aggregate, bitumen and filler used in this study; also Marshall test was conducted, as well as the Indirect tensile Strength (ITS) in relation with the Wheel Tracking Tests (WTT) to assess the performance on the asphalt mixture. Various tests were done during the study, various factors such as stability, flow, air voids,voids filled with binder (VFB), and voids in the mineral aggregate (VMA) were evaluated. The study was conducted with CDQ percentage variation of 2%, 4% and 6% and 4.4% optimum bitumen content was obtained from the neat asphalt.

The results of the study showed that the use of Calcined quarzite dust led to an increase in Marshall stability from 15kN to 21.1 kN, increased Indirect Tensile Strength Strength ratio from 82% to 88%, ITS dry from 900.2kPa to 1,130.6kPa and ITS wet from 740kPa to 990kPa. With relation to wheel tracking tests the ITS value greater than 800kPa expect less than 10mm rutting depth for a 20,000 cycles passes. This study therefore shows that asphalt mixes with 4.5% CQD in the asphalt mixture can be used as a means to enhance the stability and stiffness.

DECLARATION

I, AMULE LOKORTO MOISE REG NO: S21B32/036, hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any award.

AMULE LOKORTO MOISE

Signature: .... **Date** 17/04/2025

APPROVAL

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

NAME: Dr. MORRIS OLENG

DATE:……………………………………….

SIGNATURE:……………………………….

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LIST OF ACRONYMS AND ABBREVIATIONS

ACV	Aggregate Crushing Value
AASHTO	American Association of the State Highway and Transportation Officials
AIV	Aggregate Impact Value
ASTM	American Society for Testing Materials
BS	British Standard
CQD	Calcined Quarzite Dust
CMA VMA	Cold Mix Asphalt Voids in Mineral Aggregate
CML	Central Material Laboratory
Gmm	Theoretical Maximum Specific Gravity
MoWT	Ministry of Works and Transport
OBC	Optimum Bitumen Content
ITS	Indirect Tensile Strength
HMA	Hot mix asphalt
WMA	Warm Mix Asphalt
WTT	Wheel Tracking Tests
XRF	X-Ray Fluorescence

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

As the traffic in the country increases, the demands for major improvement in road construction and infrastructure because of the increasing findings. Road pavements are divided into two categories in the world of highway engineering: flexible pavements and rigid pavements. The use of Portland cement is for making rigid pavements, while bitumen and aggregates are used to create flexible pavements. A mixture of bitumen, aggregates, mineral fillers, and additives forms asphalt concrete. Because of its flexibility and capacity to function in various applications, asphalt concrete is frequently used in road pavement construction (Asphalt Institute, 2021).

Asphalt concrete is prepared in three known methods, including Hot Mix Asphalt (HMA), Warm Mix Asphalt, and Cold Mix Asphalt, with the choice often influenced by geographical and climatic factors. For instance, HMA is the most used, providing a safe, durable, and comfortable surface for road users.

Flexible pavement roads are primary constructed in Uganda due to their ability to deform and move slightly under heavy traffic loads and environmental changes. However, flexible pavements with asphalt concrete can experience several types of challenges such as rutting, cracking, shoving, thermal fatigue, distresses or failure over time.

Pavement is a conglomeration of materials. These materials, their associated properties, and their interactions determine the strength of the pavement, therefore their properties should meet the specifications. Material properties such as aggregate gradation, binder grade, binder content, and air void content are mainly concerned. Specifics of loading include tire pressure, contact area, load magnitude, and surrounding factors like temperature. To achieve the desired pavement performance, these parameters must be properly incorporated into the design of the asphalt mixture (Pavement Interactive, 2021).

A few years after the reconstruction of the Kampala - Jinja road in Bweyogerere at chainage 5+820, rutting reoccurred, which can result in higher maintenance costs and financial strains. Because maintenance and reconstruction before its design life becomes expensive, these crises can have a major effect on a country's economy (IMF, 2024).

Several research have been focused on assessing the performance of the flexible pavement by replacing or partially replacing its mixtures to overcome these problems. To enhance the qualities of bitumen and aggregates, a variety of fillers such as granite powder, limestone powder, Ordinary Portland Cement, and numerous agricultural byproducts like Rice Husk Ash and Coconut Shell Ash, have been explored (Zhang et al., 2020). Furthermore, adding plastic elements like polyvinyl chloride and low-density polyethylene has shown improving the mechanistic properties of asphalt mixtures. Particularly, calcined quartzite dust has been recognized for its capacity for enhancing overall durability, improve heat resistance, and improve moisture resistance (Smith et al., 2021).

The purpose of this study is to evaluate how calcined quartzite dust can increase flexible pavement’s resistance to rutting.

1.2 PROBLEM STATEMENT

Rutting is one of the common problems with flexible pavements, especially in area with slow traffic flow, such climbing lanes and intersections (Chilukwa, 2019). This happens when the bituminous binder softens as a result of the pavement's high temperature, making it less able to withstand the shear stress from the traffic load. Rutting is the results from rapid shear displacement along the wheel path, this caused by a various factors, such as poor mix design with avoid less than 3% of air voids reducing contact surface area, inadequate compaction and large axle loads in high traffic volumes; rutting is also caused by incompatibility or use of expired filler material case of hydrated lime.

For instance, rutting was observed along Kampala-Jinja highway in Bweyogerere at chainage 5+820. (Kyamuwendo, 2021). Despite that in 2022 the reconstruction of the road by Energo Projekt company, early deformation reoccurred.

The objective of this study is to improve the asphalt properties and its performance by employing calcined quartzite dust as a filler. This method attempts to mitigate the pavement's resistance to rutting by improving its thermal stability and shear deformation from traffic load.

1.3 MAIN OBJECTIVE

To Assess the use of calcined quartzite dust as a filler to enhance rutting resistance in asphalt concrete.

1.4 SPECIFIC OBJECTIVES

1. To determine the physical and mechanical and chemical properties of calcined quartzite dust, aggregates and bitumen.
2. To determine the optimum filler and bitumen content mix design of the asphalt concrete.

3. To determine the performance of asphalt concrete incorporated with calcined quartzite dust.

1.5 RESEARCH QUESTIONS

1. What are the properties of Calcined Quartzite dust, bitumen and aggregates?

2. What is the Optimum Bitumen Content of Asphalt Concrete to achieve the desired performance?

3. What are the properties of Asphalt Concrete incorporated with Calcined Quartzite dust compared to asphalt concrete without calcined quartzite dust.

1.6 JUSTIFICATION

Calcined Quartzite dust (CQD) is a by-product generated from the processing of the quartzite rock dust, consisting mainly of silica content with about 85-95% of Silicon dioxide (SiO_2) content and other minerals such as Aluminum oxide (Al_2O_3) 2-5%, Iron oxide (Fe_2O_3) 1-3% and Calcium oxide (Sun, Y., Zhao, Y., Qiu, J. et al. 2022). research have demonstrated that silica content in the aspahalt concrete can improves bitumen and aggregate adhesion, this increases rutting resistance and fatigue cracks in the pavement by lowering the asphalt binder's temperature weakness.

Furthermore, due to its larger specific surface area, CQD filler improve the interaction of aggregate particles and asphalt binder. These properties are vital for the pavement's overall performance and longevity since they improve the load distribution and decreased deformation under traffic loads (Smith et al. 2021).

Furthermore, calcined quartzite dust’s thermal stability makes it a better alternative to conventional fillers because it tolerates rising of temperatures without compromising the integrity of the pavement; which is useful in areas or regions with significant temperature fluctuations where pavement performance is essential (Johnson and Lee, 2019). Therefore, the exploration of CQD as a filler in asphalt concrete mixtures presents a promising future for enhancing the performance and sustainability of flexible pavements.

1.7 GEOGRAPHICAL SCOPE OF STUDY

The area of study is in Bweyogerere chainage 5+820, reference marked on the road along the Kampala - jinja highway.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Roads provide various services for moving people and goods from one place to another. Road pavement is that mixture of aggregate, binder (bitumen or cement), and filler to make concrete which is laid on the road surface. In Highway Engineering, there are two types of road pavements commonly recognized; flexible pavements and rigid pavements.

Flexible pavements are constructed with bitumious materials like asphalt concrete. Portland Cement Concrete is used in rigid pavement making . In Uganda most roads are surfaced using flexible pavement.

2.2 Types of Road Pavements

a) Rigid Pavement

These pavements are made of Portland Cement Concrete, Compared to flexible pavement rigid pavements rely on their sufficient flexural strength to transfer the wheel load, functions as stiff slab (Papagiannakis and Masad, 2024). They are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course (Tom & Rao, 2007). the rigid pavement is the most preferred in high traffic regions such as major highways, due to their durability and resistance to deformation (Mallick and Tahar El-Korchi, 2008).

b) Flexible Pavement

These pavements are rather flexible in their structural action under loading. Consist of asphalt concrete, flexible pavements are composed of layered systems, including surface, base and subbase layer. The flexible pavements are the most constructed type of road in the word (Qiao, Y., Dawson,et all, 2020),due to their ability to varying subgrade conditions, and throughout theirs service life, they are design to withstand high traffic loads, changing environmental conditions and deteriorate.

2.3 TYPES OF ASPHALT CONCRETE

1. Hot Mix Asphalt (HMA)

This type of mix is composed of aggregate and a viscous binding agent, and is produced at a temperature range of about 149 - 177°C. There are typically three subcategories of HMA: Dense-graded mixes, stone matrix asphalt, and open-grade mixes. Dense-graded mixes are often used in high traffic road due to their durability. This mix contains more asphalt cement, while also adding binders and fibers to the mix (Wolf, Sean. 2014).

2. Warm Mix Asphalt (WMA)

This mix is produced at a temperature range from 10-38°C less than a batch of HMA. There are multiple WMA technologies used in the United States, which include foaming effect, organic additive, and chemical package. The foaming effect is used to increase workability. Water is added to lower the temperature and causes the volume of the asphalt binder to expand, which results in the foam. The organic additive improves the flow by reducing the asphalt viscosity and is used to avoid permanent deformation (Wolf, Sean. 2014).

3. Cold Mix Asphalt (CMA)

It is generally a blend mix with emulsified or cutback asphalt. Emulsified asphalts may be anionic or cationic, available in MS or SS grades. The aggregate component can rage from a dense-graded crushed aggregate to a granular soil having a relatively high percentage of dust.

2.4 Types of failure in the flexible asphalt

The the primary issues with flexible pavement failures include:

Fatigue cracking: results from horizontal tensile strain at the pavement bottom.

Rutting: is the indicator of permanent deformation or rut depth along wheel load path.

Thermal cracking: includes both low-temperature cracking and thermal fatigue cracking.

2.5 Components of Flexible Pavement

Typically, flexible pavement includes a seal coat, surface course, tack coat, binder course, prime coat, base course, sub-base course, compacted sub-grade, and natural Subgrade (Aalim M, 2020).

Seal Coat: is a thin surface treatment used to water-proof the surface and to provide skid resistance to a pavement.

Prime coat: is an application of viscous cutback bitumen to an absorbent surface like granular bases on which the asphalt concrete layer is placed. It provides bonding between two layers. prime coat penetrates into the layer below the treated layer, filling the voids, and water-proof surface.

Surface course: is the directly layer in contact with traffic loads, they are usually constructed with dense graded asphalt concrete(AC). It provides friction, smoothness, safe driving surface to the users, etc. Also it will prevent water infiltration into the underlying layers. It must be tough to resist the distortion under traffic and provide a smooth and skid resistant riding surface, and must be waterproof to protect the entire base and subgrade from the weakening effect of water (Nouman, M., Maqbool, Z., Ali, S., & Saleem, A. 2021).

Binder course: is a layer below surface course, helps to distribute load to the base course.

Base course: is the road layer of material immediately below the binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, treated and untreated or stabilized materials.

SubBase: This is the layer below the base course, it provides structural support, improve drainage, and reduce the intrusion of fines from the sub-grade.

Subgrade: this is a layer below subbase consist of natural soil prepared and compacted to stand the stresses from the layers above. It is essential that the soil sub-grade is not over stressed. The compaction is done to the desirable density, near the optimum moisture content.

2.6 Process of flexible pavement design

1. Estimating design traffic loading

The design life is the period during which the road is expected to carry traffic at a satisfactory level of service, without requiring major rehabilitation or repair work. It is implicit, however, that certain maintenance work will be carried out throughout this period in order to meet the expected design life. This process involves: Design traffic loading, design traffic class, probability distribution of traffic, axle and wheel load distribution (MoWT, 2010).

1. Determining subgrade strength

The subgrade strength is the other most important factor, apart from traffic loading, which governs the pavement structural configuration. It is assumed in this guide that the first stages of determining nominally uniform sections in terms of subgrade condition will have been undertaken. This can be based on geological and soil property assessments, the subgrade of the soil can be assessed by insitu test of Dynamic Cone Penetrometer (DCP) test or laboratory testing for CBR. The DCP testing accordance to the **BS 1377 : Part 4 : 1990** to determine the Califoria Bearing Ration (CBR) of the soil. Therefore helps to determine the subgrade class (MoWT, 2010).

Subgrade Class Designation						
	S1	S2	S3	S4	S5	S6
Subgrade CBR ranges (%)	2	3-4	5-7	8-14	15-29	30+

Table 1 Subgrade Class Designation (MoWT, 2010).

2.7 Construction Materials used in the Surfacing Layer

The surfacing layer comprises of two different layers, which are the wearing course and binder course having different gradation characteristics and thicknesses respectively. They are constructed with Asphalt Concrete.

Asphalt concrete (AC) is a heterogeneous material that consists of bitumen (binder), natural or artificial aggregate, mineral filler, additives and air voids. Asphalt concrete is widely used as a pavement construction material (Hunter, 2014).

2.7.1. Bitumen

The American Society for Testing and Materials (ASTM) defines bitumen as a generic class of amorphous, dark colored, cementitious substances, natural or manufactured, composed principally of high molecular mass hydrocarbons, soluble in carbon di-sulphide (ASTM D8-83, 1984).

The bitumen is derived from two sources from petroleum crude oil and the second category from the natural asphalt deposits (Bag). bitumen is characterized by:

1. Penetration of Bituminous Materials

Test references: ASTM D 5-86.

The penetration test is used to measure consistency of bituminous materials expressed as the distance in tenths of a millimeter that a standard needle vertically penetrates a sample of the material under known conditions of loading, loading time and temperature (ASTM,2019).

Penetration, 1/10 mm	0-49	50-149	150-249	250-
Maximum diff. between highest and lowest determination	2	4	6	8

Table 3.5-2 Test precision

Penetration 25 °C, 100 g, 5 s	Acceptable difference, 2 results	
	One operator	Two laboratories
Bitumen < 50 pen., units (1/10 mm)	< 1	< 4
Bitumen > 50 pen., % of mean value	< 3	< 8

Table 2 Penetration variation (ASTM,2019).

2. Softening Point Test

Test references: ASTM D 36-70

The softening point test is used to measure and specify the temperature at which bituminous binders begin to show fluidity. The softening point is also helps in evaluating the uniformity of shipments and sources of supply. The softening point is also an indicative of the tendency of the material to flow at elevated temperatures encountered in service (ASTM,2019).

One operator	Two laboratories
1.1°C	2.0°C

Table 3 Test precision (ASTM,2019).

3. Density of Bituminous Binders

Test references: ASTM D70-97

The objective of this method is to determine the relative density and density of semi-solid bituminous materials such as bitumen (ASTM,2019).

Test precision

Duplicate determinations of relative density shall not be considered suspect only if they differ by more than the limits given in table.

	One operator	Two laboratories
Relative density	0.002	0.005

Table 4 Test precision (ASTM,2019).

2.7.2 Aggregate

Aggregates are granular materials such as, gravel and crushed stone that are used in construction to produce concrete or for flexible pavement mixture.we have many types of aggregate such as grinite, marble, etc.

For the flexible pavement mixture the selection of aggregate plays a key role in its performance, specific tests such as Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV), Ten Percent Fines Value (TFV), Soundness, Flakiness Index are required, following the required standards and specifications according to the (MoWT 2010). in Uganda.

1. Aggregate Crushing Value (ACV)

Test reference: BS 812: Part 110: 1990

ACV is a measure of the resistance of an aggregate to crushing under gradually applied compressive load (CML, 2000).

Objective

To measure the resistance of aggregates to crushing under a gradually applied load. Weak aggregates could potentially compromise the integrity of the pavement structure.

2. Aggregate Impact Value (AIV)

Test reference: BS812: Part 112: 1990.

Aggregate Impact Value is a measure of the resistance of an aggregate to sudden sock or impact. It is used in the construction and civil engineering industry to assess the quality and suitability of aggregates for use in road construction and other structural applications (CML, 2000).

