

**Assessment of Volcanic Ash as a Filler Material in Hot-Mix Asphalt (HMA) using
SUPERPAVE Methodology**

Haimanot Girma Jemaneh



A Thesis Submitted to the Department of Civil Engineering

College of Civil Engineering and Architecture

**Presented in Partial Fulfillment of the Requirement for the Degree of Master's in
Civil Engineering (Specialization in Geotechnical Engineering)**

Office of Graduate Studies

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Geotechnical Engineering**

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Adama, Ethiopia

Declaration

I hereby declare that this Master Thesis entitled “**Assessment of Volcanic Ash as a Filler Material in Hot-Mix Asphalt (HMA) using SUPERPAVE Methodology**” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Haimanot Girma Jemaneh

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “**Assessment of Volcanic Ash as a Filler Material in Hot-Mix Asphalt (HMA) using SUPERPAVE Methodology**” prepared under my guidance Haimanot Girma Jemaneh submitted in partial fulfillment of the requirements for the degree of Masters of Science in Geotechnical Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

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Approval Page

I, the advisors of the thesis entitled “**Assessment of Volcanic Ash as a Filler Material in Hot-Mix Asphalt (HMA) using SUPERPAVE Methodology**” and developed by Haimanot Girma Jemaneh, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Cement
Al_2O_3	Aluminum Oxide
ASTM	American Society for Testing and Materials
AV	Air Voids
CaO	Calcium Oxide
CBR	California Bearing Ratio
CTindex	Cracking Tolerance Index
DSR	Dynamic Shear Rheometer
ERA	Ethiopian Roads Authority
ERASTS	Ethiopian Roads Authority Standard Technical Specification
Fe_2O_3	Ferric Oxide
Gmm	Theoretical Maximum Specific Gravity
GRAVIMETRIC	Gravimetric Analysis
HF	Hydrofluoric Acid
HMA	Hot Mix Asphalt
ITS	Indirect Tensile Strength
K_2O	Potassium Oxide
LiBO_2	Lithium Metaborate
LHS	Left-Hand Side
LOI	Loss on Ignition

MDD	Maximum Dry Density
MgO	Magnesium Oxide
MR	Resilient Modulus
Na ₂ O	Sodium Oxide
Ndes	Number of Design Gyration
Nini	Initial Number of Gyration
Nmax	Maximum Number of Gyration
OMC	Optimum Moisture Content
PG	Performance Grade
PI	Plasticity Index
RHS	Right-Hand Side
SGC	Superpave Gyrotory Compactor
SiO ₂	Silicon Dioxide
VFA	Voids Filled with Asphalt
VMA	Voids in Mineral Aggregate

Abstract

This study aimed to evaluate the performance and geotechnical suitability of volcanic ash fillers namely pumice and cinder as alternatives to conventional stone dust in Hot Mix Asphalt (HMA), using the SUPERPAVE mix design methodology. The motivation stemmed from the need for sustainable, locally available materials that can enhance pavement performance while reducing reliance on traditional fillers. A series of laboratory tests were conducted to assess the volumetric and mechanical properties of asphalt mixtures incorporating varying proportions of pumice and cinder as filler materials. These included evaluations of bulk and theoretical maximum specific gravity, voids in mineral aggregate (VMA), air voids (AV), voids filled with asphalt (VFA), moisture susceptibility through tensile strength ratio (TSR), and permanent deformation through creep stiffness index. The geotechnical properties of pumice and cinder were also assessed using maximum dry density (MDD), optimum moisture content (OMC), California Bearing Ratio (CBR), and swell potential. The results revealed that all mixtures containing volcanic ash fillers satisfied the SUPERPAVE design criteria. Cinder based mixtures closely mirrored the control mix with 100% stone dust in terms of compaction, stability, and stiffness, while pumice slightly increased air void content due to its lightweight and porous nature. Nonetheless, when blended appropriately, pumice still performed within acceptable limits. TSR values for all mixtures exceeded the minimum 80% requirement, confirming resistance to moisture-induced damage. Creep stiffness results for all mixes were well below the 0.5% deformation threshold set by the ERA Pavement Design Manual, indicating good rutting resistance. Geotechnically, both pumice and cinder demonstrated favorable CBR values above 30%, minimal swell and sufficient dry density for structural use, with cinder exhibiting particularly desirable compaction characteristics. The study concluded that volcanic ash materials, especially cinder, are technically viable and sustainable alternatives to stone dust in asphalt mixture design. Their use can enhance mixture performance and support environmentally conscious infrastructure development. It is recommended that bitumen content be adjusted when using pumice to compensate for its absorptive nature, and that further field performance evaluations be conducted to validate long-term behavior. The findings support broader adoption of locally sourced volcanic materials in flexible pavement construction as part of a sustainable engineering approach.

Keywords: Hot Mix Asphalt, Volcanic Ash, SUPERPAVE, Cinder, Pumice, Filler, Bituminous Mixture, Sustainability, Geotechnical Properties

1. INTRODUCTION

1.1. Background of the study

The application of alternative materials in pavement construction has seen a growing interest due to increasing demands for sustainability and the efficient use of locally available resources. This change is more applicable in geotechnical engineering, wherein it is critical to understand material response under mechanical and environmental loading. Increasing cost and environmental impact of conventional construction materials have prompted researchers and engineers to find more sustainable options towards infrastructure development.

Volcanic ash in the forms of red ash (or cinder) and pumice has been found to be a suitable substitute for traditional mineral fillers like stone dust in Hot Mix Asphalt (HMA). Naturally occurring pozzolanic materials like these are characterized by their fine particle size, silica contents, and ability to improve the cohesion of the mixture, and hence suitable for utilization to strengthen the geotechnical properties of the asphalt mixture.

For HMA design, mineral fillers play a key role in regulating the binder characteristics, interaggregate void space filling, and affecting the stiffness, strength, and durability of the mixture. Geotechnically, specific surface area, gradation, and specific gravity of the fillers become most important. They directly influence volumetric properties like bulk specific gravity, theoretical maximum specific gravity, air voids, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). They are responsible for determining the mechanical stability and deformation characteristics of the pavement.

The Superpave mix design system developed by the Strategic Highway Research Program (SHRP) is employed in this research to evaluate the possibility of replacing volcanic ash with part stone dust in asphalt mixtures. Superpave provides a performance-based method that conforms with geotechnical engineering practice by incorporating traffic loads, environmental conditions, and material response into mixture design.

The research aims to study the effects of pumice and red ash on the volumetric and performance characteristics of asphalt mixtures. Through an examination of the effects of these substitute fillers in the Superpave system, the research enables the search of sustainable high-performance pavement materials from readily available local sources.

The experimental work for this study will be carried out using materials sourced from the Adama-Awash Expressway project site. This key transportation corridor, located in the eastern part of Ethiopia, links the towns of Adama and Awash and serves as a vital route for freight traffic between Addis Ababa and the Port of Djibouti. The project road spans approximately 125 km, and due to its role in accommodating heavy truck traffic, has experienced significant pavement distress particularly rutting and fatigue cracking. As such, it provides an ideal case study for assessing the performance of alternative filler materials under realistic loading conditions.

1.2. Statement of the problem

In many regions, there is an abundant presence of volcanic ash, yet its potential as a filler material in Hot Mix Asphalt (HMA) has not been fully explored. Meanwhile, the availability of stone dust commonly used as a conventional filler can be limited, especially in areas without nearby stone quarries. Even where it is accessible, the mining and processing of stone dust involve quarry blasting and crushing operations that contribute to environmental degradation.

Although volcanic ash particularly pumice and red cinder possesses favorable characteristics such as fine particle size, high silica content, and pozzolanic activity, its performance as a filler within HMA has not been adequately studied, especially under the SUPERPAVE mix design framework. The implications of using volcanic ash in terms of mixture stiffness, resistance to deformation, and overall volumetric performance remain unclear due to the lack of comprehensive testing.

Previous research hints at the mechanical and moisture-resistance benefits of volcanic ash in asphalt mixtures, but standardized methods for its integration are still lacking. Without sufficient empirical data, engineers and road designers are hesitant to adopt volcanic ash as a reliable alternative. This gap in knowledge prevents wider implementation of a potentially sustainable and cost-effective resource.

To address this, the present study investigates how pumice and cinder volcanic ashes, when blended with or used in place of stone dust, affect the performance of asphalt mixtures. Laboratory tests were conducted on samples prepared from the Adama-Awash Expressway, using varying filler proportions and evaluated through the SUPERPAVE methodology. This research aims to determine whether volcanic ash can meet performance standards for modern pavements and contribute to environmentally responsible road construction by reducing the need for quarry derived materials.

1.3. Objectives

1.3.1. General Objective

The primary objective of this study was to evaluate the geotechnical performance of pumice volcanic ash and red volcanic ash cinder as filler materials in combination with crushed stone on the performance of hot-mix asphalt (HMA) using the SUPERPAVE Mix Design Method. The study aimed to assess the feasibility of these alternative fillers in improving the mechanical, durability, and moisture resistance properties of asphalt mixtures while promoting sustainable and cost-effective road construction practices.

1.3.2. Specific Objectives

This research was designed to achieve the following specific objectives:

- **Characterization of Filler Materials:** Analyze the physical and chemical properties of pumice and red cinder, including pozzolanic activity, particle size, and specific gravity.
- **Evaluation of Volcanic Ash as Filler in HMA:** Assess the effects of replacing stone dust with volcanic ash (at 25%, 50%, 75%, and 100%) on HMA volumetric properties such as air voids, VMA, and VFB.
- **Assessment of Performance Characteristics in HMA:** Examine the impact of volcanic ash fillers on HMA performance, including rutting resistance, fatigue resistance, moisture susceptibility (TSR), resilient modulus, creep index, and cracking tolerance index.
- **Comparison with Conventional Filler Materials:** Compare the performance of volcanic ash fillers with stone dust to verify compliance with SUPERPAVE standards and assess geotechnical suitability.
- **Development of Practical Recommendations:** Develop guidelines for the effective use of volcanic ash fillers in HMA for future road construction applications.

1.4. Significance of the study

This study is of high significance in the creation of sustainable and economical road building technologies by evaluating the feasibility of the application of volcanic ash fillers in hot-mix asphalt (HMA). The rising cost, environmental footprint, and declining availability of conventional fillers such as stone dust, cement, and fly ash necessitate the identification of alternative materials capable of enhancing pavement performance while achieving sustainability. By investigating the effects of red volcanic ash cinder and pumice volcanic ash as filler materials, the study provides excellent information on their impact on the mechanical and volumetric properties of HMA, even more so in the SUPERPAVE mix design system.

The study contributes to the field of pavement engineering through the assessment of the impact of volcanic ash on some of the most important performance parameters like rutting

resistance, fatigue cracking resistance, and moisture susceptibility. Such properties are critical towards HMA mix design optimization, long-term durability, and structural integrity of road pavements. Furthermore, the findings of this research have practical implications to the construction of roads in regions where volcanic ash is prevalent and can be used to reduce the use of costly and environmentally expensive quarrying operations for conventional fillers.

Environmentally, this study recognizes the potential of volcanic ash in minimizing the adverse effects of aggregate extraction, such as land degradation and habitat loss. By utilizing volcanic ash in asphalt mixtures, this study promotes resource efficiency and complements the global sustainability agenda in infrastructure development. The research further provides policymakers, transport authorities, and industry stakeholders with evidence-based recommendations on the implementation of volcanic ash as viable alternative filler in HMA production.

Last but not least, the findings of this study are expected to serve as a stepping stone for additional research in new material uses, guiding the development of standard specifications for incorporating volcanic ash in asphalt mixtures. The successful implementation of volcanic ash as a filler material can contribute to more resilient and cost-effective road networks, particularly in volcanic regions, fostering economic growth and enhancing transportation infrastructure sustainability.

1.5. Delimitations and limitations of the study

This study focused specifically on assessing pumice and red volcanic ash cinder as substitute fillers for hot-mix asphalt (HMA), using the SUPERPAVE mix design method. The research was limited to lab tests carried out on asphalt samples that included different proportions of volcanic ash 25%, 50%, 75%, and 100% combined with crushed stone dust, with the bitumen content kept constant. The work was centered on the Adama–Awash Expressway project in Ethiopia, where all materials were collected and tested under controlled laboratory conditions.

While the study explored several key performance indicators, there were certain boundaries to what it covered. Because the experiments were conducted in the lab, they did not fully account for field realities such as live traffic loads, temperature changes over time, or the aging of asphalt under long-term use. The research also concentrated on only measuring the mechanical and volumetric characteristics of the mix like the rutting resistance, cracking behavior, and resistance to moisture without including longer term, real world pavement performance tests.

Another limitation was geographical scale. Since the materials were recovered from one highway project, the results are not likely to be applicable to climates, soils, or traffic elsewhere. Volcanic ash from other sources could also have different chemical and physical properties that weren't examined in this study. Finally, even though this research presents

worthwhile technical comments, it did not take into account whether volcanic ash used as filler in road building is economically or realistically produced on a grand scale.

Despite these limitations, the findings make good basis. They show the potential of volcanic ash as sustainable and efficient alternative filler, and they present a window for further research with field trials to test the performance of these blends under real road conditions and in other geographic locations.

2. LITERATURE REVIEW

2.1. General

The literature review provides a broad analysis of existing research related to the use of filler materials in hot-mix asphalt (HMA), with a particular focus on volcanic ash as alternative filler. The selection of proper fillers plays a major role in enhancing the performance and durability of asphalt pavements, influencing properties such as stiffness, moisture resistance, and long-term stability.

