INVESTIGATING THE USE OF WASTE POLYETHYLENE TEREPHTHALATE AND CEMENT KILN DUST ON THE PROPERTIES OF HOT MIX ASPHALT.

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A FINAL YEAR RESEARCH AND DESIGN PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

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ABSTRACT

This study investigated the utilization of waste Polyethylene terephthalate (PET) and waste cement kiln dust (CKD) to enhance the characteristics of Hot Mix asphalt (HMA). It is wise to find sustainable solutions for reusing these materials in engineering applications, particularly in road construction, to mitigate the environmental impact of plastic and cement kiln dust. Polyethylene terephthalate exhibited superior performance in enhancing the moisture resistance of PET-modified asphalt. Various tests like penetration value test, softening point test, and ductility value test were conducted to assess PET's effectiveness, with PET proportions ranging from 2% to 10% by weight of bitumen. The findings indicated a reduction in penetration values and an increase in softening point values with higher PET percentages, although challenges of phase separation between the polymer and bitumen were observed. To address this issue, cement kiln dust was introduced into the PET-bitumen mixture to facilitate effective bonding. Different percentages of CKD were tested, and the addition of 2% CKD by weight of bitumen yielded improved results in storage stability testing. The indirect tensile strength ratio notably increased by 92.5%, indicating enhanced resistance of asphalt to moisture damage facilitated by PET. Overall, the research aimed to enhance the properties of HMA to bolster its resilience against moisture damage and potentially overcome phase separation challenges in modified asphalt.

DECLARATION

I, Kwesiga Raymond, hereby declare that this is my original work, is not plagiarized and has never been submitted to any institution of higher learning for any academic award.

SIGNATURE.. DATE.................................

KWESIGA RAYMOND

APPROVAL

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

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

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DEDICATION

This report is dedicated to my parents, teachers and mentors, whose guidance, patience and encouragement have shaped me into the person I am today. Your unwavering support has been instrumental in my academic journey, and I am deeply grateful for your belief in my potential. This achievement is as much yours as it is mine.

Thank you for everything.

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ABBREVIATION

AC- Asphalt Concrete

ACV – Aggregate Crushing Value

PET- Polyethylene Terephthalate

CKD- Cement Kiln Dust

HMA- Hot Mix Asphalt

TFV-Ten Percent Fines

ITS-Indirect Tensile Strength

AIV-Aggregate Impact Value

GDOT – Georgia Department of Transportation

CHAPTER 1: INTRODUCTION

1.0 **Introduction**.

Flexible pavements endure exposure to natural elements like water, temperature fluctuations, and oxygen, leading to bitumen aging (Wei et al., 2021). Throughout this aging process, oxygen oxidizes the polar components in bitumen, increasing its viscosity and stiffness. Consequently, micro cracks form, providing pathways for water to infiltrate the bitumen-aggregate interface (Jose and Jorge, 2015), resulting in reduced adhesion between bitumen and aggregates. This diminished adhesion significantly impacts pavement layers, ultimately compromising durability, decreasing skid resistance, and heightening the risk of vehicle accidents, particularly on high-speed roads (Li et al., 2019). To enhance the mechanical properties of aggregates and improve asphalt pavement durability, various plastic materials, such as Low-Density Polyethylene (LDPE), Polyvinyl Chloride (PVC), Polyvinyl Acetate (PVA), Polypropylene (PP), PET, and HDPE, have been applied as coatings. The incorporation of thermoplastic modifiers into conventional bitumen enhances its viscoelastic behavior and alters its rheological properties (Appiah et al., 2017). However, polymer-modified asphalt faces the challenge of phase separation, where plastic modifiers separate from the asphalt binder due to factors like incompatibility, temperature fluctuations, and binder drainage (Zhu, 2016). Mesoscopic fillers aid in controlling and slowing down the phase separation process (Zhong, 2011). This issue can be mitigated through the addition of mineral powder fillers like cement kiln dust, which exhibit mesoscopic characteristics such as a high surface area, active functional groups, and adoption capacity, with an average size ranging between 0.1 and 0.5 microns. Incorporating these mineral powders addresses phase separation problems by enhancing compatibility, improving adhesion, and enhancing rheological properties (Biro et al., 2021).

1.1 Background.

The flexible pavement road network of Uganda is majorly paved with bitumen because bituminous pavements provide a safe, long-lasting and comfortable surface for road users. The performance of flexible pavements is highly dependent on properties of bitumen especially because of its binding properties and has seen widespread adoption worldwide, with various governments allocating substantial resources for nationwide road network upgrades (Ridmika, 2019). Uganda, for instance, predominantly employs flexible pavement due to its ability to provide road users with a safe, long-lasting, and comfortable surface. However, The Kihihi – Ishasha road, a newly constructed in 2022 developed cracks even before completion in the already tarmacked spots. These cracks are visible at Kinyashweera in Nyamwegabira sub-county, Nyamirama and Kanyantorogo sub- County in kanungu district (Amanya, 2022).

1.2 Problem statement.

The Kihihi – Ishasha road, a newly constructed road in 2022 developed cracks even before completion in the already tarmacked spots. The problem of rapid deterioration of the pavement can be linked to the rheological and chemical properties as well as the thermal sensitivities of bitumen resulting in the permanent deformation from fatigue cracking and moisture damage (Nguyen, 2005). The findings from the reviewed studies indicate that the inclusion of PET in asphalt mixtures improves resistance to moisture susceptibility (Usman, 2024). However, no conclusion has been made on polymer modified asphalt that faces a challenge of phase separation (Ameri and Nasr, 2016). Addition of these mineral powders such as cement kiln dust in asphalt addresses the problem of phase separation by improving compatibility, enhancing adhesion and through improvement of rheological properties (Biro et al., 2021). Therefore, this research investigates the use of polyethylene terephthalate and cement kiln dust to modify bitumen in order to hypothetically improve on the properties of the asphalt mix.

1.3 Main Objective.

To investigate the use of waste Polyethylene terephthalate and cement kiln dust on the properties of hot mix asphalt.

1.3.1 Specific Objectives.

i. To determine properties of cement kiln dust, aggregates and bitumen
ii. To study the storage stability and phase separation of polymer modified asphalt
iii. To determine optimum bitumen content for modified asphalt

iv. To determine the indirect tensile strength of the modified hot mix asphalt

1.4 Research Questions

i. What are the properties of cement kiln dust, aggregates and bitumen?
ii. What is the storage stability and phase separation of polymer modified asphalt?
iii. To determine optimum bitumen content for modified asphalt?
iv. What is the indirect tensile strength of the modified hot mix asphalt?

1.5 Justification

The detachment of aggregates from bitumen leads to surface layer deterioration, significantly impacting the durability of pavements (Akshatha et al., 2019). The non-biodegradable property of polyethylene terephthalate enhances asphalt's resilience to extreme temperature changes, thus promoting road longevity. All grades of polyethylene exhibit remarkable chemical resistance, making them impervious to strong bases and resistant to mild oxidants and reducing agents. The application of a plastic coating on aggregate surfaces reduces permeability, thereby enhancing mixture cohesion and offering partial protection against moisture damage to roads (Alave et al., 2021). Mesoscopic fillers, varying from nanometers to microns, become preferentially immersed into the slow dynamic phase and phase interface due to entanglement with polymer chains (Yiu Ling, 2011). Cement kiln dust, a byproduct of cement manufacturing with a large surface area, mitigates phase separation issues by enhancing compatibility, improving adhesion, and refining rheological properties (Biro et al., 2021).

1.6 Significance of the Study

The incorporation of polyethylene terephthalate (PET) and cement kiln dust (CKD) into hot mix asphalt (HMA) offers several significant advantages for pavement performance and sustainability. PET, a plastic material, enhances HMA durability, increasing resistance to moisture damage, rutting, and fatigue cracking (Li et al., 2015). These results in longer-lasting pavements, reducing maintenance needs. Moreover, by recycling plastic waste, the use of PET diverts materials from landfills and reduces environmental impacts (Moghaddam et al., 2019). CKD, a byproduct of cement production, contributes to improved HMA properties by enhancing resistance to rutting and providing added strength (Silva et al., 2018). The combined application of PET and CKD results in an HMA mix with enhanced stiffness and strength, better crack resistance and improved workability (Yin et al., 2019). Furthermore, the incorporation of CKD supports the recycling of industrial waste, aligning with sustainable construction practices and potentially leading to cost savings by reducing the reliance on virgin materials.

1.7 Geographical Scope

The scope of this study is along the Construction of a 78.5 km road that connects to the Uganda – Democratic - Republic of Congo border, the kihihi –ishasha –Kanungu road was designed in 2018 and costs 118 billion shillings is being undertaken by the China Human International Corporation (CHICO).

CHAPTER 2: LITERATURE REVIEW

2.1 Polymer Modified Asphalt (PMA)

Polymer-modified asphalt is a type of asphalt mix that incorporates polymer additives to enhance its performance characteristics. These additives can improve the durability, elasticity, and resistance of the asphalt to various environmental and load-related stresses (Jung et al., 2017). Polymer-Modified Bitumen represent a group of road paving binders designed specifically to improve the durability of bitumen pavements and to counteract the most frequent road problems, such as viscoelastic deformations of roads carrying heavy traffic, low-temperature cracking-up of wearing courses during winter, and fatigue-related cracks. (Wójcik et al, 2017).

Importance of bitumen modification

The objectives of bitumen is a question of modifying the behavior at the extreme temperatures reached by the pavement, maintaining a sufficiently high consistency at high temperatures to avoid sweating and permanent deformation, reducing fragility at low temperature to avoid cracking and tearing of gravel. These objectives also depend on the fields of application and the planned techniques: surface dressings, thin mats, draining asphalt, wearing courses for roads with heavy traffic, base course for roads with heavy traffic, anti-crack membranes, screeds sealing of works of art (PIARC, 1999).

Modification process

There are two methods to mix plastics into bitumen. In the wet process, waste plastic along bitumen is melted and stirred in hot bitumen around 150^0C using a high shear mixer to produce waste plastic modified bitumen (Pallavi Gupta, 2016).

In the dry process, waste plastic is added to hot aggregates to get plastic coated aggregates; optimum bitumen is then added to produce waste plastic modified asphalt (Pallavi and Gupta, 2016).

Polyethylene Terephthalate (PET) in Hot Mix Asphalt

Polyethylene terephthalate (PET) is a thermoplastic polymer that is commonly used in plastics and packaging. PET can be added to asphalt to improve its strength, durability, and resistance to cracking.

PET (polyethylene terephthalate) is a widely used thermoplastic polymer with a high melting point, commonly employed in the production of drinking bottles.

Numerous studies have been investigated for incorporating PET into asphalt mixtures, primarily involving dry processes where shredded PET bottles are used to replace aggregates. Pre-mixing PET with heated aggregates is essential to ensure adequate coating of the aggregates with the shredded PET plastics.

Processed PETs with finer dimensions 2.36mm to 425micrometre sieve sizes exhibited superior moisture resistance compared to PETs with sizes ranging from passing 2.36mm sieve to 2mm sieve (Dalhat et al., 2019).

El-Naga and Ragab (2019) have quantified the advantages of integrating 12% PET, which results in a 2.81 fold increase in pavement service life and a 20% reduction in asphalt layer thickness. It is well known that adding PET reduces the likelihood of moisture and heat cracking while also improving fatigue and rutting resistance (Ahmadinia et al., 2012). However, phase separation and a drop in the specific gravity of asphalt mixtures might result from non-uniform PET distribution (Ameri and Nasr, 2016).

Numerous investigations have looked into using the glycolysis reaction to change the basic asphalt by turning PET into a liquid form for use in a wet process (Ameri and Nasr, 2016). According to Mashaan et al. (2021), the ideal PET level for modifying asphalt is between 6 and 8%. This corresponds to better resistance to rutting and fatigue. It was discovered that two novel additive materials for asphalt modification—Thin Liquid Polyol PET (TLPP) and Viscous Polyol PET (VPP)—improved the binder blends' low-temperature cracking resistance, fatigue resistance, and stripping resistance (Gürü et al., 2014). PET and triethylenetetramine (TETA) were mixed via an aminolysis process to create a PET-derived additive that was then used to increase the resistance to cracking and rutting in reclaimed asphalt pavement (RAP) (Leng et al., 2018).

Utilizing waste materials like PET in Hot Mix Asphalt (HMA) can effectively cut costs and enhance asphalt mix properties. In a study by Abu Salem et al. (2021), PET fibers were introduced into HMA as a binder additive across various proportions. The investigation assessed forty different combinations of modified HMA mixes, focusing on parameters such as unit weight, air voids, and void in mineral aggregate (VMA), Marshall Stability, and Marshall Flow. Integration of PET fibers resulted in improved Marshall Stability and overall bulk properties of the hot mix asphalt. Void contents in PET-modified HMA decreased with increasing PET content up to 15% addition, while Marshall Stability increased up to 30% of PET content. Nevertheless, higher fiber contents led to decreased Marshall Stability. The study concluded that a mix with 30% PET content could be optimized to meet Marshall Criteria for medium and low traffic roads. However, polymer-modified asphalt faces challenges related to phase separation. Phase separation, a complex phenomenon in polymer-modified asphalt, has been extensively investigated in recent years. Addition of polymers to asphalt can trigger phase separation, causing reduced stability and heightened sensitivity to temperature changes (Zhang et al., 2019). To better comprehend phase separation mechanisms in polymer-modified asphalt, researchers have employed various analytical methods like small-angle X-ray scattering (SAXS) and transmission electron microscopy (TEM) (Wang et al., 2020). These studies have revealed that the morphology and distribution of polymeric particles within the asphalt matrix significantly influence phase separation behavior (Liu et al., 2017). Additionally, the use of recycled polymers in asphalt modification has been found to notably impact phase separation behavior, potentially leading to reduced thermal stability and accelerated aging (Chen et al., 2020; Wang et al., 2019).

2.1.1 Mitigation of phase separation using mineral fillers.

The addition of mineral fillers to polymer-modified asphalt has been found to be an effective strategy for mitigating phase separation and improving the overall performance of asphalt mixtures. According to (Liu et al., 2017), the incorporation of mineral fillers can reduce the amount of phase separation and improve the rheological properties of the asphalt mixture. This is because the mineral fillers act as a nucleation site for the polymer chains, which helps to hinder the phase separation process. Furthermore, the use of nanoscale mineral fillers has been found to be particularly effective in reducing phase separation in polymer-modified asphalt (Wang et al., 2019). The small size of the mineral fillers allows them to penetrate deeper into the asphalt matrix, where they can more effectively hinder phase separation. In addition to reducing phase separation, the incorporation of mineral fillers can also improve the thermal stability and resistance to aging of polymer-modified asphalt (Zhang et al., 2019). This is because the mineral fillers can absorb some of the heat generated during the aging process, which helps to reduce the rate of degradation. Overall, the addition of mineral fillers to polymer-modified asphalt is a promising approach for mitigating phase separation and improving the long-term performance of asphalt mixtures. The storage stability test directly reflects whether substantial phase separation occurs (Ming and Wei, 2019). Since no separation happened in the stable polymer modified asphalt, focus was placed on phase separation in the unstable polymer modified asphalt (Jiqing Zhu, 2016)

2.1.2 Cement Kiln Dust (CKD) in Hot Mix Asphalt Mixture

CKD is a waste material produced during the cement manufacturing process. It is typically released into the environment, contributing to air pollution and respiratory difficulties for residents living near cement plants (Louzi, 2021). To mitigate these environmental impacts, researchers are investigating cost-effective and efficient ways to incorporate CKD into various applications, including HMA mixtures. In a study conducted by (Louzi et al., 2021), the influence of CKD as a filler material on HMA qualities was examined. The study found that using CKD instead of limestone as a filler resulted in a higher optimal binder concentration in HMA mixtures. While there was no significant difference in Marshall Stabilities between mixtures containing limestone filler and 5% CKD, the addition of 5% CKD to the limestone mixtures increased the indirect tensile strength (ITS) by 16.67% after 96 hours. These findings suggest that CKD can be a suitable alternative to traditional fillers in HMA mixtures.

Cement kiln dust (CKD) is a byproduct of the cement manufacturing process. It is a fine powder that contains a variety of minerals, including calcium, magnesium, and silicon. CKD has been shown to be an effective additive for improving the properties of asphalt, including reducing phase separation. Additions of these mineral powders address the problem of phase separation by improving compatibility, enhancing adhesion and through improvement of rheological Properties (Biro et al., 2021).

Aggregates

Aggregates can originate from natural or manufactured origins. Natural aggregates stem from various types of rock, which fall into three main geological categories.

I. **Igneous rock**; primarily crystalline, forms through the cooling of molten rock beneath the Earth's surface.
II. **Sedimentary rocks**; result from the deposition of insoluble material, such as the remnants of existing rock settling in bodies of water. They exhibit a layered structure and are further categorized based on their primary mineral

composition, such as calcareous (e.g., limestone, chalk) or siliceous (e.g., sandstone, shale).

III. **Metamorphic rock**; develops from the alteration of igneous or sedimentary rocks under significant heat and/or pressure, leading to changes in their mineral composition compared to the original rock.

Bitumen

Bitumen is a hydrocarbon, black, viscous adhesive binder material that is used to bind the aggregate in road construction. It is composed of hydrocarbons (carbon and hydrogen) with low proportions of oxygen, nitrogen and sulfur as well as metals with insignificant traces.

In asphalt mixture, bitumen provides coated materials and this is because of its essential bonding property allowing the agglomeration of the materials. An optimal asphalt mix design is anticipated to yield a mixture that possesses sufficient strength, durability, resistance to fatigue and permanent deformation, environmental friendliness, and cost-effectiveness (J. Corté, 2005).

Moreover, the use of bitumen in road engineering is largely justified by its high bonding qualities, adhesive power especially on minerals. Due to its complexity, the chemical composition of bitumen is never really defined (J. Corté, 2005)

Enable to be characterized from a chemical point of view, pure bitumen is defined by two parameters describing its consistency. And these include;

i. Penetration test; this is a method of determining the consistency of Bitumen at 25°C. The penetrability of a bituminous binder is “the consistency, in tenths of a millimeter, corresponding to the vertical penetration of a reference needle into a sample testing of the material, under prescribed conditions of temperature, load and duration of application of the load (Wójcik et al, 2017).

ii. The softening point; this test represents the temperature at which the material reaches a certain consistency (Wójcik et al, 2017) Ring ball temperatures vary between 30 and 150°C

In practice, 60/70 class bitumen must have penetrability between 60 and 70 dmm, and a ball-ring softening temperature between 47 and 56°C.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This chapter shows procedures that are followed to achieve the objectives set and the collection of materials as well as the test that will be conducted on the material

3.2 Acquisition of materials

Plastic selection

The waste plastics specifically mineral drinking water bottles were collected from in Nabuti plastic collection plant (Northing 38265, Easting 470814) in Mukono. Waste PET drinking water bottles were used and melted.

Aggregate selection.

The granite aggregates were obtained from Namawonjja Quarry in Zirobwe. Aggregates used were those used in the asphaltic concrete wearing course (AC 14) along Kihihi – Ishasha road. This implies that the nominal size of aggregates is 14mm.

Bitumen

Bitumen was obtained from China State laboratory in Namasuba Kampala district. The bitumen 60/70 was selected because it was the type of bitumen that was used along the Kihihi - Ishasha road, the project scope. The bitumen 60/70 has thermo-plastic properties which cause the material to soften at high temperatures and harden at lower temperatures.

Cement kiln dust.

The cement kiln dust was obtained from Hima cement limited headoffices in Namanve industrial park.

The cement kiln dust will be used in five different percentages by weight of bitumen. The selected percentages will include 0%, 1%, 1.5%, 2%, 2.5%.