Objective

To measure the resistance of aggregates to a sudden impact or shock. This is crucial for aggregates used in road construction as they are constantly subjected to impacts from moving vehicles.

3. Ten Percent Fine Value (TFV)

Test reference: BS 812: Part 111: 1990.

To measure the resistance of aggregates against a gradually applied compressive load. This test provides a measure of the strength of the aggregate and is particularly useful for evaluating the suitability of aggregates for use in road construction and other structural applications. The TFV was intended to determine the load necessary to crush a prepared aggregate sample to yield 10% of material passing a specified sieve after crushing (CML, 2000).

4. Flakiness Index

Test reference: BS 812-P105:1-1989

The Flakiness Index of a an aggregate sample is found by separating the flaky particles and expressing their mass as a percentage of the mass of the sample. The test is applicable to material passing a 63 mm sieve and retained on a 6.3 mm sieve (CML, 2000).

The Flaky particles were considered undesirable since they could be weak by nature and break easily under strong loads, especially when used as base course and in coarse aggregates. When an aggregate's thickness was less than 60% of the average sieve size, it was categorized as flaky.

5. Los angeles abrasion test

Test reference: BS 812: Part 111:1990.

To measure the resistance of aggregates to wearing or abrasion. It can also be to determine the hardness of the aggregates. It evaluates the toughness and abrasion resistance of aggregate materials which is crucial for determining their suitability for use in road in constructions particularly in wearing surfaces where high resistance to wear and tear is required (CML, 2000).

6. Soundness of Aggregates by use of Sodium Sulphate

Test references: ASTM C 88 - 90

The objective of this test is to provide a preliminary estimate of the soundness of aggregates subject to weathering action for use in concrete and road pavements. The Soundness test by use of Sodium Sulphate covers the testing of aggregates to estimate their soundness when subjected to weathering (ASTM,2019).

The following is the standard required for theses tests

ACV	< 45%
AIV	< 25%
TFV DRY AND WET	> 110 KN
FLAKINESS INDEX	< 25%
LAAV	< 30%
SOUNDNESS	< 12%
SPECIFIC GRAVITY	2.5-2.9

Table 5 Standard limit for aggregate test according to BS

2.7.3 FILLER

Fillers are fine materials with particle sizes under 0.075mm. They can come from natural sources, like crushed rock fines, or be added materials such as cement, lime, or ground rock. Natural fillers come from crushed rocks, while manufactured fillers include hydrated lime, cement, ash, or slag. Higher filler content increases brittleness and the likelihood of cracking during use.

A. Function of Filler

As a result, the asphalt mixture pavement should be resistant to water and frost, pavement deformations, fatigue cracks and and temperature resistance so the filler help in the

Filling the voids in the aggregate to create a denser mixture increasing in the resistance and durability,also facilitate asphalt binder to interact with aggregates and the stability of the mixture.

B. Chemical testing of filler material

B.1 X-Ray Fluorescence

Test reference: ASTM E1621-22

This method is suitable for providing data on the chemical composition of filler material. It is intended for routine production control and for determination of chemical composition for the purpose of certifying material specification compliance (ASTM,2019). The method aimed to determine the chemical composition of the Lime Kiln Dust mineral filler.

B.2 sieve analysis

Test reference: ASTM D546-1

The method is used to determine compliance of mineral fillers with the grading requirements of Specification D242 (ASTM,2019).

2.7.4 Marshall Test

References: ASTM D 1559-89

The Marshall test is use to evaluate the physical properties of asphalt specimens related to plastic deformation properties of asphalt mixes.

Main principles

The Marshall test is used with bitumen or bitumen cutback where the maximum aggregate size is 25.4 mm or less. Asphalt specimens are loaded on their cylindrical side-edges with a Marshall loading head at specified loading rate and temperature. The resistance against plastic flow is measured (CML, 2000).

2.7.6 Indirect Tensile Strength Test

Test references: ASTM D3967

The test procedure is used to determine the indirect tensile strength and E- modulus of asphalt concrete. The results can be used to evaluate the relative quality/strength of materials as well as in pavement design, evaluation and analysis.

Required equipment

Testing machine, typically Marshall type test apparatus (loading speed of 2” / minute), an indirect tensile stress loading frame, water bath accurate to 1.0 °C

In the middle of each plate is a loading strip. These should be at least be of the same length as the test specimen height. The width of the loading strips should be 12.7 mm, with the same curvature as the test specimen.

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

This chapter details the different experiments and techniques that were carried out while tackling the different objectives of this study that is to say chemical composition of CQD, its performance in asphalt concrete and carrying out a mix design for the optimum percentage usage of CQD filler material. It constitutes detailed information about sample collection, preparation, mix design and different tests that were carried out. Experimental Research was carried out at stirling Civil engineering Limited and Makerere Geology department to achieve the desired specific objectives of this research study.

3.2 Material acquisition and preparation

The Quartzite rock Dust used in this research was obtained from Jomayi Stones Limited located in Seeta. The Quartzite Rock Dust was then placed in 2 sacks and transported to Stirling Civil Engineering Ltd where it was crushed to powder using a LAAV machine to obtain smaller sizes passing throught sieve 600 and 300 micrometer. The quartzite rock dust was then taken to Makerere University Department of Geology and Petrolium studies to be calcined. The dust was placed in an electric kiln at temperatures ranging between 800^0C to 1000^0C for two hours to obtain CQD. The XFR test was carried on non calcined and calcined material.

3.2 Testes required

1. Aggregate Crushing Value (ACV)

I. Main principals

ACV is determined by measuring the material passing a specified sieve, then crushed under a load of 400 kN. The test is suitable to fraction aggregates passing a 14 mm sieve and retained on a 10 mm sieve. The method is not suitable for testing soft aggregates expected with ACV higher than 30 (CML, 2000).

II. Test Procedure

The cylinder of the test apparatus is placed in position on the base-plate,place a third of test specimen, each third being compacted by 25 strokes of the tamping rod evenly distributed over the surface of the layer. The apparatus with the specimen and plunger were placed in position, between the platens of the compression testing machine.; an applied force of 400kN at a uniform rate for about 10 min.

Weigh the tray and the aggregate and record the mass of aggregate used (M_1) to the nearest 1 g.

The whole specimen were Sieved on the 2.36 mm sieve until no further significant amount passes. Weigh and record the masses of the fraction passing and retained on the sieve to the nearest 1 g (M_2 + M_3 respectively). If the total mass (M_2 + M_3) differs from the initial mass (M_1) by more than 10 g, the it requested to discard the result and test a further specimen.

III. Calculations

To calculate the ACV expressed as a percentage to the first decimal place for each test specimen from the following equation:

$$\mathbf{ACV} = \frac{\mathbf{M2}}{\mathbf{M1}} \times \mathbf{100}$$

Where

M_1 is the mass of the test specimen (in g)

M_2 is the mass of the material passing the 2.36 mm sieve (in g)

2. Aggregate Impact Value (AIV)

I. Main Principles

The test can be performed in either in dry or in a soaked condition. The test is applicable to a standard fraction aggregates passing a 14 mm sieve and retained on a 10 mm sieve (CML, 2000).

II. Test Procedures

Dry condition

Fix the cup of the specimen in position and place the test specimen in it and compact by 25 strokes of the tamping rod, the sample is place under the hammer which fall freely on to the aggregate to achieve a total of 15 blows.

The crushed aggregate were removed and poured on a tray, the weighing of the tray and the aggregate specimen and record the mass of aggregate used (M_l) to the nearest 0.1 g.

Sieve the whole specimen in the tray on the 2.36 mm sieve until no further significant amount passes. Weigh and record the masses of the fraction passing and retained on the sieve to the nearest 0.1 g (M_2 + M_3 respectively). If the total mass ($M_2 + M_3$) differs from the initial mass M_l by more than 1 g, the sample is also discard and requist for further tests.

Soaked Condition

Same apply as in dry condition, except that the number of blows of the hammer is the number of blows that yield between 5 % and 20 % fines, and 15 blows were also used.

The crushed specimen is removed from the cup and dry in the oven at a temperature of 105 ± 5^{O}C for at least 12 hours. Allow the material to cool and weigh to the nearest 0.1 g and record the mass of the test specimen (M_l), the the procedure for recording the masses same as applied for dry condition.

III. Calculations

To calculate the AIV expressed as a percentage to the first decimal place for each test specimen from the following equation:

$$\mathbf{AIV = \frac{M2}{M1} \times 100}$$

Where

M_l is the mass of aggregates or mass of the oven-dried test specimen (in g)

M_2 is the mass of aggregates or mass of the oven-dried material passing the 2.36 mm sieve (in g).

3. Ten Percent Fine Value (TFV)

I. Main Principles

The 10 % Fines Value (TFV) is determined by measuring the load required to crush a prepared aggregate sample to give 10 % material passing a specified sieve after crushing usually sieve 14/10mm. The test is also known as the 10% Fines Aggregate Crushing Test 10 %. The test can be performed in both a dry condition and in a soaked condition (CML, 2000).

The test is applicable to both weak and strong aggregates. The TFV test resembles the determination of the ACV, which requires a force equal to 400 kN to be applied on the test sample.

II. Calculations

To calculate the force F (in kN), to the nearest whole number, required to produce 10 % fines for each test specimen, from the following equation:

$$\mathbf{TFV} = \frac{\mathbf{14F}}{\mathbf{m+4}}$$

Calculate the mean of the two results to the nearest 10 kN for forces of 100 kN or more, or to the nearest 5 kN for forces less than 100 kN.

4. Flakiness Index (FI)

I. Main Principles

The Flakiness Index of an aggregate sample is found by separating the flaky particles and expressing their mass as a percentage of the mass of the sample. The test is applicable to material passing a 63 mm sieve and retained on a 6.3 mm sieve (CML, 2000).

II. Test Procedure

The first step is to carry out a sieve analysis using the sieves given in the CML, it is required to discard all aggregates retained on the 63 mm sieve and all aggregate passing the 6.3 mm sieve.

Weigh each of the individual size-fractions retained on the sieves, and store them in trays with their size marked on the trays, from the sums of masses of the fractions in the trays (M_1), then calculate the individual percentage retained on each of the various sieves. It is also required to discard any fraction whose mass is 5 % or less of mass M_1 record the mass remaining (M_2). Combine and weigh all the particles passing each of the gauges. (M_3)

III. Calculations

The value of the Flakiness Index is calculated from the expression:

$$\mathbf{FI} = \frac{\mathbf{M3}}{\mathbf{M2}} \times \mathbf{100}$$

5. Los Angeles Abrasion test value (LAAV)

I. Main Principles

The Los Angeles test is a measures the degradation of mineral aggregates from a combination of actions including abrasion, impact and grinding in a rotating steel drum containing a specified number of steel spheres. As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact or crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate impacts and the cycle is repeated (CML, 2000).

After the prescribed revolution of 500 revolutions, with a speed of 30 to 33 rpm; the contents are removed from the drum and the aggregate is sieved through 1.70mm sieve to measure the degradation as a percent loss.

II. Calculations

Express the loss which is difference between the original mass (m1) and the final mass (m_2) of the test sample as a percentage of the original mass of the test sample, from the equation:

$$\textbf{LAA value} = \left(\frac{\mathbf{m1-m2}}{\mathbf{m1}}\right) \times \mathbf{100\,(\%)}$$

6. Soundness of Aggregates by use of Sodium Sulphate

I. Main Principles

The Soundness test by use Sodium Sulphate to cover the testing of aggregates helps to estimate their soundness when subjected to weathering. This was done by repeated immersion in saturated solutions of sodium sulphate followed completely dehydrate the salt precipitated in permeable pore spaces. This test method provides information helping in judging the soundness of aggregates when adequate information is not available from service records of the material exposed to actual weathering conditions (CML, 2000).

7. Marshall Mix Design

I. Main priciples

The results from Marshall Mix Design are often used to set up asphalt mix formulation and specifications (CML, 2000).

The binder content is varied in steps of typically 0.5% around an assumed optimum binder content, for example it can vary from 2%, 2.5%, 3%,… etc. The optimum binder content is determined by which best complies with Marshall stability, flow, void content, voids filled with binder and density requirements for the mix being investigated (Asphalt Institute, 2015).

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability (ASTM,2019). During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm or 0.01¨ increments at the same time when the maximum load is recorded (Transportation Research board, 2017).

II. Test procedures

A. **Specimen preparation:** Approximately 18,000g of bitumen, aggregates and filler is heated to a temperature of 175 − 190^{o}C but bitumen was heated to a temperature of 121 − 125^{o}C with the first trial percentage of bitumen (from 3% to 5% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly at a temperature for homogeneous mixture. The mix is placed in a preheated mould and compacted with rammer with 70 blows on either side at temperature of 138^{o}C to 149^{o}C.

B. **Bulk specific gravity of mix (Gm):** is the specific gravity while considering the air voids in the mixture is find by: **Gm =** $\frac{\mathbf{Wm}}{\mathbf{Wm-Ww}}$

where, Wm is the weight of mix in air, Ww is the weight of mix in water, Note that Wm − Ww gives the volume of the mix.

C. **Air voids percent (Vv):** Vv is the percent of air voids by volume in the specimen and is given by: **Vv =** $\frac{\mathbf{(Gt - Gm) \times 100}}{\mathbf{Gt}}$

where Gt is the theoretical specific gravity of the mix, and Gm is the bulk or actual specific gravity of the mix.

D. **Percent volume of bitumen (Vb):** is the percent of volume of bitumen to the total volume and given by: **Vb =** $\frac{\frac{\mathbf{Wb}}{\mathbf{Gb}}}{\frac{\mathbf{W1+W2+W3+Wb}}{\mathbf{Gm}}}$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of fine aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, Gb is the apparent specific gravity of bitumen, and Gm is the bulk specific gravity.

E. **Voids in mineral aggregate (VMA):** is the volume of voids in the aggregates, and is the sum of air voids and volume of bitumen, and is calculated by

VMA = Vv+Vb

where, Vv is the percent air voids in the mix, and Vb is percent bitumen content in the mix.

F. **Voids filled with bitumen (VFB):** is the voids in the mineral aggregate frame work filled with the bitumen, and is calculated as: **VFB =** $\frac{\mathbf{Vb \times 100}}{\mathbf{VMA}}$

where, Vb is percent bitumen content in the mix and VMA is the percent voids in the mineral aggregate.

G. Determine Marshall stability and flow Marshall stability refers to the maximum load required to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain (50mm per minute). While the stability test is in progress dial gauge is used to measure the vertical deformation of the specimen. The deformation at the failure point expressed in units mm is called the Marshall flow value of the specimen (Dr. Tom V. Mathew, 2009).

8. Indirect Tensile Strength Test

I. Main principles

A load is applied on two diametrically opposite sides. This induces a tensile stress in the test specimen. The test is performed with a constant deformation speed until failure occurs,the test is done in dry and wet condition; the maximum load is recorded and is used to calculate the indirect tensile strength(CML, 2000).

II. Results

Maximum load is recorded Newton, for the Calculations the indirect tensile strength is calculated by equation:

$$\mathbf{S_t} = \frac{(636.62 \times P_{ax}}{(t \times D)})$$

Where:

S_t = indirect tensile strength (kPa)

Pmax = maximum load at failure (N)

t = height of the specimen (mm)

D = diameter of the specimen (mm)

And the material's E-modulus is calculated using the formula:

$$\mathbf{E_{mod} = 6.1 \times S + 100\ (MPa)}$$

Additional Calculation

Calculate the specimen's dry bulk density based on the registered dry mass and height/diameter measurements (mass/volume).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents in detail the results obtained from each of the tests carried out on the materials used for the experimental investigation, including quality control tests on the materials and the specimen. The results will be in the graphical representations and analysis showing relationship between the variables for each test objective carried out. Also covers discussion on the materials findings including the material behaviour under each test.

4.2 Chemical Composition of Filler

Various tests were conducted to examine the chemical and physical properties of Calcined Quartzite Dust. The chemical properties were determiner from XREF-Spectrometer analysis. The Department received sample to be analyzed for $Al2O_3$, SiO_2 and Fe_2O. During analysis the sample was ground to fine powder (< 0.063mm), from which a pressed powder pellet was prepared and scanned using an XRF spectrometer (Epsilon 1) for Al_2O_3, SiO_2 and Fe_2O_3, determination. The content is expressed in weight percentages (wt%) as shown in the figure 2 .