Traditional fillers, including stone dust, cement, and fly ash, have been widely used due to their ability to develop the mechanical characteristics of asphalt mixtures. Though, concerns related to environmental sustainability, resource reduction, and the increasing costs of conventional fillers have prompted to explore alternative materials that are both cost-effective and environmentally friendly. Expansion of the rural road network in Ethiopia requires the availability of low-cost materials for road construction(Hearn et al., 2019).

This chapter explores various aspects of filler materials in asphalt mixtures, including their physical and chemical properties, their impact on pavement performance, and previous studies on the use of volcanic ash in road construction. Additionally, the review discusses the SUPERPAVE mix design practice, its role in optimizing HMA performance, and the significance of alternative fillers in endorsing sustainable infrastructure development. By synthesizing existing knowledge, this chapter establishes a foundation for understanding the potential benefits and challenges associated with using volcanic ash as filler in HMA, providing context for the experimental investigations conducted in this study.

2.2. Overview of Hot Mix Asphalt and Filler Materials

For the construction of road pavements throughout the world, one of the essential materials required is asphalt mixture. It is widely known that asphalt mixture is a heterogeneous material that essentially consists of different constituents including asphalt, natural or recycled aggregate, fillers, and air voids(Al-Bayati et al., 2020).Hot Mix Asphalt (HMA) is a composite material widely used in flexible pavement construction, composed of coarse and fine aggregates, mineral filler, and asphalt binder. One of the essential components influencing the performance of HMA is the mineral filler, which fills the voids between aggregate particles and interacts with the asphalt binder to improve stiffness and cohesion. To attain high quality and extended service life, the demands of hot mix asphalt (HMA) for high thermal stability, low-thermal crack resistance, and water stability have been steadily growing with the fast growth of the economy, science, and technology(Fayissa et al., 2022).

Fillers contribute to the overall performance by improving resistance to permanent deformation, moisture damage (ITS), and thermal cracking. Conventionally, stone dust has served as the standard filler material due to its availability and compatibility with asphalt binders. The use of different filler materials is one of the effective techniques adopted to improve pavement quality and performance(Gopalam et al., 2020).

With growing interest in sustainability and cost-effective construction materials, alternative fillers such as volcanic ash, pumice, and red ash have emerged as viable options. Volcanic ash, being a pozzolanic material with high silica content, is hypothesized to influence the stiffness and bonding properties within the asphalt matrix. The addition of volcanic ash to the HMA as Filler has positively improved the performance of volumetric properties of mixture. The use of volcanic ash alone as a Filler in the production of hot asphalt mixtures increased the maximum stability of the mixture. The use of only volcanic ash as filler allows the asphalt mixture to have a higher moisture resistance when it is produced from the optimal bitumen content(Fayissa et al., 2022).

The role of mineral fillers extends beyond volumetric adjustment. From a geotechnical engineering standpoint, fillers significantly affect the load-distribution mechanism, shear resistance, and stiffness modulus of the asphalt mixture. Fillers with high specific surface areas, such as volcanic ash, provide greater contact with the binder, enhancing the mastic's viscosity and the mixture's ability to resist deformation under load.

2.3. Mineral Fillers in Asphalt Mixtures: Geotechnical Implications

Asphalt concrete is the most commonly used material in pavement because of its superior service performance in providing driving comfort, stability, durability and water resistance. The escalating cost of materials and energy and lack of resources available have motivated highway engineers to explore new alternatives in building new roads(Yilmaz et al., 2011).

Mineral filler used in asphalt mixtures consists of fine-grained mineral particles either naturally present in or separately added to the aggregate system. It has often been defined as the portion of aggregates passing through a 0.075mm sieve (ASTM D242, 2000) and also referred as mineral dust or rock dust. As an important component of the composite asphalt mixture, mineral fillers were generally treated as being suspended in the asphalt binder without particle particle contact and contributed to the toughening and stiffening of the asphalt binder (Chen et al., 2022).

Mineral fillers play a critical role in the structural and performance characteristics of Hot Mix Asphalt (HMA), functioning as a fine component that fills the voids between aggregate particles and significantly influences the mix's densification, stiffness, and durability. Mineral filler in addition to affecting the mechanical properties of asphalt is also important with respect to stripping or moisture damage(John, 2021).

From a geotechnical viewpoint, the choice of mineral filler can influence several key properties of HMA, such as compact ability, shear strength, and moisture resistance. Fillers with higher surface areas can increase asphalt absorption, resulting in thicker binder films that affect durability and aging characteristics. Additionally, their physical and chemical properties such as particle shape, specific gravity, surface texture, and chemical reactivity can directly impact the filler-asphalt mastic, which governs the viscoelastic behavior of the mixture under varying loading and environmental conditions. It can be concluded that it is important to carefully select the mineral filler type and proportion in order to improve the asphalt mixture Performances(Chen et al., 2022).

Geotechnical, mineral fillers contribute to the internal friction angle and cohesion of the mix, enhancing its ability to endure traffic-induced stresses without excessive deformation. Filler materials with angular particle shapes and rough textures, such as crushed stone dust or volcanic ash, provide improved mechanical interlock within the aggregate skeleton, leading to higher resistance to rutting. The graded mineral aggregate composed of coarse aggregate, fine aggregate, and mineral powder is the main component of hot asphalt mixture (HMA), and it occupies a mass ratio of more than 95% in HMA (Liu et al., 2021).Conversely, rounded fillers may reduce inter-particle friction and adversely affect shear strength.

Chemical composition also plays a role in the filler's contribution to HMA performance. Fillers containing pozzolanic oxides such as silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) may show cementitious or pozzolanic reactions when in contact with moisture, especially in acidic or alkaline environments. These reactions can increase binder-filler bonding and improve the durability of the mix. Volcanic ashes are known to exhibit latent pozzolanic properties due to their amorphous silica content, and their incorporation in HMA could provide both physical filling and chemical reactivity advantages.The change of pavement materials can be rendered directly by applying the modifier to the bitumen and aggregate combinations during the mixing process. A substitution of standard filler material with another suitable material that can be identified or easily found in nature is the most ancient usage of asphalted aggregate mix alteration. This is known as filler substitution(Ab Manaf et al., 2021).

In conclusion, the geotechnical implications of incorporating various mineral fillers into asphalt mixtures are multifaceted. Optimal filler selection, informed by physical and chemical evaluations, can enhance key performance indicators such as density, moisture susceptibility, fatigue life, and deformation resistance. Understanding these implications is essential for the effective design and long-term functionality of asphalt pavements, especially under heavy loading and climatic variability.

2.4. Surface Area

The aggregate surface area is one important property that affects the amount of asphalt needed to coat the aggregate. The total surface area of an aggregate mixture is dependent primarily on the gradation. Aggregate gradations that deviate above the maximum density line are defined as “fine” while those that deviate below the maximum density line are “coarse”(By Nigatu Wudineh Advisor Professor Alemayehu Teferra, 2015).

Mineral fillers generally possess much finer particles than the coarse and fine aggregates in HMA, and their surface area can vary significantly depending on the mineral origin and grinding process. Studies have shown that fillers with larger surface areas, such as fly ash, lime, or finely ground pozzolanic materials like pumice, tend to improve binder absorption and enhance the bonding at the mastic level. However, excessive surface area can lead to increased binder demand, potentially compromising the volumetric and mechanical properties of the mix if not properly accounted for during the mix design phase. Conversely, materials with lower surface areas may provide insufficient binder interaction, resulting in reduced cohesion and poorer resistance to moisture-induced damage.

In the context of sustainable filler alternatives, volcanic ashes such as pumice and red cinder offer variable surface area characteristics due to differences in porosity and particle morphology. The porous, lightweight nature of pumice typically results in higher surface area compared to denser fillers like stone dust or red cinder. Analysis of Equation for surface area indicates that as particle diameter decreases, the surface area per unit mass increases. Using this equation, a simple estimate of surface area can be determined for the purpose of comparing different aggregate gradations. It should be noted that the results of this equation are approximate.(By Nigatu Wudineh Advisor Professor Alemayehu Teferra, 2015).

$$SA = \sum S_{af, No.} \cdot P_{No.} \quad \text{in kg/m}^2$$

Where SA is surface area or m²/kg
 S_{af, No.} is the surface area factor for sieve number No. and
 P_{No.} is the percentage passing by weight that sieve

In conclusion, surface area serves as a governing parameter for evaluating filler performance in HMA. Its role in determining binder demand, coating efficiency, and mastic behavior underlines the importance of comprehensive characterization of alternative filler materials in both laboratory and field settings.

2.5. Volcanic Ash/Rock

Volcanic rock is a material primarily composed of aluminum silicate in a crystalline or amorphous form. It has been studied and used in some applications for several years ago.

Volcanic rocks can be used for several industrial purposes including cleaner substances and polishing compounds, they may be used as an ingredient in asphalt, and in agriculture as fertilizer. Additionally, they may also be used for painting, construction, insulation, and fillings purposes, solar cell, and volcanic gas reservoirs. The environmental implications of utilizing waste materials and industrial by-products for the production of pavements would be enormous (Valentin et al., 2021). The required application of volcanic rock depends on geometric shape (particle size and surface area) in addition to chemical and mineral composition. Most volcanic rocks contain a wide spectrum of silica, alumina, iron oxides and other oxides in minor proportions. The mineralogical composition and properties of the volcanic rock depend on the origin of the magma and eruption conditions (Alraddadi & Assaedi, 2021).

Volcanic rocks commonly come in the form of scoria and pumice. The scoria has colors ranging from black to poorly red while the pumice has colors from black to white with a porous or vesicular structure. Pumice is a volcanic rock that is abundantly present and therefore inexpensive, consisting of various chemical compositions that vary depending on its location. Because of its global availability, pumice has been used in many fields such as environmental and industrial applications. It is a natural material of volcanic origin produced by the release of gases during the solidification of lava. The cellular structure of pumice is created by the formation of bubbles or air voids when gases contained in the molten lava flowing from volcanoes become trapped on cooling. The cells are elongated and parallel to one another and are sometimes interconnected (Anwar Hossain, 2004)

Volcanic rock often contains a high content of silica. Scoria and pumice both contain high amounts of silica ranging between 40–52 wt% and 63–75 wt%, respectively. It can be distinguished between pumice and scoria based on the content of the silica. If the content of silica in the volcanic rock is larger than 50%, the volcanic rock will be pumice, and if it is lower than 50% will be scoria. The variance observed on the physical appearance of the rocks (such as color) is because of the different chemical composition and mineralogical composition of the volcanic rock which may in turn due to the historical conditions of volcanic eruption and volatile matter from the lower layers of Earth. In general, the pumice contains a high percentage of silica, about 71%, and at the same time it contains high percentages of aluminum, potassium, and calcium, while the percentages of, magnesium, and iron are low. For this reason, this type contains high percentages of light-colored minerals. While, the scoria contains less than 48% of silica and is rich in dark-colored minerals due to the high levels of calcium, magnesium, and iron. For example, if a volcanic rock contains a high amount of magnetite (Fe_3O_4) the color tend to be black, and if a volcanic rock contains hematite (Fe_2O_3) the color tend to be red. While if a volcanic rock contains a high amount of silica the color will be white (Alraddadi & Assaedi, 2021).

2.6. Superpave Mix Design Methodology and Volumetric Compositions

The Superpave (Superior Performing Asphalt Pavement) system was developed to improve the durability and performance of asphalt pavements by considering traffic loading, climatic conditions, and material properties. It includes material selection, gradation control, volumetric mix design, and performance evaluation. The mix design method is a product of the Strategic Highway Research Program (SHRP). (“Aggreg. Prop. Perform. Superpave-Designed Hot-Mix Asph.,” 2005). A proper mix design alone will not ensure the expected pavement performance. Consistency of the end product must be ensured through management and quality control operations of asphalt (Zaumanis et al., 2016).

2.6.1. Bulk and Theoretical Maximum Specific Gravity

The bulk specific gravity (G_{mb}) and the theoretical maximum specific gravity (G_{mm}) are fundamental in determining the volumetric characteristics of asphalt mixtures, which directly affect pavement durability and performance. As determined for compacted asphalt mixtures by ASTM D2726 or AASHTO T 166, the ratio of the oven-dry mass of a unit volume of asphalt mixture (including the volumes of aggregate, binder and air) to the mass of the same volume of water. G_{mb} is applicable to any laboratory- or field-compacted specimen including cores, beams, slabs, etc (Asphalt Institute MS-2, 1993).

The bulk specific gravity (G_{mb}) refers to the ratio of the weight of a compacted asphalt specimen to its bulk volume, which includes the volume of air voids within the specimen. It provides understanding into the density and compaction level of the mix and is broadly used in calculating critical parameters such as air voids (AV), voids in mineral aggregate (VMA), and voids filled with asphalt (VFA).

On the other hand, the theoretical maximum specific gravity (G_{mm}) represents the specific gravity of the asphalt mixture assuming zero air voids. It is calculated as the ratio of the mass of a loose asphalt mix to the volume it would occupy without any entrapped air. This parameter is important for computing air void content and evaluating the compact ability and design competence of the mixture. As determined for loose asphalt mixtures by ASTM D2041 or AASHTO T 209, the ratio of the oven-dry mass of a unit volume of asphalt mixture (including the volumes of the aggregate and binder only) to the mass of the same volume of water (Asphalt Institute MS-2, 1993).

The difference between G_{mm} and G_{mb} forms the basis for computing the air void content, a critical standard for ensuring appropriate permeability, resistance to moisture damage, and lasting durability of asphalt pavements. Studies have shown that fillers, including alternative materials like volcanic ash, can impact these specific gravity values due to variations in particle size, shape, and absorption characteristics. A compacted asphalt Specimen for (G_{mb}), the Superpave Gyratory Compactor (SGC) has been used to compact an all range of mixes (Rasoola et al., 2024).