Flow chart of mix design of methodology

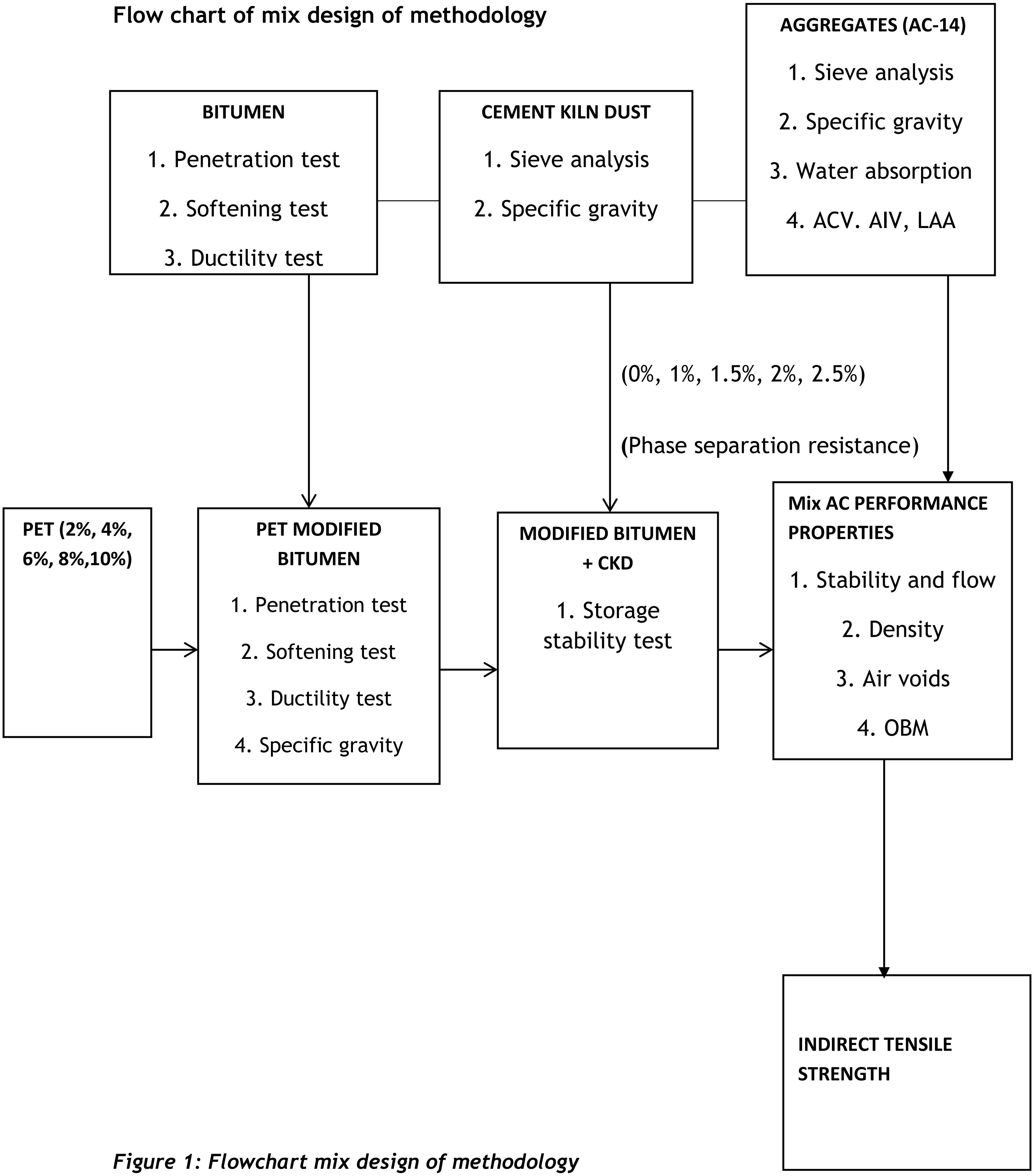


Figure 1: Flowchart mix design of methodology

3.3 PREPARATION OF MATERIALS

3.3.1 Sample Preparation of neat bitumen and modified bitumen

Sample Preparation for neat bitumen

The sample of bitumen 60/70 will be prepared in accordance to the ASTM D5. An amount of bitumen put in oven and heated up to a flowing state.

Preparation of modified bitumen

The bitumen will be modified under wet process which consists of introducing waste shredded plastic into bitumen at a given temperature. The following procedures were followed while preparing the samples.

i. A sample of about 500g of bitumen 60/70 will be selected, heated to a flowing state at a temperature of 170^0C.

ii. The Plastics bottles were cut to irregular shapes so as enough quantity can fit into the container.

iii. The cut pieces were washed and dried. The pieces were then placed into the furnace and melted at a temperature of 300^0C until it the plastics starts to flow.

iv. Different percentages of PET to weight of bitumen were measured by Mass of bitumen was 500g.

v. The molten PET is then mixed with bitumen that was heated at a temperature of 170^0C.

vi. At this, stage different tests are carried out on modified bitumen.

vii. Cement kiln dust will be measured per weight of bitumen in four different percentages namely 0%, 1%, 1.5%, 2%, and 2.5%. Then each percentage will be introduced in the mass of bitumen and mixed for about 5 minutes to obtain a homogeneous material.

3.4.0 TESTS ON BITUMEN.

3.4.1 Specific gravity test

Apparatus:

i. Specific gravity bottle of 50 ml capacity,

ii. ordinary capillary type with 6 mm diameter neck or wide mouthed capillary type bottle with 25 mm diameter neck

iii. Balance having least count of 1g

Reference; this test will be done in accordance with ASTM D 70-76.

3.4.2 Penetration test

Apparatus

To perform this test, a penetrometer and dial gauge will be used.

This test is conducted as follow;

i. The bitumen is heated until it becomes fluid then poured in containers to a depth such that when cooled, the depth of the sample will be at least 10mm greater than the expected penetration.

ii. The samples are left in a room temperature for 4 hours and then conditioned in bath of water with 25°C in an one hour.

iii. The apparatus is mounted (mount the needle on the penetrometer by lowering it until its tip touched the surface of the bitumen.)

iv. After one hour each sample is taken from water bath and subjected to penetration for 5 seconds. The penetration is repeated for at least three times and the readings are taken, then the average result represents the grade of bitumen.

Reference; this test will be done in accordance with ASTM D 5

3.4.3 Softening point

Test procedures

This test will be done in different steps as stated below

i. The ring and ring plate will be smeared with oil to avoid bitumen to stick on them after cooling.

ii. The bitumen will be poured into the rings and let them to cool for about 4 hours at a room temperature

iii. Next, each horizontal bitumen disk supporting a steel ball is heated at a controlled rate in a liquid bath while it is cast in shouldered brass rings. The average temperature at which the two disks soften to the point that each ball covered in bitumen can fall a distance of 25 mm is known as the softening point.

Test reference; this test will be done in accordance with ASTM D 36

3.5 TESTS 0N AGGREGATES

3.5.1 Sieve analysis test.

Test Reference: This test will be performed on aggregates of sizes 14/20, 10/14, 6/10, and 0/6 mm

Apparatus

To perform this test, different equipment including Metal trays, BS Sieve brushes, and Riffle box will be used.

Test procedure

i. To perform this test, a sample of aggregate is taken; riffle to take a representative homogeneous material, then washed if there is a presence of organic matter in it.

ii. Dry the sample at a temperature of 105 to 110^{o}C and take it weight as m1

iii. Assemble the sieve column in a decreasing order of the openings of the mesh by adding the cover and the bottom container

iv. Pour the sample in the topmost sieve and cover it,

v. Shake the sieves manually or by the help of a sieve shaker until no more material passed through each sieve.

vi. Weigh the material retained on each sieve. The material retained on each sieve can be weighed individually or cumulatively. Cumulative weights provide the percentage of particles retained on the sieves progressively, while individual weights provide the percentage retained on an individual sieve.

Reference: this test will be done following the BS1377

3.5.2 Relative density and water absorption test

Objective of the test.

This method is used to determine the dry density of aggregates retrieved on a 4.75 mm sieve.

Equipment

i. Balance with accuracy 0.01g

ii. Sample container (wire cloth basket)

iii. Water bath and device to suspend the sample container into the bath

iv. Heating oven which can maintain a temperature of 110 ± 5 °C.

v. Distilled water.

Test Procedure:

i. The sample of aggregate is sieved on a 4.75-mm sieve then the mass of the sample is adjusted according to the nominal maximum aggregate size.

ii. The sample is washed thoroughly to remove dust from the surfaces.

iii. The sample is soaked in a water bath water for 24 ± 4 hours.

iv. Then the saturated surface dry condition by drying the surface of the aggregate with absorbent cloth.

v. Weighted of the sample with saturated surface and transferred to a wire basket that is previously tarred in water.

vi. The basket is weighed with sample in water, at 25°C.

vii. To determine the dry weight, the water is poured off without losing any material. Then the sample is dried in an oven at 105-110°C and the mass of the oven-dried sample is recorded.

Calculation

Apparent density, p_{bd} = $(\frac{A}{A-C})/0.997$ (g/cm^3)

Water absorption = $\frac{B-A}{A}$*100%

With A=mass of oven dried sample

B=mass of saturated dry sample

C=mass of saturated surface dry

3.5.3 Aggregate Crushing Value (ACV)

Apparatus

The apparatus used doing this test include; Sieve of 2.36mm with the top cover and a receiver, a plunger, steel cylinder, scoop, steel Tamping rod, compression testing machine, brush (to brush the sieve in case the is any residue),weighing machine, and ACV mold.

Test procedures

i. Assemble and Calibrate the acv machine
ii. weigh the empty cylinder
iii. Fill the mold with three layers of the dry sample and strike each layer with 25 strokes of the tamping rod.
iv. Level the surface of the material and insert the crushing plunger into the mold
v. Weight the mold filled with aggregate and record the weight
vi. Transfer the sample to the mold in 3 layer and make 25blows for each layer
vii. Place the plunger on top of the mold
viii. Place the mold (with sample and plunger) on the plate of the concrete compression machine.
ix. Apply 400 KN force gradually over a period of 10 minutes.

x. After 10 minutes; release force, pour the material in a clean tray and determine its total weight (m1).

xi. Sieve the crushed aggregate in a 2.36mm sieve and measure the mass of retained and mass of passing (m2).

Calculation

The acv is given by

$ACV = [M2/\ M1] \times 100$

References BS 812: Part 110: 1990

3.5.4 Ten Percent Fines Value (TFV)

Sample preparation and Test procedure:

The procedures are as follows;

i. This test is done on material retained on the 10mm sieve.

ii. Then the material is placed in the ACV mold in three layers, whereby each layer is tamped with 25 stokes using a tamping rod then leveled and inserted by the crushing plunger in the mold where it is compressed with the compression machine with a required load.

iii. Then sieve the compressed material in a 2.36mm sieve and record the weight of the material retained on that sieve.

Calculations:

To determine the required force to cause penetration of 20mm

Weight of material passing 2.36mm sieve = m1 – m2

% passing of material passing 2.36mm sieve (M) = (m1 – m2) x 100

TFV = 14 f M + 4

Where f = the force that caused penetration of 20mm.

m1 is the weight of the material after compression

m2 the material, retained on 2.36mm sieve

M = percentage passing 2.36mm sieve (ranging 7.5% – 12.5%)

3.6 CEMENT KILN DUST

3.6.1 Grading (BS 812-P103-1)

Apparatus

i. Sieves of sizes 28 mm, 20 mm, 14 mm, 10 mm, 5 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, 150 µm, 75 µm.

ii. A balance readable and accurate to 0.5 g.

iii. A drying oven capable of maintaining a temperature of 105 °C ± 5 °C.

iv. Metal containers and metal trays.

v. Scoop and sieve brushes.

Procedure

Three samples of the material will be prepared and washed through a 425-micron sieve and retained on a 75-micron sieve, respectively. The samples will then be dried in an oven at 105 °C ± 5 °C. Grading of the cement kiln dust using various sieves will be conducted, and the percentage passing each of the sieves will be compared with the specifications provided in (BS 882 1992) Table 3. These values will be used during the blending process for determining the mix design.

3.6.2 Specific Gravity (BS 812: PART 2)

Apparatus

i. Pycnometer.
ii. Balance readable to 0.1g.
iii. Well-insulated oven with temperatures of 105 °C ± 5 °C.

Procedure

The pycnometer will be weighed with its stopper, and the mass recorded as A. Three samples of cement kiln dust will be prepared. A sample of cement kiln dust will be placed in the pycnometer, filling it about half full. Petrol will be added to the cement kiln dust in the pycnometer until it is about half full. Thorough shaking will ensure the removal of entrapped air, and more petrol will be added until it reaches the graduated mark. The outside will be dried and weighed to obtain B. The pycnometer will be emptied, cleaned, and refilled with clean petrol until it reaches the graduated mark. The outside will be wiped dry and weighed to obtain C. The removed sample will be placed in the oven for 16-24 hours at a temperature of 105 °C ± 5 °C, and then it will be weighed at an oven-dry basis, obtaining D.

The Specific Gravity will be calculated using the following equation: Specific Gravity = D/ (D-(B-C))

3.7 STORAGE STABILITY TEST

The bitumen used as an asphalt binder is penetration grade 60/70 (AC60/70)

Test method

To assess the modified asphalt's high temperature storage stability, a hot storage test is carried out. A 25 mm diameter by 140 mm tall metal tube was filled with roughly 50g of modified asphalt. After that, the sample is kept at 163 ± 5°C for 48 ± 1 hour in a vertical vessel. Subsequently, it is removed and placed in a freezer set at -6.7 ± 5^0 C for a minimum of 4 hours in order to fully harden the sample. The tube is then divided into three equal pieces. The top and bottom ends undergo additional analysis in accordance with the ASTM D 36 ring and ball softening point test to assess any variances in features. One of the most crucial parameters of the initial properties on modified asphalt is the softening point difference between the top and bottom parts of the tube. If this difference is less than 2.2^0 C, the sample may be considered storage stable blend (ASTM D5926)

3.8.0 MARSHALL MIX DESIGN

Marshall Method for designing hot asphalt mixtures is used to determine the optimum bitumen content to be added to specific aggregate blend result a mix where the desired properties of strength and durability are met. According to standard 75-blow Marshal Design method designated as (ASTM D 1559-89). Marshal test procedure is used in evaluating and designing bituminous mixes and for paving jobs.

In this research project the Marshall test is conducted on AC14 job mix with bitumen modified with polyethylene terephthalate and cement kiln dust at different percentages.

The major properties of bituminous mix to be suitable for paving applications are stability, flexibility, durability, and skid resistance. Traditional mix design methods are established to measure the optimum bitumen content which would have optimum performance due to its optimum stability and durability

The test is conducted on unmodified asphalt and modified asphalt.

Density

The density of AC is given by $SG = \frac{W_{air}}{W_{SSD} - W_{HO2}}$

With W air = weight of specimen in air (gram)

W_{H02}= weight of specimen in water (gram)

W_{SSD}= weight of specimen with surface dry (gram)

Voids in the Mix

It is determined by $V = 100 - \{\frac{P_{bit}}{SG_{bit}} + \frac{P_{agg}}{SB_{agg}}\}$×D

With SG = specific gravity of the material, P = proportion of the material in the mix and D = density of the specimen (gr/cm3)

Test Procedure

i. measure 18000 g of aggregates, blend in the desired proportions

ii. Heat the aggregates to the mixing temperature which is about 170 to 190 C.

iii. Add bitumen to the heated aggregate and mixed to produce asphalt.

iv. The Marshall specimen was placed in a heated Marshall mold with a collar and base, Spade the mixture around the sides of the mold. Place filter papers under the sample and on top of the sample.

v. Then the mold containing asphalt is placed in the Marshall Compaction pedestal and compact the material with 50 blows of hammer (or as specified) invert the sample, and compact the other face with the same number of blows.

vi. Allow the sample to stand for a few hours to cool then obtain the sample mass in air and submerged in a water bath at 60 degrees.

vii. Then subjected the sample to compression and record the flow and stability

Reference

Marshall Mix design will be carried out according to ASTM D1559

3.9.0 **INDIRECT TENSILE STRENGTH** (ITS)

Significance

The ITS is used to access the tensile properties of the bituminous mix and this indicates the resistance of the asphalt mix to moisture susceptibility and a measure susceptibility to water.

Procedure

The moisture susceptibility of the asphalt concrete mixtures was evaluated using ASTM D4867. The result of this test is the ITS and Tensile Strength ratio. In this test, a set of specimens were prepared for each mix according to Marshall procedure and compacted to 7±1 % air voids using different numbers of blows per face that varied from (25 to 45) in our experiments. The set consists of 6 specimens and divided into two subsets, one set (control) was tested at 25°C and the other set (conditioned) was subjected to one cycle of freezing and thawing then tested at 25°C, but for our case, we used 8 specimens to cater for any errors by neglecting one. The test involved loading the specimens with compressive load at a rate of (50.8mm/min). Wide steel strips which are curved at the interface with specimens. These specimens failed by splitting along the vertical diameter. The indirect tensile strength which is calculated according to Eqn. (1) of the conditioned specimens (ITSc) is divided by the control specimens (ITSd), which gives the tensile strength ratio (TSR) as in the following Eqn. (2).

ITS = 2*P/π*t*D…………… Eqn. 1

$TSR = ITSc / ITSd$…………… Eqn. 2

Where;

i. ITS= Indirect tensile strength
ii. P = Ultimate applied load
iii. t = Thickness of specimen
iv. D = Diameter of specimen

Secondary data collection

The laboratory test procedures and data interpretation will be obtained from the literature review and test specification.

Data analysis methods

The data obtain will be analyzed by the help of excel. This tool helps in the creation of graphs which explain the behavior of the material in relation to various conditions such as temperature, but also the relationship between two or more component.

CHAPTER 4: RESULTS AND DISSCUSION

4.1 Introduction

This chapter presents results from the tests carried out in this study. The data is analyzed and discussed from the results of the tests carried out. The tests carried out were to determine the properties of cement kiln dust, bitumen and aggregates. The tests carried out to achieve this objective include: Aggregate Crushing Value, Ten Percent Fines Value, and Grading for aggregates; and Softening Point, Penetration, and ductility test for bitumen. To find the optimum bitumen content in the asphalt mix where the aggregate grading and type of bituminous binder is predetermined, the Marshall Mix design was carried out. The density and volumetric properties of asphalt mix are determined using the Marshall test.

4.1.1 Properties of cement kiln dust.

The table 4.1 shows that the cement kiln dust is mostly fine since it shows a bigger percentage passing in all of the bigger sieves. The results show that the highest percentage of 89.1% through the 0.075m sieve size that the cement kiln dust has a small particle size.

Table 1 : properties of cement kiln dust.

Properties	Results	Specifications
Grading; %passing,0.075mm	89.1	85 – 100

This indicates that it is suitable as a mesoscopic material to solve the problem of phase separation in the polymer modified asphalt since it has a large surface area. This process can be controlled through addition of mineral powders that exhibit mesoscopic characteristics such as high surface area (Biro et al., 2021).

4.1.2 Properties of bitumen

From the table4.2, the penetration test gave a penetration of 62.2 which means that our bitumen used was of penetration grade 60/70pen. The softening point value of 52.2 ℃ lies within the range of (49-56) ℃. The specific gravity of the samples is within the specified range of 1.01 -1.06. Ductility value obtained was 115cm which also satisfied the specification that is required.

Table 2: properties of bitumen

Properties	Result	Specification
Penetration,(25^{0}C),mm/10	62.2	60/70
Softening point (ring and ball),(^{0}C)	52.4	46/54
Ductility,(25^0), cm	115	Min 100
Density,(g/cm^3)	1.02	1.01/1.06

The penetration value of the bitumen indicates that 60/70 bitumen is suitable to be used in our climate. And the softening point value implies that the bitumen is suitable for mixing into the asphalt since it is not susceptible to flowing within the average climatic temperatures.

The bitumen will be used because the average bulk specific gravity of bitumen (Gb) was 1.02 g/cm3 according to the result in Table 4.2 above. Since it is greater than 1g/cm3, therefore it is heavier than water and it also lesser than 1.06, therefore it contains less impurities and this implies that the bitumen is suitable for use in testing procedures.

Ductility value means that the bitumen can be stretched to this value without breaking indicating that it has a strong cohesive force. This also means that the binder can elongate and fill the voids making the mixture easily compacted. This implies that it suitable for road use.