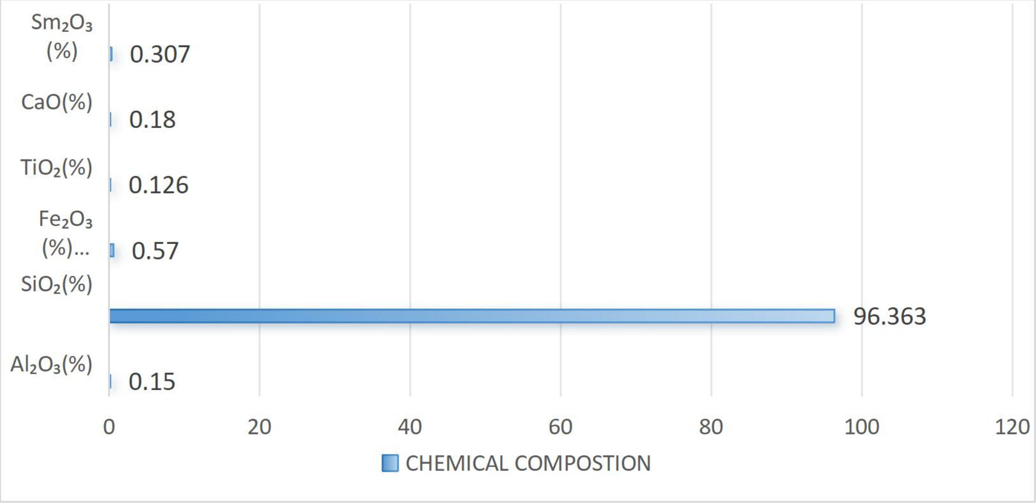


Figure 1 Chemical composition of Quartzite dust before calcination.

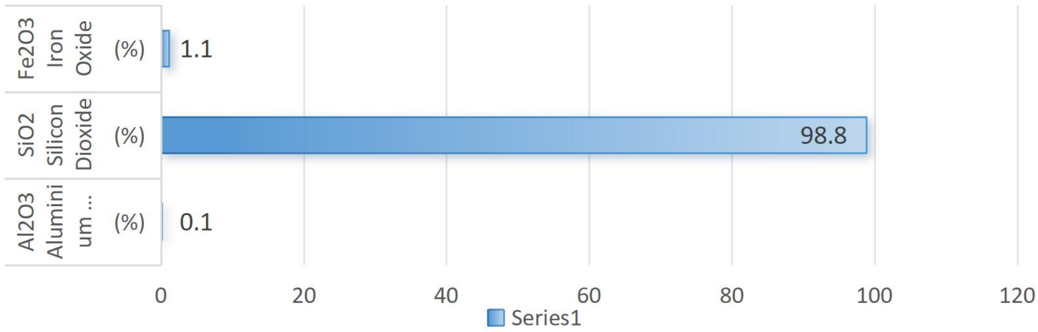


Figure 2 Chemical composition of Quartzite dust after calcination.

iron Increase: Fe203 rose from 0.57% to 1.1%, due to calcination concentrating iron by removing volatile components.

Aluminum Decrease: Al20, dropped from 0.15% to 0.1%, due to their change in structure. And other elements or impurities such as SM203, CaO, and TiO2, were removed, during the calcination process; these impurities are removed to ensure the material stability is not compromised as they react with components such as water in nature.

The chemical composition of the CQD shows about 98.8 % of SiO_2, which has been shown to improve the adhesion and bonding between aggregates and bitumen in the asphalt as its increases the rutting resistance of asphalt mixture (None V. Udaya Bhanu and Rao, 2016).

4.3 Specific Gravity of the Filler

(A) Wt. OVEN dry sample (gm)	484.32	364.73
(B) Wt. of Pycnometer containing water alone (gm)	1805.22	1769.65
(C) Wt of Pyconometer containing Sample and water (gm)	2095.58	1993.87
SPECIFIC GRAVITY OF FILLER $\frac{A}{A+(B-C)}$	2.497	2.596
AVERAGE	2.546	

Table 6 Specific Gravity of Filler

The average value of specific gravity was 2.546 as shown in Table 6 which lies within the required standard range of 2.4 to 3.0 according to AASHTO T100-95(1995). This implied that this filler material was suitable to be used in the study.

4.4 Aggregate Crushing Value Test Results (ACV)

A.C.V		
(A) WT BEFORE CRUSHING (gm)	2756.4	2754.5
(B) WT AFTER CRUSHING (gm)	2755.6	2754.4
(C) WT RETAINED AFTER CRUSHING (gm)	2291.1	2278.1
(D) WT PASSING SIEVE 2.36 mm	464.5	476.3
A.C.V(%) (D/B)*100	16.9	17.3
AVERAGE RESULTS %	17.1	

Table 7 Aggregate Crushing Value Test result.

The Aggregate Crushing Value In accordance with BS PART 110:1990 which state that the A.C.V percent should be less than 30%. Table 12 shows an average percentage of 17.1%; this implies that the aggregates is strong enough to resist under crush or compressive loading making it suitable to be used in the asphalt mixture.

4.5 Aggregate Impact Value Test Results (AIV)

A.I.V			
(A) WT BEFORE TEST (gm)	353	345.5	353.4
(B) WT AFTER TEST (gm)	352.5	345.5	353.4
(C) WT RETAINED AFTER TEST (gm)	297.3	290.4	295.9
(D) WT PASSING SIEVE 2.36 mm	55.2	55.1	57.5
A.I.V(%) (D/B)*100	15.7	15.9	16.3
AVERAGE %	**16.0**		

Table 8 Aggregate Impact Value Test Results

As for the A.C.V, the A.I.V also should ranger with a percentage less than 30% according to BS 812PART 110:1990 specification. As shown in the table 13 the aggregate passed the test and implies that have strong resistance to the sudden shock therefore it is suitable to be used in the this study.

4.6 Los angels abrasion value

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		4,955.0
GRADING USED FOR TEST:					
Wt of Mat. Retained on 1.7mm sieve : gm		4,010.0		Average: %	18.9
Wt of fine material _ gm		945.0			
Percentage of wear_ %		18.9		Spec Req	%

Table 9 Los Angeles abrasion value result.

From the table above the value of ACV was 18.9 % which is below the required value of 30% this indicates that the aggregates are satisfactorily strong to resist wearing. The Los Angeles abrasion value evaluates aggregate hardness and resistance to wear; lower values indicate durable aggregates.

4.7 Ten Percent Fine Value Test Results

10% FINE VALUE DRY			
Test no	1	2	3
crushing force (kn)	250.6	250.6	
wt. of aggreg (gm)after crushing (m1)	2778.9	2792.5	
wt. of aggreg. retained on sieve 2.36 mm (m3)	2461.2	2490.1	
wt.aggreg.(gm) passing sieve 2.36 mm (m2)	317.7	302.4	
ten % fine value (m=m2/m1*100)	11.4	10.8	
average results % (m)	11.1		
average crushing force (f)	250.6		
F= $\boxed{\frac{14F}{M+4}}$			
231.9	DRY	231.9	KN

Table 10 TFV results.

10% FINE VALUE SOAKED			
TEST NO	1	2	3
crushing force (kn)	250.6	250.6	
wt. of aggreg (gm)after crushing (m1)	2767.7	2743.5	
wt. of aggreg. retained on sieve 2.36 mm (m3)	2425.6	2385.9	
wt.aggreg.(gm) passing sieve 2.36 mm (m2)	342.1	357.6	
ten % fine value (m=m2/m1*100)	12.4	13.0	
average results % (m)	12.7		
average crushing force (f)	250.6		
$F = \boxed{\dfrac{14 \quad F}{M \quad + \quad 4}}$ 210.1 KN SPEC >110	SOACKED	WET/DRY(%)=	91% SPEC >75%

Table 11 TFV soaked result.

The TFV Dry obtained was 231.9KN and the TFV Soaked was 210.1KN as shown in Table 15 and 16 with the maximum force applied to the aggregates of 250.5 KN According to BS 812: Part 111:1990 specification, force of Ten Percent Fines Value wet/dry is greater than 75% , as it is indicate in the table the percent obtain was 91% which is greater than 75% required. Therefore, the aggregate was suitable to be use for this study.

4.8 Combined specific gravity of aggregates and water absoption results

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

Table 12 Combined specific gravity of aggregates and water absorption results

4.9 Flakiness Index result

BS sieve size(mm)		50.0	37.5	28.0	20.0	14.0	10.0	6.3	Total
Weight retained gm (A)						184.2	959.1	1158.5	2301.8
Riffled weight (if needed) gm (B)						184.2	959.1	523	
Coorrection factor a/b (C)						1	1	2.215	
Wt. Passing sieve gm (D)						54.0	150.0	110.0	
Wt. Retained on sieve gm (E)						130.2	809.1	413.0	
Corrected Wt. Passing (dxc) (F)						54.0	150.0	243.7	447.7
Flakiness Index = $\frac{TOTALF}{TOTALA} * 100$				FI =	19.4				

Table 13 Flakiness Index result

According to BS 812-105 specification standard, the presence of flaky or elongated particles shouldn't exceed 25% of the weight of coarse aggregate therefore it will make the aggregates undesirable for this study and from the result showing in the table 18 the aggregates is desirable to be used in asphalt concrete. This indicates that there are more angular aggregates which provide better interlocking in the mixture improving its stability.

4. 10 Bitumen Tests results

Table 14 Bitumen Tests results

The average penetration test was 66 mm which lies within range 0f 60-70 according to ASTM D5 specification, implies that the material is qualified to be grade 60/70 was suitable in terms of the hardness and consistency of the mix.

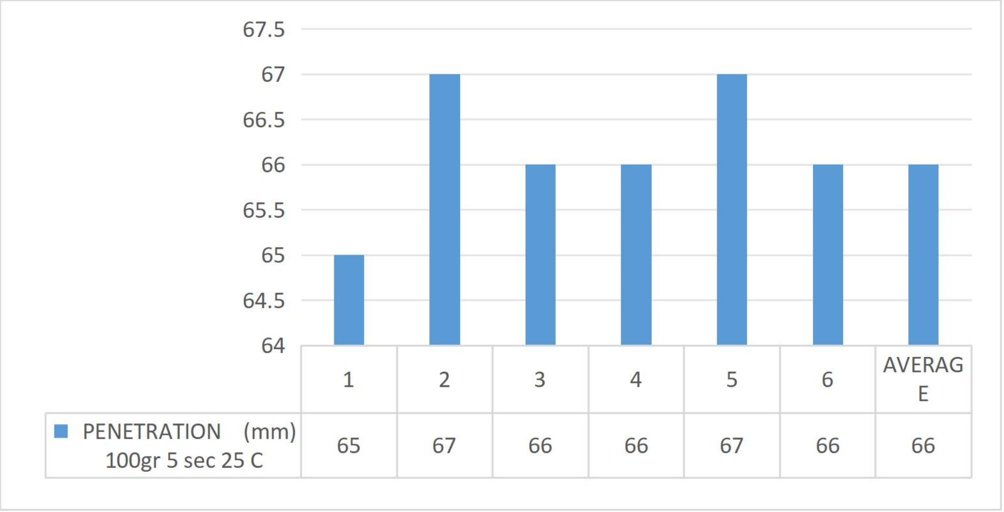


Figure 3 Penetration test result

The average value of softening point was 49 ˚C as shown in the table 19 which also lies within range of 49-56 ℃ according to the ASTM D36 specification .softening point temperature is a temperature at which bitumen becomes soft enough to allow the steel ball to sink at specified distance. As the the bitumen gives the value in the range it was favourable to be used in the design.

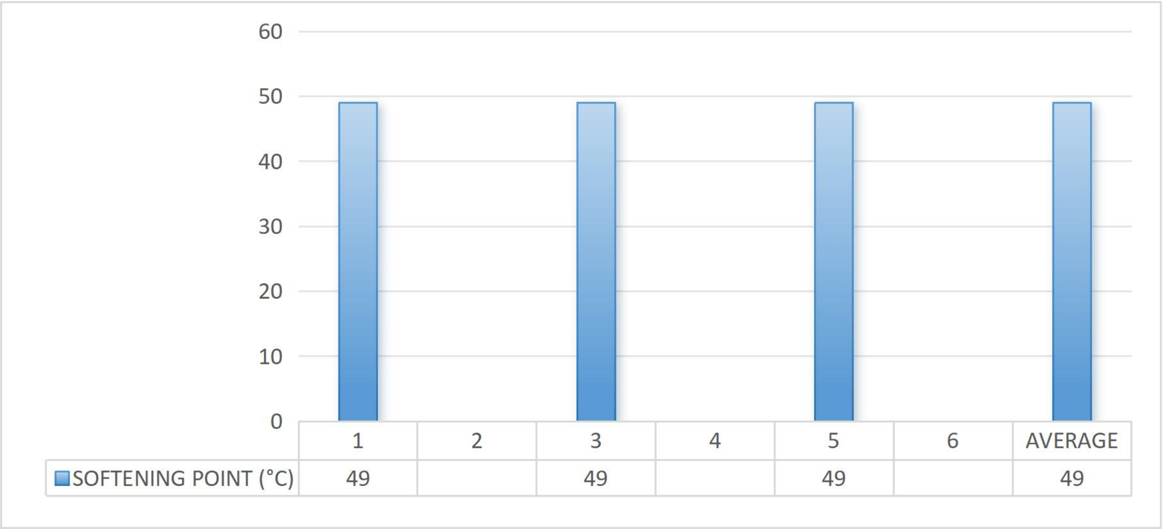


Figure 4 Softening point result.

With the average value obtained of 1.03 for the specific gravity shown in the table which lies within range according to ASTM D70 specification. The density of bitumen gives proper homogeneity and coating of the asphalt mix with the right proportions in the mix design.

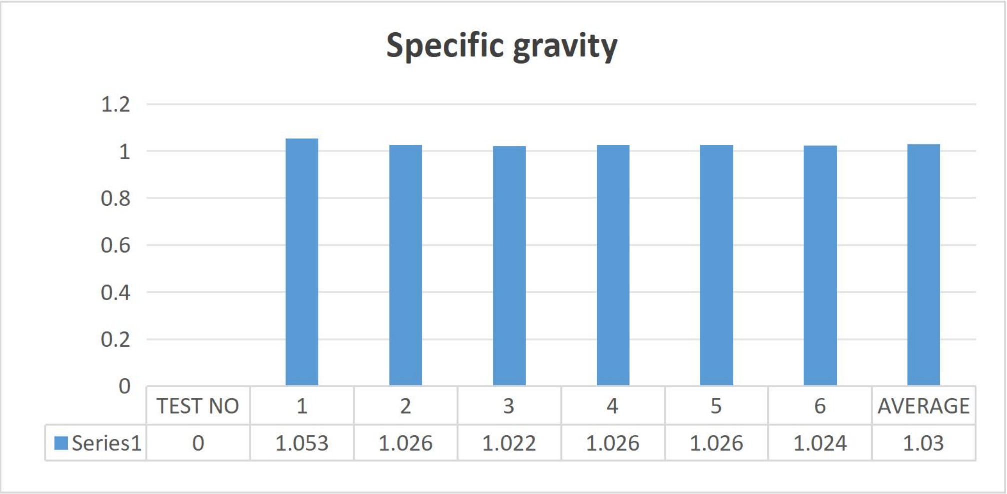


Figure 5 Specific Gravity of Bitumen

4.11 Job Mix Formula Test Results

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

Table 15 AC 20 individual gradation

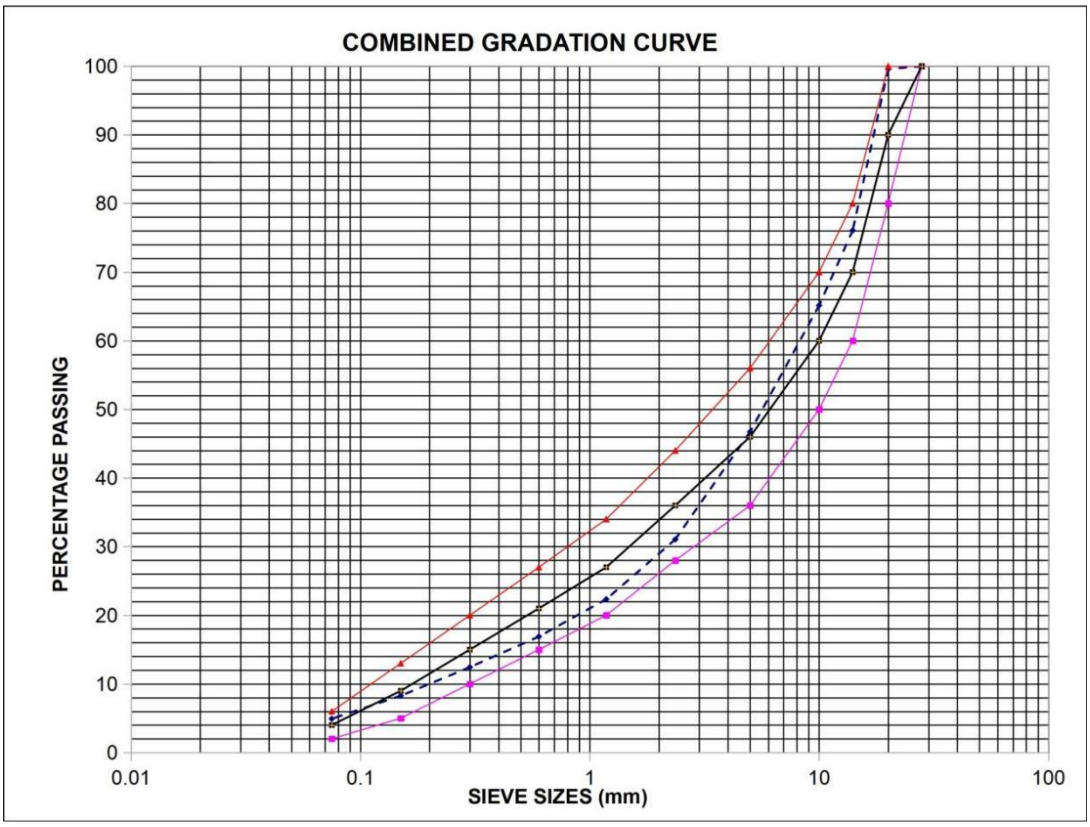


Figure 6 Combined Graduation Curve.