Researchers have also distinguished that lightweight fillers, such as pumice, tend to reduce the bulk specific gravity of the mix, whereas denser materials like cinder may help keep or increase it, depending on the blend proportion. Thus, understanding the influence of various fillers on Gmb and Gmm is important for achieving a balanced mix design that meets performance specifications.

2.6.2. Air Voids in Compacted Mixture

The durability of an asphalt pavement is a function of the air void content of the in place HMA pavement. The lower the air voids, the less permeable the mixture becomes. An air void content that is too high provides passageways through the mix that allow damaging air and water to enter. An air void content that is too low can lead to rutting, shoving, flushing or bleeding (Asphalt Institute MS-2, 1993).

The air voids in a paving mixture are small pockets of air between the asphalt coated aggregate particles. A certain percentage of air voids is necessary in the finished HMA to allow for additional compaction under traffic and a slight amount of asphalt expansion because of temperature increases. In general, the design air void level in a laboratory-compacted sample of HMA is 4 percent. For special uses, a lower or higher design air void content may be specified. Job specifications usually require that, for dense graded mixes, pavement compaction achieve an air void content of less than 8 percent to minimize permeability (Asphalt Institute MS-2, 1993).

According to the SUPERPAVE design system, maintaining an optimal level of air voids typically around 4% is essential for achieving a balanced mixture that resists both rutting and cracking (AASHTO M 323). Too few air voids can cause bleeding and instability under high temperatures, while excessive air voids can lead to increased permeability, oxidation, and moisture damage, ultimately reducing pavement life. If maintaining of an optimal level of air void in a total mixture is not achieved, the void in a mineral aggregate and the optimum bitumen content decreases (Berhanu, 2020).

Air void content is affected by a variety of factors, including aggregate gradation, compaction effort, and the type and content of mineral filler. In particular, the incorporation of alternative fillers such as pumice and cinder both derived from volcanic ash has been observed to influence air void structure due to their particle morphology and density of aggregates of various sizes that must be completely coated by the binder, that is, the bitumen (Moghadas Nejad et al., 2012). Lightweight, porous fillers like pumice may increase AV due to higher absorption and reduced mix compact ability, whereas denser materials like cinder may help achieve target air voids more readily due to better packing characteristics.

Proper control of air voids is thus essential not only for meeting design specifications but also for ensuring the resilience of asphalt mixtures to moisture infiltration, freeze-thaw cycles, and traffic-induced stresses. This is especially important in mixtures incorporating unconventional fillers, where volumetric adjustments may be necessary to achieve a durable and stable pavement structure.

2.6.3. Voids in the Mineral Aggregate

Maintaining adequate VMA is essential to ensure durability, resistance to moisture damage, and proper asphalt film thickness within the mix. A low VMA may result in insufficient asphalt binder, leading to premature aging, cracking, or stripping. Conversely, excessively high VMA can increase binder content beyond optimal levels, potentially reducing the mixture's stability and increasing the risk of rutting. VMA describes the portion of space in a compacted asphalt pavement or specimen which is not occupied by the aggregate. VMA is expressed as a percentage of the total volume of the mix(Chadboun et al., 1999).

Given that mix designs typically aim for 4 percent air voids, voids in the mineral aggregate (VMA) must remain high enough to achieve an adequate asphalt film thickness, which results in a durable asphalt pavement. HMA mixtures with below minimum VMA values will have thin films of asphalt and will provide an HMA pavement with low durability. Therefore, reducing asphalt content by lowering VMA is actually counterproductive and detrimental to pavement quality(Asphalt Institute MS-2, 1993).

The SUPERPAVE mix design system, as developed under the Strategic Highway Research Program (SHRP), sets minimum VMA requirements based on nominal maximum aggregate size (NMAS) to ensure sufficient binder availability and performance under traffic loading and environmental conditions (AASHTO M 323). These requirements are particularly important when incorporating alternative fillers like pumice or cinder, which can influence VMA due to their distinct physical characteristics such as particle texture, porosity, and specific gravity. VMA is the volume of intergranular void space between the aggregate particles of a compacted paving mixture(Chadboun et al., 1999).

Replacement of conventional mineral fillers with volcanic ash derived materials has observed notable changes in VMA values. For example, lightweight fillers like pumice tend to increase VMA due to their lower specific gravity, which enhance binder absorption and reduce mixture density. In contrast, denser fillers such as cinder can lead to slightly lower VMA values while still maintaining the required binder volume, depending on the blend ratio. Filler type has a significant impact on the mechanical properties of HMA mixtures(Al-Bayati et al., 2020).

Understanding and controlling VMA is therefore key for designing asphalt mixtures that exhibit balanced performance in terms of strength, durability, and resistance to deformation, particularly when using non-traditional filler materials.

2.6.4. Voids Filled with Asphalt

Voids Filled with Asphalt (VFA) is the percentage of inter granular void space between the aggregate particles (VMA) that contains or is filled with effective binder. VFA is used to ensure proper asphalt film thickness in the mix. If it is too low, the mix will have poor durability, or if it is too high, the mix can be unstable. The acceptable range of VFA varies depending upon the traffic level. Higher traffic requires a lower VFA, because mixture strength and stability are a greater concern. Lower traffic requires a higher range of VFA to

increase HMA durability. A VFA that is too high, however, may yield a tender mix and cause bleeding (Asphalt Institute MS-2, 1993).

The SUPERPAVE mix design system sets recommended ranges for VFA based on the design number of gyrations (N_{des}) and traffic level, generally suggesting values between 65% and 75% for most applications (AASHTO M 323). Maintaining VFA within these limits ensures that enough binder is present to coat the aggregate particles and provide durability, while preventing excessive binder content that might lead to rutting and bleeding. VFA is generally known as the degree of VMA filled by asphalt or it refers to the ratio of the volume of effective binder to the VMA and it is usually evaluated as a percentage (Al-Bayati et al., 2020).

Studies have shown that VFA is particularly sensitive to changes in binder content, aggregate gradation, and the type of filler used. Fillers, especially those with high surface areas, can absorb more binder, thereby influencing the amount available to fill voids. For instance, pumice, a lightweight and porous volcanic material, tends to absorb more asphalt binder due to its high surface area and rough texture. This can result in lower effective VFA unless the binder content is adjusted accordingly. On the other hand, cinder, being denser and less absorptive, helps retain adequate VFA levels without requiring significant increases in binder content to enhance the performance of asphalt concrete mixtures (Al-Hadidy, 2024).

Proper VFA levels are critical in controlling the asphalt film thickness on aggregates, which directly affects the mixture's resistance to oxidation, fatigue cracking, and moisture damage. Therefore, when incorporating alternative fillers such as volcanic ash derivatives, careful evaluation of their effects on VFA is essential to optimize the mix for long term pavement performance.

2.7. Compaction and Gyratory Effort

Compaction plays a key role in determining the performance of asphalt mixtures by reducing air voids and enhancing aggregate interlock. Inadequate or excessive compaction can severely impact the mixture's mechanical stability, resistance to deformation, and durability. The SUPERPAVE mix design system introduced the Superpave Gyratory Compactor (SGC) to simulate field compaction and provide consistent, reproducible specimens under laboratory conditions. To achieve the required density, hot-mix asphalt pavements require adequate compaction. amount of energy to accomplish best degree of compaction varies depending on Gradation, asphalt content, filler kind form, and compaction are all factors to consider (Rasoola et al., 2024)

The SGC applies a combination of static pressure and gyratory shearing action to compact the asphalt mix at a fixed angle and pressure, producing cylindrical specimens with controlled density and orientation of aggregate particles. The compaction process is characterized by three key gyration levels: N_{ini} (initial gyrations) indicates the mixture's resistance to compaction during placement, N_{des} (design gyrations) represents the target compaction level for mix design and N_{max} (maximum gyrations) represents the upper limit to prevent over-

compaction and damage to the aggregate structure, analyses are recommended to cover a wide variety of materials under various conditions(Huang et al., 2005).

The required number of gyrations for each stage is selected based on expected traffic volume and climatic conditions. Higher traffic volumes generally require higher compaction efforts to ensure that the mixture can withstand repeated loading over time. To achieve the required density, hot mix asphalt pavements must be properly compacted. Amount of energy necessary to achieve the best degree of compaction varies according to the gradation, bituminous content, filler kind and form, compaction equipment, and other factors. Many studies have shown that mineral filler properties have a significant impact on the properties of HMA mixtures . It has pushed for environmental regulation and the subsequent implementation of a dust collection system to return the majority of fines to the HMA mixture(Rasoola et al., 2024).

Numerous studies have shown that filler type and content significantly influence compaction characteristics. Fillers with high surface area, such as finely ground pumice, can increase binder absorption, thereby reducing effective lubrication and making compaction more challenging. This may lead to higher air voids and the low-thermal resistance of bituminous glue(Fayissa et al., 2022). On the other hand, cinder, with its denser and more angular particles, can contribute to improved internal friction and aggregate interlock, potentially enhancing compact ability depending on its gradation and interaction with other aggregates and it can be recommended for areas that experience moisture damage without worrying about environmental and natural resource restrictions(Rasheed et al., 2023).

Understanding the compaction behavior of mixtures containing alternative fillers like volcanic ash is essential for optimizing the mix design. Effective compaction confirms not only mechanical reliability and durability but also influences the long term performance by minimizing permeability and improving resistance to moisture induced damage.

3. EXPERIMENTAL STUDY

3.1. Study Area and Design

This study was conducted along the Adama–Awash Expressway, a key road corridor in Ethiopia connecting central parts of the nation with its eastern border. The study targeted a 60 kilometer stretch of expressway, which is part of a larger 126 kilometer road plan. This corridor not only improves local connectivity but also reinforces regional trade by linking Ethiopia with Djibouti, its major exit to the sea.

The expressway is also important in the transport infrastructure of Ethiopia by giving an alternative shorter route of goods transportation to and from the port that does not use the longer northern route. Because of its economic importance, the corridor has been one of the most significant areas of road development and policy reform, particularly in expanding transport systems capacity and facilitating easier cross-border trade.

The area experiences a range of climate conditions throughout the year. During the dry season, temperatures can rise above 30°C during the day and fall to around 10°C at night. In contrast, the rainy season brings more moderate daytime temperatures generally between 20°C and 25°C with cooler nights. Rainfall varies significantly between regions: upland areas can receive over 1,000 mm annually, while lower, drier zones near the road corridor typically receive much less, around 200–600 mm.

This research considered the expressway's full geographical coverage, including its intersections and surrounding terrain. The evaluation also took into account local soil conditions, elevation, and drainage features all of which are important for understanding how road materials perform over time. Special emphasis was placed on capturing data that would help assess construction techniques, reduce structural risks, and improve the long term durability of the road.