4.1.3 Properties of aggregates

From the table below, the value of ACV was 13 which is within the required value. The lower the aggregate crushing value, the stronger the aggregates. All properties were within the specified specifications.

Table 3: Physical properties of aggregates

Property	Result	Specification
Ten percent fines value Ratio (%)	83	Min 75
Aggregate Crushing value (%)	13	Max 25
Los Angeles Abrasion Value (%)	20	Max 25

Aggregate Crushing value indicates that the aggregates are satisfactorily strong to resist gradual load. This in turn means that there will be few fines formed to affect the durability of the road. This also means that there are few fines formed when carrying out tests such as the Marshall Compaction, which could affect the Stability and Volumetric Properties of the Mix and hence a wrong Mix Design. This shows that the aggregates would give a longer service life and a more economical performance. Aggregate abrasion measures the degradation of aggregates when subjected to abrasion and impact, the abrasion value should be Max 25 to resist abrasion.

Since tested material had an abrasion value of 20% the aggregates are tougher and more resistant to abrasion.

4.1.4 Effect of Polyethylene Terephthalate on penetration of bitumen

The penetration test is commonly used to control the penetration grade. The variations in penetration values with different percentages of PET, as depicted in the figure below, clearly demonstrate a reduction in consistency as PET is incorporated. Compared to neat bitumen, the reductions are 2.2%, 4.6%, 6.3%, 11.2%, and 14.4% with the addition of 2%, 4%, 6%, 8%, and 10% of PET, respectively. These results indicate that as the PET content increases in the mix, the penetration values for modified bitumen decrease.

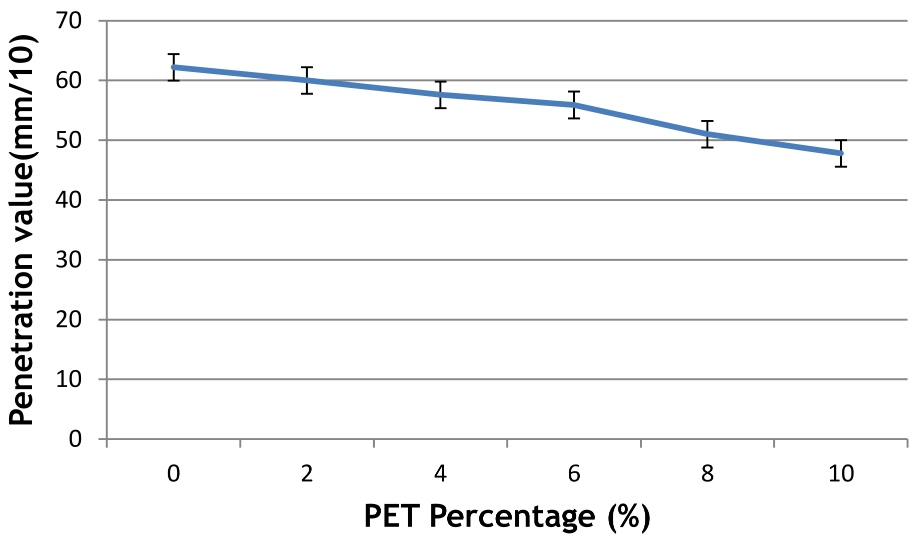


Figure 2: ***showing the penetration value against Pet percentage***

What penetration test shows or indicates the measure of the consistency of bitumen. Increase in penetration of bitumen increases the stabilization thickness of the asphalt layer and makes it more difficult for water to penetrate (Mohsen Esfahani, 2021). From the results, penetration values were increasing on addition of PET meaning the thickness of bitumen increased and this would increase resistance to moisture damage.

4.1.5 Effect of Polyethylene Terephthalate on Ductility of Bitumen

Bitumen needs to create flexible, thin films around the aggregates, enhancing their physical interlocking. Inadequate ductility of the binder material could leave the pavement surface exposed. However, excessively high ductility can lead to undesirable stretching of the pavement structure, resulting in non-uniform shape, while too low ductility can cause cracking. Hence, bitumen must possess a specific level of ductility. With an increase in PET content in the mix, the ductility of the modified binder decreases. As PET amounts range from 2% to 10%, the ductility of plain bitumen decreases by 2%, 8%, 11%, 16%, and 20%, respectively.

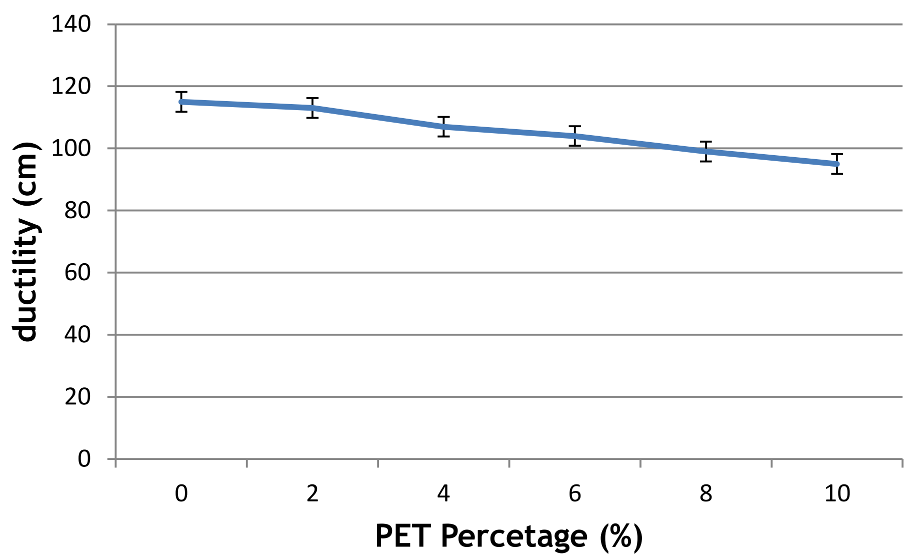


Figure ***3: Ductility values against PET percentages.***

The reduction in ductility is attributed to the interlocking of polymer molecules with bitumen, which aids in preventing water penetration into the bitumen mixtures, thereby offering resistance to moisture damage over time. According to the findings, the ductility values fall within the permitted limits of the Indian Standard, which mandates a minimum ductility value of 75 cm.

4.3.3 Effect of Polyethylene Terephthalate on softening point of bitumen.

Increasing PET content in the mix leads to a rise in the softening point. The results demonstrate that PET enhances the softening point value.

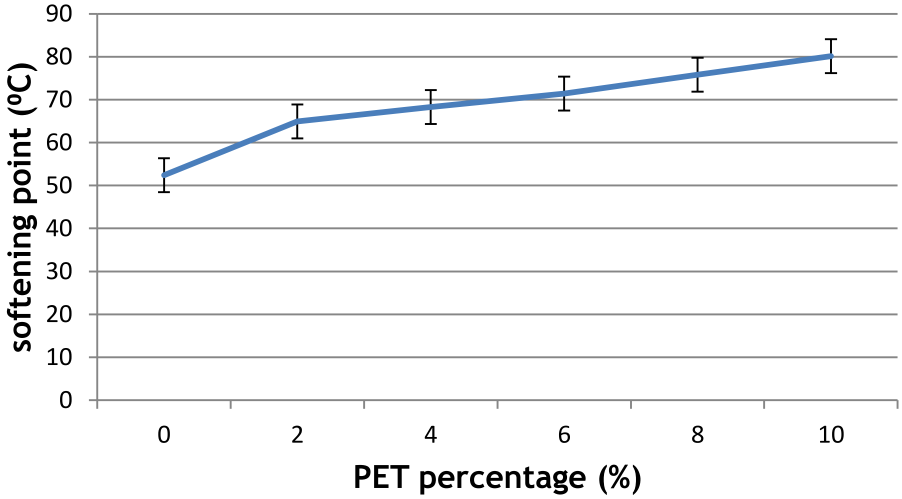


Figure 3: ***Showing softening point values against pet percentage***

This indicates that the binder is now far more resistant to the effects of heat and is less likely to soften in hot weather. The use of PET would make the improved binder less susceptible to temperature fluctuations. In hot temperatures, there will be less of a tendency for it to soften (Malik Ahmad, 2022). By reducing the impact of heat on the bituminous mix, PET will finally stop the bitumen from softening and preventing any opportunities for moisture penetration. In the long run, this will shield PET-modified bitumen against moisture degradation.

4.2 STORAGE STABILITY TEST RESULTS

Table 4 summarizes the storage stability test results of PET modified bitumen using different percentages of 0%, 1%, 1.5%, 2%, 2.5% of cement kiln dust. As shown in the table, the top samples of modified bitumen had a higher softening point compared to the bottom samples.

Table 4: Storage stability test results

CKD (%)	Softening point (^0C)			Specification	Remark
	Top	Bottom	Difference (^0C)		
0	92.3	75.2	17.1	Max 10^0C	Not stable
1.0	77.5	69.5	8.0	Max 10^0C	Stable
1.5	74.2	70.2	4.0	Max 10^0C	Stable
2.0	65.2	63.4	1.8	Max 10^0C	Very Stable
2.5	58.4	55.2	3.2	Max 10^0C	Stable

All bottom samples seemed to be slightly modified and contained a small amount of PET samples. Though , based on the difference in softening points between the top and bottom samples, all the PET modified bitumen tested in the study satisfied the Georgia Department Of Transport specifications requirement of 10^0C except for 0% cement kiln dust. Although, the rest satisfied the GDOT requirements except for 0%, only 2% showed a relatively lower value compared to the rest. Further studies indicate that if difference between softening points of top and bottom samples is less than 2.2^{0}C, then the blend is highly stable (Mohd Ezree, 2012). Thus, 2% CKD was selected as a satisfactory percentage for the mixture to solve phase separation

4.3 AC14 COMBINED GRADATION CURVE.

Figure 5 below shows the particle size distribution of the combined grading of the asphalt mix. Figure shows the AC14 combined gradation and it also shows that the grading lay in the specified grading envelopes. The green line is the finer side, the red line is the coarser side and the maroon line is the grading curve obtained.

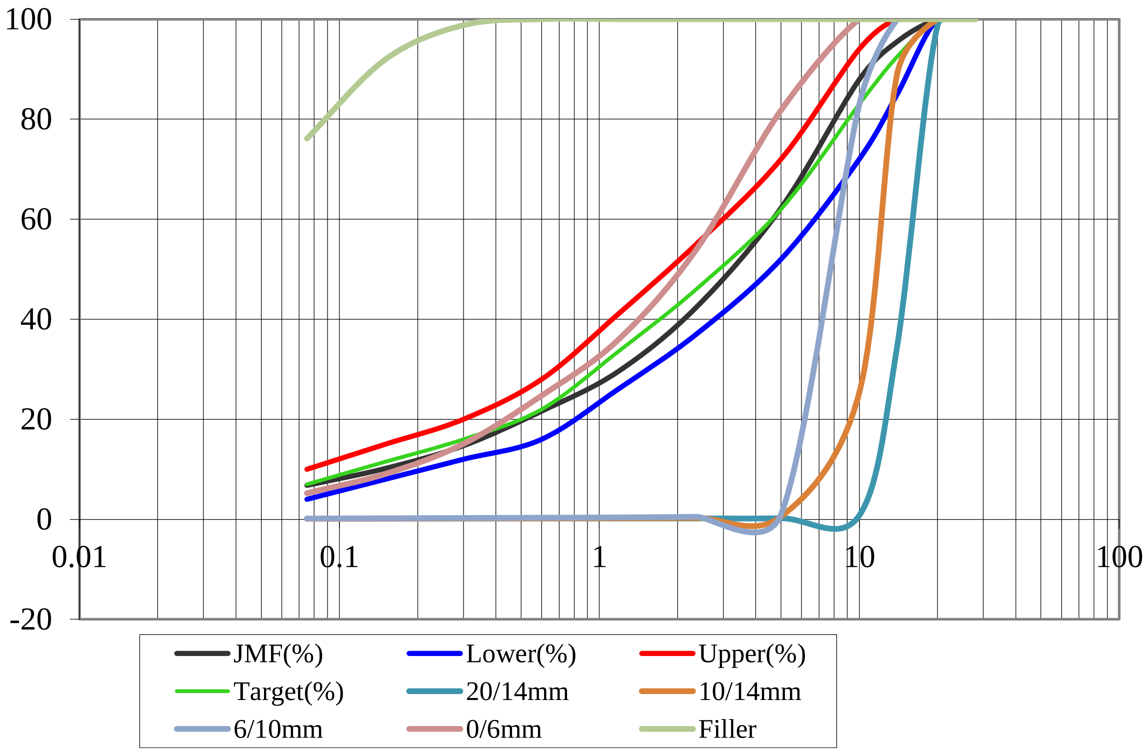


Figure 4: showing the combined gradation of AC14

The 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 proves the moisture resistance and lowers water penetration into the asphalt mix.

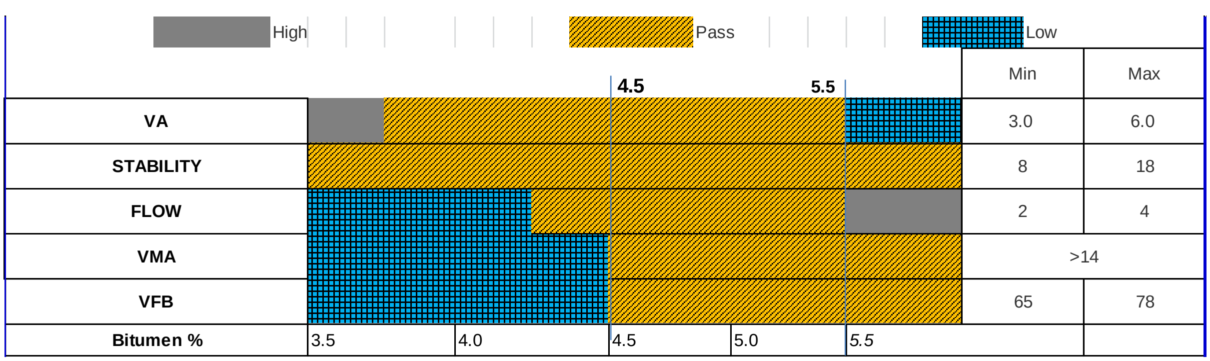
4.4 OBTIMUM BITUMEN CONTENT

Table 5 summarizes the values of the Marshall properties to determine the optimum bitumen content were in the range specifications. The specifications; stability (8-18) KN, air voids (3-6) %, flow (2-4) mm, VMA (min 14%), VFB (65-78) %. So they are within the ranges of asphalt specifications of Uganda. The stability value increases with increasing bitumen content up to a maximum after which the stability decreases. The stability value increased from 14.4 KN at 3.5 % bitumen content to 16.07 at 4.5% bitumen content, and then reduced to 15.47KN at 5.5% bitumen content. The flow value increases with increase in bitumen content. The density value increases with increase in bitumen content up to a maximum after which the density decreases. The percentage of air voids decreases with increase in bitumen content.

4.4.1 MARSHAL PROPERTY RESULTS

Table 5: showing marshal property results

Property	Result					Specification
	Bitumen content (%)					
	3.5	**4.0**	**4.5**	**5.0**	**5.5**	
Density (g/cm^3)	2.310	2.324	2.329	2.339	2.346	**N/A**
Air voids (%)	7.26	6.35	5.07	4.50	4.10	**3 - 6 %**
Stability (KN)	14.40	14.53	16.07	15.87	15.47	**8 - 18 KN**
Flow (mm)	1.77	2.05	2.66	3.10	4.09	**2 - 4 mm**
VMA (%)	14.17	14.07	14.34	14.42	14.63	**>14%**
VFB (%)	48.45	54.43	64.28	68.21	71.12	**65 - 78 %**



Bitumen content %	*Min*	4.50
	Max	5.50
	Av.	5.00
As Optimum Bitumen Content		**5.00**

The test property values were put in a reasonably consistent pattern for bitumen mix to show the different properties that passed and those that did not satisfy the specifications. The results obtained were compared on the range above and the optimum bitumen content was obtained from the range that passes the common range. Figure above shows various parameters obtained from the Marshall Tests. The optimum bitumen content was obtained by determining the average of 4.5 and 5.5. OBC was 5 %.

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

The test results in the table 6 below helped in making comparisons between the unmodified bitumen on asphalt concrete and modified bitumen on asphalt concrete. The Va, VMA, VFB, stability and flow of neat bitumen or for unmodified bitumen all satisfied the specifications. The results were within the limits. The indirect tensile strength of unmodified bitumen obtained was 87% which also satisfied the limit. The Indirect tensile strength was used to assess the tensile strength of the material in order to predict the resistance of the mixture to moisture damage. Whereas for modified bitumen, Flow results showed a slight increase but remained within the limits, meaning the modified asphalt did not much affect the flow of the asphalt concrete. Stability results increased beyond target limits on addition of modified bitumen. The ITS ratio of Asphalt Concrete increased by 92.9%.

Table 6 showing results for modified and unmodified bitumen

Property	Result		Specification
	Unmodified asphalt	Modified asphalt	
Va(%)	4.6	4.8	3 - 5 %
VMA (%)	14.5	15.1	Min 15
VFB (%)	67.6	67.9	65 - 78 %
Stability (KN)	15.7	22.5	8 - 18 KN
Flow (mm)	3.07	3.18	2 - 4 mm
Bulk specific gravity (g/cc)	2.336	2.320	NA
Max specific gravity of mix (g/cc)	2.450	2.437	NA
VIM (%)	3.2	3.2	Min 3
ITS Ratio (%)	87.0	92.9	≥80

The table 6 results above show that the mix design results that correspond to modified asphalt conclude that the properties of the modified bitumen are so superior to those of the unmodified asphalt. The Indirect tensile strength shows that there's improved adhesion between the binder and aggregate, and cohesion in the bitumen binder in the Mix and this implies that there is greater resistance to tensile stresses from traffic and other components of the environment because the stresses applied by the loads are normally resisted by the cohesive and adhesive forces of the Asphalt Mixes. It is a test to determine the moisture resistivity of Asphalt Concrete; hence there is increased moisture resistance for the sample modified by PET since moisture induced damage on aggregates is observed to be less compared to that of neat bitumen mix (on saturated ITS samples). This suggests that the mixture exhibits sufficient properties to mitigate the impact of moisture resistance on Asphalt Pavements.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS.

5.1 Conclusions.

This research was conducted to address the problem of premature deterioration of flexible pavements and finding solution by incorporating PET and cement kiln dust in the road mixes to improve the resistance of bituminous concrete to surface deformation such as moisture damage. Different tests were carried out such as penetration test, softening test, ductility test, aggregate tests, Marshall Mix design and indirect tensile strength. Based on the result obtained from these tests, conclusion was made as follows;

i. The ITS value for the conditioned wet samples and the TSR value 92.9% for the wet process indicate that the mixture was least susceptible to water damage.

ii. The results show that the addition of CKD into the polymer modified bitumen reduces phase separation effect and the 2% dosage of the waste cement kiln dust was used since it showed a tremendous result in reducing the separation between the PET and the binder.

iii. The optimum bitumen content obtained was 5% and the PET dosage was 6% with 2% cement kiln dust. The result showed a better performance in stability and TSR value.

iv. The indirect tensile strength of the modified asphalt with 6% PET and 2% CKD with 5% OBC showed a higher value that the unmodified sample.

5.2 Recommendations.

i. Further studies are recommended to study and analyze the behavior of phase separation in polymer modified asphalt between the binder and the polymer.

ii. Future research assessing the environmental performance using life cycle cost assessment and the economic performance using a life cycle analysis.