The table 20 shows the particle size distribution of the combined grading of the AC 20 mix. And the Figure above shows the AC 20 combined gradation and it also shows that the gradings lie in the specified grading envelopes of both the upper and lower limits according to (MoWT ,2010). The orange line is the finer side, the pink line is the coarser side and the black line is the grading curve we obtained from the mass grading. Our curve starts at the finer side and then moves on to the coarser side and then to the fine side and coarse side again, with the bigger percentage towards the coarser side. This means there's more coarse aggregates than the fine aggregates in the mix and this implies that the particle distribution of the aggregates achieved a proper mechanical interlock of aggregates which positively affects the durability of the mixture.

This grading is achieved by using the try and error method so as to obtain the different percentages of the aggregates and filler so that the mix design fits between the upper and lower limits of the gradation curve target grading. The AC 20 mix composed of different sizes of aggregates to begin with the passing

28 mm and retained on 14/20 mm, 10/14, 6/10, 0/6 mm and then filler of 2%, as stated in the MoWT design Manuel mineral filler in the mix should not excess 5%.

4.12 Marshall Mix design to Determine Optimum Bitumen Content

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

Table 16 Performance of different bitumen percentages

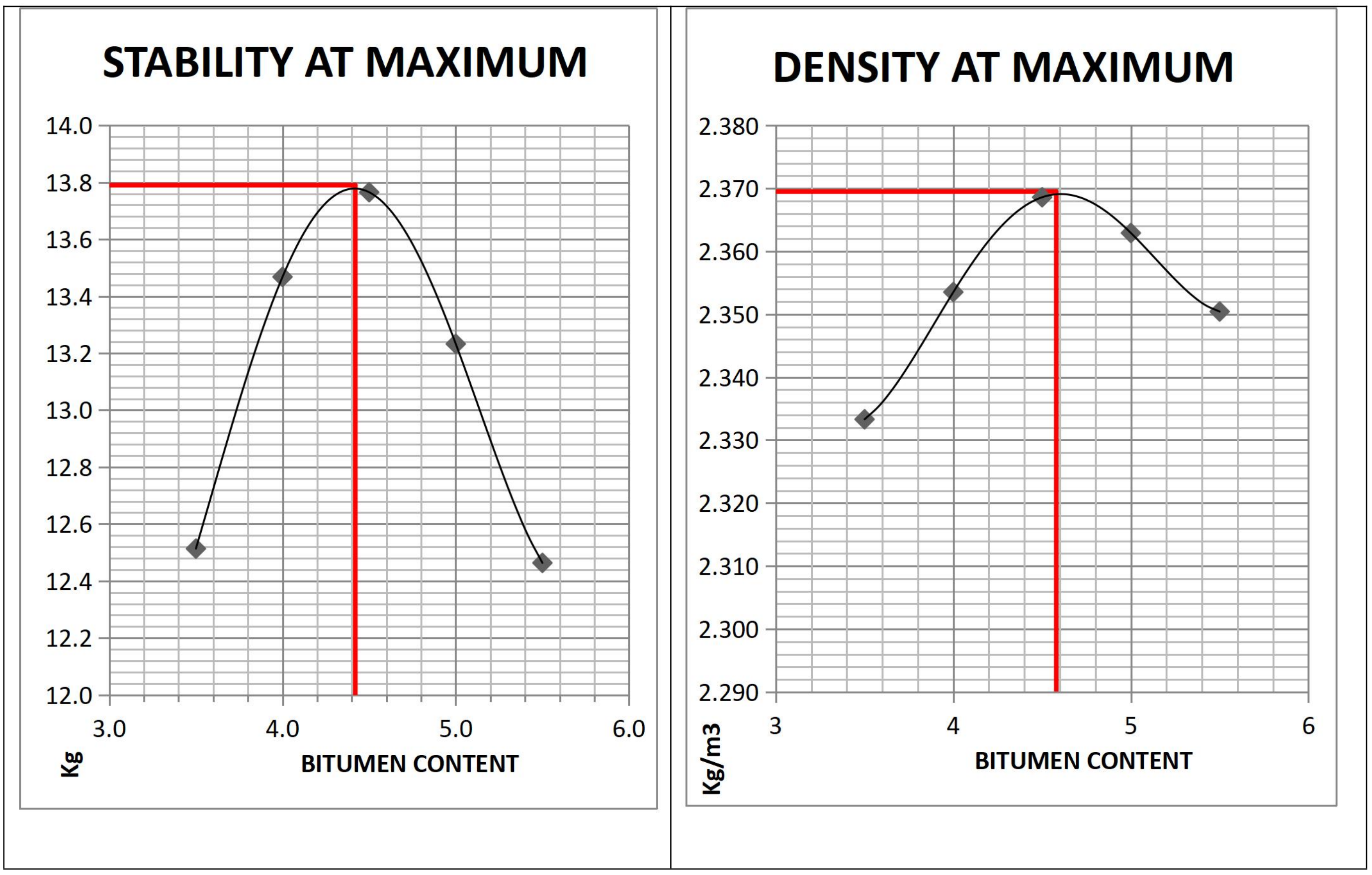


Figure 7 Marshall Stability and Density

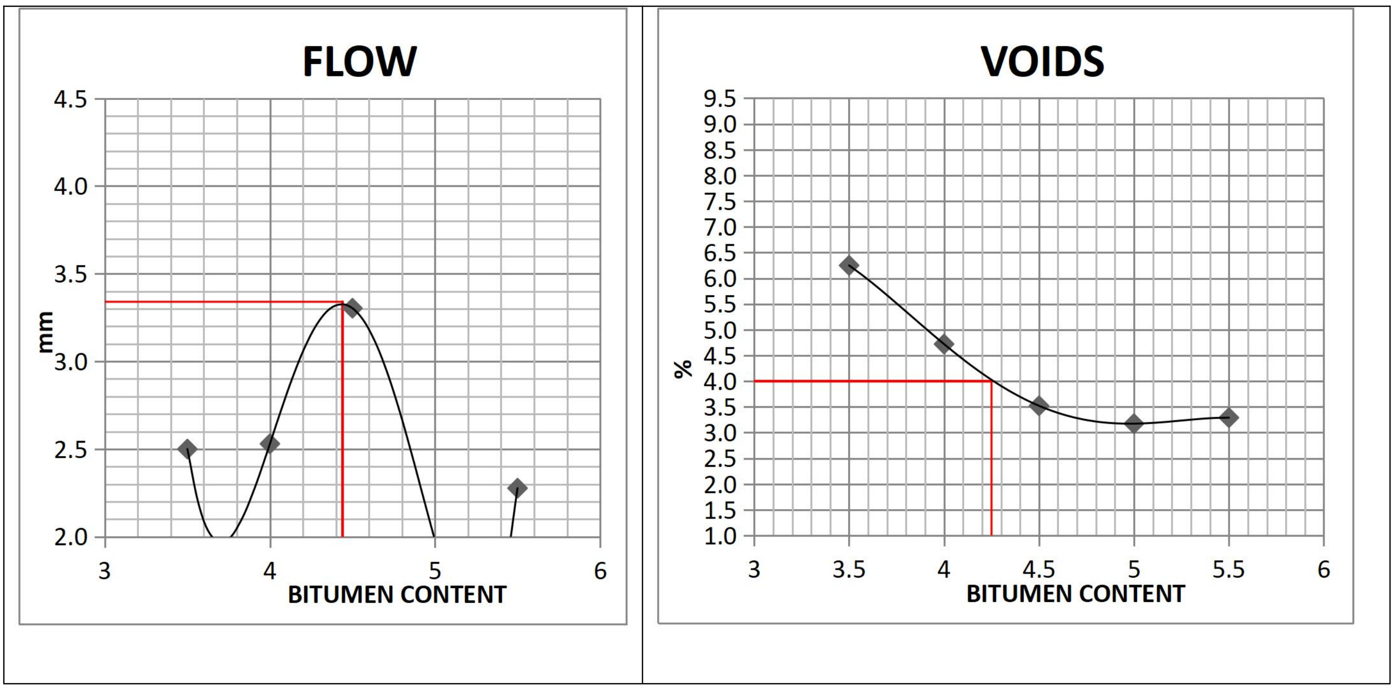


Figure 8 Marshall Flow and Voids

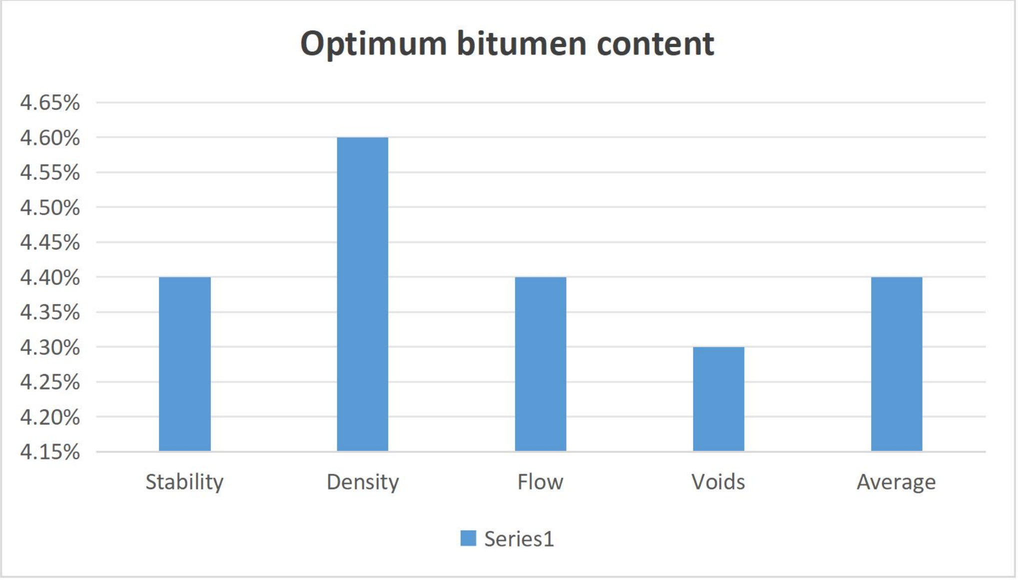


Figure 9 Bitumen content achieved

The average bitumen content for the asphalt mixture was obtained as 4.4 % from the stability, density, flow and voids as seen in the figure 9. This percentage was considered to be used as the Optimum Bitumen Content in this Research Design.

4.13 Asphalt Design Mix Proportion for AC 20

Material Composition	Aggregate Blending Proportions (%)	Aggregate Mass (g)	Composition Asphalt Concrete (g)	Mass in the Mix (g)
Bitumen	4.4	_	_	_
14/20mm	32	5760	253.4	5507
10/14mm	6	1080	47.52	1032
6/10mm	6	1080	47.52	1032
0/6mm	51	9180	403.9	8776
Natural filler	0.5	90	3.96	86.04
CQD filler	4.5	810	35.64	774.4
	100	18000	792	17208
TOTAL = ΣC4 + ΣC5				**18000**

Table 17 Asphalt design mix. for AC 20

The Table above shows the mix proportions of a given mass 18,000g used in the mixture with 4.4% of OBC and 4.5% of calcined quarzite Dust filler to produce the Marshall specimens. To obtain the following;

i. Mass of aggregate from $\left(\frac{blending\ \%}{100} \times\ Mass\ to\ blend\right)$,

ii. Composition asphalt concrete from $\left(\frac{Agg.Mass \times OBC}{100}\right)$

iii. Mass in the mix from $(Agg.Mass - \text{Composition Asphalt Concrete})$

4.14 Performance Tests for Asphalt

BITUMEN CONTENT	4.4 %		
Marshall Mix Test Results	Neat asphalt mix with Stone Dust	4.5 % CQD	Specification (MoWT, 2010)
MARSHALL FLOW (mm)	2.9	3.6	2-4
MARSHALL STABILITY 75 BLOWS (KN)	15.0	21.9	> 8
MARSHALL AIR VOID 75 BLOWS	4.8	4.8	3-5
VOID IN MINERAL AGGREGATE (%)	14.4	15.1	> 14 %
VOID FILLED WITH BINDER (%)	66.7	68.3	65% - 75%
Indirect Tensile Strength @ 25 C (Dry) Kpa	900.2	1,130.6	
Indirect Tensile Strength Wet Kpa	740	990	
$\frac{ITS\ WET}{ITS\ DRY} \times 100$	82	88	> 80%

Table 18 Summary of Marshall Mix Results

Marshall stability

The Marshall stability value increased from 15 KN with neat asphalt stone dust to 21.9 kN with CQD filler as shown in figure 10; the Stability test measures the maximum load a compacted asphalt specimen can withstand before failure, this also indicate the mixture's resistance to deformation under traffic loads.

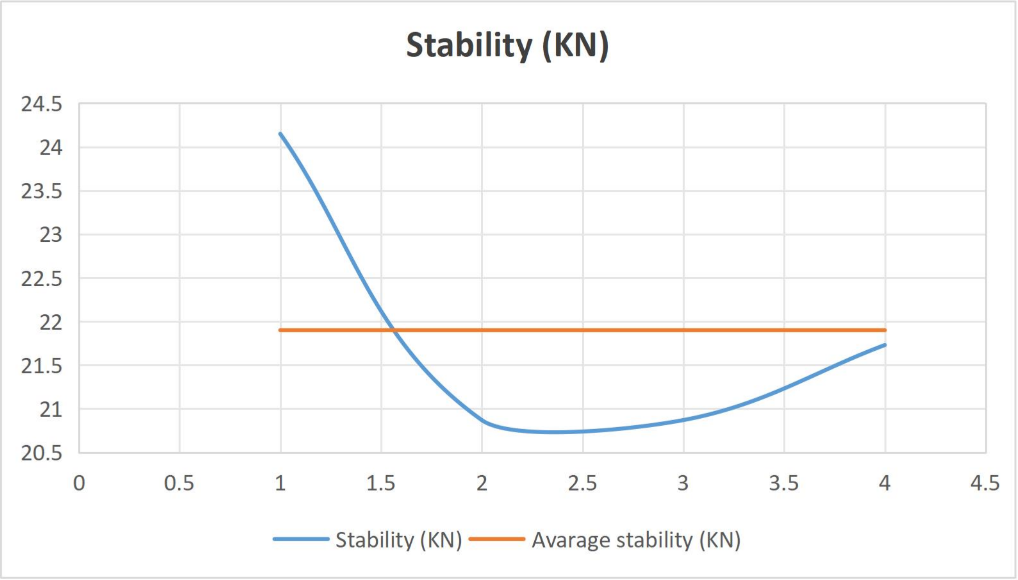


Figure 10 Marshall Stability

Marshall flow test

The flow value increased by from 2.8 mm to 3.6 mm with CQD filler. The flow value measures the flexibility and ability to deform without cracking, particularly in region with high temperature variation. As shown in figure 11 the flow with QCD increases as it remains in the specification envelop.