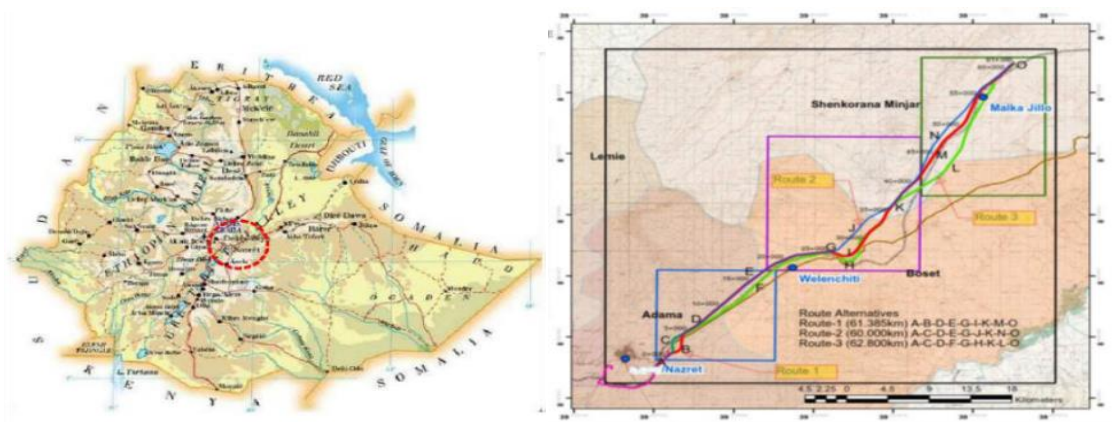


Figure 3-1: Project Location Map

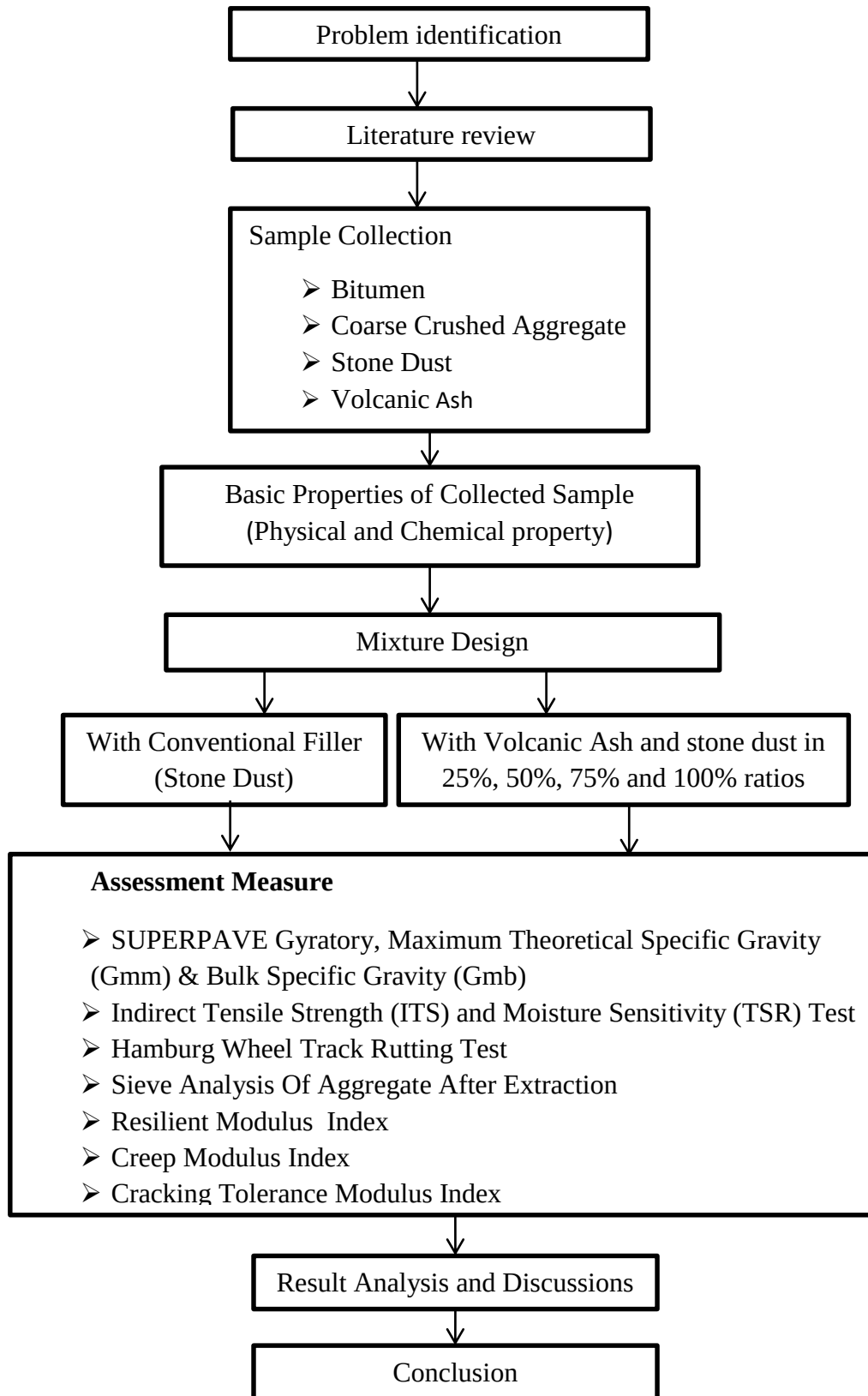


Figure 3.2: Design methodology (procedure)

3.2. Physiographic of the study

3.2.1. Terrain Classification:

Four categories of terrain classification have been defined as shown below;

Table 3.1 Transverse slope for Terrain Classification

Nature of Terrain	Transverse Terrain Slope (%)
Flat	0-5
Rolling	>5-25
Mountainous	>25-50
Steep	>50

Table 3.2 Terrain Classification

From(Km)	To(Km)	Length(m)	Terrain Type
00+000	08+200	8200	Rolling
08+200	21+900	13,700	Flat
21+900	33+000	11,100	Rolling
33+000	44+800	11,800	Flat
44+800	57+300	12,500	Rolling
57+300	61+552	4,252	Flat

3.2.2. Climate of the Area

Climate is influenced by latitude, altitude, land and water surfaces, mountain barriers, local topography, and such atmospheric features as prevailing winds, air masses and pressure centers. Based on climatic classifications of Ethiopia, the climate of the proposed project road area can be grouped under Kolla (hot-warm) climatic zone of average annual rainfall of 600mm. Based on the available meteorological data; the average monthly rainfall in the project area is summarized in the Following Table.

Table 3.3 Average monthly rainfall Data

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Rainfall mm	10	20	50	60	60	63	220	200	100	30	10	5

Table 3.4 Ethiopian Climate Zone, According to ERA 2013 Site Investigation Manual

Climate Zone	Elevation (masl)	Average Temperature(C)	Average Annual Rain fall (mm)	Remarks
Wurch (cold)	>3200	<10	<800	
Dega (cool-cold)	2300-3200	10-16	1000-2000	
Weinadega (warm-cool)	1500-2300	16-20	1200	
Kolla (hot-warm)	500-1500	20-28	600	Kolla (hot-warm) climate in which all the Road Corridor located here.
Berha (hot)	<500	28-34	<400	

3.3. Mix Design selection

Designing asphalt mixtures using a performance-based approach helps ensure that the materials used will hold up well under real world conditions. This method doesn't just look at the physical or volumetric properties of the mixture it also includes tests that evaluate how the mix will perform over time, especially in relation to durability, moisture resistance, and structural stability.

The mix design process typically unfolds in four main steps. First, the materials are selected this means choosing the right type of asphalt binder and aggregate based on how well they meet performance requirements. Second, a proper blend of aggregates is developed; establishing a mix that provides the needed gradation and mechanical stability. The third step is achieving the correct amount of asphalt binder by testing various levels of binder until the mix meets the specified performance and volumetric requirements. Lastly, the mix's moisture sensitivity is tested to ensure it will not readily disintegrate under wet conditions, an often-cited cause for pavement failure.

Several considerations guide these decisions, including the local climate (moisture and temperature) as well as expected traffic volumes and the pavement structure. These considerations help decide how the mixture is composed to create long lasting, durable roads.

In formulating the aggregate blend, utmost attention is paid while mixing the materials so that good packing, stability, and compatibility with the binder are ensured. This enables the ultimate mix to achieve important volumetric targets such as air voids, Voids in Mineral Aggregate (VMA), and Voids Filled with Asphalt (VFA) which are essential to ensure road quality and avoid conditions such as rutting or cracking.

Having determined the aggregate structure in finality, the second step is determining the optimum asphalt binder content. This entails changing the binder levels in test mixes and noting how the mix performs. The aim is to determine a binder percentage that achieves the desired characteristics according to SUPERPAVE standards. This procedure also allows one to check whether minor variations in binder content such as those that can readily arise from mass production would affect the performance of the mix and help engineers achieve more uniform results in the field.

3.4. Material Characteristics

3.4.1. Mineral Aggregate characteristics

Coarse and fine aggregate will be produced by crushing of rock obtained by blasting of hard solid fresh rock formation. Crushing will be multi-stage machinery so that aggregates of all sizes will be obtained in angular form. The following sizes have been crushed at the Crusher Plant and separated at the Asphalt Plant for the intended purpose.

Table 3.5 Screen used in crusher and asphalt plants

Aggregate Crushing	Splitting at Asphalt Plant
	Filler
0 - 5	0 - 4
5 - 7	4 - 7
7 - 15	7 - 14

The aggregate samples intended for use in asphalt mixtures must be tested for laboratory quality testing. The tests are conducted according to the relevant specifications to ensure that the aggregates meet the necessary performance requirements. The quality testing involves a series of tests such as toughness and abrasion resistance, which determine the ability of the aggregate to withstand wear and mechanical breakdown from traffic loads. Durability and soundness tests evaluate how resistant the aggregate is to weathering and degradation due to environmental conditions like moisture and temperature fluctuations.

In addition, surface texture and particle size of the aggregates are evaluated as these influence the compaction, bonding, and workability characteristics of the asphalt mixture. Angularly shaped aggregates having rough surfaces tend to have better interlock and binder adhesion. Cleanliness and the absence of deleterious materials are also tested for key factors in determining that the aggregates are free from impurities to ensure they do not adversely affect the quality of the mix.

Fine as well as coarse aggregates must be clean and should not include decomposed material, vegetable material, or other harmful material. The presence of such quality parameters guarantees that a high-performance and strong asphalt pavement is produced, one capable of withstanding environmental stresses as well as traffic loads.

3.4.1.1. Aggregate Consensus Properties

Agreement characteristics of the aggregates play a key role in determining the performance of the asphalt mixture as per the Superpave process. Such characteristics ensure the chosen aggregate mixture maintains the end asphalt mix workability, stability, and durability. Specific tests are done during design to determine if the chosen aggregate mixture meets the criteria stipulated by AASHTO M323-04.

Coarse Aggregate Angularity must conform to the percentage of fractured faces determined by testing in accordance with ASTM D5821. This property will provide a measure of the aggregate particle's ability to interlock, which will help with load-carrying capacity and resistance to deformation.

Fine Aggregate Angularity is measured by AASHTO T304 (Method A), which calculates the un-compacted void content of the fine aggregates. Higher void contents indicate more angular, textured particles generating internal friction as well as overall mix stability.

For Elongated and Flat Particles, the demand is measured by ASTM D4791. Particular focus is on the particles that are retained between the 9.5 mm and the 4.75 mm sieves, and the material must not exceed the value according to a 5:1 length-to-thickness ratio. Elevated percentages of elongated and flat particles can affect compaction and the structural response of the mix.

The Sand Equivalent test, conducted in accordance with ASTM T176, evaluates the presence of clay and other fine contaminants in the aggregate. Meeting the sand equivalent criteria ensures that the fine aggregates are clean and will not negatively impact the moisture resistance or performance of the asphalt mix.

Overall, these consensus properties guide the selection and combination of stockpile aggregates to achieve a mix design that aligns with the Superpave system's expectations for strength, durability, and resistance to distress.

Table 3.6 Summary of Consensus Property of Stockpile Aggregates

Aggregate Sizes	Flakiness Index, %	Flat and Elongated %	Fine Aggregate Angularity %	Coarse Aggregate Angularity %	Sand Equivalent
0/4	-	-	47.6	-	60.5
4/7	-	6.5	-	100	-
7/14	5.8	4.8	-	100	-
Criteria	< 35%	<10%	> 45%	100%	> 50%

3.4.1.2. Aggregate Source Properties

When tested in accordance with AASHTO T96, the Los Angeles Abrasion shall not be greater than 35%. And Water Absorption of the coarse aggregate shall not exceed 2% by mass, when tested in accordance with AASHTO T85 and T84.

Table 3.7 Summary of Hot-bin Aggregates Specific Gravities and water absorptions

Aggregates Size	Specific Gravity (Bulk)	Specific Gravity (SSD)	Apparent Specific Gravity	Water Absorption (%)
Stone Filler	-	-	2.915	-
4mm ~ 0mm	2.698	2.732	2.794	1.28
7mm ~ 4mm	2.658	2.692	2.751	1.27
14mm ~ 7mm	2.649	2.678	2.728	1.08

When testing in accordance with ASTM C88-90, the aggregates shall have a maximum Sodium sulphate soundness of 10%.

Table 3.8 Summary of Source Property of Stockpile Aggregates

Aggregate Sizes	Los Angles Abrasion	TFV DRY Kn	TFV WET/DRY %	Aggregate Crushing Value ACV	Sodium Sulphate Soundness
0/4	-	-			0.8
4/7	24.13	202.1	83.8	17.86	
7/14	24.13	202.1	83.8	17.86	
Criteria	<35%	>160 KN	>75%	< 25%	<10%

3.4.1.3.Presence of Deleterious Materials in Aggregates

As per ERASTS 2014 Table 6402/5: Properties for Asphalt Aggregates, the following additional tests have been conducted to determine presence of Deleterious Materials in Aggregates.

Table 3.9 Summary of Deleterious materials tested for Aggregate Stockpiles

Aggregate Sizes	Clay Lumps	Light weight	Linear Shrinkage	Organic Matter	Plasticity Index
0/4	0.2	0	0.0	0	NP
4/7		0	-	0	-
7/14		0	-	0	-
Criteria	< 1%	<1%	<2%	0	<4%

3.4.1.4.Bitumen Affinity of Aggregates / Coating and Stripping

As per ERASTS 2014 Table 6402/5: Properties for Asphalt Aggregates, the Aggregate Coating to bitumen by Static Immersion Test tested as per ASTM D3625, shall be >95%.



Figure3.3 Aggregates showing over 95% Coating of Bitumen after Static Immersion Test

3.4.2. Asphalt Binder

Asphalt binder is supplied in various forms and grades having a wide range of consistency from fluid to hard and brittle. Mostly there are five type of penetration grades asphalt cement for use in road, airport and other construction: (ref. AASHTO-M20).

Table 3.10 Different Type of Bitumen grades

1. 40/50 pen,	2. 60/70 pen,
3. 85/100 pen,	4. 120/150 pen
5. 200/300 pen,	

Climate can have a major impact on mix and pavement performance for a given pavement structure. In colder climates, softer, less viscous asphalt is recommended to produce a mix which is less susceptible to low temperature shrinkage cracking. In hot climate, harder, more viscous asphalt is normally used to obtain more stability from asphalt adhesion as well as from aggregate interlock.

According to recent meteorological report from National Meteorology Agency Adama Branch Directorate the Project area is classified as warm and moderately hot its annual mean temperature is approximate around 33.1⁰C. Based on the prevailing temperature of the project area, the selected bitumen type for the captioned the project is 40/50 penetration grade bitumen.

Penetration graded specifications for bituminous binders focus on the low service temperature (25°C) properties of the binder. However, in much of the roads the main failure mechanism is related to deformation at high service temperature. This implies that penetration graded bitumen can be more prone to rutting than viscosity graded bitumen. This resulted in the development of the Superpave Performance Grading (PG) system.

However, it can be shown that the PG grade is in fact a surrogate for viscosity. Penetration Grade with viscosity graded specification would have advantages over a penetration based specification, where high temperatures are experienced. It would also be cheaper and simpler to implement than the performance grade system. Accordingly, the project 40/50 penetration grade bitumen subjected to required tests in accordance with ERA flexible pavement design manual 2013 section 8.4.2 as illustrated in the under table.