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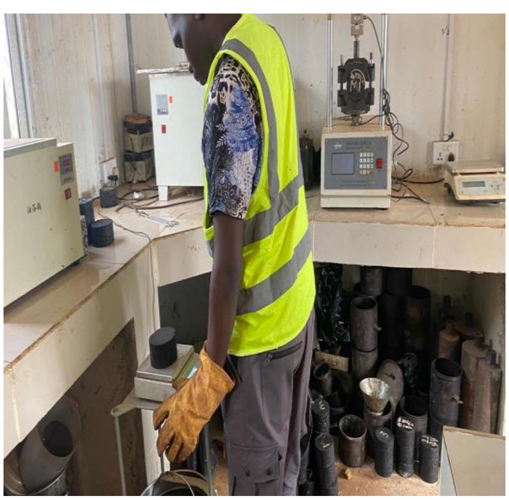
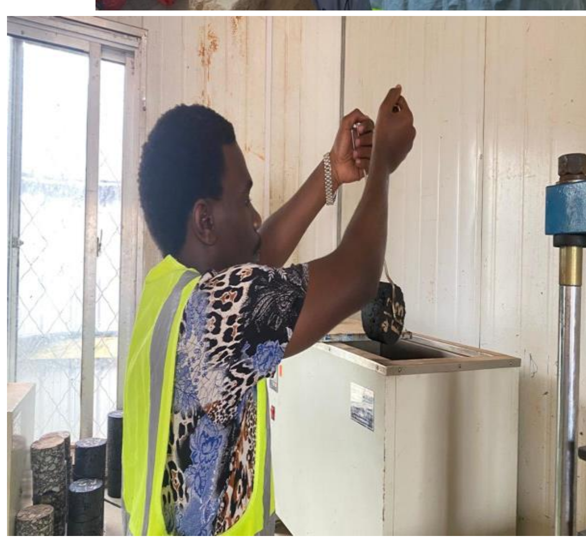
APPENDICES

Appendix 1: Laboratory preparation photos





Appendix 2: Laboratory results

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SUMMARY OF THE TEST RESULT ON ASPHALT CONCRETE SURFACING (AC14)
using Modified Bitumen(6%PET:2%CKD)

Road Name:	/			Sample Ref .		/		
Chainage / Location	/			Sampling Date:		/		
Mixture Source	Lab Mix			Test Date:		20-Feb-2024		
Hot bin Propotions	Agg. Size	14/20mm	10/14mm	6/10mm	0/6mm	Filler	Bitumen Content OBC %	5.0
	%age	6	5	13.5	71	4.5		
Test Parameter		Unit	Test Method		Specifications		AC14	
Extracion	Bitumen Content	%	ASTM D2172-88		±0.3%		5.0	
Marshall	Va	%	ASTM D1559-89		3 - 5		4.8	
	VMA	%			Min 15		15.1	
	VFB	%			65-78		67.9	
	Stability	KN			8-18		22.5	
	Flow	mm			2-4		3.18	
	Bulk Specific gravity	g/cc			NA		2.320	
Maximum Specific Gravity of Mix	Gmm	g/cc	ASTM D2041-95		NA		2.437	
Refusal Lab Compaction	VIM	%	TRL ORN 31		MIN 3		3.2	
ITS	Dry	Kpa	AASHTO T 283		MIN 800		1362	
	Ratio	%			≥80		92.9	

Remark: *Stability results are observed to have increased even Beyod target limits on addition of Modified Bitumen.*
Flow results showed a slight increase but remains with in the Limits
ITS: Strength was observed to increase on addition of modified Binder.
Moisture Induced damage on aggregates is observed to be less compared to that of Neat Bitumen Mix (on Saturated ITS samples)

Contractor's Representative(CSCEC)

Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	20/02/2024	Date:	21/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
P.O.Box 29285 Kampala
21 FEB 2024
(CSCEC)

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INDIRECT TENSILE STRENGTH (MOISTURE SUSCEPTIBIRITY) AASHTO T 283

Chainage /Location:	Lab		
Sample ref:	Lab Mix	Date of sampling	
Type of Mix:	AC14	Date of testing	17-Feb-2024
Grade of Bitumen:	Modified Bitumen	Technician	LAB TEAM

	Unit	Code	DRY			WET		
No. Blows			30	30	30	30	30	30
Diameter	mm	D	101	101	101	101	101	101
Thickness	mm	t	67.5	69.2	68.1	68.2	67.9	68.2
Weight in Air	gr	A	1221.4	1201.4	1205.7	1209.7	1207	1200.5
Weight in water after soaking	gr	B	687.5	677.9	679.1	680.4	679.7	680.8
Weight in air after soaking	gr	C	1228.5	1209.6	1212.5	1215.1	1214.3	1210.5
Volume	cc	E	541.0	531.7	533.4	534.7	534.6	529.7
BULK DENSITY	gr/cc	F	2.258	2.260	2.260	2.262	2.258	2.266
Correction Factor	-	C'	1.000	1.000	1.000	1.000	1.000	1.000
Corrected Specific Gravity	gr/cc	F'	2.258	2.260	2.260	2.262	2.258	2.266
Max, Specific Gravity	Gmm	G	2.437	2.437	2.437	2.437	2.437	2.437
Air Voids,(100 x (G-F')/G)	%	H	7.4	7.3	7.2	7.2	7.4	7.0
Volume of Air Voids ,(H x E/100)		I	39.8	38.7	38.7	38.3	39.3	37.1
Load reading	KN	P	14.20	15.10	14.94	13.72	13.05	14.21
Tensile strength, 2xP/(π x t x D)	Kpa		1326.7	1376.1	1383.5	1269	1212	1314
Average Tensile Strength	Kpa			1362			1265	

			Specification
Average Tensile Strength Dry	**(Kpa)**	1362	Min 800
Average Tensile Strength Wet	**(Kpa)**	1265	N/A
Tensile Strength Ratio (Tsw/Tsd)*100	**%**	93	>80%

Remark:

For the Contractor (CSCEC)

Technician	***Materials Engineer***
Sign: Amza	***Sign:*** [signature]
Date: 17/02/2024	***Date:*** 18/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
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PRD MIX DESIGN DATA SHEET - EXTENDED MARSHALL (300x2 blows)
REFUSAL DENSITY TEST (TRL ORN 31)

Chainage/Location:			
Sample Ref.:		Grade of Bitumen:	Modified Bitumen
Source:	Lab mix	No. of Blows:	300x2
Type of Mix:	AC14	Date of sampling	
Mix Temp ℃.:	150	Date of testing	15-Feb-2024
techinician	Lab Team		

Item	Core thickness			Average core thickness	Wt. air	Wt. in water	Wt. SSD	Volume	Gmb	Gmm	%voids	Average %voids
1	60.8	61.4	61.0	61.1	1205.6	695.4	1206.2	510.8	2.360	2.437	3.2	3.2
2	60.9	60.5	60.5	60.6	1204.3	694.1	1205.4	511.3	2.355		3.3	
3	61.2	61.4	61.3	61.3	1202.4	694.8	1203.4	508.6	2.364		3.0	
Average				**61.0**	**1204.1**	**694.8**	**1205.0**	**510.2**	**2.360**	**2.437**	**3.2**	**MIN 3%**

Remarks:

Contractor's Representative(CSCEC)

Laboratory Technician	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 15/02/2024	Date: 16/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	5.0% OBC	Date of sampling	
Type of Mix:	AC14	Date of testing	9-Feb-2024
Grade of Bitumen:	Modified Bitumen	Technician	Lab Team

Temperature(℃)					
Test no.				1	2
Weight of Mixed Material sample	g	A		1274.2	1243.2
Weight of pyconometer and water	g	B		9840.1	9878.5
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11114.3	11121.7
Weight of pyconometer +water + sample After De-Airing	g	D		10591.8	10611.2
Volume of Mix	g	E	C-D	522.5	510.5
Gmm	g	F	A/E	2.439	2.435
Average Density(g/cm3)				2.437	

Remarks

Representative(CSCEC)

Technician	***Materials Engineer***
Sign: Hamza.	***Sign:*** [signature]
Date: 9/02/24	***Date:*** 10/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	LAB TRIAL MIX AT OPTIMUM		
Source:	LAB TRIAL MIX	Grade of Bitumen:	Modified Bitumen
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	11-Feb
Sample Ref.:	5.0% OBC	Technician	Lab Team

Sl. No.	Description			Test Numbers 1	2	3	Average
1	Bulk Specific gravity of Total aggregate	Gsb		2.597			
2	Effective Specific gravity of Total Aggregate	Gse		2.632			
3	Specific Gravity of Bitumen	Gb		1.012			
4	Bitumen % by wt. Of Total Mix	Pb		5.00			
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb	95.0			
6	Maximum Specific Gravity of Mix	Gmm		2.437			
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb (Gse*Gsb)}	0.52			
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)	4.48			
9	Wt. Of specimen in air	Wa		1158.2	1197.6	1199.7	1185.2
10	Wt. Of specimen in water	Ww		662.8	684.4	685.4	677.5
11	Wt. Of specimen in air(SSD)	Wssd		1161.8	1200.5	1202.7	1188.3
12	Volume of specimen	V	Wssd-Ww	499.0	516.1	517.3	510.8
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.321	2.320	2.319	**2.320**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	10.26	10.26	10.26	**10.26**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	84.92	84.88	84.84	**84.88**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*1	4.76	4.80	4.84	**4.80**
17	%voids in Mineral Aggregate	VMA	100-Vagg	15.08	15.12	15.16	**15.12**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	68.04	67.86	67.68	**67.86**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			22.40	23.10	21.90	**22.47**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			22.40	23.10	21.90	**22.47**
23	Flow(mm)			3.14	3.18	3.21	**3.18**

Remarks:

Representative(CSCEC)	
Laboratory Technician(CSCEC)	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 11/02/24	Date: 12/02/2024

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SUMMARY OF THE TEST RESULT ON ASPHALT CONCRETE SURFACING (AC14)

on Neat Bitumen 60/70

Road Name:	/					Sample Ref .	/	
Chainage / Location	/					Sampling Date:	11-Feb-2024	
Mixture Source	Lab Mix					Test Date:	15-Feb-2024	
Hot bin Propotions	Agg. Size	14/20mm	10/14mm	6/10mm	0/6mm	Filler	Bitumen Content OBC %	5.0
	%age	6	5	13.5	71	4.5		

Test Parameter		Unit	Test Method	Specifications	AC14
Extracion	Bitumen Content	%	ASTM D2172-88	±0.3%	5.0
Marshall	Va	%	ASTM D1559-89	3 - 5	4.6
	VMA	%		Min 15	14.5
	VFB	%		65-78	67.6
	Stability	KN		8-18	15.7
	Flow	mm		2-4	3.07
	Bulk Specific gravity	g/cc		NA	2.336
Maximum Specific Gravity of Mix	Gmm	g/cc	ASTM D2041-95	NA	2.450
Refusal Lab Compaction	VIM	%	TRL ORN 31	MIN 3	3.2
ITS	Dry	Kpa	AASHTO T 283	MIN 800	1133
	Ratio	%		≥80	87.0

Remark

Contractor's Representative(CSCEC)

Technician		Materials Engineer	
Sign:	Ahmza	Sign:	[signature]
Date:	15/02/24	Date:	16/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
P.O.Box 29285 Kampala
16 FEB 2024
(CSCEC)

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INDIRECT TENSILE STRENGTH (MOISTURE SUSCEPTIBIRITY) AASHTO T 283

DETERMINATION OF NO. OF BLOWS FOR INDIRECT TENSILE STRENGTH

Sample ref:	LAB TRIAL	Date of sampling	
Chainage /Location:		Date of testing	13-Feb-2024
Type of Mix:	AC14	Mix Temp ℃:	150.0
Grade of Bitumen:	60/70	Technician	LAB TEAM

Specimen Number	Bitumen content	No. Blows	Thickness	Weight in Air	Weight in water after soaking	Weight in air after soaking	Volume	BULK DENSITY	GMM	Air voids	Average Va.
	%		mm	gm	gm	gm	cc	gm/cc	gm/cc	%	%
1	5.0	20	67.6	1226.6	685.0	1232.3	547.3	2.241	2.450	8.5	8.4
2			66.7	1219.3	683.2	1225.0	541.8	2.250		8.1	
3			67.8	1228.8	685.7	1235.0	549.3	2.237		8.7	
1	5.0	30	65.9	1220.5	695.2	1225.2	530.0	2.303		6.0	6.1
2			66.2	1229.9	698.5	1232.2	533.7	2.304		5.9	
3			65.4	1222.1	692.3	1224.5	532.2	2.296		6.3	
1	5.0	35	64.9	1208.9	698.6	1212.8	514.2	2.351		4.0	4.6
2			64.2	1217.1	698.3	1219.0	520.7	2.337		4.6	
3			64.9	1218.9	696.2	1220.9	524.7	2.323		5.2	

Remarks: Choose 30 blows on both sides since they give voids in the range of (6-8)%

For the Contractor (CSCEC)

Technician		***Materials Engineer***	
Sign:	Amza	***Sign:***	[signature]
Date:	13/02/2024	***Date:***	14/02/2024

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INDIRECT TENSILE STRENGTH (MOISTURE SUSCEPTIBIRITY) AASHTO T 283

Chainage /Location:	Lab		
Sample ref:	Lab Mix	Date of sampling	
Type of Mix:	AC14	Date of testing	17-Feb-2024
Grade of Bitumen:	60/70	Technician	LAB TEAM

	Unit	Code	DRY			WET		
No. Blows			30	30	30	30	30	30
Diameter	mm	D	101	101	101	101	101	101
Thickness	mm	t	68.2	67.6	67.8	67.9	68.8	68.7
Weight in Air	gr	A	1202.1	1197.4	1201.3	1201	1198	1205.8
Weight in water after soaking	gr	B	679.7	678.6	681.3	683.7	677.6	679.9
Weight in air after soaking	gr	C	1208.5	1201.6	1207.5	1210.1	1202.3	1212.5
Volume	cc	E	528.8	523.0	526.2	526.4	524.7	532.6
BULK DENSITY	gr/cc	F	2.273	2.289	2.283	2.282	2.283	2.264
Correction Factor	-	C'	1.000	1.000	1.000	1.000	1.000	1.000
Corrected Specific Gravity	gr/cc	F'	2.273	2.289	2.283	2.282	2.283	2.264
Max, Specific Gravity	Gmm	G	2.450	2.450	2.450	2.450	2.450	2.450
Air Voids,(100 x (G-F')/G)	%	H	7.2	6.5	6.8	6.9	6.8	7.6
Volume of Air Voids ,(H x E/100)		I	38.0	34.2	35.8	36.1	35.6	40.3
Load reading	KN	P	12.58	11.89	12.12	11.38	10.29	10.45
Tensile strength, 2xP/(π x t x D)	Kpa		1163.3	1109.2	1127.3	1057	943	959
Average Tensile Strength	Kpa			1133			986	

			Specification
Average Tensile Strength Dry	**(Kpa)**	1133	Min 800
Average Tensile Strength Wet	**(Kpa)**	986	N/A
Tensile Strength Ratio (Tsw/Tsd)*100	**%**	87	>80%

Remark:

For the Contractor (CSCEC)

Technician	***Materials Engineer***
Sign: Amza	***Sign:*** [signature]
Date: 17/02/2024	***Date:*** 18/02/2024

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REFUSAL DENSITY (BS 598 PART104)

Type of Asphalt:	AC14		
Mixture Source	Lab Mix		
Bitumen content OBC (%)	5.0%	Testing Date	14 Feb 2024
Sample Description:			

Loose Material											
Core Number	BC	Blows	Core Thickness	Weight in Air	Weight in water after soaking	Weight of SSD	Volume	Gmb	GMM	VIM	Remarks
No.			mm	gm	gm	gm	cc	g/cc	g/cc	%	
1	5.0	200	64.0	1201.4	691.7	1203.4	511.7	2.348	2.450	4.1	
2			63.8	1189.5	685.5	1191.4	505.9	2.351		4.0	
3			63.1	1195.6	688.4	1197.4	509.0	2.349		4.1	
1	5.0	300	62.8	1199.3	697.1	1201.9	504.8	2.376		3.0	Selected
2			62.9	1191.6	688.5	1192.6	504.1	2.364		3.5	
3			63.0	1198.5	695.0	1199.8	504.8	2.374		3.1	
1	5.0	400	63.1	1201.4	697.5	1202.5	505.0	2.379		2.9	
2			63.7	1197.6	693.1	1198.4	505.3	2.370		3.2	
3			63.4	1186.3	687.2	1187.6	500.4	2.371		3.2	

For the Contractor (CSCEC)

Technician		***Materials Engineer***	
Sign:	Hmza	*Sign:*	[signature]
Date:	14/02/2024	*Date:*	15/02/2024

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PRD MIX DESIGN DATA SHEET - EXTENDED MARSHALL (300x2 blows)
REFUSAL DENSITY TEST (TRL ORN 31)

Chainage/Location:			
Sample Ref.:			
Source:	Lab mix	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	300x2
Mix Temp ℃.:	150	Date of sampling	
techinician	Lab Team	Date of testing	15-Feb-2024

Item	Core thickness			Average core thickness	Wt. air	Wt. in water	Wt. SSD	Volume	Gmb	Gmm	%voids	Average %voids
1	61.6	61.0	61.7	61.4	1204.1	696.6	1205.1	508.5	2.368	2.450	3.3	3.2
2	61.1	61.4	61.4	61.3	1202.2	696.9	1203.1	506.2	2.375		3.0	
3	62.0	62.5	62.5	62.3	1208.2	699.5	1209.9	510.4	2.367		3.4	
Average				**61.7**	**1204.8**	**697.7**	**1206.0**	**508.4**	**2.370**	**2.450**	**3.2**	**MIN 3%**

Remarks:

Contractor's Representative(CSCEC)

Laboratory Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 15/02/2024	Date: 16/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	5.0% OBC	Date of sampling	
Type of Mix:	AC14	Date of testing	9-Feb-2024
Grade of Bitumen:	60/70	Technician	Lab Team

Temperature(℃)						
Test no.				1	2	
Weight of Mixed Material sample	g	A		1277.8	1203.5	
Weight of pyconometer and water	g	B		9840.1	9878.5	
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11117.9	11082	
Weight of pyconometer +water + sample After De-Airing	g	D		10596.8	10590.2	
Volume of Mix	g	E	C-D	521.1	491.8	
Gmm	g	F	A/E	2.452	2.447	
Average Density(g/cm3)					2.450	

Remarks

Representative(CSCEC)

Technician	***Materials Engineer***
Sign: Hamza	***Sign:*** [signature]
Date: 9/02/24	***Date:*** 10/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	LAB TRIAL MIX AT OPTIMUM		
Source:	LAB TRIAL MIX	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	11-Feb
Sample Ref.:	5.0% OBC	Technician	Lab Team

Sl. No.	Description			Test Numbers 1	2	3	Average
1	Bulk Specific gravity of Total aggregate	Gsb		2.597			
2	Effective Specific gravity of Total Aggregate	Gse		2.645			
3	Specific Gravity of Bitumen	Gb		1.018			
4	Bitumen % by wt. Of Total Mix	Pb		5.00			
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb	95.0			
6	Maximum Specific Gravity of Mix	Gmm		2.450			
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb / (Gse*Gsb)}	0.72			
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)	4.28			
9	Wt. Of specimen in air	Wa		1208.8	1202.7	1209.9	1207.1
10	Wt. Of specimen in water	Ww		692.8	690.5	694.7	692.7
11	Wt. Of specimen in air(SSD)	Wssd		1210.3	1205.1	1212.6	1209.3
12	Volume of specimen	V	Wssd-Ww	517.5	514.6	517.9	516.7
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.336	2.337	2.336	**2.336**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	9.82	9.82	9.82	**9.82**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	85.46	85.50	85.46	**85.47**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*1	4.63	4.59	4.63	**4.62**
17	%voids in Mineral Aggregate	VMA	100-Vagg	14.54	14.50	14.54	**14.53**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	67.54	67.72	67.54	**67.60**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			16.30	15.20	15.50	**15.67**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			16.30	15.20	15.50	**15.67**
23	Flow(mm)			3.02	3.11	3.08	**3.07**

Remarks:

Representative(CSCEC)

Laboratory Technician(CSCEC)	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 11/02/2024	Date: 12/02/2024

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Summary of Bitumen Storage stability Results

Bitumen type:	*Modified Bitumen With PET*	*Supplier/ Origin: SB Company*	
Testing date:	*26-Jan-24*	*Sample Date:*	*18-Jan-24*

%age Cement Kiln Dust	Softening point(℃)		Difference	Remarks
	Top	Bottom	<2.2 ℃	ASTM D5926
1.0%	77.5	69.5	8.0	*Not stable*
1.5%	74.2	70.2	4.0	*Not stable*
2.0%	65.2	63.4	1.8	*Stable*
2.5%	58.4	55.2	3.2	*Not stable (Softening point decreased gradually)*