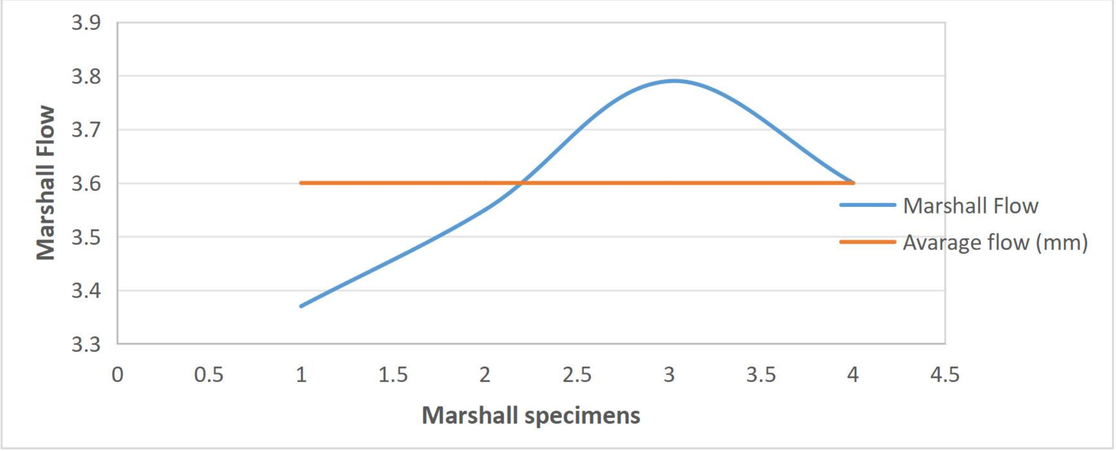


Figure 11 Marshall Flow result

Air Voids

Air voids are crucial for the durability of flexible pavements, this test measures the air voids percentage in the compacted asphalt mixture; which affects the durability and resistance to moisture damage. Excessive air voids in the mixture can lead to permeability problems causing damage in the sub-layer of the pavement due to water infiltration. Therefore, it is essential to maintain air voids within the specified range require d to ensuring pavement performance and longevity. The figure 12 shows that the 4.8% air void in the mix was within the specification.

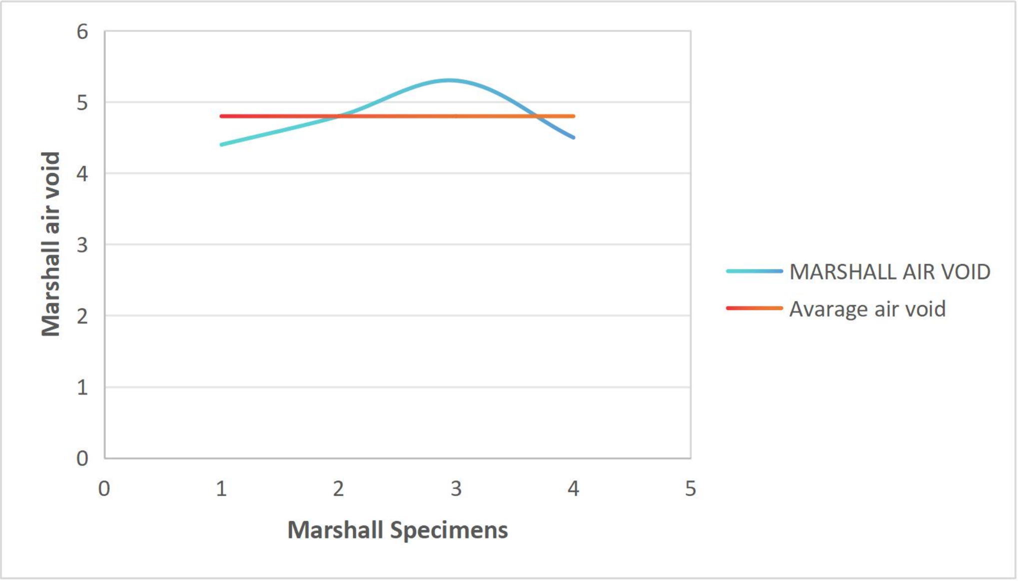


Figure 12 Air voids test result

Voids in Mineral Aggregates (VMA)

The VMA value in the mix was measured 15.1% falls within the specification and it rises compare to the neat asphalt mix indicating it exceeds the minimum requirement of 14%. the VMA measures the volume of voids between the aggregate particles, which must be sufficient to accommodate the asphalt binder and air voids. A higher VMA facilitates better interlocking of particles within the asphalt mixture, thereby improving its resistance to deformation and rutting.

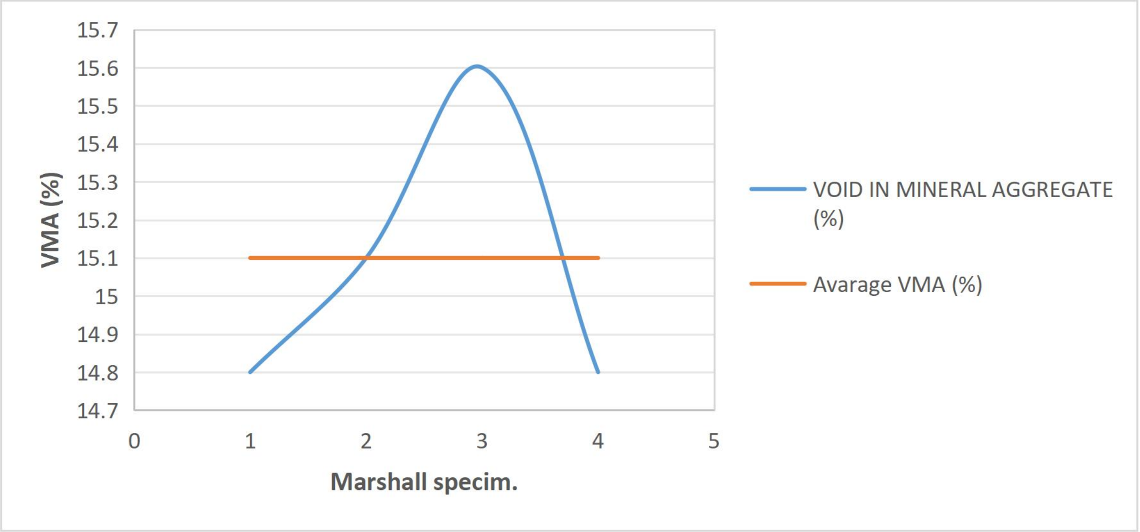


Figure 13 VMA test result

Voids Filled with Bitumen (VFB)

The VFB measured at 68.3% which indicates that the voids were adequately filled, ensuring sufficient asphalt binder content and facilitating proper compaction. VFB measures the VMA percentage that is filled with asphalt binder, indicating the mix's ability to resist moisture damage and ensure proper compaction. A higher VFB promotes better cohesion and adhesion between aggregate particles, thereby enhancing the overall strength and durability of the pavement structure.

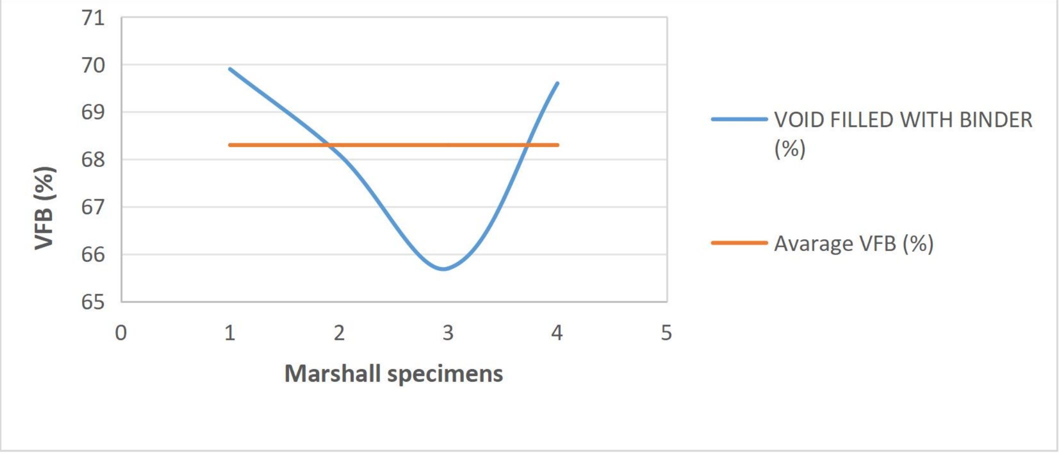
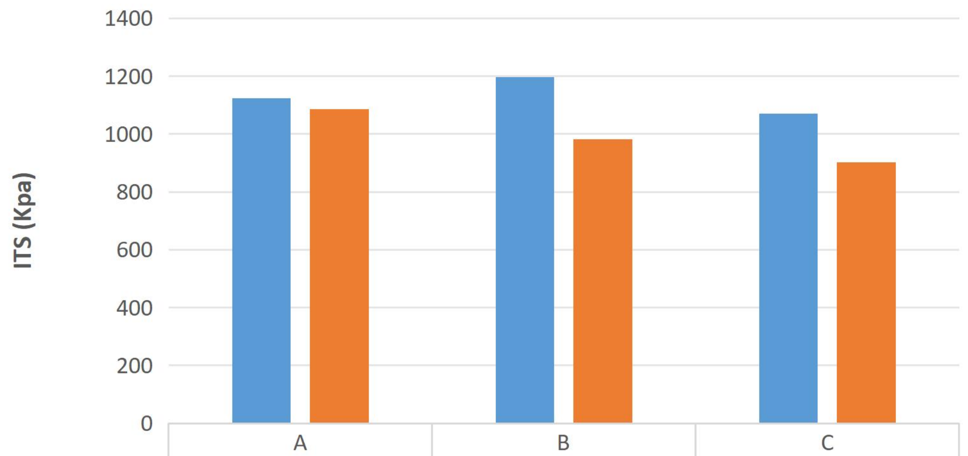


Figure 14 VFB test result

4.15 Indirect Tensile Strength (ITS)



	A	B	C
ITS DRY	1124.4	1197.4	1069.8
ITS WET	1086.9	981.3	902.4

Figure 15 ITS analysis

The average ITS wet over the dry obtained was 88% which which is 8% above the required percentage. This ITS measures the mixture's ability to resist tensile stresses, which are critical for pavement support under traffic and thermal loading, high ITS values indicate a stronger mix with better resistance, it also evaluates the mix's resistance to moisture induced damage and fatigue. The ITS test helps engineers optimize the asphalt binder content and aggregates gradation to achieve a balance between tensile strength and other properties such as Stability, flow, air voids and volumetric analysis.

Stiffness modulus

(E)=(6.1×ITS)+100

From the ITS achieved the (E) gives =(6.1×990)+100= 6,139 Mpa

For AC 20 the Stiffness modulus varies between 5,000 to 10,000 Mpa

This implies that the mixture can handle deformation without causing cracking or rutting unless there is issue with sub-structure of the road.

4.16 Wheel Tracking Test.

Wheel tracking performance, which is usually evaluated using tests like the Hamburg Wheel Tracking Test (WTT), is the degree to which asphalt pavements withstand deformation, such as rutting, under repeated wheel loads (AASHTO T 324). And in the Indirect Tensile Strength test (ITS), measures a compressive load applied along the diameter of a cylindrical specimen to induce tensile stress and assess the performance of the mixture (AASHTO T 283). ITS is used to evaluate moisture damage and cracking resistance; its correlation with rutting performance is less well established.

1. The Relationship Between Wheel Tracking Performance and ITS

Based on various studies better resistance to rutting or deformation under wheel loads is also related to higher ITS values, which indicates stronger tensile strength; in the Wheel Tracking Tests repetitive loading can result in permanent deformation, the material's ability to resist tensile stresses is crucial, and this connection occurs because ITS represents that ability. Rutting is related to tensile yield modulus generated from ITS, according to (Nascimento, Guimarães and Castro, 2021). who examined the mechanical properties from the French wheel tracker. This investigation was done underwater to evaluate moisture resistance.

2. Practical Implications and Research Gaps

In regions or areas with high temperature where rutting is more common, engineers can use ITS tests to evaluate Rutting possibility by ensuring that the mixes have enough stiffness. The requirement for standardized tests settings and effect of aging on this correlation as suggested by (Briliak and Remišová,2022). are among the study gaps that still exist. Variations in aggregate gradation, binder type, and ambient conditions can also impact the results. This implies that although ITS is valuable indicator various factors should be considered such as air voids.

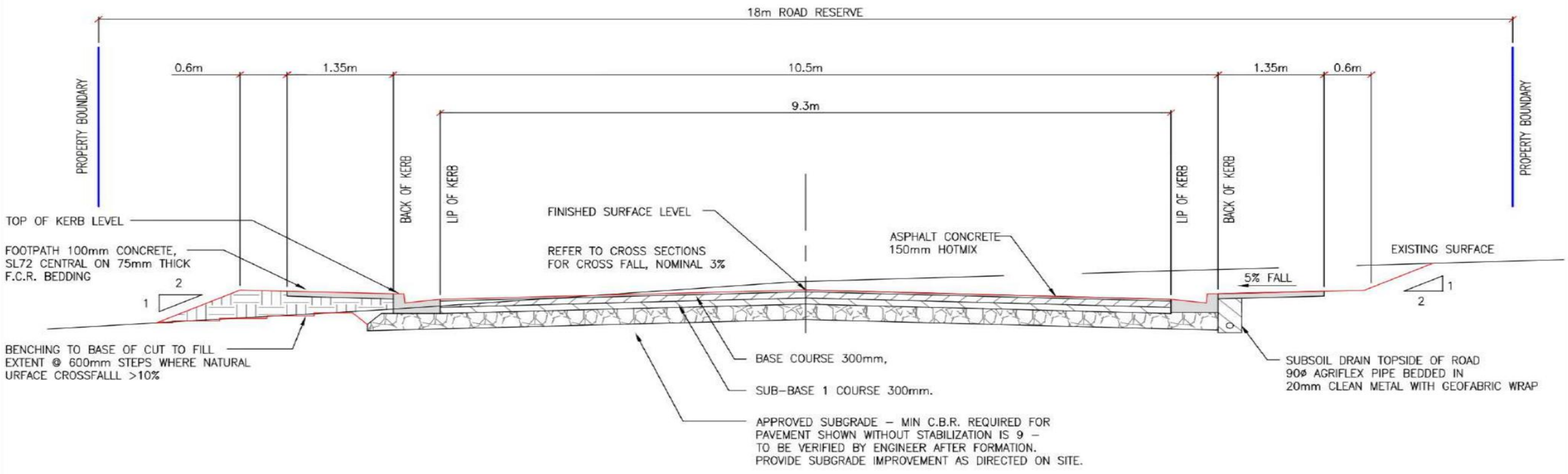
3. Conclusion.

The literature supports a moderate correlation between ITS and rutting performance, higher ITS values generally indicate better resistance to rutting. If the ITS is > 800kPa for rut depths is < 10mm, and if ITS < 600kPa rut depths are > 15mm this aligns with certain studies, especially those testing at high temperatures, such as the WVU research thesis indicate . However, exact values can vary, and further research under specific conditions is recommended for precise application (Srinivasan, 2004).

ITS (kPa)	**Estimated Rut Depth (mm at 20,000 passes)**	**Interpretation**
<600	>15 mm	Poor, high rutting risk
600-800	10-15 mm	Moderate, may need validation
>800	<10 mm	Good, likely low rutting

Table 19 The Relationship Between Wheel Tracking Performance and ITS.

4. Engineering drawing of typical flexible pavement



TYPICAL ROAD CROSS SECTION

SCALE 1:50

TYPICAL CROSS SECTION	
PROJECT TITLE	ENHANCING RUT RESISTANCE IN ASPHALT CONCRETE USING CALCINED DUST AS A FILLER
AUTHOR	GONZA EDGAR S21B32/132 AMULE MOISE S21B32036
SCALE	1:50

Figure 16 Typical Road Cross Section - ASPHALT CONCRETE-Size Layout

5. Road layer design

Vehicle class	Station	Growth rate	Given that:
Minibuses	4,507	6.0%	1. Design life (y) = 15 years 2. N = 2 years 3. Assume the road length is 1,000m 4. Width is 12 m
Buses	3	4.5%	
Pick-ups	1,845	5.0%	
2-Axle Trucks	507	5.0%	
3-Axle Trucks	44	4.0%	

Table 20 Given road surveying data

Description	Mini Buses	Buses	Pick-Ups Cars	2-Axle Trucks	3-Axle Trucks
Gross Weight (t)	3.00	15.00	3.00	12.00	20.00
Front Axle Load (t)	1.00	3.00	1.00	4.00	4.00
Rear Axle Load 1 (t)	2.00	6.00	2.00	8.00	8.00
Rear Axle Load 2 (t)	-	6.00	-	-	8.00

Table 21 Axle load distribution

We obtain the following;

Vehicle Class	Rate (%)	Fo (Veh/d)	Fp (Veh/d)	W (esa)	G	Y (yrs)	Ti(msa)
Minibuses	6.0%	3,005	3,376	0.0019	1.5481	15	0.054
Buses	4.5%	220	2	0.5124	1.3911	15	0.008
Pick-Ups	5.0%	1,230	1,382	0.0019	1.5481	15	0.022

2-Axle Trucks	**5.0%**	**338**	**373**	**0.9552**	**14.818**	**15**	**2.813**
3-Axle Trucks	**4.0%**	**29**	**32**	**1.8699**	**13.420**	**15**	**0.440**

Table 22 Traffic class obtained

Cumulative Design Traffic, T = 365 x Fp x W x G x Y x 10-6 (in msa) T = 3.335, msa corresponds to a traffic class of T5. Assure the following

AASHTO guide procedure assume the following

- **a road to carry a design ESAL of 2×10^6.**
- **it takes about a week for water to be drained from within the pavement and the pavement structure to be exposed to moisture levels of saturation about 30% of the tim**
- **Resilient modulus of asphalt concrete at 68°F = 450,000 lb/in**
- **CBR value of base course material = 100**
- **CBR value of subbase course material = 20**
- **CBR value of subgrade material = 6**

Since the pavement is to be designed for the kampala -jinja highway in bweyogerere , the following assumptions are made.