Table 3.11 Quality test for bitumen

40/50 Penetration Grade Bitumen					
S. No.	Properties	Method	Unit	Specification	Result
1	Penetration at 25°C, 100gm, 5 Sec	ASTM D5	0.1mm	40-50	45
2	Softening Point (Ring and ball)	ASTM D36	°C	Min 49	52.4
3	Flash Point	ASTM D92	°C	Min 230	329
4	Ductility at 25°C, 5cm/min	ASTM D38	cm	Min 100	>100
5	Solubility in Trichloroethylene	ASTM D2042	%wt	Min 99	99.9
6	Retained Penetration after TFOT	ASTM D5	%	Min 55	66
7	Spot Test	AASHTO T102	-	-	Negative
8	Specific Gravity at 25 °C	ASTM D70	-	1.01-1.06	1.0285
9	Absolute Viscosity @ 60°C	ASTM D2171	Pa.S	Min 220	356
10	Kinematic Viscosity @ 135°C	ASTM D2170	cSt	270-700	478
After Rolling Thin Oven (RTFO)-ASTM D2872					
11	Mass Change	ASTM D2872	%	Max 0.3	0.06
12	Viscosity @ 60°C, % of original	ASTM D2171	Pa.s	Max 300	237
13	Increase in softening point	ASTM D36	°C	Max 7	6.2

3.4.3. Physical Properties of Filler

In asphalt mixture design, ensuring that solid particles are adequately coated with asphalt binder is essential to achieve the desired performance characteristics. This coating efficiency is closely linked to the surface area of the filler material, typically expressed in square meters per kilogram of dry solids (m²/kg). The specific surface area of an aggregate blend is calculated by multiplying the surface area factors of different particle sizes by their percentage passing through standard sieve sizes, with finer particles contributing more significantly to the total surface area. Among these aggregate fractions, mineral fillers stand out for their ability to influence asphalt performance due to their fine nature and high surface area.

As filler content increases, the overall surface area of the mixture rises, directly impacting binder demand, workability, and mixture stability. This increase can improve asphalt binder absorption, potentially enhancing adhesion and resistance to moisture damage, while also affecting the stiffness and durability of the mixture. Various methods exist to estimate the surface area of mineral fillers, with surface area factors assigned to different sieve sizes to quantify their contribution to binder-filler interactions. Fillers with higher surface areas, such as finely ground volcanic ash, are particularly significant in dense-graded and gap-graded mixtures, where they influence compaction behavior, void structure, and resistance to deformation.

Understanding key physical properties of mineral fillers such as surface area, particle shape, and absorption characteristics enables engineers to optimize asphalt mixture designs for improved rutting resistance, fatigue life, and overall durability. In the current study, the mineral fillers used include crushed stone, pumice, and cinder, all passing the No. 200 sieve. Representative samples of pumice were collected from Km 3+900 Right Hand Side (RHS), while cinder samples were obtained from Km 29+600 Left Hand Side (LHS), allowing for a practical evaluation of their suitability as alternative filler materials in hot-mix asphalt applications.



Figure 3.4 Sampling of pumice Volcanic Rock and Red Volcanic Ash cinder material

Additional tests on pumice and cinder revealed distinct differences in geotechnical behavior. Pumice displayed a maximum dry density (MDD) of 0.670 g/cm^3 and optimum moisture content (OMC) of 17.3%, while cinder exhibited a much higher MDD of 1.746 g/cm^3 and lower OMC of 10.7%. These values affirm cinder's denser and more compactable nature. In terms of California Bearing Ratio (CBR), both materials exceeded 30%, with pumice at 32% and cinder at 35%, demonstrating their strength and load-bearing capacity. Swell values were minimal 0.21% for pumice and 0.11% for cinder indicating limited volumetric instability upon saturation. Table 3.13 summarizes the test results.

Table 3.12 Quality test of volcanic ashes

TEST PERFORMED		TEST RESULTS			TEST METHODS
		Pumice	Cinder		
COMPACTION TEST	MDD at 100%	0.670	1.746	g/cm ³	AASHTO T-180 Method D/ ASTM D 1557
	OMC	17.3	10.7	%	
CBR	CBR at 95% MDD	32.0	35.0	%	AASHTO 193/ ASTM D 1883
	SWELL	0.21	0.11	%	
SOIL PLASTICITY	LIQUID LIMIT (LL)	NP	NP	%	AASHTO T-89/90/ ASTM D 4318
	PLASTIC LIMIT (PL)	NP	NP	%	AASHTO T-89/90/ ASTM D 4318
	PLASTICITY INDEX(PI)	NP	NP	%	AASHTO T-89/90/ ASTM D 4318
SOIL CHARACTER	SOIL CLASSIFICATION	A-1-b	A-1-b		AASHTO M 145

3.5. Experimental work (Superpave Methodology)

The SUPERPAVE method is a structured approach used to design asphalt mixtures that can handle different climate conditions and traffic loads. It ensures the road surface performs well over time by carefully guiding how materials are selected, blended, and tested.

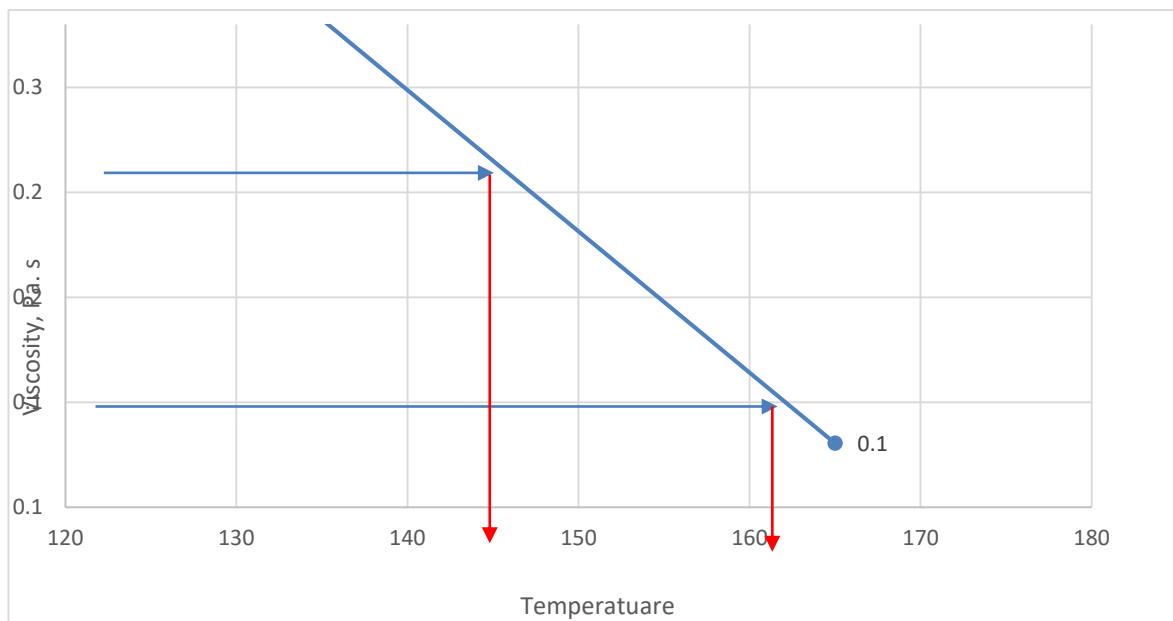
The process begins with picking the right materials this includes selecting an asphalt binder suited to the weather and expected traffic. The binder is then tested against a system that corresponds to it with the range of local traffic stresses and temperatures. The aggregates, or the crushed stones used in the mixture, also need to meet certain standards of size, shape, and strength so that the final mix won't crack or deform easily.

Once the materials are chosen, they are blended in proper proportions to meet certain gradation requirements. This is done to make the mixed material compact well and be stress-resistant. Engineers then go on to conduct a volumetric mix design, where trial mixes are made to find optimum binder amount to use. These blends are then tested to see if and how

well they meet specifications for air voids, voids in mineral aggregate (VMA), and voids in asphalt (VFA) all critical indicators of how well the blend will perform.

A main step in the process is compaction. To simulate how the asphalt will be packed down on the road, the Superpave Gyratory Compactor (SGC) is used. This machine presses and rotates the mix to mimic the forces it will face in the field. The number of times the mix is compacted (called gyrations) depends on the traffic volume and environmental conditions expected. This step helps determine whether the mixture will be strong enough to resist rutting and other forms of long-term damage.

Figure 3.5 Temp Vs Viscosity relationship for the 40/50 penetration graded bitumen



The design mixture must be compacted in accordance with AASHTO T312-04, and the number of gyrations must be as defined in AASHTO R35-04, Table-1.

Table 3.13 Number of gyrations with respect to Traffic level (ESALs)

Traffic Level (ESALs)		Ninitial	Ndesigh	Nmaximum
A	< 0.3 million	6	50	75
B	0.3 – <3 million	7	75	115
C	3 – <10 million	8	100	160
D	≥10 million	9	125	205

Table 3.14 Traffic Level-D has the following compaction efforts using the Gyratory Compactor

Compaction Effort	No of Cycles
Nini	9
Ndes	125
Nmax	205

After the asphalt samples are compacted, they are tested to see how well they perform under stress. These tests check how resistant the mix is to common pavement problems like rutting from heavy traffic, cracking from repeated loads, and damage caused by temperature changes. Some of the tests used include the Hamburg Wheel Tracking Test, which simulates rutting from wheel loads; the Dynamic Modulus Test, which measures the stiffness of the mix; and the Indirect Tensile Strength Test, which helps assess how likely the mix is to crack.

Once these tests are complete, the results are compared with standard performance requirements. If the mixture doesn't meet the expected levels, adjustments can be made either by changing the amount of binder, modifying the aggregate blend, or tweaking the mixture's internal structure to improve performance.

This process by process approach will ensure that the resultant asphalt mixture will be long lasting, durable, and suitable to the native environment and traffic conditions. The SUPERPAVE system is meant to produce roads which will perform and last longer by anticipating and minimizing failures in pavements.

3.5.1. Preparation of Specimen

Preparing specimens of Superpave asphalt is a well-organized process that simulates real life conditions within a laboratory environment. It starts with aggregate choice and mixing to the intended gradation. The aggregates are next heated and mixed with a 40/50 penetration grade asphalt binder at a temperature of 150°C to 165°C such that the binder coats all particles evenly.

Following blending, the asphalt mixture under goes short term conditioning then it is placed in an oven at the compaction temperature for about two hours to simulate aging, which usually occurs during production and transportation of hot mix asphalt.

After conditioning, the warm mixture is transferred into a preheated mold for compaction using the Superpave Gyratory Compactor (SGC). The inside of the mold and base plate are

lightly oiled to prevent the mix from sticking, and a paper disc may be placed at the base for easier removal of the finished specimen. The SGC compacts the mix by applying 600 kPa of pressure and rotating the mold at 30 revolutions per minute with a 1.25° gyration angle.

Compaction is measured through three key gyration levels: Nini (9 gyrations), Ndes (125 gyrations), and Nmax (205 gyrations). These represent different phases of pavement life Nini evaluates early compaction resistance, Ndes is used to find the optimal binder content by targeting 4% air voids, and Nmax checks for over compaction, ensuring the mix maintains enough void space to avoid rutting.

During compaction, the specimen's height is tracked after each gyration to create a compaction curve showing how air voids decrease with more gyrations. Once the compaction is finished, the sample is carefully removed and cooled. Its dimensions and weight are recorded, and further analysis is carried out to determine its bulk specific gravity (G_{mb}). These measurements are used to calculate critical volumetric properties such as air voids (V_a), voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). This process ensures the final asphalt mix aligns with Superpave standards and is compacted properly for long term durability.

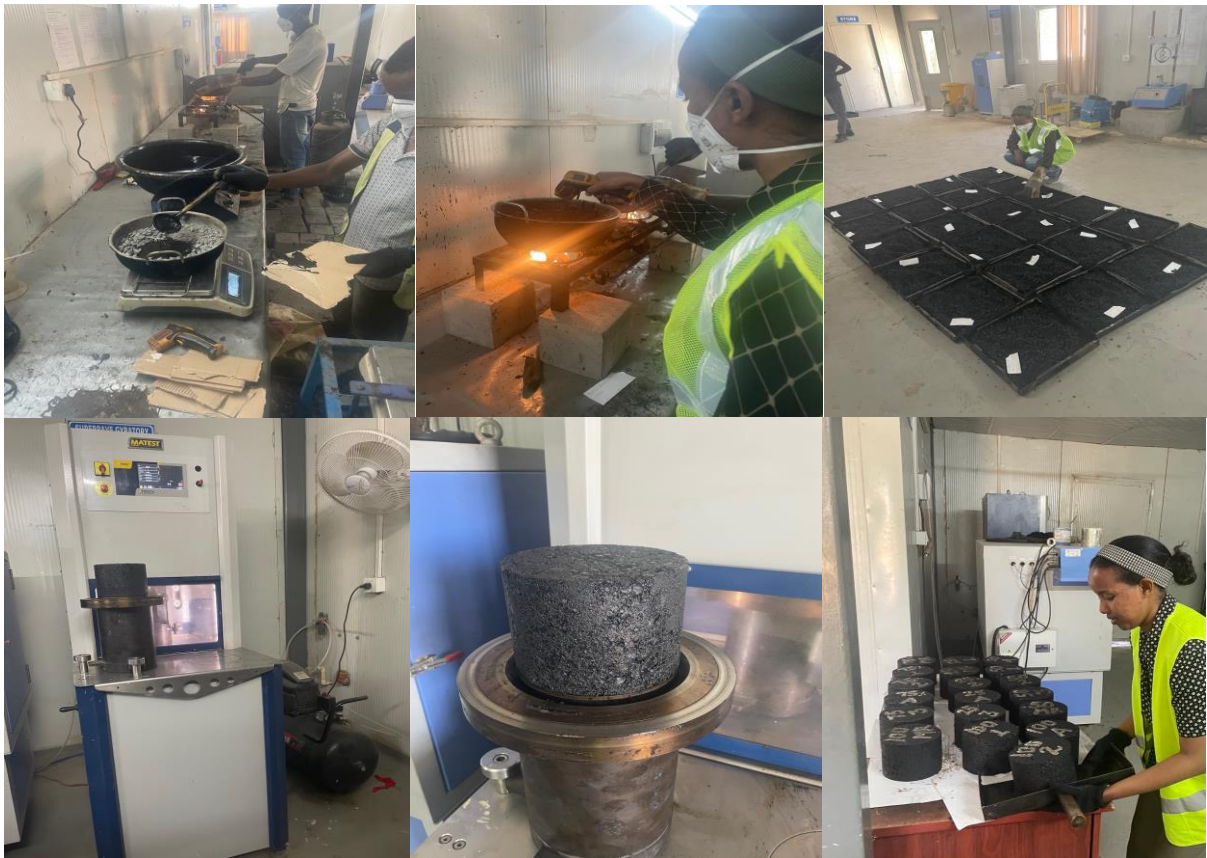


Figure 3.5 Preparation of asphalt specimens in accordance with the Superpave methodology

3.5.2. Partial Replacement of Filler

In this study, a set of asphalt mixtures were prepared depending on various percentages of mineral fillers in order to explore the effect of replacement of conventional stone dust by other materials such as pumice and red ash to some extent. The control mix consisted of 100% stone dust as filler material. In the replacement scenarios, the stone dust was substituted to some extent by pumice and red ash in incremental proportions.