Lab Technician	Materials Engineer
Signature: Hmza ,	Signature: [signature]
Date: 26/01/2024	Date: 27/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD P.O.Box 29285 Kampala 27 JAN 2024 (CSCEC)

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD

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Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*0% CKD*	*Supplier/ Origin:*	*SB Company*
Testing date:	*30-Jan-24*	*Sample Date:*	*5-Jan-24*
Bath Fluid:	*Water* ☑	*Glycerin* ☐	

Time (minutes)	Temp. (°C)	Temp. rise (°C)
0	3.9	
1	8.8	4.9
2	13.9	5.1
3	19.0	5.1
4	24.3	5.3
5	29.1	4.8
6	33.5	4.4
7	39.1	5.6
8	45.0	5.9
9	49.7	4.7
10	54.7	5.0
11	58.9	4.2
12	63.4	4.5

Time (minutes)	Temp. (°C)	Temp. rise (°C)
12	67.9	
13	72.9	5.0
14	77.8	4.9
15	83.1	5.3
16		
17		
18		
19		
20		
21		
22		
23		
24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1(Top)	Ring 2(Bottom)	Difference
Temperature when the ball touches the bottom (°C)	92.3	75.2	17.1

Laboratory Technician	Materials Engineer
Signature Hamza,	Signature [signature]
Date: 30/01/24	Date: 31/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD

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Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*1% CKD*	*Supplier/ Origin:*	*SB Company*
Testing date:	*30-Jan-24*	*Sample Date:*	*5-Jan-24*

Bath Fluid: *Water* ☒ *Glycerin* ☐

Time (minutes)	Temp. (^oC)	Temp. rise (^oC)
0	4.1	
1	9.2	5.1
2	14.1	4.9
3	19.5	5.4
4	24.1	4.6
5	29.7	5.6
6	33.8	4.1
7	38.4	4.6
8	44.2	5.8
9	49.8	5.6
10	54.8	5.0
11	59.5	4.7
12	64.2	4.7

Time (minutes)	Temp. (^oC)	Temp. rise (^oC)
12	68.7	
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1(Top)	Ring 2(Bottom)	Difference
Temperature when the ball touches the bottom (^oC)	77.5	69.5	8.0

Laboratory Technician	Materials Engineer
Signature Hamza.	Signature [signature]
Date: 30/01/24	Date: 31/01/2024

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Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*1.5% CKD*	*Supplier/ Origin:*	*SB Company*
Testing date:	*30-Jan-24*	*Sample Date:*	*5-Jan-24*
Bath Fluid:	*Water* ☑	*Glycerin* ☐	

Time (minutes)	Temp. (°C)	Temp. rise (°C)
0	4.9	
1	10.1	5.2
2	15.2	5.1
3	19.9	4.7
4	25.1	5.2
5	30.1	5.0
6	35.2	5.1
7	40.3	5.1
8	45.4	5.1
9	49.9	4.5
10	55.2	5.3
11	60.1	4.9
12	64.9	4.8

Time (minutes)	Temp. (°C)	Temp. rise (°C)
12	70.1	
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1(Top)	Ring 2(Bottom)	Difference
Temperature when the ball touches the bottom (°C)	74.2	70.2	4.0

Laboratory Technician	Materials Engineer
Signature Hamza	Signature [illegible]
Date: 30/01/24	Date: 31/01/2024

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Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*2.0% CKD*	*Supplier/ Origin:*	*SB Company*
Testing date:	*30-Jan-24*	*Sample Date:*	*5-Jan-24*
Bath Fluid:	*Water* ☑	*Glycerin* ☐	

Time (minutes)	Temp. (^{0}C)	Temp. rise (^{0}C)
0	5.1	
1	9.8	4.7
2	14.8	5.0
3	20.2	5.4
4	24.8	4.6
5	30.2	5.4
6	35.1	4.9
7	40.2	5.1
8	45.6	5.4
9	49.8	4.2
10	54.8	5.0
11	59.9	5.1
12	66.2	6.3

Time (minutes)	Temp. (^{0}C)	Temp. rise (^{0}C)
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1(Top)	Ring 2(Bottom)	Difference
Temperature when the ball touches the bottom (^{0}C)	65.2	63.4	1.8

Laboratory Technician	Materials Engineer
Signature: Hamza.	Signature: [signature]
Date: 30/01/2024	Date: 31/01/2024

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Summary of Bitumen Test Results

Bitumen type:	*60/70(2% PET)*	*Supplier/ Origin: SB Company*	
Testing date:	*19-Jan-24*	*Sample Date:*	*18-Jan-24*

Penetration value	60.4	ASTM D 5
Softening(Ring & Ball)	64.9	ASTM D36/ AASHTO T 053
Density (g/cm3)	1.02	ASTM D70
Ductility(cm)	113	AASHTO T051-94

Lab Technician	Materials Engineer
Signature: Hamza.	**Signature:** [signature]
Date: 19/01/24	**Date:** 20/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD P.O.Box 29285 Kampala 20 JAN 2024 (CSCEC)

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Email: cscecjiangbo@gmail.com

Penetration Test for Bitumen

Testing Method ASTM D 5

Bitumen type:	*60/70*	*Supplier/ Origin: SB Company*	
Testing date:	*19-Jan-24*	*Sample Date:*	*18-Jan-24*

Measurement no.	1	2	3	Remarks
Penetrometer dial reading				
Initial reading	0.14	0.07	0.09	
Final reading	6.11	6.14	6.17	
Penetration value	59.7	60.7	60.8	
Average penetration value		60.4		

Laboratory Technician	Materials Engineer
Signature: Hmza .	Signature: [signature]
Date: 19/01/2024	Date: 20/01/2024

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Email: cscecjiangbo@gmail.com

Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*60/70(2% PET)*	*Supplier/ Origin:*	*SB Company*
Testing date:	*19-Jan-24*	*Sample Date:*	*5-Jan-24*
Bath Fluid:	*Water* ☑	*Glycerin* ☐	

Time (minutes)	Temp. (^{0}C)	Temp. rise (^{0}C)
0	5	
1	7.7	2.7
2	13.1	5.4
3	16.1	3.0
4	22.0	5.9
5	27.1	5.1
6	32.4	5.3
7	37.9	5.5
8	42.5	4.6
9	47.1	4.6
10	52.3	5.2
11	56.8	4.5
12		

Time (minutes)	Temp. (^{0}C)	Temp. rise (^{0}C)
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

**** temp rise is 5 ± 0.5 °C per minute***

Sample No.	Ring 1	Ring 2	Average
Temperature when the ball touches the bottom (^{o}C)	64.8	65	64.9

Laboratory Technician	Materials Engineer
Signature [signature]	Signature [signature]
Date: 19/01/24	Date: 20/01/2024

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Density of Bituminous Binders

Ref: ASTM D70

Bitumen type	*50/70(2% PET)*	*Supplier/ Origin*	*SB Company*
Testing date	*19-Jan-24*	*Sample Date:*	*18-Jan-24*

		Test1	Test 2	Mean
Pycnometer No.		A	B	
Mass of dry Pycnometer, g	A	56.70	52.30	
Mass of Pycnometer + filled with water	B	178.20	181.10	
Mass of Pycnometer Partially filled with sample	C	129.4	126.3	
Mass of Pycnometer Plus Sample Plus Water	D	179.5	182.3	
Relative Density=	C-A/(B-A)-(D-C)	1.018	1.016	1.017

Materials Technician	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 19/01/24	Date: 20/01/2024

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DETERMINATION OF DUCTILITY (AASHTO T051-94)

Sample Ref:	*N/A*	Bitumen Grade:	*60/70(2% PET)*
Source:	*SB Company*	Sampling date:	*18-Jan-24*
Location:	*N/A*	Testing date:	*19-Jan-24*
Test Temperature:	*25º C*	Tested by:	*Lab Team*

Pouring Temperature, º C	:	140	
In Air	:	30	{Spec: 30-40min }
In water bath before Trimming	:	30	{Spec: 30min }
In water bath after Trimming	:	90	{Spec: 90 ± 5min }
Rate of Pull	:	50	{Spec : 50 ± 2.5/mm/min}

Test Property	Briquette Number			mean value
Ductility value(cm)	1	2	3	Specification (ASTM D113) >100
	112.9	113	113.1	113

Materials Technician	Materials Engineer
Sign: Hamza .	Sign: [signature]
Date: 19/01/24	Date: 20/01/2024

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Summary of Bitumen Test Results

Bitumen type:	*60/70(8% PET)*	*Supplier/ Origin: SB Company*	
Testing date:	*20-Jan-24*	*Sample Date:*	*18-Jan-24*

Penetration value	51.0	ASTM D 5
Softening(Ring & Ball)	75.8	ASTM D36/ AASHTO T 053
Density (g/cm3)	1.010	ASTM D70
Ductility(cm)	99	AASHTO T051-94

Lab Technician	Materials Engineer
Signature: [signature]	Signature: [signature]
Date: 20/1/24	Date: 19/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD P.O.Box 29285 Kampala 19 JAN 2024 (CSCEC)

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Penetration Test for Bitumen

Testing Method ASTM D 5

Bitumen type:	*60/70*	*Supplier/ Origin: SB Company*	
Testing date:	*20-Jan-24*	*Sample Date:*	*18-Jan-24*

Measurement no.	1	2	3	Remarks
Penetrometer dial reading				
Initial reading	0.05	0.08	0.09	
Final reading	5.19	5.14	5.19	
Penetration value	51.4	50.6	51.0	
Average penetration value		51.0		

Laboratory Technician	Materials Engineer
Signature: Hamza	Signature:
Date: 20/01/2024	Date: 19/01/2024

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Email: cscecjiangbo@gmail.com

Summary of Bitumen Test Results

Bitumen type:	*60/70(Neat)*	*Supplier/ Origin: SB Company*	
Testing date:	*10-Jan-24*	*Sample Date:*	*5-Jan-24*

Penetration value	62.2	ASTM D 5
Softening(Ring & Ball)	52.4	ASTM D36/ AASHTO T 053
Density (g/cm3)	1.02	ASTM D70
Ductility(cm)	115	AASHTO T051-94

Lab Technician	Materials Engineer
Signature: Hamza .	Signature: [signature]
Date: 10/01/2024	Date: 11/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION (CSCEC) LTD
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11 JAN 2024

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Email: cscecjiangbo@gmail.com

Penetration Test for Bitumen

Testing Method ASTM D 5

Bitumen type:	*60/70*	*Supplier/ Origin: SB Company*		
Testing date:	*10-Jan-24*	*Sample Date:*	*5-Jan-24*	
Measurement no.	1	2	3	Remarks
Penetrometer dial reading				
Initial reading	0.13	0.13	0.10	
Final reading	6.41	6.34	6.27	
Penetration value	62.8	62.1	61.7	
Average penetration value	62.2			

Laboratory Technician	Materials Engineer
Signature: Hamza .	Signature: [signature]
Date: 10/01/2024	Date: 11/01/2024

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Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*AP1*	*Supplier/ Origin:*	*SB Company*
Testing date:	*10-Jan-24*	*Sample Date:*	*5-Jan-24*
Bath Fluid:	*Water* ☑	*Glycerin* ☐	

Time (minutes)	Temp. (°C)	Temp. rise (°C)	Time (minutes)	Temp. (°C)	Temp. rise (°C)
0	5.2		12		
1	7.3	2.1	13		
2	12.4	5.1	14		
3	15.9	3.5	15		
4	21.2	5.3	16		
5	27.0	5.8	17		
6	32.1	5.1	18		
7	38.4	6.3	19		
8	42.0	3.6	20		
9	47.1	5.1	21		
10			22		
11			23		
12			24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1	Ring 2	Average
Temperature when the ball touches the bottom (°C)	52	52.7	52.4

Laboratory Technician		Materials Engineer	
Signature	Hamza	Signature	[signature]
Date:	10/01/2024	Date:	11/01/2024

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Density of Bituminous Binders

Ref: ASTM D70

Bitumen type	*60/70(Neat)*	*Supplier/ Origin*	*SB Company*
Testing date	*7-Jan-24*	*Sample Date:*	*5-Jan-24*

		Test1	Test 2	Mean
Pycnometer No.		A	B	
Mass of dry Pycnometer, g	A	56.60	52.40	
Mass of Pycnometer + filled with water	B	178.10	181.20	
Mass of Pycnometer Partially filled with sample	C	127.4	122.3	
Mass of Pycnometer Plus Sample Plus Water	D	179.3	182.5	
Relative Density=	C-A/(B-A)-(D-C)	1.017	1.019	1.018

Materials Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 7/01/2024	Date: 08/01/2024

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DETERMINATION OF DUCTILITY (AASHTO T051-94)

Sample Ref:	N/A	Bitumen Grade:	60/70(Neat)
Source:	SB Company	Sampling date:	5-Jan-24
Location:	N/A	Testing date:	11-Jan-24
Test Temperature:	25° C	Tested by:	Lab Team

Pouring Temperature, ° C : 140

In Air : 30 {Spec: 30-40min }

In water bath before Trimming : 30 {Spec: 30min }

In water bath after Trimming : 90 {Spec: 90 ± 5min }

Rate of Pull : 50 {Spec : 50 ± 2.5/mm/min}

Test Property	Briquette Number			mean value
Ductility value(cm)	1	2	3	Specification (ASTM D113) >100
	114.7	115.2	114.5	115

Materials Technician	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 10/01/2024	Date: 11/01/2024

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Email: cscecjiangbo@gmail.com

AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date		27/12/2023	
Location: (km)	Zirobwe Quarry	Testing Date		7 Jan 2024	
Material source	Namawonjja quarry in zirobwe	Technician		Group	
Diameter(mm)	20-14	14-10	10-6	6-0	Filler (Cement Kiln Dust)
28	100.0	100.0	100.0	100.0	100
20	98.7	100.0	100.0	100.0	100
14	34.7	89.1	99.9	100.0	100
10	0.8	25.3	82.9	100.0	100
5	0.2	0.5	1.0	81.8	98
2.36	0.2	0.3	0.5	53.9	97
1.18	0.2	0.2	0.4	35.8	96
0.6	0.2	0.2	0.3	24.7	94
0.3	0.2	0.2	0.3	15.1	93
0.15	0.1	0.1	0.2	9.1	91
0.075	0.1	0.1	0.2	5.2	89
Pan	0.1	0.1	0.1	4.0	0

Remarks:

Materials Technician	Materials Engineer
Sign: Hmza	Sign: [signature]
Date: 7/01/2024	Date: 08/01/2024

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P.O.Box 29285 Kampala
08 JAN 2024
(CSCEC)

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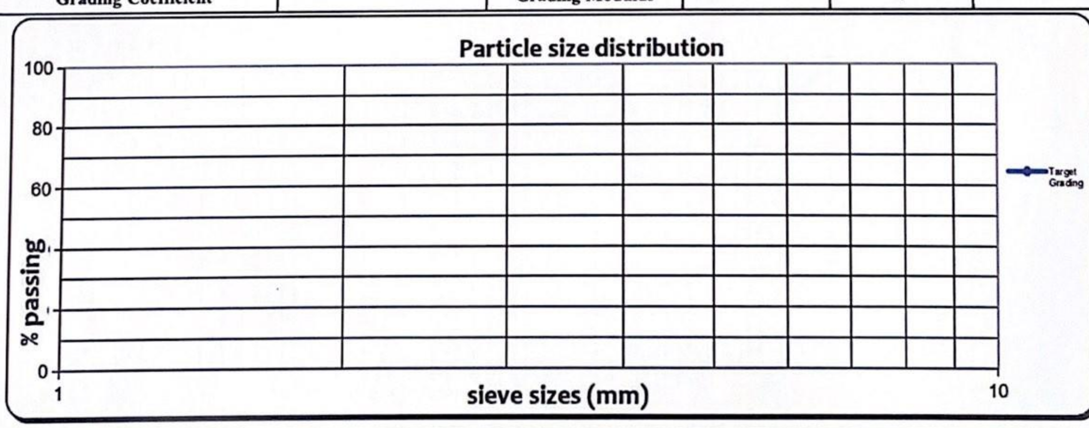
Email: cscecjiangbo@gmail.com

AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date	27/12/2023
Location: (km)	Zirobwe Quarry	Testing Date	7 Jan 2024
Material source	Namawonjja quarry in zirobwe	Technician	Group
Sample Description	AC-14 (20-14mm)		
Mass of dry Sample (gm)	6613		

Diameter(mm)	Partial Retained Mass(g)	Cumulative Retained Mass(g)	Cumulative Retained(%)	% Passing	
28	0.0	0.0	0.0	100.0	
20	85.6	85.6	1.3	98.7	
14	4234.5	4320.1	65.3	34.7	
10	2243.1	6563.2	99.2	0.8	
5	36.4	6599.6	99.8	0.2	
2.36	1.9	6601.5	99.8	0.2	
1.18	0.7	6602.2	99.8	0.2	
0.6	0.2	6602.4	99.8	0.2	
0.3	0.4	6602.8	99.8	0.2	
0.15	0.5	6603.3	99.9	0.1	
0.075	0.5	6603.8	99.9	0.1	
Pan	0.9	6604.7	99.9	0.1	
Grading Coefficient		**Grading Modulus**		.	



Remarks:

Materials Technician		Materials Engineer	
Sign:	Hmza	Sign:	[signature]
Date:	7/01/2024	Date:	08/01/2024

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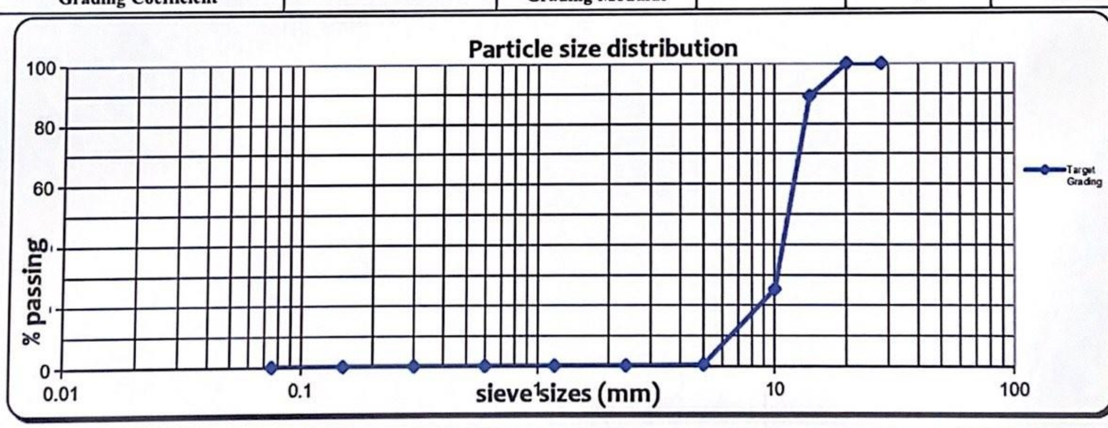
Email: cscecjiangbo@gmail.com

AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date	27/12/2023
Location: (km)	Zirobwe Quarry	Testing Date	7 Jan 2024
Material source	Namawonjja quarry in zirobwe	Technician	Group
Sample Description	AC-14 (14-10mm)		
Mass of dry Sample (gm)	5763.3		

Diameter(mm)	Partial Retained Mass(g)	Cumulative Retained Mass(g)	Cumulative Retained(%)	% Passing	
28	0.0	0.0	0.0	100.0	
20	0.0	0.0	0.0	100.0	
14	626.7	626.7	10.9	89.1	
10	3677.5	4304.2	74.7	25.3	
5	1428.2	5732.4	99.5	0.5	
2.36	14.8	5747.2	99.7	0.3	
1.18	3.5	5750.7	99.8	0.2	
0.6	1.3	5752.0	99.8	0.2	
0.3	1.2	5753.2	99.8	0.2	
0.15	1.9	5755.1	99.9	0.1	
0.075	2.2	5757.3	99.9	0.1	
Pan	0.8	5758.1	99.9	0.1	
Grading Coefficient		**Grading Modulus**		.	