Reliability level (R) = 99%

Standard deviation (S_o) = 0.45

Initial serviceability index pi= 4.5

Terminal serviceability index pt = 2.5

Determine a suitable pavement structure, Mr of subgrade = 6 x 1500 lb/in = 9000 lb/in. From the design serviceability loss graph we got a SN = 4.42

Determine the structural layer from the graph based on CBR of each layer:

a1: 0.44, a2: 0.14, and a3: 0.09 (surface layer, base and subbase layer)

Determine the drainage coefficient (m): m2 and m3 : 0.80

let's substitute in the formula of the Structural Number SN= a1D1 + a2D2m2 + a3D3m3

Assume the layers thickness in inches : D1 = 6", D2 = 12", D3 = 12"

SN = a1D1 + a2D2m2 + a3D3m3

4.42 < (0.44 x 6) + (0.14 x 12 x 0.80) + (0.09 x 0.80 x 12)

4.42 < 4.85

Conclusion

Asphalt Concrete (surface layer) = 6” = 150mm

Roadbase = 12” = 300mm

Subbase: 12” = 300mm

From the given road length of 1,000m, width of 12m, and height of 0.15m gotten from calculation above, we can quantify the material to be used in this section.

Solution

Volume $= (1000 \times 12 \times 0.15) = 1{,}800\,\mathrm{m}^3$, when covert to tons = 2,520T, this gives a total mass to blend of 2,520,000,000 g.

For each component:

Aggregate Mass Required: we take Mass need to cover the road dived by the the lab mass for each aggregate and filler multiply by each lab mass.

Bitumen Mass Required: Total mass of bitumen required by the mass at lab multiply by mass in the lab.

We get $\frac{2{,}520{,}000{,}000}{18{,}000} = 140{,}000$

Let's calculate for each component:

I. For 14/20mm: Lab mass in the mix = 5,507 g,

Required mass = 5,507 g × 140,000 = 770,980,000g = 770.98T

II. For 10/14mm: Lab mass in the mix = 1,032 g,

Required mass = 1,032 g × 140,000 = 144,480,000g = 144.48T

III. For 6/10mm: Lab mass in the mix = 1,032 g,

Required mass = 1,032 g × 140,000 = 144,480,000g = 144.48T

IV. For 0/6mm: Lab mass in the mix = 8,776 g,

Required mass = 8,776 g × 140,000 = 1,228,640,000g = 1,228.64T

V. For Natural filler: Lab mass in the mix = 86.04 g,

Required mass = 86.04 g × 140,000 = 12,045,600g = 12.046T

VI. For CQD filler: Lab mass in the mix = 774.4 g,

Required mass = 774.4 g × 140,000 = 108,416,000g = 108.416T

VII. Bitumen Total: Lab mass in the mix = 792 g,

Required mass = 792 g × 140,000 = 110,880,000g = 110.88T

Table of the calculated required masses for each component:

Material	**Lab Mass in the mix (g)**	**Required Mass (g)**	**Required Mass (T)**
14/20mm	5507	770,980,000	770.98

10/14mm	1032	144,480,000	144.48
6/10mm	1032	144,480,000	144.48
0/6mm	8776	1,228,640,000	1,228.64
Natural filler	86.04	12,045,600	12.046
CQD filler	774.4	108,416,000	108.416
Bitumen	792	110,880,000	110.88

Table 23 Table of the calculated required masses for each component

The approach involves scaling the lab mix proportions to road work scale using the total required mass.

5. Cost Analysis

On market the price of AC 20 equal to 650,000 ugx (180.6 Usd)per ton, now for the 1,800m^3 which is about 2,520 tons the amount of money required will be $(650{,}000 \times 2{,}520) = 1{,}638{,}000{,}000 \text{ ugx} \approx 455{,}000 \text{ Usd}$/Km.

CHAPTER FIVE : CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study aimed assess the use of calcined quarzite dust as filler to enhance rut resistance in the flexible pavements. It was achieved through material suitability tests (physical, mechanical and chemical tests) which consist following these methods; ACV test, Flakiness Index, AIV test, Ten Percent Fines Value (TFV) test, specific gravity, water absorption test on both aggregates and filler, x-ray fluorescence on the filler, softening point test, penetration test to determine the engineering properties aggregate, bitumen and Calcined quartzite dust filler.

The second method was Marshall Mix Design of asphalt class 20 (AC-20), was used to determine the optimum bitumen content (OBC) to be used in the mix design and volumetric properties of the asphalt incorporated CQD were determined in comparison to neat asphalt mixture with hydrated lime. The optimal design mix achieved was 4.4% for the OBC and 4.5% for the optimum filler content used.

The performance test which is Indirect Tensile Strength was carried out to determine the stiffness and durability properties of asphalt mixtures with CQD compare to the neat asphalt mix with Hydrated lime filler. The study, concluded that; the CQD improved the ITS from 900kPa with the conventional filler to 990kPa, the Marshall stability also increased significantly from 15kN to 21.9 kN indicating resistance to rutting under varying heavy traffic loads hence ensure the durability of the pavement.

5.2 Recommendations

5.2.1 Recommendations based on Conclusion

Based on the findings of this research project,

1) Consider a batch total mass of 18,000g should be Implement with 4.5 % of Calcined quarzite dust as partial replacement for the conventional filler like lime dust in the asphalt mix design. and 4.4 % of Optimum Bitumen Content to be used in the mixture.
2) The the material batching used for AC 20 should be 14/20, 10/14, 6/10, 0/6 and filler material for Asphalt Concrete 14 mix design for wearing course.

5.2.2 Recommendations for Future Studies

1) Studies should be carried out to investigate the long-term durability and aging performance under real-word conditions.

2) the study should assess the alternative Binder compatibility with calcined quarzite dust using materials such as polymer modified bitumen.

The effect of the temperature on the storage of filler material should be investigated as it influences the fatigue response.

3) Evaluate the economic feasibility of using the CQD compared to the conventional filler, by considering the availability, processing cost of the material e.g calcination, and life-cycle saving.

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APPENDICES

Image 1 Wet sieving for grading

Image 2 Quartzite filler sieving

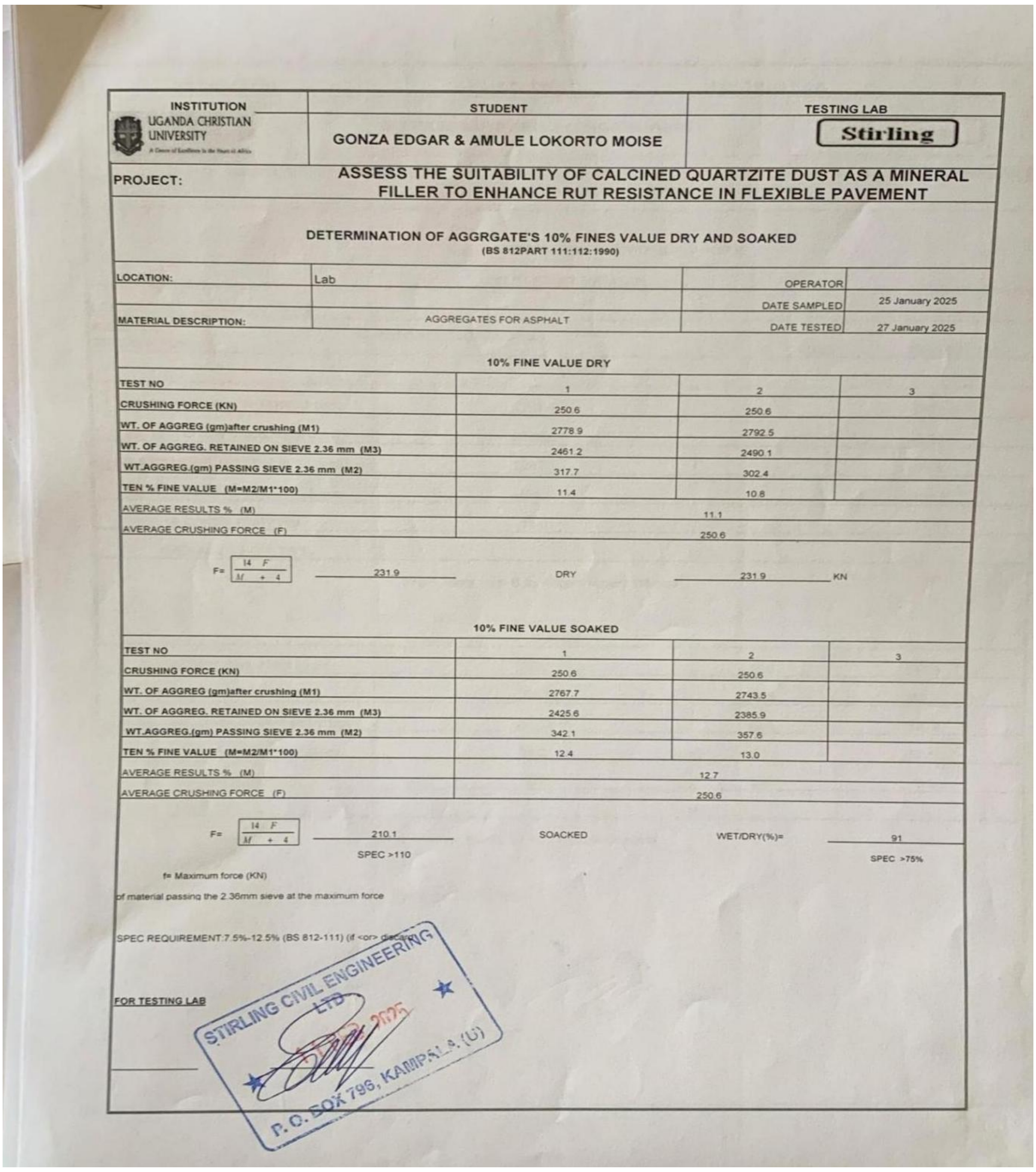
 Image 3 Marshall Mix preparation	 Image 4 The Marshall sample mixed homogeneously
 Image 5 Bitumen Penetration test	 Image 6 Sample preparation for

	compaction
	
Image 7 Temperature monitoring before compaction	Image 8 Sample after compaction
 Image 9 Maximum Specific Gravity test (Gmm)	

	Image 10 Stability and Flow tests

APPENDIX

APPENDIX A: Physical and mechanical properties of Bitumen and Aggregates.



INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

PROJECT: ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT

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

LOCATION:	Lab	OPERATOR	
		DATE SAMPLED	25 January 2025
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT	DATE TESTED	27 January 2025

10% FINE VALUE DRY

TEST NO	1	2	3
CRUSHING FORCE (KN)	250.6	250.6	
WT. OF AGGREG (gm)after crushing (M1)	2778.9	2792.5	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2461.2	2490.1	
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	317.7	302.4	
TEN % FINE VALUE (M=M2/M1*100)	11.4	10.8	
AVERAGE RESULTS % (M)	11.1		
AVERAGE CRUSHING FORCE (F)	250.6		

$F = \frac{14\ F}{M + 4}$ 231.9 DRY 231.9 KN

10% FINE VALUE SOAKED

TEST NO	1	2	3
CRUSHING FORCE (KN)	250.6	250.6	
WT. OF AGGREG (gm)after crushing (M1)	2767.7	2743.5	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2425.6	2385.9	
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	342.1	357.6	
TEN % FINE VALUE (M=M2/M1*100)	12.4	13.0	
AVERAGE RESULTS % (M)	12.7		
AVERAGE CRUSHING FORCE (F)	250.6		

$F = \frac{14\ F}{M + 4}$ 210.1 SOACKED WET/DRY(%)= 91

SPEC >110 SPEC >75%

f= Maximum force (KN)

of material passing the 2.36mm sieve at the maximum force

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

FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD
2025
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

PROJECT:	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

LOCATION:	MUKONO SITE	Oparator	
MATERIAL DESCRIPTION:	AGGREGATES FOR ASPHALT	Date	27/Jan/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2756.4		2754.5
(B) WT AFTER CRUSHING (gm)	2755.6		2754.4
C) WT RETAINED AFTER CRUSHING (gm	2291.1		2278.1
(D) WT PASSING SIEVE 2.36 mm	464.5		476.3
A.C.V(%) (D/B)*100	16.9		17.3
AVERAGE RESULTS %	17.1		

NB If c+d is more than B by 10gms repeat the test

A.I.V

(A) WT BEFORE TEST (gm)	353	345.5	353.4
(B) WT AFTER TEST (gm)	352.5	345.5	353.4
(C) WT RETAINED AFTER TEST (gm)	297.3	290.4	295.9
(D) WT PASSING SIEVE 2.36 mm	55.2	55.1	57.5
A.I.V(%) (D/B)*100	15.7	15.9	16.3
AVERAGE RESULTS %	16.0		

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

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

<u>FOR TESTING LAB</u>

STIRLING CIVIL ENGINEERING LTD
11 FEB 2025
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling 0

PROJECT	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT

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

JOB:	MUKONO SITE	OPERATOR	
LOCATION :	MUKONO CRUSHER	TOTAL BY DRY WT. OF THE SAMPLE:	5,000.0
SUPPLIER:	STIRLING	MOISTURE CONSTANT:	
MATERIAL:	ASPHALT AGGREGATES	DATE SAMPLED:	25/Jan/2025
SPECIFICATION...		DATE TESTED:	27/Jan/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 4,955.0

GRADING USED FOR TEST:
Wt of Mat. Retained on 1.7mm sieve : 4,010.0

Average: % 18.9

Wt of fine material gm 945.0

Percentage of wear_ % 18.9

Spec Req %

FOR TESTING LAB

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P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

PROJECT — **ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT**

FLAKINESS INDEX OF AGGREGATES (BS 812 PART 105.2 1990)

Location:	STIRLING LAB	Operator:	
Material:	COMBINED AGGREGATES FOR AC 20 ASPHALT	Date:	25/01/2025

weight of sample (gms) 5874.2

BS sieve Size	Weight Retained (gm) (from grading sheet)	% Retained	Minimum Weight Required (gm)
50 mm	0	0.0	50,000
37.5mm	0	0.0	35,000
28mm	0	0.0	15,000
20mm	0	0.0	5,000
14mm	184.2	3.1	2,000
10mm	959.1	16.3	1,000
6.3mm	1158.5	19.7	500
Total	2301.8	39.2	

s less than 5% that size is not tested for flakiness

BS sieve size(mm)		50.0	37.5	28.0	20.0	14.0	10.0	6.3	Total
Weight retained gm (A)						184.2	959.1	1158.5	2301.8
iffled weight (if needed) gm (B)						184.2	959.1	523	
Coorrection factor a/b (C)						1	1	2.215	
Wt. Passing sieve gm (D)						54.0	150.0	110.0	
Wt. Retained on sieve gm (E)						130.2	809.1	413.0	
Corrected Wt. Passing (dxc) (F)						54.0	150.0	243.7	447.7

Flakiness Index = $\frac{TOTAL F}{TOTAL A} * 100$ 19.4

FOR TESTING LAB

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

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling
PROJECT	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT	

TRUCK No.	STOCKPILE 1	DELIVERY NOTE No.
LOCATION		OPERATOR: Lab team
SUPPLIER		CONTAINER NO.: 0
TEST METHOD: EN 12591-2000		TRUCK NO: 0
11-Oct-22		
BITUMEN TYPE 60/70		

BITUMEN TESTS

TEST NO	3		D		7	6	2'	IFF	AVERAGE	TEST METHODS	REMARKS
PENETRATION 100gr 5 sec 25 C	67 64 65		70 63 67		69 65 65	68 67 64	67 68 66	65 68 64	66	ASTM D5	60-70
SOFTENING POINT (°C)		49.0		49.0					49.0	ASTM D36	(48-56)°C
BITUMEN AFFINITY									>95		>95
SUPECIFIC GRAVITY	1.053		1.026		1.022	1.026	1.026	1.024	1.03	ASTM D70	1.01-1.06

Materials Engineer.