Replacement levels of pumice were 25% stone dust + 75% pumice, 50% stone dust + 50% pumice, and 75% stone dust + 25% pumice. Similarly, red ash was included in the ratios of 25% stone dust + 75% red ash, 50% stone dust + 50% red ash, and 75% stone dust + 25% red ash. In addition to this, 100% pumice and 100% red ash mixtures were also evaluated. This approach allowed for a systematic comparison of how every filler combination influenced the physical and mechanical properties of hot mix asphalt, in terms of volumetric properties and durability.

4. RESULT AND DESCUSSIONS

4.1. Introduction

This chapter explains and discusses the experimental findings of the study on the use of volcanic ash in specific pumice and red ash as partial replacement of traditional stone dust filler in Hot Mix Asphalt (HMA). The analysis conforms to the objectives of the study outlined in Chapter One and is approached with a geotechnical engineering perspective, with emphasis on the impact these alternative fillers have on the mechanical, volumetric, and structural properties of the asphalt mixtures.

To evaluate the fill ability of volcanic ash as filler, a comprehensive series of laboratory tests were carried out. Physical and chemical tests on the filler samples, along with such important volumetric properties as Bulk Specific Gravity (Gmb), Theoretical Maximum Specific Gravity (Gmm), Air Voids (Va), Voids in Mineral Aggregate (VMA), and Voids Filled with Asphalt (VFA) were taken into account. In addition to this, various performance based tests were carried out Tensile Strength Ratio (TSR), Resilient Modulus, Creep Index, and Cracking Tolerance Index to mimic how the mixtures would act under actual loading and environmental conditions.

Each of these subsections addresses a specific target of research and reports comparative study of mixtures containing different volumes of volcanic ash and the control mixture consisting solely of stone dust. The results open a window of understanding toward the potential to use volcanic ash in HMA design and what implications it can have on the structural integrity, durability, and long term pavement performance especially for locations where common filling materials are scarce or are environmentally challenging to access.

4.2. Characterization of Filler Materials

4.2.1. Physical Properties (Particle Size Distribution, Specific Gravity, Surface Area)

The physical properties of mineral fillers, mainly particle size distribution, specific gravity, and surface area, play a key role in determining their performance within Hot Mix Asphalt (HMA) mixtures. These characteristics influence the packing density, volumetric properties, binder absorption, and overall mechanical behavior of the asphalt mix their physical properties, which are believed to significantly influence bituminous mixture performance, were determined as shown in the table below.

Table 4.1 Physical properties of mineral fillers

Sieves (mm)	Stone Dust	Pumice	Cinder
	% of passing		
0.15	100.00	100.00	100
0.075	92.24	93.32	81.48
Pan	0.00	0.00	0.00
Specific Gravity of Filler	2.915	2.425	2.928
Plastic Index	NP	NP	NP
Surface area (m ² /kg)	30.88	30.58	26.7

The particle size distribution of the filler materials was assessed following AASHTO T11 (Materials Finer than 75 μm [No. 200] Sieve by Washing) and ASTM C136 (Sieve Analysis of Fine and Coarse Aggregates). Results showed that all three fillers stone dust, pumice volcanic ash, and red ash cinder completely passed through the 0.15 mm sieve. However, distinctions became evident at the finer 0.075 mm sieve. Pumice exhibited the highest passing rate at 93.32%, followed by stone dust at 92.24%, while red ash cinder trailed at 81.48%. These findings indicate that pumice and stone dust are finer in texture, which may enhance their interaction with asphalt binder and promote better densification of the asphalt matrix. In contrast, the relatively coarser red ash particles may offer less binder filler contact but potentially improve structural rigidity.

Specific gravity was determined according to ASTM C128 (Standard Test Method for Relative Density and Absorption of Fine Aggregate). Pumice showed the lowest specific gravity at 2.425, reflecting its porous and lightweight nature. Stone dust and red ash cinder yielded higher and closely related values 2.915 and 2.928, respectively suggesting denser, less absorptive behavior. The lower specific gravity of pumice may lead to higher asphalt binder demand due to increased internal voids, whereas the denser red ash and stone dust can aid in better load distribution and reduced film thickness of the asphalt.

Plasticity tests conducted in line with AASHTO T90 (Plastic Limit and Plasticity Index of Soils) classified all three filler types as non-plastic (NP). This non plastic behavior is advantageous in asphalt applications, as plastic fines tend to retain moisture, potentially causing stripping and long term durability issues in pavements.

Though surface area is not a standard measure in typical aggregate testing, it was evaluated to understand the potential extent of binder filler interaction. Both pumice and stone dust exhibited relatively high surface areas $30.58 \text{ m}^2/\text{kg}$ and $30.88 \text{ m}^2/\text{kg}$, respectively while red ash cinder registered a lower value of $26.7 \text{ m}^2/\text{kg}$. A larger surface area can contribute to a stronger asphalt mastic by increasing the binder's adhesion to filler particles, thereby enhancing the mixture's internal cohesion.

In summary, pumice volcanic ash, having finer grading and higher surface area, has the potential to improve workability and compatibility of asphalt mixtures but also the potential for higher binder consumption. Red volcanic ash cinder, denser and coarser, has the potential for adding higher strength and stiffness to the mix. These physical properties are important to recognize in joint anticipation of filler performance and achieving maximum joint contribution to Superpave mix design.



Figure 4.1 physical properties testing of fillers

4.2.2. Chemical Composition and Pozzolanic Activity

The chemical constitution of the fillers of volcanic ash was examined to ascertain their mineral composition and their potential pozzolanic activity. The major and minor oxides of red volcanic ash cinder and pumice volcanic ash were determined by a blend of analytical techniques like HF acid digestion, LiBO_2 fusion, gravimetric analysis, colorimetry, and atomic absorption spectroscopy (AAS). These analyses were performed to standard procedures for analysis of powdered rock and soil oxides.

The results revealed that pumice volcanic ash is comprised of primarily silicon dioxide (SiO_2) at 70.88%, followed by aluminum oxide (Al_2O_3) at 8.48%, and ferric oxide (Fe_2O_3) at 7.8%. The remaining are sodium oxide (Na_2O) – 5.14%, potassium oxide (K_2O) – 3.42%, calcium oxide (CaO) – 0.76%, and magnesium oxide (MgO) – 0.22%. Loss on ignition (LOI) was achieved at 2.49%, which shows a strong presence of volatile materials or unburned content. Total pozzolanic oxides ($\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$) for pumice were achieved at 87.16%, which is higher than the minimum of 70% by ASTM C618 for natural pozzolans in Class N, thus determining that pumice is most likely to be reactive and can be used as mineral filler.

The red volcanic ash cinder, on the other hand, showed a SiO_2 content of 52.68%, along with higher levels of Al_2O_3 - 16.28% and Fe_2O_3 - 11.34%. Notably, CaO and MgO were significantly more prominent in cinder, measured at 10.12% and 4.96%, respectively, indicating a more alkaline nature. These basic oxides can enhance cementitious reactivity but may require careful consideration in terms of moisture susceptibility. The LOI for red ash cinder was relatively low at 0.51%, reflecting minimal unburned residue. The cumulative pozzolanic oxides in red ash summed up to 80.30%, also meeting ASTM C618 criteria.

The high reactive silica and alumina content in both materials enables pozzolanic reactions that can improve bitumen stiffness and durability in asphalt mixtures. The superior SiO_2 content in pumice enhances mastic cohesion and resistance to rutting and fatigue, while the iron and alumina-rich profile of red ash cinder may be advantageous in high-stress pavements, albeit with greater sensitivity to moisture.

In conclusion, the chemical properties obtained through LiBO_2 fusion, HF attack, gravimetric, colorimetric, and AAS methods demonstrate that both pumice and red volcanic ash cinder meet established pozzolanic criteria, reinforcing their viability as alternative mineral fillers in Hot Mix Asphalt (HMA) using the SUPERPAVE methodology.

Table 4.2 Chemical composition of the volcanic ash fillers

Major and Minor oxides	Pumice Volcanic Ash (%)	Red Volcanic Ash Cinder (%)
SiO₂ – Silicon Dioxide	70.88	52.68
Al₂O₃ – Aluminum Oxide	8.48	16.28
Fe₂O₃ – Ferric Oxide	7.8	11.34
CaO – Calcium Oxide	0.76	10.12
MgO – Magnesium Oxide	0.22	4.96
Na₂O – Sodium Oxide	5.14	2.58
K₂O – Potassium Oxide	3.42	0.64
TiO₂ – Titanium Dioxide	0.42	0.1
MnO – Manganese Oxide	0.28	0.18
P₂O₅ – Phosphorus Pentoxide	0.04	0.96
LOI (Loss on Ignition)	2.49	0.51

4.3. Volumetric Properties of HMA Mixtures

Volumetric characteristics are essential measures of Hot Mix Asphalt (HMA) mixture performance, durability, and overall quality. These characteristics govern the mix's capacity to resist deformation, moisture damage, and aging and maintain desirable air voids and binder film thickness for long-term durability. In the SUPERPAVE mix design system, Bulk Specific Gravity (G_{mb}), Air Voids (AV), Voids in Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA), and compaction effort at various gyrations (N_{ini}, N_{des}, N_{max}) were determined. Some other performance factors such as maximum theoretical specific gravity (G_{mm}), tensile strength ratio (TSR), rutting resistance by wheel tracking depth, dust-to-binder ratio, and bitumen content were also determined.

These parameters were evaluated in series of mixtures with varying levels of proportion of volcanic ash fillers pumice and red ash (cinder) as alternatives for normal stone dust filler partially or fully. The tests were conducted with the objective of gauging the effects of these substitute fillers on the compactability, stability, susceptibility to moisture, and overall volumetric performance of HMA mixtures. Laboratory tests were performed according to standard procedures like AASHTO T 166 for Gmb, AASHTO T 209 for Gmm, AASHTO T 283 for TSR, AASHTO R 35 for volumetric mix design requirements, and ASTM D6307 for asphalt content determination. The results of all the aforementioned tests are provided in Table 4.3 below:

Table 4.3 Summary of Asphalt Concrete Test Result

Type of Test Conducted	Properties	Filler Type	Stone Dust	Pumice				Cinder			
		Specification Limit	100% Stone Dust	25% Pumice and 75% Stone	50% Pumice and 50% Stone	75% Pumice and 25% Stone	100% Pumice	25% Cinder and 75% Stone	50% Cinder and 50% Stone	75% Cinder and 25% Stone	100% Cinder
SUPERPAVE Properties of Bitumen Mixture	Bulk S.G of Compacted mix	NA	2.401	2.395	2.377	2.367	2.367	2.394	2.414	2.415	2.410
	AV	3 - 6	4.10	3.8	4.8	5.1	5.1	4.60	3.90	3.50	3.70
	VMA(%)	≥ 14	15.20	14.01	14.70	15.01	15.00	14.00	13.30	13.30	13.40
	VFA(%)	65 - 75	73.00	72.70	67.50	66.30	66.40	67.40	71.00	73.40	72.70
	Nini(%)	≤ 89	87.30	87.50	86.60	86.40	86.40	86.80	87.50	87.80	87.60
	Ndes(%)	96% ± 1%	95.90	96.20	95.20	94.90	94.90	95.40	96.10	96.50	96.30
	Nmax(%)	≤ 98%	96.90	97.70	96.20	95.20	95.50	96.40	97.70	97.50	96.70
MTD	Gmm	NA	2.503	2.490	2.495	2.493	2.492	2.509	2.511	2.504	2.502
Moisture - Induced Damage	TSR(%)	≥ 80	84.40	84.10	87.10	88.60	90.10	83.90	85.30	87.20	88.40
Max. Wheel Tracking Depth	Max Depth(mm)	≤ 7	0.90	1.70	1.40	1.10	0.90	1.90	1.60	1.40	1.10
Dust to Binder Ratio		0.8 - 1.6	1.28	1.20	1.14	1.33	1.14	1.58	1.38	1.08	1.01
Extraction	Bitumen Content/Mix (%)	± 0.3 Design Binder Content	5.45	4.95	4.72	4.95	4.77	4.72	4.84	4.74	4.81

4.3.1. Bulk Specific Gravity (Gmb)

Bulk specific gravity (Gmb) is a fundamental volumetric characteristic that reflects the density of compacted Hot Mix Asphalt (HMA) and provides information about the compact potential and packing efficiency of the aggregates in the mixture. The value was determined according to AASHTO T 166, which prescribes the method for determining the bulk specific gravity of compacted asphalt mixtures by the saturated surface dry (SSD) method.