Remarks:

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	7/01/2024	Date:	08/01/2024

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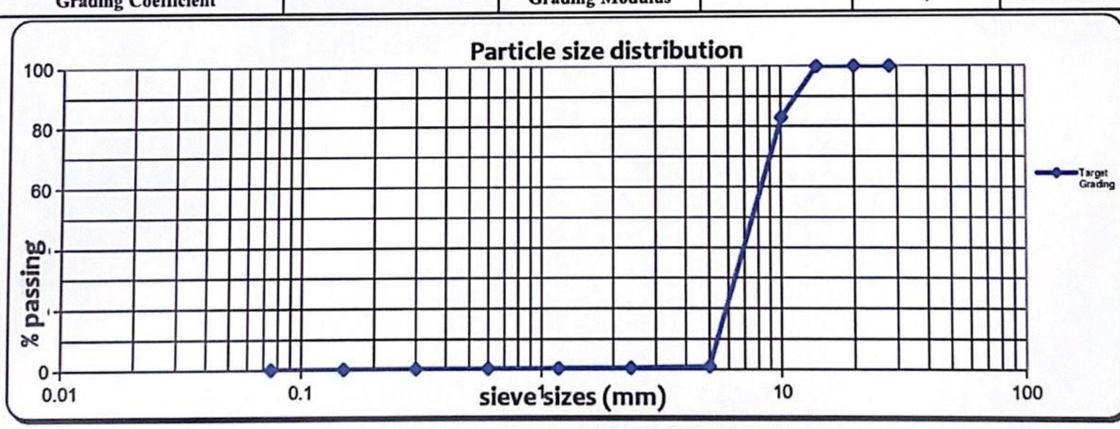
Email: cscecjiangbo@gmail.com

AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date	27/12/2023
Location: (km)	Zirobwe Quarry	Testing Date	7 Jan 2024
Material source	Namawonjja quarry in zirobwe	Technician	Group
Sample Description	AC-14 (10-6mm)		
Mass of dry Sample (gm)	4956.1		

Diameter(mm)	Partial Retained Mass(g)	Cumulative Retained Mass(g)	Cumulative Retained(%)	% Passing	
28	0.0	0.0	0.0	100.0	
20	0.0	0.0	0.0	100.0	
14	5.8	5.8	0.1	99.9	
10	840.5	846.3	17.1	82.9	
5	4061.0	4907.3	99.0	1.0	
2.36	23.4	4930.7	99.5	0.5	
1.18	6.7	4937.4	99.6	0.4	
0.6	3.2	4940.6	99.7	0.3	
0.3	2.7	4943.3	99.7	0.3	
0.15	2.6	4945.9	99.8	0.2	
0.075	2.5	4948.4	99.8	0.2	
Pan	0.3	4948.7	99.9	0.1	
Grading Coefficient		**Grading Modulus**		.	



Remarks:

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	7/01/2024	Date:	08/01/2024

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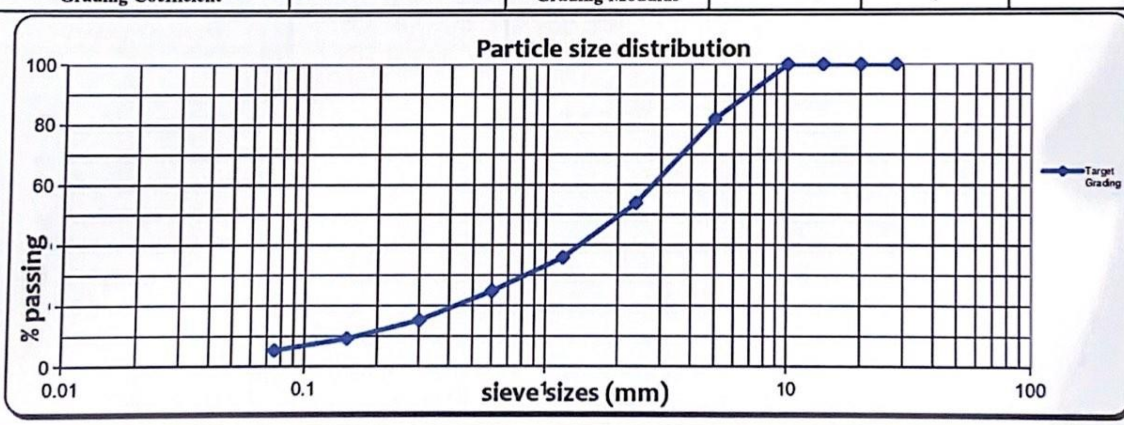
AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date	27/12/2023
Location: (km)	Zirobwe Quarry	Testing Date	8 Jan 2024
Material source	Namawonjja quarry in zirobwe	Technician	Group
Sample Description	AC-14 (6-0mm)		
Mass of dry Sample (gm)	6891.2		

Diameter(mm)	Partial Retained Mass(g)	Cumulative Retained Mass(g)	Cumulative Retained(%)	% Passing	
28	0.0	0.0	0.0	100.0	
20	0.0	0.0	0.0	100.0	
14	0.0	0.0	0.0	100.0	
10	0.0	0.0	0.0	100.0	
5	1255.4	1255.4	18.2	81.8	
2.36	1920.1	3175.5	46.1	53.9	
1.18	1245.6	4421.1	64.2	35.8	
0.6	765.8	5186.9	75.3	24.7	
0.3	664.5	5851.4	84.9	15.1	
0.15	415.3	6266.7	90.9	9.1	
0.075	264.7	6531.4	94.8	5.2	
Pan	84.3	6615.7	96.0	4.0	
Grading Coefficient		**Grading Modulus**		.	



Remarks:

Materials Technician		Materials Engineer	
Sign:	Hmza.	Sign:	[signature]
Date:	8/01/2024	Date:	09/01/2024

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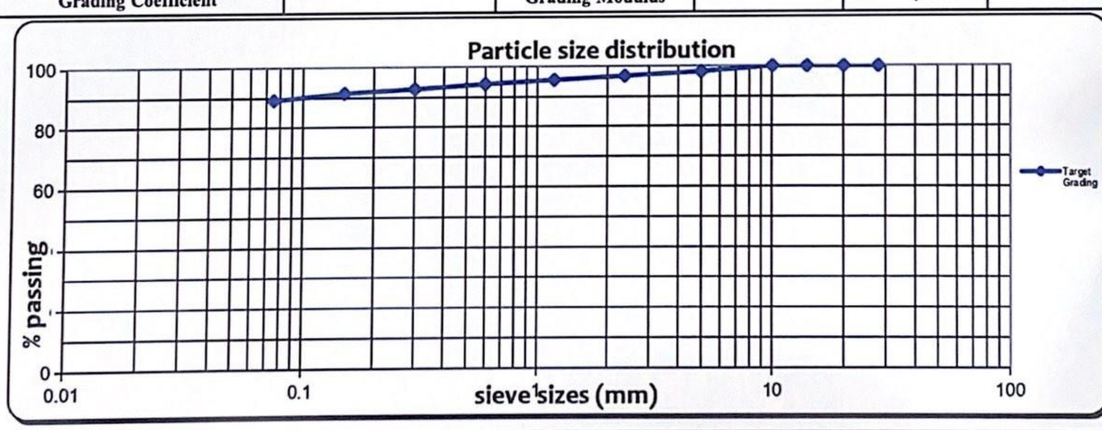
AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date	13 Jan 2024
Location: (km)	Kasese	Testing Date	15 Jan 2024
Material source	Hima Cement Factory	Technician	Group
Sample Description	AC-14 (Cement Kiln dust)		
Mass of dry Sample (gm)	500		
Mass of dry Sample after washing	57.4		

Diameter(mm)	Partial Retained Mass(g)	Cumulative Retained Mass(g)	Cumulative Retained(%)	% Passing	
28	0.0	0.0	0.0	100.0	
20	0.0	0.0	0.0	100.0	
14	0.0	0.0	0.0	100.0	
10	0.0	0.0	0.0	100.0	
5	9.0	9.0	1.8	98.2	
2.36	6.9	15.9	3.2	96.8	
1.18	6.4	22.3	4.5	95.5	
0.6	6.3	28.6	5.7	94.3	
0.3	7.8	36.4	7.3	92.7	
0.15	6.7	43.1	8.6	91.4	
0.075	11.2	54.3	10.9	89.1	
Pan	442.6	496.9			
Grading Coefficient		**Grading Modulus**		.	



Remarks:

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	15/01/2024	Date:	16/01/2024

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SPECIFIC GRAVITY FOR FINE AGGREGATES (FILLER<0.075)

TEST METHOD ASTM - D854

Location:	Kasese	Sampling Date:	2024-01-13
Material Source:	Hima Cement Factory	Tested Date:	2024-01-15
Sample description	Cement Kiln Dust	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of Pycnometer filled with Water only	A	g	326.1	326.2	
Mass of Pycnometer filled with kerosene only	B	g	272.3	272.3	
Density of Kerosene	C=A/B	Cm3	0.835	0.835	
Mass of Oven-dry sample in air	D	g	84.2	85.2	
Mass of Pycnometer + sample +kerosene	E	g	327.5	328.1	
Mass of sample in kerosene	F=B-E	g	55.2	55.8	
Volume of sample	G=D-E	cm3	29.0	29.4	
Bulk specific Gravity of Filler, Gsb	Gsb=(A/E)*C	Mg/m^3	2.424	2.419	2.422

Remark:

Representative(CSCEC)

Materials Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 15/01/2024	Date: 16/01/2024

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RELATIVE DENSITY AND WATER ABSORPTION FOR FINE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:	Zirobwe Quarry	Sampling Date:	2023-12-27
Material Source:	Kasangati Asphalt Plant	Tested Date:	2024-01-05
Sample description	(0-6mm) Hot Bins	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of saturated surface-dry aggregate in air	A	g	415.1	447.0	
Mass of Pycnometer + sample + water	B	g	2039.7	2053.9	
Mass of Pycnometer filled with water only	C	g	1777.5	1771.6	
Mass of oven-dry aggregate in air	D	g	410.3	441.7	
Particle density on an oven-dry basis	$P_d = \frac{D}{A-(B-C)}$	Mg/m^3	2.683	2.682	2.683
Particle density on a saturated and surface-dry basis	$P_s = \frac{A}{A-(B-C)}$	Mg/m^3	2.715	2.714	2.714
Apparent Particle density	$P_a = \frac{D}{D-(B-C)}$	Mg/m^3	2.770	2.771	**2.771**
Water Absorption	$W_{abs} = 100x\left(\frac{A-D}{D}\right)$	%	1.2	1.2	**1.2**

Remark:

Representative(CSCEC)

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	05/01/2024	Date:	06/01/2024

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RELATIVE DENSITY AND WATER ABSORPTION FOR FINE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:	Zirobwe Quarry	Sampling Date:	2023-12-27
Material Source:	Kasangati Asphalt Plant	Tested Date:	2024-01-05
Sample description	(6-10mm) Hot Bins	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of saturated surface-dry aggregate in air	A	g	787.4	789.2	
Mass of Pycnometer + sample + water	B	g	2040.6	2042.1	
Mass of Pycnometer filled with water only	C	g	1547.6	1547.6	
Mass of oven-dry aggregate in air	D	g	783.5	785.6	
Particle density on an oven-dry basis	$P_d = \frac{D}{A-(B-C)}$	Mg/m^3	2.661	2.666	2.664
Particle density on a saturated and surface-dry basis	$P_s = \frac{A}{A-(B-C)}$	Mg/m^3	2.675	2.678	2.676
Apparent Particle density	$P_a = \frac{D}{D-(B-C)}$	Mg/m^3	2.697	2.699	**2.698**
Water Absorption	$W_{abs} = 100x\left(\frac{A-D}{D}\right)$	%	0.5	0.5	**0.5**

Remark:

Representative(CSCEC)

Materials Technician	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 05/01/2023	Date: 06/01/2024

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RELATIVE DENSITY AND WATER ABSORPTION FOR COARSE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:	Zirobwe Quarry	Sampling Date:	2023-12-27
Material Source:	Kasangati Asphalt Plant	Tested Date:	2024-01-05
Sample description	(10-14mm) Hot Bins	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of Saturated Surface-dry aggregates in air	A	g	2482.1	2510.3	
Mass of basket + Sample in Water	B	g	1795.0	1812.5	
Mass of basket in Water	C	g	238.3	238.3	
Mass of Oven-dryaggregates	D	g	2473.8	2501.0	
Particle density on an oven-dry basis	$P_d = \frac{D}{A-(B-C)}$	Mg/m³	2.673	2.672	2.672
Particle density on a saturated and surface-dry basis	$P_s = \frac{A}{A-(B-C)}$	Mg/m³	2.682	2.682	2.682
Apparent Particle density	$P_a = \frac{D}{D-(B-C)}$	Mg/m³	2.697	2.699	**2.698**
Water Absorption	$W_{abs} = 100x\left(\frac{A-D}{D}\right)$	%	0.3	0.4	**0.4**

Remark:

Representative(CSCEC)

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	05/01/2024	Date:	06/01/2024

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RELATIVE DENSITY AND WATER ABSORPTION FOR COARSE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:	Zirobwe Quarry	Sampling Date:	2023-12-27
Material Source:	Kasangati Asphalt Plant	Tested Date:	2024-01-05
Sample description	(14-20mm) Hot Bins	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of Saturated Surface-dry aggregates in air	A	g	2783.5	2858.9	
Mass of basket + Sample in Water	B	g	1986.0	2031.8	
Mass of basket in Water	C	g	238.3	238.3	
Mass of Oven-dryaggregates	D	g	2775.3	2850.7	
Particle density on an oven-dry basis	$P_d = \frac{D}{A-(B-C)}$	Mg/m^3	2.679	2.676	2.678
Particle density on a saturated and surface-dry basis	$P_s = \frac{A}{A-(B-C)}$	Mg/m^3	2.687	2.683	2.685
Apparent Particle density	$P_a = \frac{D}{D-(B-C)}$	Mg/m^3	2.701	2.696	**2.699**
Water Absorption	$W_{abs} = 100x\left(\frac{A-D}{D}\right)$	%	0.3	0.3	**0.3**

Remark:

Representative(CSCEC)

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[signature]
Date:	05/01/2024	Date:	06/01/2024

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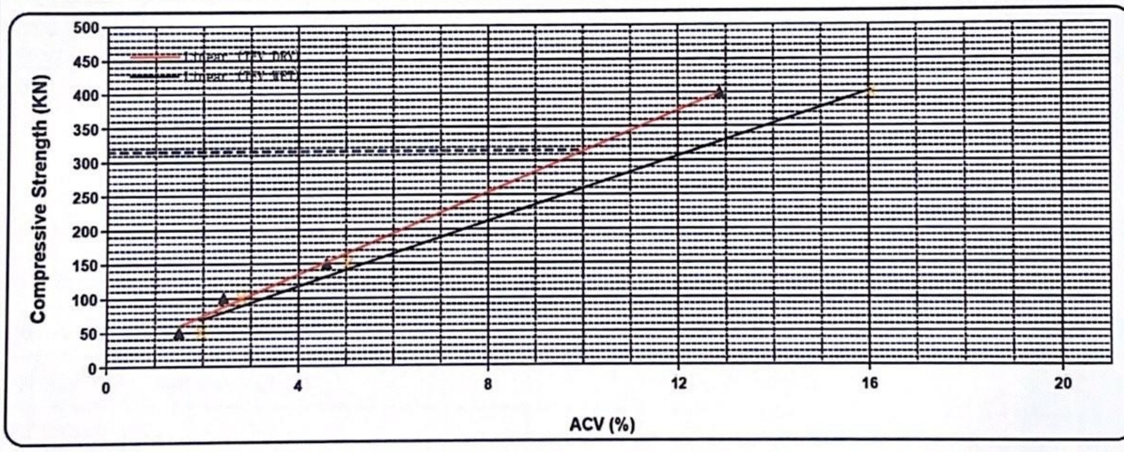
SAMPLE STATION	N/A	SAMPLE NO.	N/A
MATERIAL TYPE	ASPHALT AGG	DATE SAMPLED	27-Dec-23
MATERIAL SOURCE	NAMAWOJJA ZIROBWE QUARRY	DATE TESTED	8-Jan-24
MATERIAL DESRIPTION	(10-14)mm	SAMPLED BY	Lab Team

DETERMINATION OF TEN PERCENT FINES VALUE

BS 812 Part 111 : 1990

Sample Number	Method	Compressive Strength (KN)	Load (min)	Weight of total specimen (W1 g)	Weight of fine Passing 2.36 mm (W2 g)	Aggregate Crushing Value (W2/W1*100%)	Remark
A-1	Dry condition		50	2418.3	36.4	1.51	
A-2			100	2416.0	58.7	2.43	
A-3			150	2413.9	110.9	4.59	
A-4			400	2410.8	310.4	12.88	
B-1	Soaked condition		50	2459.8	48	1.95	
B-2			100	2474	69	2.79	
B-3			150	2483.9	125.0	5.03	
B-4			400	2479.9	398.1	16.05	



Compressive Strength for 10% Fines values in Dry condition (TFV Dry):	315 KN
Compressive Strength for 10% Fines values in Soaked condition (TFV Wet):	262 KN
TFV Ratio Wet / Dry Test (%)	83 %
ACV (%)	13

Tested By: (Lab Technician)	Approve by: (Materials Engineer)
Sign: Hmza .	Sign:
Date 8/01/2024	Date 09/01/2024

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LOS ANGELES ABRASION VALUE (LAAV)

TEST METHOD ASTM C131-2001

Location:	Zirobwe	Tested Date:	8 Jan 2024
Sampling Date:	27 Dec 2023	Material Source:	Namawojja quarry
Tested By:	Lab Team	Sample description	Asphalt Agg

Sieve Size		Mass of indicated sizes (g)			
Passing	Retained on	Grading to be used			
		A	B	C	D
37.5mm	25.0mm	1250±10			
25.0mm	19.0mm	1250±10			
19.0mm	12.5mm	1250±10	2500±10		
12.5mm	9.5mm	1250±10	2500±10		
9.5mm	6.3mm			2500±10	
6.3mm	4.75mm			2500±10	
4.75mm	2.36 mm				5000±10
Total		5000±10	5000±10	5000±10	5000±10

Sample Description	Asphalt Agg(6-10)mm				
Grading Used	Grading C				
Specimen reference		1	2	3	Average
Mass of tray + test specimen (g)		5266.9	5269.1		
Mass of tray alone (g)		257.1	257.1		
Mass of original test specimen (g)	M_1	5009.8	5012.0		
Mass of material retained on 1.7mm sieve (g)	M_2	4032.5	4023.5		
Mass of material passing 1.7mm sieve (g)	M_1-M_2	977.3	988.5		
LAA Value (%)	$\frac{M_1 - M_2}{M_1} x100$	19.5	19.7		**19.6**

Remark:
Grading C was used aggregates (6-10 mm)

Lab Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 8/01/2024	Date: 09/01/2024

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ABSTRACT OF MARSHALL MIX DESIGN TEST VALUES

Bitumen Content%	Density (g/cm³)	Air Voids% (va)	Stability (kN)	Flow (mm)	VMA(%)	VFB(%)
3.5	2.310	7.26	14.40	1.77	14.17	48.45
4.0	2.324	6.35	14.53	2.05	14.07	54.43
4.5	2.329	5.07	16.07	2.66	14.34	64.28
5.0	2.339	4.50	15.87	3.10	14.42	68.21
5.5	2.346	4.10	15.47	4.09	14.63	71.12
Spec.Limits	**N/A**	**3 - 6%**	**8-18 KN**	**2-4mm**	**>14%**	**65-78%**

Calculations

Sp, gravity of Total Agg(Gsb)

Hotbin Proportins:	Filler	0/6	6/10	10/14	14/20		
	4.5	71.0	13.5	5.0	6.0	=	2.697
	3.077	2.683	2.664	2.672	2.678		

Trends and Relations of the Test data

The test property curves plotted as described above have been found to follow as reasonably consistent pattern for Bitumen mix. Trends generally noted are outlined below.

a. The stability value increases with increasing BT content up to a maximum after which the stability decreases.

b. The flow value increases with increasing BT content

c. The Density value increases with increasing BT content up to a maximum after which the density decreases.

d. The % of Air voids decreasing with increasing BT content.