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

TUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

PROJECT	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT
TEST	SPECIFIC GRAVITY
TEST METHOD	ASTM:C128-97

Sample Ref:	AC 20 MM	Technician :	
SOURCE:	Mukono Stirling quarry	Sampling date:	25-Jan-25
Aggregate size :	COMBINED	Testing date:	27-Jan-25
Description of aggregates:	HOT BINS		

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

REMARKS

STIRLING CIVIL ENGINEERING LTD
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FOR TESTING LAB

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling
PROJECT	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT	

JOB: ASPHALT MIX DESIGN

LOCATION: MUKONO LAB — 22-Jan-25

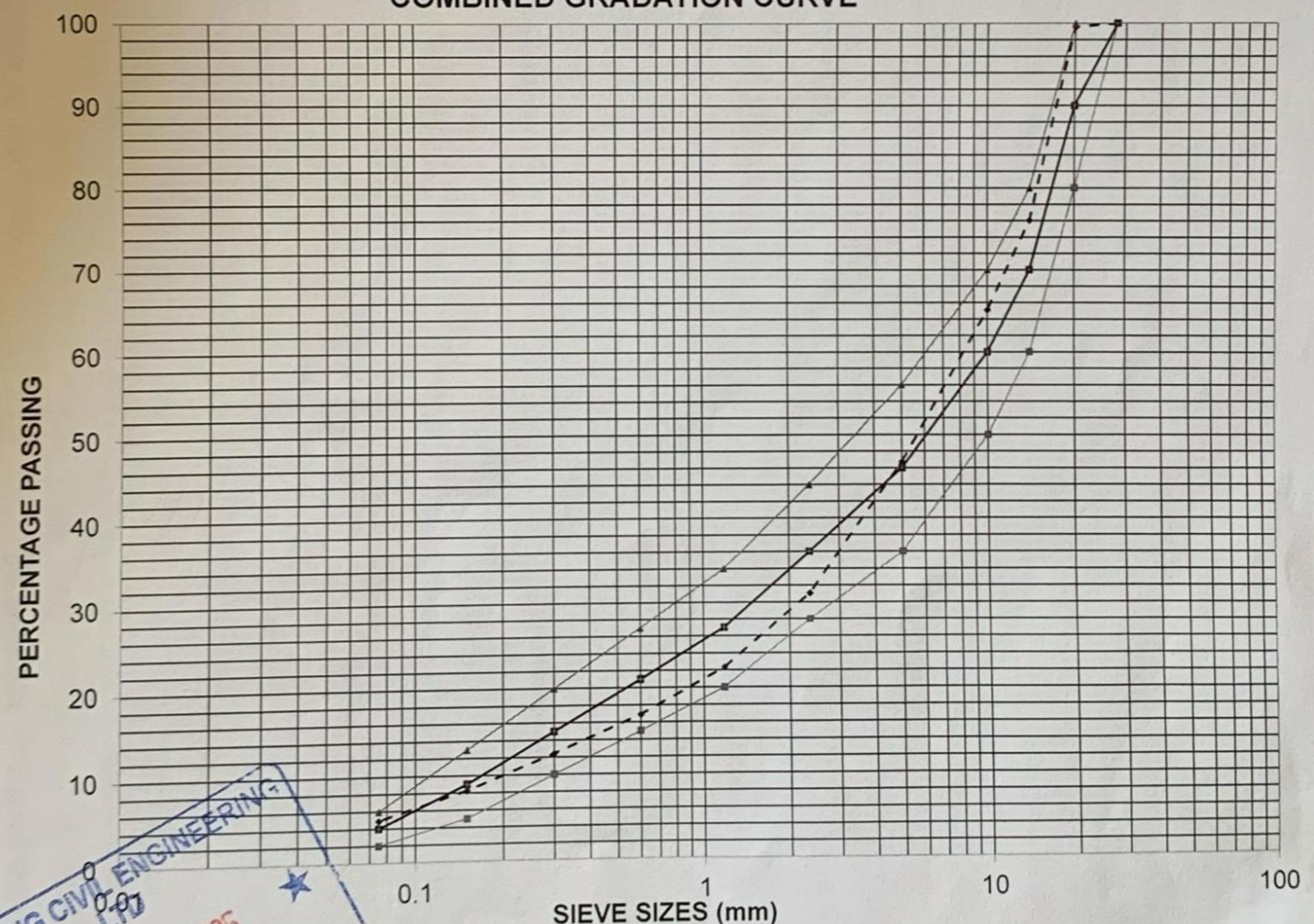
SUPPLIER: HOTBIN No1

SAMPLE No

MATERIAL: AC 20 INDIVIDUAL GRADATION

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

COMBINED GRADATION CURVE



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FOR TESTING LAB

FOR STUDENTS

APPENDIX B: X-ray fluorescence (XRF) test results of quartzite dust.

MAKERERE UNIVERSITY

P.O. BOX 7062, Kampala, Uganda
Email: geology@cns.mak.ac.ug
Website: http://geology.mak.ac.ug/

Tel: + 256 - 414 - 541258
Fax: + 256 - 414 - 531061

WE BUILD FOR THE FUTURE

College of Natural Sciences
School of Physical Sciences
DEPARTMENT OF GEOLOGY AND PETROLEUM STUDIES

Friday, 07 February 2025

Gonza Edgar and Amule M.
UCU Students

Dear Sir/Madam,

RE: <u>ANALYSIS OF QUARTZ DUST SAMPLE</u>

The Department received one sample to be analysed for Al_2O_3, SiO_2 and Fe_2O. During analysis the sample was ground to fine powder (< 0.063mm), from which a pressed powder pellet was prepared and scanned using an XRF spectrometer (Epsilon 1) for Al_2O_3, SiO_2 and Fe_2O_3, determination. The results below expressed in weight percentages (wt %) were obtained.

Sample No	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)
Quartz Dust sample	0.1	98.8	1.1
Detection Limit	1.0	1.0	1.0

Analyst:...

KASAKA MOSES

Geochemistry Laboratory

MAKERERE UNIVERSITY

P.O BOX 7062, Kampala, Uganda
Tel+ 256-414-541258
Email: geology@cns.mak.ac.ug
Fax +256-414-531061
Website: http:// geology.mak.ac.ug/

College of Natural Sciences

School of Physical Sciences

DEPARTMENT OF GEOLOGY AND PETROLEUM STUDIES

Wednesday, 19th March 2025

Gonza Edgar and Amule M.

UCU students

Dear Sir/Madam,

RE: ANALYSIS OF QUARTZITE DUST SAMPLE BEFORE CALCINATION

The department received one sample to be analyzed for the chemical composition of quartzite dust that had been obtained from quartzite rock. During the analysis the sample was ground to a fine powder (<0.063mm) from which a pressed powder pellet was prepared and scanned using an XRF spectrometer (Epsilon). The results below expressed in weight percentages (wt%) were obtained.

Sample No	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	TiO_2 (%)	CaO (%)	Sm_2O_3 (%)
Quartz Dust sample	0.15	96.363	0.57	0.126	0.18	0.307
Detection limit	1.0	1.0	1.0	1.0	1.0	1.0

Analyst: M. Kasaka

KASAKA MOSES

Geochemistry Laboratory

APPENDIX C: Marshall and Indirect tensile strength test results (ITS)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling STIRLING
PROJECT :	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT	

A/C 20 ASPHALT MIX DESIGN

SUMMARY OF A/C 20 JOB MIX TEST RESULTS

			BITUMEN CONTENT		
AGGREGATE TESTS	ACHIEVED	SPECIFIED	MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
Coating and Stripping	>95	>95%	MARSHALL FLOW	2.9	2—4
Sodium Soundness	2.1	<12%	MARSHALL STABILITY 75BLOWS	15.0	8-18
Water Absorption	0.2	< 2%	MARSHALL AIR VOIDS 75BLOWS	4.8	3—5
TFV Dry	231.9	>110kN	VOIDS IN MINERAL AGGREGATES	14.4	>14%
TFV Soaked Wet/Dry ratio	91%	>75%	VOIDS FILLED WITH BINDER	66.7	65—75%
Flakness Index	19.4	< 25%	INDIRECT TENSILE STRENGTH @ 25C	900	>800kpa
			INDIRECT TENSILE WET STRENGTH	82	>80% of dry
Sand Equivalent	—	< 45	AIR VOIDS AT REFUSAL DENSITY (PRD)	3.1	>3%
LAA	18.9		BITUMEN CONTENT AFTER EXTRACTION	4.6	±0.3
ACV	17.1				
AIV	16.0				
			BITUMEN CONTENT		4.4

SIGNED TESTING LAB

STIRLING CIVIL ENGINEERING LTD

P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

SSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMEN

Field Ref. No.		Lab. no.		Chainage sample 1:	Sampling date:	22-Jan-25
Sample grade:	AC 20	Compaction:	75 blows	Chainage sample 2:	Testing date:	23-Jan-25
Sample Description:						

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

PARAMETERS AT OPTIMUM BITUMEN CONTENT

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	1200.40	694.50	1202.50	2.363	2.352	4.8	14.4	66.6	62.3	62.6	62.5	62.5	1.03	14.7	15.14	3.32	4.560
2	1202	695.20	1204.00	2.362	2.351	4.8	14.4	66.5	62.6	62.4	62.6	62.5	1.03	13.8	14.26	3.17	4.499
3	1200	695.10	1202.50	2.365	2.354	4.7	14.3	67.0	62.4	61.9	62.0	62.1	1.04	15.1	15.73	2.77	5.678
4	1200.5	694.20	1202.50	2.362	2.350	4.8	14.4	66.4	63.0	63.4	63.0	63.1	1.01	14.1	14.20	3.34	4.251
Average Sample 1				2.363	2.352	4.8	14.4	66.7	Average Sample 1			62.6	1.0	14.4	14.8	3.2	4.7
5	1196.00	690.50	1197.00	2.361	2.350	4.9	14.4	66.3	63.1	62.7	62.5	62.8	1.02	14.7	14.99	2.70	5.552
6	1194.5	689.50	1196.50	2.356	2.345	5.1	14.6	65.3	62.8	63.0	62.9	63.7	0.99	15.3	15.18	2.77	5.481
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Sample 2				-	-	-	-	-	Average Sample 2			-		-	-	-	-
Average Sample 1 & 2				2.363	2.352	4.8	14.4	66.7	Average Sample 1 & 2			63.0	1.0	14.8	15.0		

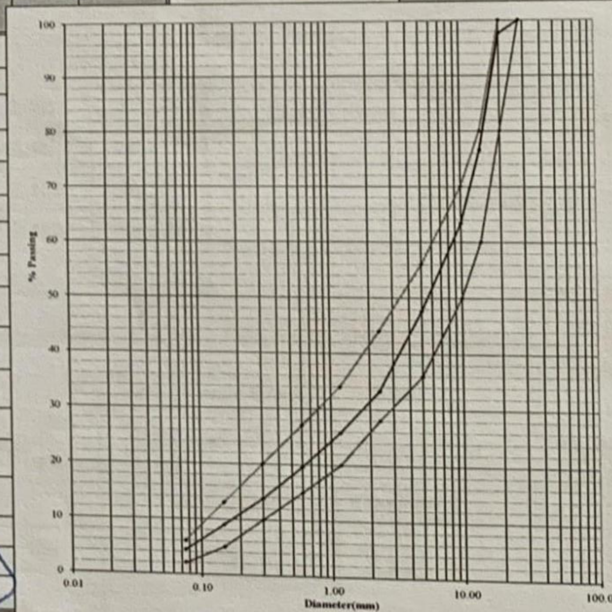
ASTM D 2172- Standard Test Method for Quantitative Extraction of Bitumen from Asphalt Mixtures

Mass (g)	Sample 1	Sample 2
Bowl	179.8	169.5
Bowl + Asphalt	1651.4	1913.2
Asphalt	1471.6	1743.7
Filter paper before extraction	28.5	33.5
Filter paper + Filler After extracti	30.2	35.3
Recovered Filler	1.7	1.8
Oven dry extracted Mtl (dry)	1402.5	1661.6
Oven dry extr. mtl + filler	1404.2	1663.4
Bitumen	67.4	80.3
% of Bitumen	4.6	4.61

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	1314.4	-	Asphalt	1230.3	-
Pycn + Water	7363.1	-	Pycn. + Water	7363.1	-
Pycnometer + Asph. + Water	8147.9	-	Pycnometer + Asph. + Water	8098.3	-
Volume of asphalt	529.6	-	Volume of asphalt	495.1	-
G_{mm}	2.482	-	G_{mm}	2.485	-
Av. G_{mm}	2.482		Av. G_{mm}	-	
Av. Gmm (Kg/m3) Sample 1& 2			2.482		

Sieve (mm)	Smp1 Mass retained	Smp2 Mass retained	Av. Mass retained	% Av. Retained	% Av. passing	JMF Lower	JMF Upper
28	0.0	-	0.0	0.0	100	100	100
20	33.2	-	33.2	2.4	98	80	100
14	295.1	-	295.1	21.0	77	60	80
10	185.5	-	185.5	13.2	63	50	70
5	222.0	-	222.0	15.8	48	36	56
2.36	200.7	-	200.7	14.3	33	28	44
1.18	105.7	-	105.7	7.5	26	20	34
0.600	86.9	-	86.9	6.2	20	15	27
0.300	81.4	-	81.4	5.8	14	10	20
0.150	67.5	-	67.5	4.8	9	5	13
0.075	65.4	-	65.4	4.7	4	2	6
Total filler	60.8	-	60.8				
Bot. Pan	6.9	-	6.9				
Extr. filler	53.9		53.9				
Sum of extr.	1404.2		1404.2				



Comment:

Materials Engineer:

STIRLING CIVIL ENGINEERING LTD
FEB 2025
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

PROJECT	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT

MARSHALL INDIRECT TENSILE TEST (AASHTO T-283-97)

BITUMINOUS MIXTURE TESTED ON 23/01/2025 | 102 | GMM 2.482 | Bit.content,% 4.4

Compacted material parameters (Plant production)

SAMPLE NO.	THICKNESS 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	GMM (maximum theoretical density) (g/cm^3) 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															
A	66.9	67.0	66.5	66.8	1192.5	684.0	1196.0	512.0	2.306	2.482	36.321	1218.5	26.000	71.6	7.1
C	65.9	66.0	66.6	66.2	1182.0	678.0	1186.5	508.5	2.301	2.482	37.009	1222.0	40.000	108.1	7.3
E	67.0	67.3	67.3	67.2	1196.5	684.0	1199.5	515.5	2.298	2.482	38.225	1220.5	24.000	62.8	7.4
G	66.8	67.2	67.8	67.3	1185.0	682.0	1190.5	508.5	2.307	2.482	35.813	1232.0	47.000	131.2	7.0
DRY															
B	66.4	65.8	66.1	66.1	1186.0	682.0	1192.5	510.5	2.300	2.482	37.414				7.3
D	67.2	67.7	67.1	67.3	1189.0	684.0	1194.0	510.0	2.308	2.482	35.717				7.0
F	66.4	66.9	66.7	66.7	1179.0	678.5	1183.5	505.0	2.311	2.482	34.706				6.9
H	67.1	66.5	67.4	67.0	1192.0	685.5	1197.5	512.0	2.305	2.482	36.520				7.1

INDIRECT TENSILE STRENGTH

DRY

SPECIMEN No	GAUGE READING (div)	LOAD RING FACTOR (kn/div)	MAXIMUM LOAD,P (kn)	SINGLE TENSILE STRENGTH,S_t (spec min 800 kPa)	AVERAGE TENSILE STRENGTH,S_t
B	39	0.213	8.3	784.1	900.2
D	44	0.213	9.4	868.4	
F	46	0.213	9.8	916.9	
H	52	0.213	11.1	1,031.4	

WET

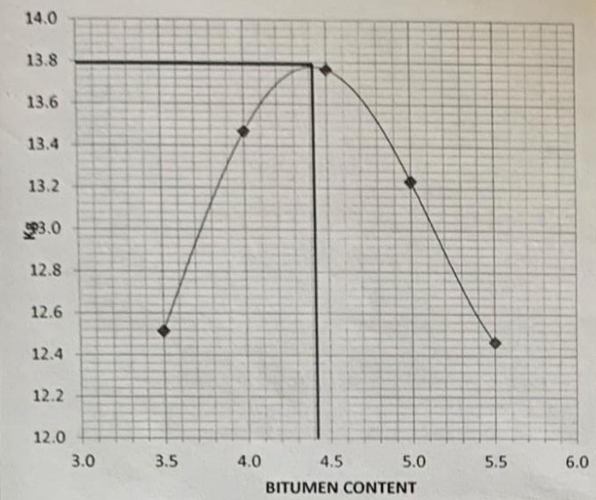
SPECIMEN No	GAUGE READING (div)	LOAD RING FACTOR (kn/div)	MAXIMUM LOAD,P (kn)	SINGLE TENSILE STRENGTH,S_t (kPa)	AVERAGE TENSILE STRENGTH,S_t (kPa)		WET/DRY (spec 80%)
A	40	0.213	8.5	795.7	740	S_t =2P/∏tD where P= maximum load(N) t=specimen thickness(mm) D=specimen diameter(mm)	82
C	37	0.213	7.9	743.1			
E	39	0.213	8.3	771.2			
G	33	0.213	7.0	651.9			

STIRLING CIVIL ENGINEERING LTD
11 FEB 2025
KAMPALA (U)

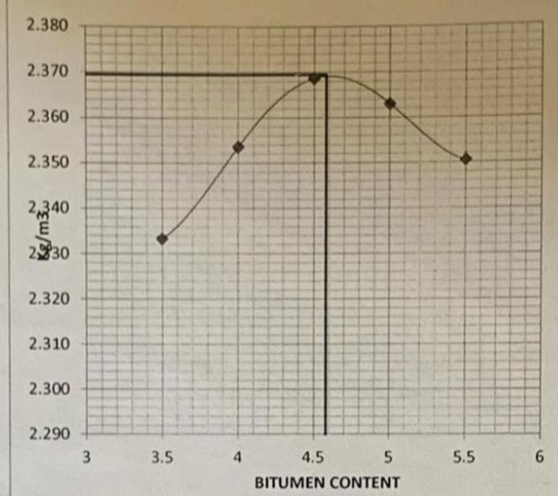
AC 20 JOB MIX DESIGN

DATE: .... 27/...