The results presented in Table 4.3.1 show the variation in bulk specific gravity for different filler replacement ratios involving pumice and red volcanic ash (cinder), compared against the control mix containing 100% stone dust. The control mix exhibited a bulk specific gravity of 2.401. When pumice was used to partially replace the stone dust, a gradual decrease in specific gravity was observed. The values declined from 2.395 at 25% pumice substitution to 2.367 at 75% and 100% pumice replacement. This reduction is attributed to the inherently lower specific gravity of pumice (2.425), as established in the physical characterization phase (Section 4.2.1), and its porous nature, which affects overall mixture density.

In contrast, the mixtures incorporating red volcanic ash (cinder) displayed relatively higher bulk specific gravity values, ranging from 2.394 at 25% replacement to 2.415 at 75% replacement. The value slightly decreased to 2.410 at 100% cinder. These figures are consistent with the higher specific gravity of cinder (2.928), which is closer to that of stone dust and therefore results in denser compacted mixtures. The mix with 75% cinder exhibited the highest bulk specific gravity (2.415), slightly surpassing even the control mix. This trend indicates the potential of cinder to enhance the density and packing characteristics of HMA mixtures, particularly when used in moderate proportions.

Generally, substitution of stone dust by volcanic ash fillers induces diverse changes in the density of mixture. Whereas, pumice serves to lower the bulk specific gravity due to its low weight per bulk unit. Cinder has the ability to maintain or even increase the compacted mix density. These phenomena emphasize the requirement for careful filler type and volume selection in such a way to meet desired performance requirements related to density during the design of asphalt mixture.



Figure 4.2 Bulk Specific Gravity (Gmb) Testing

4.3.2. Theoretical Maximum Specific Gravity (Gmm)

The theoretical maximum specific gravity (Gmm) of HMA mixes is the specific gravity of the mix when compacted in a state free of air voids. It is used as a reference for estimating other volumetric parameters, particularly air voids (AV). Gmm is of significant significance in the assessment of the overall density and performance of asphalt mix, and its calculation was carried out according to AASHTO T 209, which stipulates the vacuum test to calculate maximum specific gravity and density of bituminous paving mixtures.

The Gmm values obtained in Table 4.3 show that they varied with the percentage and quality of filler material that was introduced in the mix. The control mix of 100% stone dust possessed a Gmm of 2.503, which served as the reference against which the other mixes were compared. When pumice was partially substituted for stone dust, the Gmm showed a marginal reduction, from 2.490 (25% pumice) to 2.492 (100% pumice). This pattern is in keeping with the reduced specific gravity of pumice and its open structure, affecting the theoretical mix density.

On the other hand, cinder-containing mixtures with red ash as filler exhibited relatively higher Gmm values. At 25% replacement of cinder, Gmm was 2.509, which increased slightly to 2.511 at 50% cinder, and then fell slightly to 2.504 and 2.502 at 75% and 100% cinder, respectively. This is in line with the greater specific gravity of cinder compared to pumice, leading to a denser theoretical mix structure.

Generally, Gmm values in the above equations show that cinder and pumice have the ability to change the theoretical density of the HMA mixture depending on the level of replacement. The outcome also supports the importance of the accurate determination of Gmm for achieving reliable air void calculations together with other volumetric properties vital in mix design.



Figure 4.3 Theoretical Maximum Specific Gravity (Gmm) Testing

4.3.3. Air Voids (AV)

Air voids (AV) are the small air spaces entrapped in the dense asphalt mixture and are reported as a percentage of the total volume. Air voids are an important volumetric measure in HMA design and performance because it directly influences durability, moisture susceptibility, and pavement performance. The air voids were measured according to AASHTO T 269, which provides the standard procedure for the determination of AV using measured bulk specific gravity (G_{mb}) and theoretical maximum specific gravity (Gmm).

According to the Superpave mix design criteria, the acceptable range of air voids for a properly compacted mixture lies between 3% and 6%, ensuring sufficient space for expansion without compromising structural integrity.

As shown in Table 4.3, the control mixture containing 100% stone dust achieved an AV value of 4.10%, which is well within the recommended specification. When pumice was used as a partial replacement, AV slightly fluctuated across replacement levels. At 25% pumice replacement, the AV was 3.8%, while at 50%, 75%, and 100% replacement levels, the AV increased to 4.8%, 5.1%, and 5.1% respectively. This increasing trend in air voids correlates with the lower density and porous nature of pumice, which reduces packing efficiency and results in higher void content in the compacted mix.

On the other hand, cinder-filled mixtures displayed lower AV values in comparison to those with high pumice content. AV ranged from 4.60% at 25% cinder to 3.90%, 3.50%, and 3.70% at 50%, 75%, and 100% replacement levels, respectively. The relatively denser structure of cinder contributes to better aggregate interlock and compaction, thus reducing the void content in the final mixture.

In summary, the observed values for all mixtures remained within the acceptable Superpave range, indicating adequate compaction. However, the variations highlight how filler type and proportion directly influence the air void content and, consequently, the mechanical behavior and long-term performance of the asphalt mixtures.

4.3.4. Voids in Mineral Aggregate (VMA)

Voids in Mineral Aggregate (VMA) represent the volume of void spaces between the aggregate particles in a compacted asphalt mixture, including both air voids and those filled with asphalt binder. VMA is a key design parameter because it governs the durability, stability, and workability of the asphalt mix. The test was performed in accordance with AASHTO R 35 and AASHTO T 312, which define VMA as a function of aggregate gradation, compaction, and binder content.

The Superpave specifications recommend a minimum VMA value of 14% for mixtures using nominal maximum aggregate size of 12.5 mm, ensuring that sufficient binder is present to coat the aggregate and fill the voids while allowing space for a controlled amount of air.

As shown in the summarized results, the control mixture containing 100% stone dust achieved a VMA of 15.20%, which meets the Superpave requirements. When pumice was used as a partial replacement, VMA decreased slightly with increasing replacement level. At 25%, 50%, 75%, and 100% pumice content, the VMA values were 14.01%, 14.70%, 15.01%, and 15.00%, respectively. Although a slight drop was observed at the 25% replacement level, all mixtures with pumice maintained VMA values above the minimum threshold. This behavior can be attributed to the lower specific gravity and angular nature of pumice particles, which tend to create more internal voids, maintaining a relatively high VMA even with increased replacement.

On the other hand, the VMA values for the blended mixes containing the red volcanic ash (cinder) were relatively lower. For 25%, 50%, 75%, and 100% cinder composition, VMA values of 14.00%, 13.30%, 13.30%, and 13.40%, respectively, were recorded. The 25% cinder mix met the minimum requirement, but the mixes with 50% and above were slightly below the 14% level. This reduction can be attributed to the increased specific gravity and dense filler nature of cinder particles, which minimizes the internal voids present in the aggregate, structure.

These results verify that while pumice and cinder are both potential alternatives to fillers, they have very different impacts on VMA. Pumice is able to withstand greater VMA due to its texture and density, whereas cinder, while denser and more stable, can reduce VMA to unacceptable levels when added in high percentages without making appropriate mix design adjustments.

4.3.5. Voids Filled with Asphalt (VFA)

Voids Filled with Asphalt (VFA) represents the percentage of the voids within the mineral aggregate (VMA) that are occupied by asphalt binder in a compacted Hot Mix Asphalt (HMA) specimen. It is a critical indicator of mixture durability and fatigue resistance. Higher VFA values generally suggest better binder coverage, which improves resistance to moisture induced damage and oxidative aging. However, excessively high VFA can compromise air void levels, leading to rutting under repeated loading. According to AASHTO R 35 standards for Superpave mix design, the recommended VFA range for mixtures with a nominal maximum aggregate size of 12.5 mm is between 65% and 75%.

The control mixture, composed entirely of stone dust filler, yielded a VFA of 73.00%, placing it near the upper end of the recommended range. This indicates an optimal level of binder saturation, ensuring both durability and structural integrity without the risk of excessive compaction.

For the mixes incorporating pumice volcanic ash as a partial replacement for stone dust, a gradual decline in VFA was observed with increasing pumice content. The VFA values recorded were 72.70% for 25% pumice, 67.50% for 50% pumice, 66.30% for 75% pumice, and 66.40% for the mix with 100% pumice filler. Despite the downward trend, all values remained within the Superpave specification limits, indicating that pumice based mixtures maintained sufficient binder coverage to ensure long term performance. The slightly reduced VFA in these mixes can be attributed to the porous nature of pumice, which leads to higher VMA and thus lower relative binder filling.

In contrast, mixtures containing red volcanic ash (cinder) exhibited generally higher VFA values. The 25% cinder mix recorded 67.40%, followed by 71.00% at 50%, 73.40% at 75%, and 72.70% at 100% replacement. These results suggest that cinder enhances binder filling efficiency, particularly at mid to high replacement levels where VFA approached or exceeded 73%. This behavior is likely due to the finer texture and compact structure of cinder particles, which reduce air voids and enable better binder distribution throughout the mix.

As a conclusion, all the filler blends considered in this study satisfy the Superpave VFA requirements while pumice tends to lower the VFA due to its light nature. On the other hand, cinder accounts for mixtures that are heavier with higher binder saturation, which may be possibly best utilized in scenarios where enhanced moisture resistance and durability are required.

4.3.6. Compaction Characteristics (Nini, Ndes, Nmax)

Compaction characteristics, including initial (Nini), design (Ndes), and maximum (Nmax) gyrations, are vital signs of the densification trend of Hot Mix Asphalt (HMA) with respect to compaction. The values are based on the Superpave mix design specification provided in AASHTO R 35 and AASHTO T 312, with the Superpave Gyratory Compactor (SGC) used to simulate field compaction and traffic loading conditions. These characteristics directly impact the capacity of the mix to resist rutting, fatigue cracking, and other forms of premature failure.

Nini parameter reflects early compaction performance and is used to determine workability and placement resistance to distortion. According to Superpave specifications, the value of Nini should not be more than 89% of maximum specific gravity (Gmm) to prevent over-compaction as a result of early densification. Nini values of all mixtures in this research ranged from 86.4% to 87.8%, which was indicative of compliant and workable mixtures for all types of filler and all replacement ratios.

The Ndes value is the design traffic level target compaction level and should attain $96\% \pm 1\%$ of Gmm. The values were detected to achieve this specification by all mixes, between 94.9% and 96.5%. The control mix and the mixes containing higher cinder contents (50%, 75%, and 100%) attained slightly higher Ndes values, which represent better densification and potentially greater aggregate interlock. This is likely caused by cinder's higher specific gravity and angularity, which facilitate effective compaction and load transfer.

Nmax values measure the likelihood of over-compaction at higher gyration and must be less than 98% of Gmm. All the samples in the present work conformed to this parameter, between 95.2% and 97.7%. Control mix and cinder mixes had lower values of Nmax compared to their pumice mixes, which indicate a better response under excessive compaction stresses.

Generally, the compaction properties of the mixes mean that volcanic ash based fillers, i.e., cinder herein are in terms of good compaction performance equal to or greater than their comparative stone dust counterparts. The results confirm the feasibility of using volcanic ash in HMA from a structural and compaction perspective in such a way that the mixes reach the optimum achievable density without compromising workability or stability during field placement.



Figure 4.4 Gyratory Compactor

4.4. Performance Evaluation of HMA with Volcanic Ash Fillers

4.4.1. Rutting Resistance (Wheel Tracking Test – EN 12697-22)

Rutting is a permanent displacement of major significance for asphalt pavements under high-traffic and heat conditions. To evaluate the HMA mix rut resistance, a Wheel Tracking Test was conducted according to EN 12697-22. The test simulates cyclic traffic loading and maximum rut depth developed on the asphalt mixture surface as a function of time. The acceptable maximum rut depth is 7 mm or less for good rutting resistance.

The results showed that all the mixtures, including volcanic ash filler mixtures, met the required limit of ≤ 7 mm rut depth. The control mix of 100% stone dust produced 0.90 mm rut depth, which indicated ideal resistance to permanent deformation.

For pumice-replaced mixtures, rut depth values reduced with increased replacement level. The maximum value of 1.70 mm was recorded at 25% pumice, which then reduced as the level of pumice increased to 1.10 mm at 75% pumice and 0.90 mm at 100% pumice. The trend is that increased content of pumice improves rutting resistance, perhaps owing to the enhanced binder absorption as well as internal friction of the porous nature of the surface of pumice.

For red volcanic ash (cinder) blends, the rut depth was elevated at lower proportions of replacement. The 25% cinder blend consisted of the maximum value for rutting as 1.90 mm, followed by 1.60 mm and 1.40 mm for 50% and 75% proportions of cinder, respectively. For 100% replacement of cinder, the rut depth was 1.10 mm, indicating tremendous improvement in resistance. The downtrend with increased content of cinder is due to enhanced aggregate interlock and particle shape accounting for load resistance.

Overall, all mixtures that were tested were performing well under simulated traffic load with no sample exceeding 7 mm specification. Pumice and cinder fillers both indicated good potential in enhancing rutting resistance of the asphalt mixtures, especially at higher percentages. Results support the use of volcanic ash as a sustainable and performance-based alternative to regular stone dust in road construction projects.



Figure 4.5 Rutting resistance Testing

4.4.2. Moisture Susceptibility (Tensile Strength Ratio)

Moisture-induced damage, also known as stripping, is a major problem in asphalt pavements, particularly in environments subject to frequent rain or freeze thaw conditions. It is the deterioration of the asphalt binder-aggregate particle bond as a result of water intrusion, which reduces the structural strength and durability of the pavement. Therefore, the measurement of Hot Mix Asphalt (HMA) mixture's moisture susceptibility is important in ensuring that they are kept under long term performance under various environments.