Hamza

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22 FEB 2024
(CSCEC)

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ANALYSIS OF TEST RESULTS

BITUMEN(%)	3.5	4.0	4.5	5.0	5.5
DENSITY	2.310	2.324	2.329	2.339	2.346
BITUMEN(%)	3.5	4.0	4.5	5.0	5.5
AIR VOIDS(%)	7.26	6.35	5.07	4.50	4.10
BITUMEN(%)	3.5	4.0	4.5	5.0	5.5
STABILITY(KN)	14.40	14.53	16.07	15.87	15.47
BITUMEN(%)	3.5	4.0	4.5	5.0	5.5
FLOW(mm)	1.77	2.05	2.66	3.10	4.09
BITUMEN(%)	3.5	4.0	4.5	5.0	5.5
VMA(%)	14.17	14.07	14.34	14.42	14.63
BITUMEN(%)	3.5	4.0	4.5	5.0	5.5
VFB(%)	48.45	54.43	64.28	68.21	71.12

Hamza

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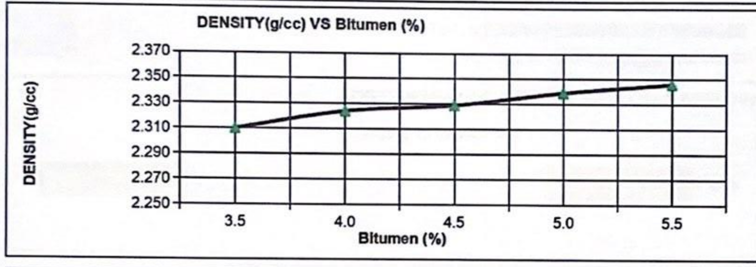
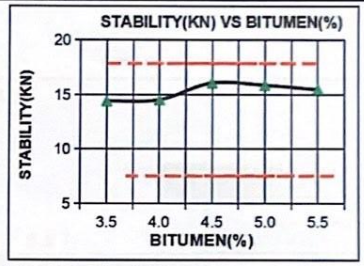
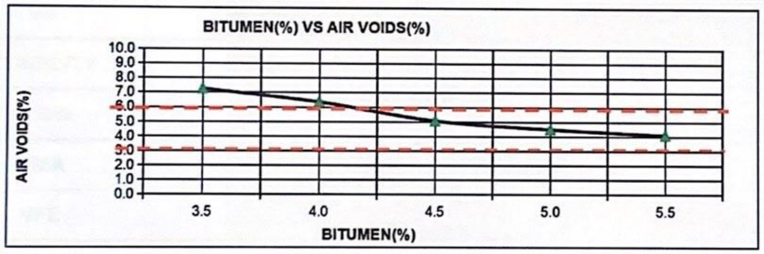
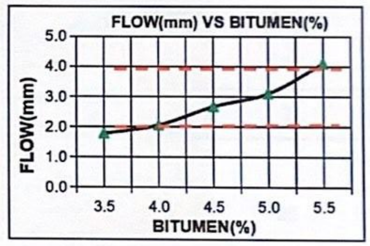
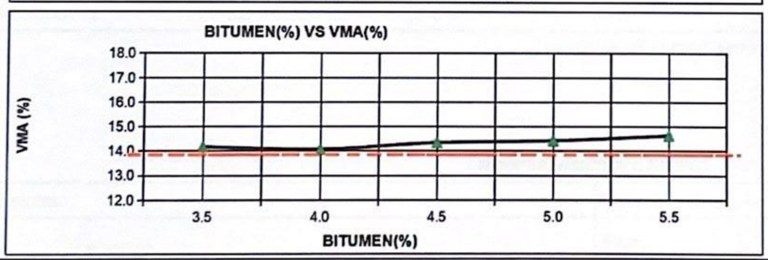
MARSHALL PROPERTIES CURVES

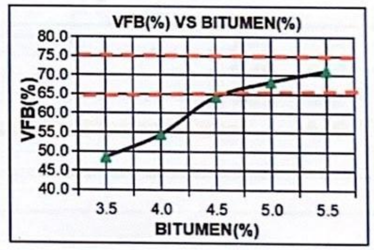












Representative(CSCEC)

Laboratory Technician			Materials Engineer	
Sign:	Hmmza		Sign	[signature]
Date:	15/02/2024		Date	16/02/2024

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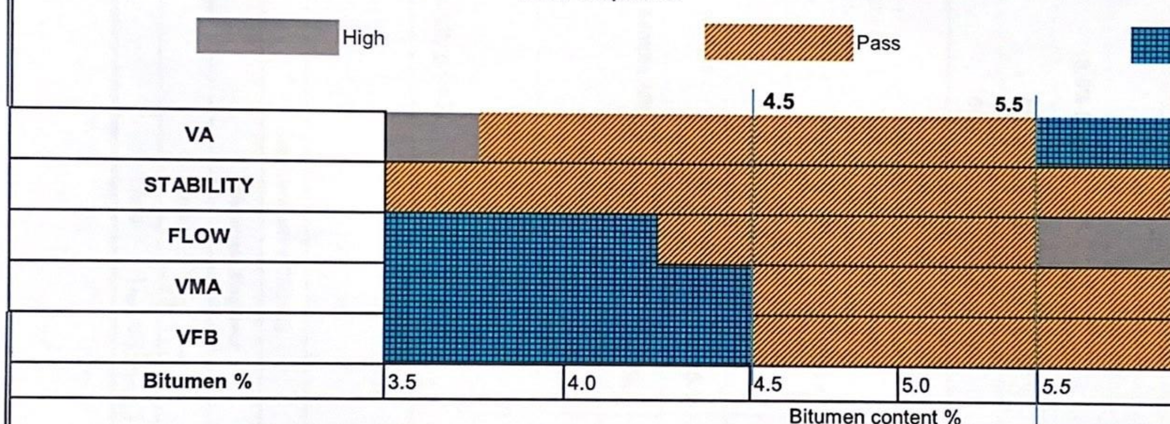
DETERMINING OBC BASED ON NARROW RANGE

MS-2 chapter 05



	Min	Max
VA	3.0	6.0
STABILITY	8	18
FLOW	2	4
VMA	>14	
VFB	65	78

Min 4.50
Max 5.50
Av. 5.00

As Optimum Bitumen Content **5.00**

Representative(CSCEC)

Laboratory Technician		Materials Engineer	
Sign:	Hmza	Sign:	[signature]
Date:	15/02/2024	Date:	16/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	3.5% Bitumen	Date of sampling	
Type of Mix:	AC14	Date of testing	8-Feb-2024
Grade of Bitumen:	60/70	Technician	Lab Team

Temperature(℃)						
Test no.				1	2	
Weight of Mixed Material sample	g	A		1235.4	1258.7	
Weight of pyconometer and water	g	B		9840.1	9878.5	
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11075.5	11137.2	
Weight of pyconometer +water + sample After De-Airing	g	D		10579.1	10632.1	
Volume of Mix	g	E	C-D	496.4	505.1	
Gmm	g	F	A/E	2.489	2.492	
Average Density(g/cm3)				2.491		

Remarks

Representative(CSCEC)

Technician	***Marerials Engineer***
Sign: Hamza	***Sign:*** [signature]
Date: 15/02/2024	***Date:*** 16/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	LAB TRIAL MIX AT 3.5% BITUMEN		
Source:	LAB TRIAL MIX	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	08-Feb
Sample Ref.:	3.5% bitumen	Technician	Lab Team

Sl. No.	Description			Test Numbers 1	2	3	Average
1	Bulk Specific gravity of Total aggregate	Gsb			2.597		
2	Effective Specific gravity of Total Aggregate	Gse			2.628		
3	Specific Gravity of Bitumen	Gb			1.018		
4	Bitumen % by wt. Of Total Mix	Pb			3.50		
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb		96.5		
6	Maximum Specific Gravity of Mix	Gmm			2.491		
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb (Gse*Gsb)}		0.47		
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)		3.03		
9	Wt. Of specimen in air	Wa		1187.0	1192.0	1194.1	1191.0
10	Wt. Of specimen in water	Ww		673.6	675.7	676.7	675.3
11	Wt. Of specimen in air(SSD)	Wssd		1187.0	1192.0	1194.1	1191.0
12	Volume of specimen	V	Wssd-Ww	513.4	516.3	517.4	515.7
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.312	2.309	2.308	**2.310**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	6.87	6.86	6.86	**6.86**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	85.92	85.81	85.77	**85.83**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*1	7.17	7.29	7.33	**7.26**
17	%voids in Mineral Aggregate	VMA	100-Vagg	14.08	14.19	14.23	**14.17**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	48.79	48.34	48.21	**48.45**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			13.60	14.00	15.60	**14.40**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			13.60	14.00	15.60	**14.40**
23	Flow(mm)			1.75	1.80	1.77	**1.77**

Remarks:

Representative(CSCEC)

Laboratory Technician(CSCEC)	Materials Engineer
Sign: Amza	Sign: [signature]
Date: 08/02/2024	Date: 09/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	4.0% Bitumen	Date of sampling	
Type of Mix:	AC14	Date of testing	8-Feb-2024
Grade of Bitumen:	60/70	Technician	Lab Team

Temperature(℃)					
Test no.				1	2
Weight of Mixed Material sample	g	A		1226.1	1238.2
Weight of pyconometer and water	g	B		9840.1	9878.5
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11066.2	11116.7
Weight of pyconometer +water + sample After De-Airing	g	D		10572.1	10618.1
Volume of Mix	g	E	C-D	494.1	498.6
Gmm	g	F	A/E	2.481	2.483
Average Density(g/cm3)				2.482	

Remarks

Representative(CSCEC)

Technician	***Materials Engineer***
Sign: [signature]	***Sign:*** [signature]
Date: 08/02/2024	***Date:*** 09/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	LAB TRIAL MIX AT 4.0% BITUMEN		
Source:	LAB TRIAL MIX	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	08-Feb
Sample Ref.:	4.0% bitumen	Technician	Lab Team

Sl. No.	Description			Test Numbers 1	2	3	Average
1	Bulk Specific gravity of Total aggregate	Gsb			2.597		
2	Effective Specific gravity of Total Aggregate	Gse			2.640		
3	Specific Gravity of Bitumen	Gb			1.018		
4	Bitumen % by wt. Of Total Mix	Pb			4.00		
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb		96.0		
6	Maximum Specific Gravity of Mix	Gmm			2.482		
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb (Gse*Gsb)}		0.65		
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)		3.35		
9	Wt. Of specimen in air	Wa		1189.5	1190.3	1194.5	1191.4
10	Wt. Of specimen in water	Ww		680.6	680.3	682.7	681.2
11	Wt. Of specimen in air(SSD)	Wssd		1191.6	1192.6	1197.2	1193.8
12	Volume of specimen	V	Wssd-Ww	511.0	512.3	514.5	512.6
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.328	2.323	2.322	**2.324**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	7.67	7.65	7.65	**7.66**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	86.07	85.88	85.85	**85.93**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*1	6.20	6.41	6.45	**6.35**
17	%voids in Mineral Aggregate	VMA	100-Vagg	13.93	14.12	14.15	**14.07**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	55.06	54.18	54.06	**54.43**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			14.40	14.60	14.60	**14.53**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			14.40	14.60	14.60	**14.53**
23	Flow(mm)			2.10	2.05	2.01	**2.05**

Remarks:

Representative(CSCEC)

Laboratory Technician(CSCEC)	Materials Engineer
Sign: Amza.	Sign: [signature]
Date: 08/02/2024	Date: 09/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	4.5% Bitumen	Date of sampling	
Type of Mix:	AC14	Date of testing	9-Feb-2024
Grade of Bitumen:	60/70	Technician	Lab Team

Temperature(℃)						
Test no.				1	2	
Weight of Mixed Material sample	g	A		1229	1228	
Weight of pyconometer and water	g	B		9840.1	9878.5	
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11069.1	11106.5	
Weight of pyconometer +water + sample After De-Airing	g	D		10568.2	10605.8	
Volume of Mix	g	E	C-D	500.9	500.7	
Gmm	g	F	A/E	2.454	2.453	
Average Density(g/cm3)					2.454	

Remarks

Representative(CSCEC)

Technician	***Materials Engineer***
Sign: Amza.	***Sign:*** [signature]
Date: 9/02/2024	***Date:*** 10/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	LAB TRIAL MIX AT 4.5% BITUMEN		
Source:	LAB TRIAL MIX	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	09-Feb
Sample Ref.:	4.5% bitumen	Technician	Lab Team

Sl. No.	Description			Test Numbers			Average
				1	3	4	
1	Bulk Specific gravity of Total aggregate	Gsb		2.597			
2	Effective Specific gravity of Total Aggregate	Gse		2.628			
3	Specific Gravity of Bitumen	Gb		1.018			
4	Bitumen % by wt. Of Total Mix	Pb		4.50			
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb	95.5			
6	Maximum Specific Gravity of Mix	Gmm		2.454			
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb (Gse*Gsb)}	0.47			
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)	4.03			
9	Wt. Of specimen in air	Wa		1198.6	1193.6	1195.1	1195.8
10	Wt. Of specimen in water	Ww		685.8	683.4	683.9	684.4
11	Wt. Of specimen in air(SSD)	Wssd		1200.5	1195.6	1197.2	1197.8
12	Volume of specimen	V	Wssd-Ww	514.7	512.2	513.3	513.4
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.329	2.330	2.328	**2.329**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	9.22	9.22	9.22	**9.22**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	85.66	85.69	85.62	**85.66**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*1	5.07	5.03	5.12	**5.07**
17	%voids in Mineral Aggregate	VMA	100-Vagg	14.34	14.31	14.38	**14.34**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	64.30	64.43	64.12	**64.28**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			16.60	15.30	16.30	**16.07**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			16.60	15.30	16.30	**16.07**
23	Flow(mm)			2.54	2.87	2.58	**2.66**

Remarks:

Representative(CSCEC)

Laboratory Technician(CSCEC)	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 9/02/2024	Date: 10/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	5.0% Bitumen	Date of sampling	
Type of Mix:	AC14	Date of testing	9-Feb-2024
Grade of Bitumen:	60/70	Technician	Lab Team

Temperature(℃)						
Test no.				1	2	
Weight of Mixed Material sample	g	A		1277.8	1203.5	
Weight of pyconometer and water	g	B		9840.1	9878.5	
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11117.9	11082	
Weight of pyconometer +water + sample After De-Airing	g	D		10596.8	10590.2	
Volume of Mix	g	E	C-D	521.1	491.8	
Gmm	g	F	A/E	2.452	2.447	
Average Density(g/cm3)					2.450	

Remarks

Representative(CSCEC)

Technician	***Materials Engineer***
Sign: [signature]	***Sign:*** [signature]
Date: 9/02/2024	***Date:*** 10/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	**LAB TRIAL MIX AT 4.5% BITUMEN**		
Source:	LAB TRIAL MIX	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	09-Feb
Sample Ref.:	5.0% bitumen	Technician	Lab Team

Sl. No.	Description			Test Numbers 1	3	4	Average
1	Bulk Specific gravity of Total aggregate	Gsb		2.597			
2	Effective Specific gravity of Total Aggregate	Gse		2.645			
3	Specific Gravity of Bitumen	Gb		1.018			
4	Bitumen % by wt. Of Total Mix	Pb		5.00			
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb	95.0			
6	Maximum Specific Gravity of Mix	Gmm		2.450			
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb (Gse*Gsb)}	0.72			
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)	4.28			
9	Wt. Of specimen in air	Wa		1194.4	1193.0	1191.5	1193.0
10	Wt. Of specimen in water	Ww		685.0	684.1	683.5	684.2
11	Wt. Of specimen in air(SSD)	Wssd		1195.5	1194.1	1192.8	1194.1
12	Volume of specimen	V	Wssd-Ww	510.5	510.0	509.3	509.9
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.340	2.339	2.339	**2.339**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	9.84	9.83	9.83	**9.83**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	85.61	85.57	85.57	**85.58**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*1	4.47	4.51	4.51	**4.50**
17	%voids in Mineral Aggregate	VMA	100-Vagg	14.39	14.43	14.43	**14.42**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	68.38	68.12	68.12	**68.21**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			14.20	16.30	17.10	**15.87**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			14.20	16.30	17.10	**15.87**
23	Flow(mm)			3.37	2.96	2.96	**3.10**

Remarks:

Representative(CSCEC)

Laboratory Technician	Materials Engineer
Sign: Amza	Sign: [signature]
Date: 9/02/2024	Date: 10/02/2024

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MAXIMAM SPECIFIC GRAVITY (DENSITY) ASTM D2041-95

Chainage /Location:			
Sample ref:	4.0% Bitumen	Date of sampling	
Type of Mix:	AC14	Date of testing	10-Feb-2024
Grade of Bitumen:	60/70	Technician	Lab Team

Temperature(℃)						
Test no.				1	2	
Weight of Mixed Material sample	g	A		1229.8	1230.1	
Weight of pyconometer and water	g	B		9840.1	9878.5	
Weight of pyconometer +water + sample Before De-Airing	g	C	A+B	11069.9	11108.6	
Weight of pyconometer +water + sample After De-Airing	g	D		10566.9	10606	
Volume of Mix	g	E	C-D	503	502.6	
Gmm	g	F	A/E	2.445	2.447	
Average Density(g/cm3)					2.446	

Remarks

Representative(CSCEC)

Technician	***Materials Engineer***
Sign: Amza.	***Sign:*** [signature]
Date: 10/02/2024	***Date:*** 11/02/2024

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MARSHALL STABILITY ANALYSIS OF BITUMINOUS MIX ASTM D1559. AASHTO T245

Chainage/Location:	LAB TRIAL MIX AT 4.5% BITUMEN		
Source:	LAB TRIAL MIX	Grade of Bitumen:	60/70
Type of Mix:	AC14	No. of Blows:	75x2
Mix Temp.:	150	Date of sampling	
Proving Ring Factor:	/	Date of testing	10-Feb
Sample Ref.:	5.5% bitumen	Technician	Lab Team

Sl. No.	Description			Test Numbers			Average
				1	3	4	
1	Bulk Specific gravity of Total aggregate	Gsb		2.597			
2	Effective Specific gravity of Total Aggregate	Gse		2.663			
3	Specific Gravity of Bitumen	Gb		1.018			
4	Bitumen % by wt. Of Total Mix	Pb		5.50			
5	Aggregate % by wt. Of Total mix.	Ps	100-Pb	94.5			
6	Maximum Specific Gravity of Mix	Gmm		2.446			
7	Absorbed Bitumen % by wt. Of Total Aggregate	Pba	100x{(Gse-Gsb)*Gb / (Gse*Gsb)}	0.98			
8	Effective Bitumen % by wt. Of Total Mix	Pbe	Pb-(Pba*Ps/100)	4.52			
9	Wt. Of specimen in air	Wa		1188.3	1189.4	1190.8	1189.5
10	Wt. Of specimen in water	Ww		682.9	682.1	683.1	682.7
11	Wt. Of specimen in air(SSD)	Wssd		1188.7	1189.4	1191.3	1189.8
12	Volume of specimen	V	Wssd-Ww	505.8	507.3	508.2	507.1
13	Bulk Specific gravity of Compacted Specimen	Gmb	Wa/V	2.349	2.345	2.343	**2.346**
14	Effective Volume of Bitumen	Vb	Gmb*Pbe/Gb	10.42	10.40	10.40	**10.41**
15	Effective Volume of Aggregate	Vagg	Ps*Gmb/Gsb	85.49	85.34	85.27	**85.37**
16	% of air voids from Gmm.	Vv	{(Gmm-Gmb)/Gmm}*100	3.97	4.13	4.21	**4.10**
17	%voids in Mineral Aggregate	VMA	100-Vagg	14.51	14.66	14.73	**14.63**
18	%voids filled with Bitumen	VFB	100*(Vma-Vv)/Vma	71.81	70.94	70.60	**71.12**
19	Marshall Stability(PR Reading)			/	/	/	**/**
20	Marshall Stability(KN)			15.80	15.40	15.20	**15.47**
21	Correction Factor			1.00	1.00	1.00	**1.00**
22	Corrected Marshall Stability(KN)			15.80	15.40	15.20	**15.47**
23	Flow(mm)			4.08	4.09	4.10	**4.09**