STABILITY AT MAXIMUM

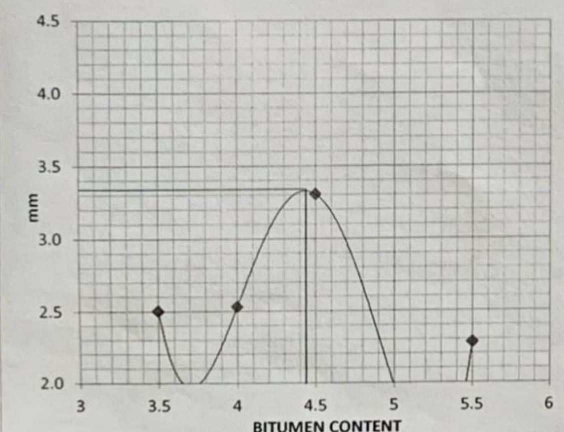


DENSITY AT MAXIMUM

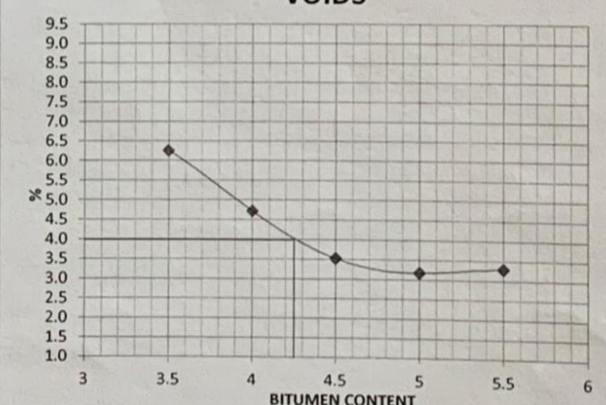


3

FLOW



VOIDS



MIX PROPORTION

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

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

Signatures: For Testing Lab ....

For Students ....

STIRLING CIVIL ENGINEERING LTD

P.O. BOX 796 KAMPALA

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling STIRLING
PROJECT :	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT	

SUMMARY OF A/C 20 TEST RESULTS

6% MINERAL FILLER

AGGREGATE TESTS	ACHIEVED	SPECIFIED	MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
			MARSHALL FLOW	3.6	2—4
			MARSHALL STABILITY 75BLOWS	16.3	8-18
			MARSHALL AIR VOIDS 75BLOWS	3.7	3—5
			VOIDS IN MINERAL AGGREGATES	14.1	>14%
			VOIDS FILLED WITH BINDER	74.2	65—75%

STIRLING CIVIL ENGINEERING LTD
FEB 2025
P.O. BOX 796, KAMPALA (U)

SIGNED TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

SSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMEN

Field Ref. No.:	Lab. no.					
Sample grade: AC 20	Compaction: 75 blows	Chainage sample 1:	6% MINERAL FILLER	Sampling date:	07-Feb-25
Sample Description:		Chainage sample 2:		Testing date:	08-Feb-25

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

PARAMETERS AT OPTIMUM BITUMEN CONTENT

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	1203.10	697.00	1204.60	2.370	2.359	3.6	14.1	74.3	63.8	64.2	64.0	64.0	0.99	16.0	15.82	3.78	4.184
2	1198.7	694.30	1200.00	2.370	2.359	3.6	14.1	74.3	62.3	63.1	62.9	62.8	1.02	16.4	16.73	3.48	4.807
3	1198.8	695.80	1200.00	2.378	2.366	3.3	13.8	76.0	63.6	63.4	63.6	63.5	1.00	15.1	15.12	3.78	4.001
4	1197.7	693.60	1201.10	2.360	2.349	4.0	14.5	72.1	63.7	64.0	64.1	63.9	0.99	17.9	17.71	3.29	5.384
Average Sample 1				2.370	2.358	3.7	14.1	74.2	Average Sample 1			63.6	1.0	16.3	16.3	3.6	4.6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average Sample 2				-	-	-	-	-	Average Sample 2			-	-	-	-	-	-
Average Sample 1 & 2				2.370	2.358	3.7	14.1	74.2	Average Sample 1 & 2			63.6	1.0	16.3	16.3		

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

Mass (g)	Sample 1	Sample 2
Bowl	179.8	169.5
Bowl + Asphalt	1651.4	1913.2
Asphalt	1471.6	1743.7
Filter paper before extraction	28.5	33.5
Filter paper + Filler After extracti	30.2	35.3
Recovered Filler	1.7	1.8
Oven dry extracted Mtl (dry)	1402.5	1661.6
Oven dry extr. mtl + filler	1404.2	1663.4
Bitumen	67.4	80.3
% of Bitumen	4.6	4.61

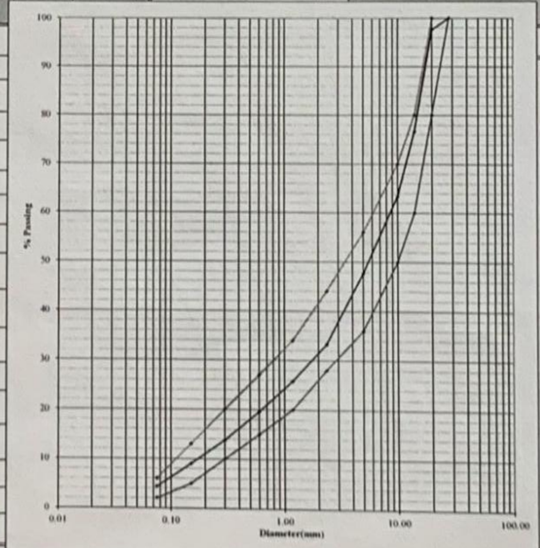
ASTM D2041- Standard Test Method for Theoretical Maximum Specific gravity and Density of Bituminous Mixtures

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	1165.6	-	Asphalt		
Pycn. + Water	8551.1	-	Pycn. + Water		
Pycnometer + Asph. + Water	9242.75	-	Pycnometer + Asph. + Water		
Volume of asphalt	473.95	-	Volume of asphalt		
G_{mm}	2.459	-	G_{mm}		
Av. G_{mm}	2.459		Av. G_{mm}	-	
Av. Gmm (Kg/m3) Sample 1& 2	2.459				

Comment:

Sieve (mm)	Smp1 Mass retained	Smp2 Mass retained	Av. Mass retained	% Av. Retained	% Av. passing	JMF Lower	JMF Upper
28	0.0	-	0.0	0.0	100	100	100
20	33.2	-	33.2	2.4	98	80	100
14	295.1	-	295.1	21.0	77	60	80
10	185.5	-	185.5	13.2	63	50	70
5	222.0	-	222.0	15.8	48	36	56
2.36	200.7	-	200.7	14.3	33	28	44
1.18	105.7	-	105.7	7.5	26	20	34
0.600	86.9	-	86.9	6.2	20	15	27
0.300	81.4	-	81.4	5.8	14	10	20
0.150	67.5	-	67.5	4.8	[illegible]	5	13
0.075	65.4	-	65.4	[illegible]	4	2	6
Total filler	60.8		60.8				
Bot. Pan	6.9	-	6.9				
Extr. filler	53.9	-	53.9				
Sum of extr.	1404.2	-	1404.2				

Materials Engineer:



STIRLING CIVIL ENGINEERING LTD
FEB 2025
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling STIRLING
PROJECT :	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT	

A/C 20 ASPHALT MIX DESIGN

SUMMARY OF A/C 20 JOB MIX TEST RESULTS

2% MINERAL FILLER

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
MARSHALL FLOW	4.2	2—4
MARSHALL STABILITY 75BLOWS	22.2	8-18
MARSHALL AIR VOIDS 75BLOWS	5.0	3—5
VOIDS IN MINERAL AGGREGATES	15.3	>14%
VOIDS FILLED WITH BINDER	67.4	65—75%

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

SIGNED TESTING LAB

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling STIRLING
PROJECT :	ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT	

SUMMARY OF A/C 20 TEST RESULTS

4.5% QUARTZITE DUST AS MINERAL FILLER

MARSHALL MIX TEST RESULTS AFTER MIX	ACHIEVED	SPECIFIED
MARSHALL FLOW	3.6	2—4
MARSHALL STABILITY 75BLOWS	21.9	>8
MARSHALL AIR VOIDS 75BLOWS	4.8	3—5
VOIDS IN MINERAL AGGREGATES	15.1	>14%
VOIDS FILLED WITH BINDER	68.3	65—75%

SIGNED TESTING LAB

STIRLING CIVIL ENGINEERING LTD
24 MAR 2025
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT

Field Ref. No.:	Lab. no.	Chainage sample 1:	4.5% QUARTZITE DUST AS MINERAL FILLER	Sampling date:	16-Mar-25	
Sample grade: AC 20	Compaction: 75 blows	Chainage sample 2:		Testing date:	17-Mar-25	
Sample Description:						

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

PARAMETERS AT OPTIMUM BITUMEN CONTENT

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	1179.60	680.40	1182.10	2.351	2.340	4.4	14.8	69.9
2	1194.5	687.40	1197.50	2.342	2.330	4.8	15.1	68.1
3	1188.8	683.70	1194.10	2.329	2.318	5.3	15.6	65.7
4	1188.4	684.60	1190.40	2.350	2.338	4.5	14.8	69.6
Average Sample 1				2.343	2.332	4.8	15.1	68.3
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Average Sample 2				-	-	-	-	-
Average Sample 1 & 2				2.343	2.332	4.8	15.1	68.3

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)
61.9	62.2	62.3	62.1	1.04	23.2	24.15	3.37	7.165
63.0	63.6	63.0	63.2	1.01	20.7	20.87	3.55	5.878
63.2	63.1	63.6	63.3	1.01	20.7	20.87	3.79	5.506
62.5	63.4	62.4	62.8	1.02	21.3	21.73	3.60	6.035
Average Sample 1			62.9	1.02	21.5	21.9	3.6	6.1
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Average Sample 2			-	-	-	-	-	-
Average Sample 1 & 2			62.9	1.0	21.5	21.9		

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

Mass (g)	Sample 1	Sample 2
Bowl	179.8	169.5
Bowl + Asphalt	1651.4	1913.2
Asphalt	1471.6	1743.7
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Filter paper + Filler After extraction	30.2	35.3
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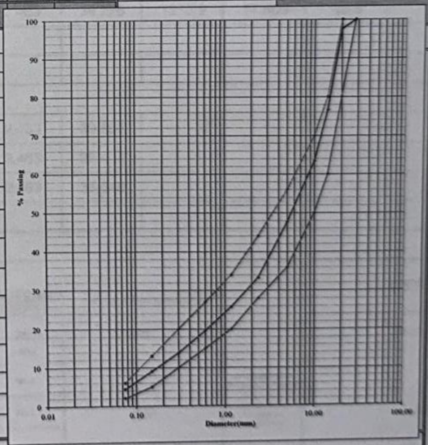
Oven dry extr. mtl + filler	1404.2	1663.4
Bitumen	67.4	80.3
% of Bitumen	4.6	4.61

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	-	Asphalt	1387.1	
Pycn. + Water	8553	-	Pycn. + Water	8553	
Pycnometer + Asph. + Water	9265.3	-	Pycnometer + Asph. + Water	9377.6	
Volume of asphalt	487.7	-	Volume of asphalt	562.5	
G_{mm}	2.461	-	G_{mm}	2.466	
Av. G_{mm}	2.461		Av. G_{mm}	2.466	
Av. Gmm (Kg/m3) Sample 1& 2			2.463		

Comment:

Sieve (mm)	Smp1 Mass retained	Smp2 Mass retained	Av. Mass retained	% Av. Retained	% Av. passing	JMF Lower	JMF Upper
28	0.0	-	0.0	0.0	100	100	100
20	33.2	-	33.2	2.4	98	80	100
14	295.1	-	295.1	21.0	77	60	80
10	185.5	-	185.5	13.2	63	50	70
5	222.0	-	222.0	15.8	48	36	56
2.36	200.7	-	200.7	14.3	33	28	44
1.18	105.7	-	105.7	7.5	26	20	34
0.600	86.9	-	86.9	6.2	20	15	27
0.300	81.4	-	81.4		14	10	20
0.150	67.5			4.8	9	5	13
0.075	65.4		65.4	4.7	4	2	6
Pan	60.8		60.8				
Bot. Pan	6.9		6.9				
Extr. filler	53.9		53.9				
Sum of extr.	1404.2	-	1404.2				



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

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	GONZA EDGAR & AMULE LOKORTO MOISE	Stirling

PROJECT: ASSESS THE SUITABILITY OF CALCINED QUARTZITE DUST AS A MINERAL FILLER TO ENHANCE RUT RESISTANCE IN FLEXIBLE PAVEMENT

MARSHALL INDIRECT TENSILE TEST (AASHTO T-283-97)

BITUMINOUS MIXTURE TESTED ON 23/01/2025 | 102 | GMM 2.463 | Bit.content,% 4.4

4.5% QUARTZITE DUST AS MINERAL FILLER

LOCATION :

SAMPLE NO.	THICKNESS: HEIGHT 1 (mm)	HEIGHT 2 (mm)	HEIGHT 3 (mm)	Av. Thickness (mm)	Compacted material parameters (Plant production): 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	GMM (maximum theoretical density) (g/cm^3) F	VOLUME OF AIR	SATURATED SPECIMEN	VOLUME OF WATER	DEGREE OF SATURATION	VIM, AIR VOIDS (%) =100*(F-E)/F spec min 3.0% G
WET															
A	65.0	64.7	64.7	64.8	1192.1	681.2	1196.6	515.4	2.290	2.463	36.284	1217.1	25.000	68.9	7.0
C	65.0	64.7	65.3	65.0	1195.2	685.1	1201.0	515.9	2.294	2.463	35.538	1214.8	19.600	55.2	6.9
E	66.2	66.8	65.8	66.3	1196.1	682.4	1202.4	520.0	2.277	2.463	39.276	1213.9	17.800	45.3	7.6
DRY															
B	65.6	65.0	64.4	65.0	1187.7	676.7	1193.6	516.9	2.275	2.463	39.552				7.7
D	64.2	64.9	64.0	64.4	1193.2	681.5	1197.5	516.0	2.289	2.463	36.442				7.1
F	65.7	66.0	65.8	65.8	1194.2	686.5	1202.1	515.6	2.293	2.463	35.640				6.9

INDIRECT TENSILE STRENGTH

DRY: SPECIMEN No.	GAUGE READING (div)	LOAD RING FACTOR (kn/div)	MAXIMUM LOAD,P (kn)	SINGLE TENSILE STRENGTH,S_t (spec min 800 kPa)	AVERAGE TENSILE STRENGTH,S_t	WET: SPECIMEN No.	GAUGE READING (div)	LOAD RING FACTOR (kn/div)	MAXIMUM LOAD,P (kn)	SINGLE TENSILE STRENGTH,S_t (kPa)	AVERAGE TENSILE STRENGTH,S_t (kPa)		WET/DRY (spec 80%)
B	55	0.213	11.7	1,124.4		A	53	0.213	11.3	1,086.9			
D	58	0.213	12.4	1,19[illegible]		C	48	0.213	10.2	981.3			
F	53	0.213	11.3	1,069.6	1,130.6	E	45	0.213	9.6	902.4	990	S_t =2P/ΠtD where P= maximum load(N) t=specimen thickness(mm) D=specimen diameter(mm)	88

STIRLING CIVIL ENGINEERING LTD
24 MAR 2025
P.O. BOX 36, KAMPALA (U)