Remarks:

Representative(CSCEC)

Laboratory Technician	Materials Engineer
Sign: Hamza .	Sign: [signature]
Date: 10/02/2024	Date: 11/02/2024

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SPECIFIC GRAVITY FOR FINE AGGREGATES (FILLER<0.075)

TEST METHOD ASTM - D854

Location:	/	Sampling Date:	2024-01-13
Material Source:	/	Tested Date:	2024-01-15
Sample description	Kasangati Asphalt Plant	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of Pycnometer filled with Water only	A	g	314.6	316.7	
Mass of Pycnometer filled with kerosene only	B	g	263.8	264.4	
Density of Kerosene	C=A/B	Cm3	0.839	0.835	
Mass of Oven-dry sample in air	D	g	122.2	119.7	
Mass of Pycnometer + sample +kerosene	E	g	352.4	351.9	
Mass of sample in kerosene	F=B-E	g	88.6	87.5	
Volume of sample	G=D-E	cm3	33.6	32.2	
Bulk specific Gravity of Filler, Gsb	Gsb=(A/E)*C	Mg/m^3	3.050	3.103	3.077

Remark:

Representative(CSCEC)

Materials Technician	Materials Engineer
Sign: Ahmza.	Sign: [signature]
Date: 15/01/2024	Date: 16/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD

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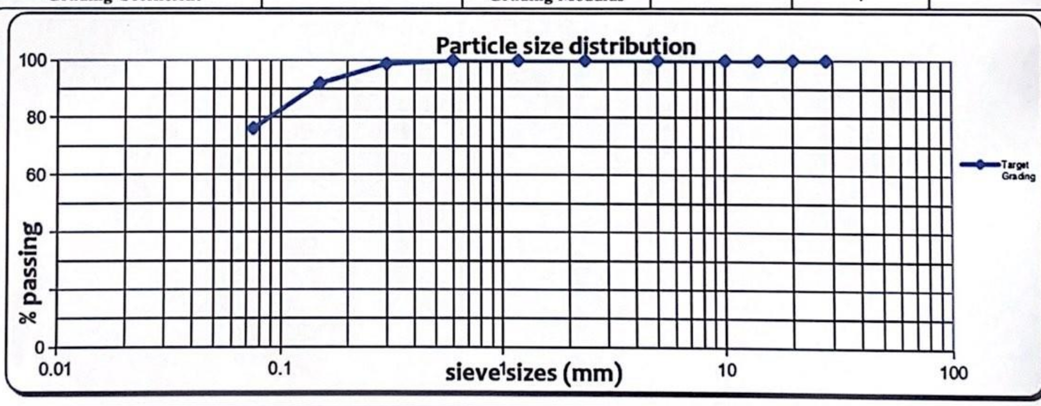
Email: csceciiangbo@gmail.com

AC 14 Aggregates particle size Distribution (BS 812-103,1:1985)

Sample Ref:	N/A	Sampling Date	13 Jan 2024
Location: (km)	/	Testing Date	15 Jan 2024
Material source	Kasangati Asphalt Plant	Technician	Group
Sample Description	AC-14 (Filler)		
Mass of dry Sample (gm)	200.7		
Mass of dry Sample after washing	66		

Diameter(mm)	Partial Retained Mass(g)	Cumulative Retained Mass(g)	Cumulative Retained(%)	% Passing	
28	0.0	0.0	0.0	100.0	
20	0.0	0.0	0.0	100.0	
14	0.0	0.0	0.0	100.0	
10	0.0	0.0	0.0	100.0	
5	0.0	0.0	0.0	100.0	
2.36	0.0	0.0	0.0	100.0	
1.18	0.0	0.0	0.0	100.0	
0.6	0.0	0.0	0.0	100.0	
0.3	2.4	2.4	1.2	98.8	
0.15	13.8	16.2	8.1	91.9	
0.075	31.7	47.9	23.9	76.1	
Pan	18.1	66.0			
Grading Coefficient		**Grading Modulus**		.	



Remarks:

Materials Technician		Materials Engineer	
Sign:	Hamza .	Sign:	[signature]
Date:	15/01/2024	Date:	16/01/2024

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Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*60/70(8% PET)*	*Supplier/ Origin:*	*SB Company*
Testing date:	*20-Jan-24*	*Sample Date:*	*5-Jan-24*

Bath Fluid:	*Water*	☑	*Glycerin*	☐

Time (minutes)	Temp. (^{0}C)	Temp. rise (^{0}C)
0	3.4	
1	8.1	4.7
2	14	5.9
3	18.8	4.8
4	23.9	5.1
5	29.0	5.1
6	34.2	5.2
7	39.0	4.8
8	44.2	5.2
9	49.2	5.0
10	54.3	5.1
11	59.1	4.8
12	64.0	4.9

Time (minutes)	Temp. (^{0}C)	Temp. rise (^{0}C)
12	68.9	
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1	Ring 2	Average
Temperature when the ball touches the bottom (^{0}C)	75.6	75.9	75.8

Laboratory Technician	Materials Engineer
Signature: [signature]	Signature: [signature]
Date: 20/01/24	Date: 20/01/2024

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Density of Bituminous Binders

Ref: ASTM D70

Bitumen type	*50/70(8% PET)*	*Supplier/ Origin*	*SB Company*
Testing date	*20-Jan-24*	*Sample Date:*	*18-Jan-24*

		Test1	Test 2	Mean
Pycnometer No.		A	B	
Mass of dry Pycnometer, g	A	56.60	52.30	
Mass of Pycnometer + filled with water	B	178.20	181.10	
Mass of Pycnometer Partially filled with sample	C	122.4	128.4	
Mass of Pycnometer Plus Sample Plus Water	D	178.8	181.9	
Relative Density=	C-A/(B-A)-(D-C)	1.009	1.010	1.010

Materials Technician	Materials Engineer
Sign: Hamza.	Sign: [signature]
Date: 20/01/24	Date: 21/01/2024

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DETERMINATION OF DUCTILITY (AASHTO T051-94)

Sample Ref:	N/A	Bitumen Grade:	60/70(8% PET)
Source:	SB Company	Sampling date:	18-Jan-24
Location:	N/A	Testing date:	20-Jan-24
Test Temperature:	25º C	Tested by:	Lab Team

Pouring Temperature, º C	:	140	
In Air	:	30	{Spec: 30-40min }
In water bath before Trimming	:	30	{Spec: 30min }
In water bath after Trimming	:	90	{Spec: 90 ± 5min }
Rate of Pull	:	50	{Spec : 50 ± 2.5/mm/min}

Test Property	Briquette Number			mean value
Ductility value(cm)	1	2	3	Specification (ASTM D113) >100
	98.5	99.1	98.7	99

Materials Technician	Materials Engineer
Sign: Amza.	Sign: [signature]
Date: 20/01/24	Date: 21/01/2024

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Summary of Bitumen Test Results

Bitumen type:	*60/70(4% PET)*	*Supplier/ Origin: SB Company*	
Testing date:	*19-Jan-24*	*Sample Date:*	*18-Jan-24*

Penetration value	57.6	ASTM D 5
Softening(Ring & Ball)	68.3	ASTM D36/ AASHTO T 053
Density (g/cm3)	1.014	ASTM D70
Ductility(cm)	107	AASHTO T051-94

Lab Technician	Materials Engineer
Signature: Hamza.	Signature: [signature]
Date: 19/01/24	Date: 20/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
P.O.Box 29285 Kampala
20 JAN 2024
(CSCEC)

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Penetration Test for Bitumen

Testing Method ASTM D 5

Bitumen type:	*60/70*	*Supplier/ Origin: SB Company*		
Testing date:	*19-Jan-24*	*Sample Date:*	*18-Jan-24*	
Measurement no.	1	2	3	Remarks
Penetrometer dial reading				
Initial reading	0.12	0.09	0.11	
Final reading	5.89	5.81	5.89	
Penetration value	57.7	57.2	57.8	
Average penetration value		57.6		

Laboratory Technician	Materials Engineer
Signature: Hamza	Signature: [signature]
Date: 19/01/24	Date: 20/01/2024

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Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*60/70(4% PET)*	*Supplier/ Origin:*	*SB Company*
Testing date:	*19-Jan-24*	*Sample Date:*	*5-Jan-24*

Bath Fluid: *Water* ■ *Glycerin* □

Time (minutes)	Temp. (°C)	Temp. rise (°C)
0	4.9	
1	8.1	3.2
2	14.5	6.4
3	17.6	3.1
4	23.4	5.8
5	28.9	5.5
6	33.4	4.5
7	38.1	4.7
8	43.2	5.1
9	48.3	5.1
10	53.1	4.8
11	57.9	4.8
12	62.1	4.2

Time (minutes)	Temp. (°C)	Temp. rise (°C)
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

** temp rise is 5 ± 0.5 °C per minute*

Sample No.	Ring 1	Ring 2	Average
Temperature when the ball touches the bottom (°C)	68.2	68.4	68.3

Laboratory Technician	Materials Engineer
Signature	Signature
Date: 19/01/24	Date: 20/01/2024

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Email: cscecjiangbo@gmail.com

Density of Bituminous Binders

Ref: ASTM D70

Bitumen type	*50/70(4% PET)*	*Supplier/ Origin*	*SB Company*
Testing date	*19-Jan-24*	*Sample Date:*	*18-Jan-24*

		Test1	Test 2	Mean
Pycnometer No.		**A**	**B**	
Mass of dry Pycnometer, g	A	56.60	52.29	
Mass of Pycnometer + filled with water	B	178.20	181.10	
Mass of Pycnometer Partially filled with sample	C	131.4	132.4	
Mass of Pycnometer Plus Sample Plus Water	D	179.3	182.2	
Relative Density=	C-A/(B-A)-(D-C)	1.015	1.014	1.014

Materials Technician	Materials Engineer
Sign: [signature]	Sign: [signature]
Date: 19/01/2024	Date: 20/01/2024

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Email: cscecjiangbo@gmail.com

DETERMINATION OF DUCTILITY (AASHTO T051-94)

Sample Ref:	N/A	Bitumen Grade:	60/70(4% PET)
Source:	SB Company	Sampling date:	18-Jan-24
Location:	N/A	Testing date:	19-Jan-24
Test Temperature:	25º C	Tested by:	Lab Team

Pouring Temperature, º C : 140

In Air : 30 {Spec: 30-40min }

In water bath before Trimming : 30 {Spec: 30min }

In water bath after Trimming : 90 {Spec: 90 ± 5min }

Rate of Pull : 50 {Spec : 50 ± 2.5/mm/min}

Test Property	Briquette Number			mean value
Ductility value(cm)	1	2	3	Specification (ASTM D113) >100
	107.1	108.2	107	107

Materials Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 19/01/2024	Date: 20/01/2024

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DETERMINATION OF DUCTILITY (AASHTO T051-94)

Sample Ref:	N/A	Bitumen Grade:	60/70(4% PET)
Source:	SB Company	Sampling date:	18-Jan-24
Location:	N/A	Testing date:	19-Jan-24
Test Temperature:	25º C	Tested by:	Lab Team

Pouring Temperature, º C	:	140	
In Air	:	30	{Spec: 30-40min }
In water bath before Trimming	:	30	{Spec: 30min }
In water bath after Trimming	:	90	{Spec: 90 ± 5min }
Rate of Pull	:	50	{Spec : 50 ± 2.5/mm/min}

Test Property	Briquette Number			mean value
Ductility value(cm)	1	2	3	Specification (ASTM D113) >100
	107.1	108.2	107	107

Materials Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 19/01/2024	Date: 20/01/2024

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Email: cscecjiangbo@gmail.com

Summary of Bitumen Test Results

Bitumen type:	*60/70(6% PET)*	*Supplier/ Origin: SB Company*	
Testing date:	*20-Jan-24*	*Sample Date:*	*18-Jan-24*

Penetration value	55.9	ASTM D 5
Softening(Ring & Ball)	71.4	ASTM D36/ AASHTO T 053
Density (g/cm3)	1.012	ASTM D70
Ductility(cm)	104	AASHTO T051-94

Lab Technician	Materials Engineer
Signature: Hmzer	**Signature:** [signature]
Date: 20/1/24	**Date:** 21/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
P.O.Box 29285 Kampala
21 JAN 2024
(CSCEC)

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Penetration Test for Bitumen

Testing Method ASTM D 5

Bitumen type:	*60/70*	*Supplier/ Origin: SB Company*	
Testing date:	*20-Jan-24*	*Sample Date:*	*18-Jan-24*

Measurement no.	1	2	3	Remarks
Penetrometer dial reading				
Initial reading	0.09	0.08	0.13	
Final reading	5.69	5.60	5.79	
Penetration value	56.0	55.2	56.6	
Average penetration value		55.9		

Laboratory Technician	Materials Engineer
Signature: Hamza.	Signature: [signature]
Date: 20/01/24	Date: 21/01/2024

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Email: cscecjiangbo@gmail.com

Softening Test for Bitumen (Ring & Ball)

ASTM D36/ AASHTO T 053

Bitumen type:	*60/70(6% PET)*	*Supplier/ Origin:*	*SB Company*
Testing date:	*20-Jan-24*	*Sample Date:*	*5-Jan-24*
Bath Fluid:	*Water* ☑	*Glycerin* ☐	

Time (minutes)	Temp. (^oC)	Temp. rise (^oC)
0	3.1	
1	8.4	5.3
2	13.2	4.8
3	18.2	5.0
4	23.1	4.9
5	27.5	4.4
6	32.5	5.0
7	37.3	4.8
8	43.2	5.9
9	48.0	4.8
10	53.2	5.2
11	58.2	5.0
12	63.4	5.2

Time (minutes)	Temp. (^oC)	Temp. rise (^oC)
12	68.1	
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

**** temp rise is 5 ± 0.5 °C per minute***

Sample No.	Ring 1	Ring 2	Average
Temperature when the ball touches the bottom (^oC)	71.2	71.5	71.4

Laboratory Technician		Materials Engineer	
Signature	Hmza.	Signature	[signature]
Date:	20/1/24	Date:	21/01/2024

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Email: cscecjiangbo@gmail.com

Density of Bituminous Binders

Ref: ASTM D70

Bitumen type	*50/70(6% PET)*	*Supplier/ Origin*	*SB Company*
Testing date	*20-Jan-24*	*Sample Date:*	*18-Jan-24*

		Test1	Test 2	Mean
Pycnometer No.		A	B	
Mass of dry Pycnometer, g	A	56.61	52.29	
Mass of Pycnometer + filled with water	B	178.20	181.10	
Mass of Pycnometer Partially filled with sample	C	128.4	131.4	
Mass of Pycnometer Plus Sample Plus Water	D	179.0	182.1	
Relative Density=	C-A/(B-A)-(D-C)	1.011	1.013	1.012

Materials Technician	Materials Engineer
Sign: *[signature]*	Sign: *[signature]*
Date: 20/1/24	Date: 21/01/2024

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DETERMINATION OF DUCTILITY (AASHTO T051-94)

Sample Ref:	*N/A*	Bitumen Grade:	*60/70(6% PET)*
Source:	*SB Company*	Sampling date:	*18-Jan-24*
Location:	*N/A*	Testing date:	*20-Jan-24*
Test Temperature:	*25º C*	Tested by:	*Lab Team*

Pouring Temperature, º C	:	140	
In Air	:	30	{Spec: 30-40min }
In water bath before Trimming	:	30	{Spec: 30min }
In water bath after Trimming	:	90	{Spec: 90 ± 5min }
Rate of Pull	:	50	{Spec : 50 ± 2.5/mm/min}

Test Property	Briquette Number			mean value
Ductility value(cm)	1	2	3	Specification (ASTM D113) >100
	104.2	104	103.9	104

Materials Technician	Materials Engineer
Sign: Hmza.	Sign: [signature]
Date: 20/1/24	Date: 21/01/2024

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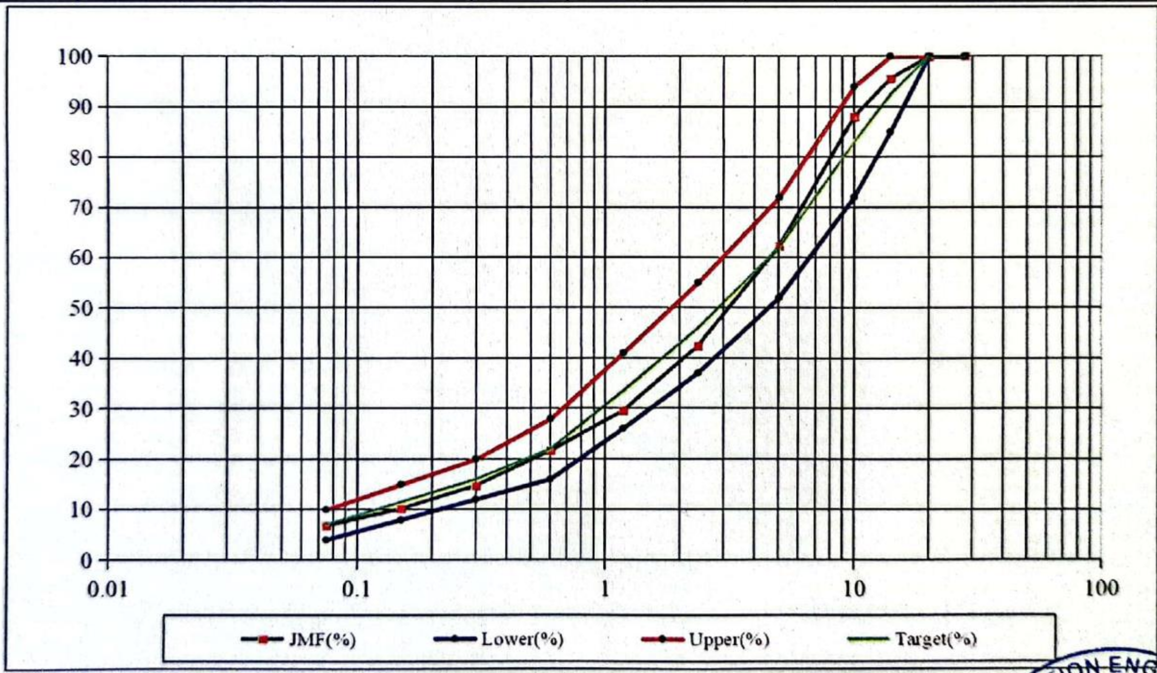
AC14 COMBINED GRADATION (Gen. Spec. TABLE - 4202/2)

LAB TRIAL MIX GRADATIONS SUMMARY

HOT BINS

Sieve size in mm	Filler	0/6mm	6/10mm	10/14mm	20/14mm	JMF(%)	Lower(%)	Upper(%)	Target(%)
	4.0	71.0	14.0	5.0	6.0				
28	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100
20	100.0	100.0	100.0	100.0	98.7	99.9	100	100	100.0
14.0	100.0	100.0	99.9	89.1	34.7	95.5	85	100	92.5
10.0	100.0	100.0	82.9	25.3	0.8	87.9	72	94	83.0
5.0	100.0	81.8	1.0	0.5	0.2	62.2	52	72	62.0
2.36	100.0	53.9	0.5	0.3	0.2	42.4	37	55	46.0
1.18	100.0	35.8	0.4	0.2	0.2	29.5	26	41	33.5
0.600	100.0	24.7	0.3	0.2	0.2	21.6	16	28	22.0
0.300	98.8	15.1	0.3	0.2	0.2	14.7	12	20	16.0
0.150	91.9	9.1	0.2	0.1	0.1	10.2	8	15	11.5
0.075	76.1	5.2	0.2	0.1	0.1	6.8	4	10	7.0



Representative(CSCEC)

Technician	Materials Engineer
Sign:	Sign:
Date: 202/01/2024	Date: 20/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD P.O.Box 29285 Kampala 20 JAN 2024 (CSCEC)