In this research, Tensile Strength Ratio (TSR) was used as the major parameter to evaluate the moisture sensitivity of HMA mixtures with volcanic ash fillers. The parameter was set in agreement with AASHTO T 283, which prescribes the conditioning and test specimen preparation methods, freezing and thawing the specimens, and indirect tensile strength testing of conditioned and unconditioned samples. The TSR is also referred to as the ratio of conditioned sample tensile strength to that of the unconditioned sample expressed as a percentage. An 80% or higher TSR is generally considered acceptable for demonstrating satisfactory resistance to moisture caused damage.

The results indicated that all mixes with or without the incorporation of pumice and red volcanic ash (cinder) had TSR values above the minimum acceptable requirement, hence proving their suitability for use under wet conditions. Specifically, the control mix

incorporating 100% stone dust had a TSR of 84.40%, while mixes incorporating pumice replacement had increasing TSR levels with a highest TSR of 90.10% for 100% pumice mix. This excellent moisture resistance is due to the fine porous structure of pumice, resulting in excellent binder absorption and high aggregate-binder adhesion.

In addition, red volcanic ash samples performed very well with TSR ranging from 83.90% (25% cinder) to 88.40% (100% cinder). This minor fluctuation at varying replacement levels illustrates how the equilibrium takes place between filler's mineral composition, surface activity, and asphalt binder interaction. Their silica and alumina content in high levels confers a beneficial adhesion property with asphalt and inherent pozzolanic activity imparted due to their volcanic origin, which may increase cohesive strength of the mastic when subjected to wet conditions.

These findings show that red volcanic ash and pumice are viable alternatives for conventional stone dust to enhance HMA mixture resistance against water. The utilization of volcanic ash and pumice not only satisfies conventional durability criteria but also adheres to sustainable construction practices using locally utilized volcanics. Maximum advantages can be drawn with adequate proportioning of these fillers and assured reliable pavement performance under moisture exposure conditions.

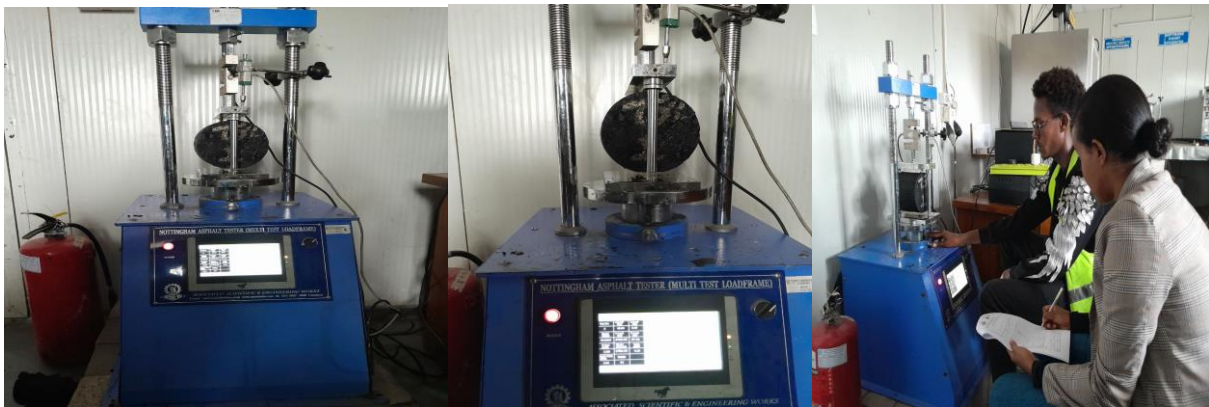


Figure 4.6 Moisture Susceptibility (Tensile Strength Ratio) testing

4.4.3. Resilient Modulus

Resilient modulus (MR) is a primary parameter to examine when assessing the load capacity and elastic behavior of Hot Mix Asphalt (HMA) mixtures in response to repeated traffic loading. It quantifies how effectively the mixture will return to its original shape after deformation, and is commonly used as a stiffness input to mechanistic-empirical performance modeling and pavement design.

In this study, the resilient modulus was determined based on ASTM D7369-11, which gives procedures for the Indirect Tension Test (IDT). Specimens were subjected to repeat axial loading at constant temperature conditions, and corresponding horizontal deformation was imparted in order to determine the modulus value. The results are summarized in the table given below. Each mixture was tested with two replicates (Specimen-1 and Specimen-2), and the average values were calculated:

Table 4.4 Summary of Resilient modulus (MR) test results

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test											Specification
Filler		100% Stone Dust	25% Pumice and 75% Stone dust	50% Pumice and 50% Stone dust	75% Pumice and 25% Stone dust	100% Pumice	25% Cinder and 75% Stone dust	50% Cinder and 50% Stone dust	75% Cinder and 25% Stone dust	100% Cinder	
Specimen-1	Resilient Modulus #1 (MPa)	6454	4063	4334	4769	6260	6161	4258	5355	4385	≥3000Mpa
	Resilient Modulus #2 (MPa)	5158	3144	4980	5147	7018	5646	4707	4519	5022	
Specimen-2	Resilient Modulus #1 (MPa)	4573	3221	4175	4536	5735	6054	4639	5355	4605	
	Resilient Modulus #2 (MPa)	5072	3207	5005	4923	6889	5615	5158	4519	4956	
Average		5314	3409	4624	4844	6476	5869	4691	4937	4742	

All mixtures exhibited average resilient modulus values above the specification threshold of 3000 MPa, confirming their structural adequacy for flexible pavement construction. The control mix (100% stone dust) showed an average modulus of 5314 MPa, serving as a benchmark.

The inclusion of pumice showed a nonlinear impact on stiffness. While the modulus decreased at 25% replacement (3409 MPa), it improved steadily with increased pumice content, peaking at 6476 MPa for the 100% pumice mix. This suggests that the light, porous structure of pumice, while reducing initial stiffness, may enhance overall elasticity and binder interaction at higher content levels.

Conversely, mixes with cinder showed a more consistent performance across different replacement ratios. The highest value was observed at 25% cinder (5869 MPa), indicating improved stiffness due to the higher specific gravity and angularity of cinder particles. However, beyond this point, stiffness showed minor reductions, yet all mixes remained within acceptable performance limits.

Overall, the data indicates that both pumice and cinder fillers contribute positively to the resilient modulus, depending on the proportion used. 100% pumice demonstrated the highest modulus, making it an excellent candidate for flexible yet strong pavement layers in areas subject to dynamic loading.



Figure 4.7 Resilient modulus (MR) Testing

4.4.4. Creep Index

Creep stiffness, measured as the rate of accumulated strain against load cycles, is a key parameter in evaluating the rutting resistance of hot mix asphalt (HMA). It reflects the material's ability to withstand permanent deformation under sustained loading, particularly in high-temperature conditions. In this study, the creep stiffness of asphalt mixtures incorporating various filler types and proportions was evaluated to assess the influence of volcanic ash (pumice and cinder) as partial or full replacements for conventional stone dust filler.

According to the ERA Pavement Design Manual (2013), Table F.6, the acceptable specification limit for creep deformation is less than 0.5%. All tested mixes in this study fell well within this limit, indicating satisfactory resistance to permanent deformation regardless of the filler type or proportion used.

The mix with 100% stone dust had the lowest creep stiffness of 0.18%, indicating high resistance to deformation. As pumice content in the mix was increased, creep stiffness rose slowly to a high of 0.36% for the mix with 100% pumice. This suggests that while pumice contributes to the structure of the mixture, its lighter and more porous character can reduce the resistance to deformation slightly relative to denser materials.

On the other hand, cinder mixes have comparatively lower creep stiffness values than their pumice equivalents. The 25% cinder-75% stone dust combination had a creep stiffness of 0.19%, whereas 100% cinder had 0.25%. These results are a confirmation that cinder, despite it being a volcanic ash material, has greater resistance to deformation compared to pumice due to it being denser and more compactable in nature.

Overall, all combinations partially or entirely replaced with cinder or pumice were in conformity with the ERA limit of < 0.5% creep deformation. This mirrors the performance possibility of the two forms of volcanic ash as potential substitute fillers in HMA, where the cinder offers a relatively superior creep resistance behavior. The above findings also demonstrate that at elevated levels of replacement; using the volcanic ash doesn't weaken the mixture's durability against permanent deformation.

Table 4.5 Summary of Creep Index Test Result

Filler	100% Stone Dust	25% Pumice and 75% Stone dust	50% Pumice and 50% Stone dust	75% Pumice and 25% Stone dust	100% Pumice	25% Cinder and 75% Stone dust	50% Cinder and 50% Stone dust	75% Cinder and 25% Stone dust	100% Cinder	Specification
Creep Stiffens (Rate of accumulated strain against load cycles) %	0.18	0.27	0.31	0.32	0.36	0.19	0.24	0.21	0.25	< 0.5 ERA Pavement Design Manual Table F.6



Figure 4.8 Creep Index Testing

4.4.5. Cracking Tolerance Index (CTIndex) %

The Cracking Tolerance Index (CTIndex) is a performance based parameter used to evaluate the flexibility and resistance of asphalt mixtures against tensile cracking. A higher CTIndex value signifies a mixture's ability to endure deformation without failing, thus contributing to its long-term durability. According to standards, a CTIndex value greater than 70% is deemed acceptable for pavement applications.

As shown in Table 4.6, the control mixture (100% stone dust) recorded a CTIndex of 91.7%, meeting the specification limit. Among the pumice-modified mixtures, the CTIndex values were 80.2%, 81.1%, 76.9%, and 75.4% for 25%, 50%, 75%, and 100% pumice replacement, respectively. All these values exceeded the threshold, indicating adequate performance, with the 50% pumice mix showing the best cracking resistance within the pumice group.

The cinder-modified mixtures demonstrated even stronger performance, with CTIndex values of 82.3%, 89.4%, 93.8%, and 89.6% for 25%, 50%, 75%, and 100% cinder replacement, respectively. The 75% cinder mixture had the highest CTIndex of 93.8%, surpassing even the control. This suggests that cinder enhances the cracking resistance of asphalt mixtures more effectively than pumice, reinforcing its potential as a reliable filler material.

Table 4.6 Summary of Cracking Tolerance Index (CTIndex) % Test Results

Filler	100% Stone Dust	25% Pumice and 75% Stone dust	50% Pumice and 50% Stone dust	75% Pumice and 25% Stone dust	100% Pumice	25% Cinder and 75% Stone dust	50% Cinder and 50% Stone dust	75% Cinder and 25% Stone dust	100% Cinder	Specification
Cracking Tolerance Index (CT _{Index}) %	91.7	80.2	81.1	76.9	75.4	82.3	89.4	93.8	89.6	>70



Figure 4.9 Cracking Tolerance Index (CTIndex) Testing

4.5. Comparison with Conventional Filler (Stone Dust)

4.5.1. Volumetric and Mechanical Performance Comparison

To evaluate the suitability of volcanic ash fillers as alternatives to conventional stone dust in asphalt mixture design, both volumetric and mechanical performance indicators were compared across all mix variants. The control mixture composed of 100% stone dust served as the benchmark against which all other filler combinations both pumice-based and cinder-based were assessed.

From the volumetric performance standpoint, the control mix demonstrated optimal properties in terms of air voids (Va), voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). However, mixtures containing volcanic ash showed values within acceptable SUPERPAVE specification ranges, indicating that partial and even full replacement of stone dust did not compromise the mix structure. Notably, mixes with cinder exhibited volumetric behavior closely aligned with that of the control, while pumice-based mixes showed slightly increased air voids and VMA values due to the material's porous nature.

In terms of mechanical performance, the inclusion of volcanic ash fillers resulted in acceptable outcomes across all indicators. Moisture susceptibility, measured through tensile strength ratio (TSR), remained above the minimum specification threshold for all mixes, affirming the adequate adhesion between aggregate and binder. Creep stiffness, used to evaluate rutting resistance, was also well within the acceptable limit ($< 0.5\%$ strain) according to the ERA Pavement Design Manual Table F.6. Interestingly, mixes incorporating cinder outperformed those with pumice in creep resistance, showcasing better load-bearing capacity and dimensional stability under repeated loading.

These findings suggest that while stone dust remains reliable filler, the use of volcanic ash particularly cinder can be a feasible and sustainable alternative. The performance metrics confirm that volcanic ash fillers, even at higher replacement levels, maintain structural integrity and satisfy SUPERPAVE requirements.

4.5.2. Suitability in Geotechnical Perspective

Geotechnically, the suitability of filler materials in asphalt mix is based on dry density, moisture content, bearing capacity, and volume stability attributes that influence the performance and durability of the pavements under traffic loading as well as climatic factors.

For the purpose of this study, pumice and cinder were analyzed in terms of their geotechnical performance through tests like maximum dry density (MDD), optimum moisture content (OMC), California Bearing Ratio (CBR), and swell potential. The tests determined distinct properties for both materials.

Pumice possessed a low MDD value of 0.670 g/cm³ and a similarly high OMC value of 17.3%, which showed its light and porous nature. These properties suggest lower compaction potential but better water retention, which can be advantageous for certain base or sub-base applications but needs to be considered when utilized as a filler material due to the possibility of binder absorption and air void increase. Despite these properties, pumice recorded a CBR of 32%, confirming acceptable load-carrying capacity. Its swell value of 0.21% is low, indicating good volumetric stability when exposed to water.

On the other hand, cinder displayed a higher MDD of 1.746 g/cm³ and lower OMC of 10.7%, reflecting its denser structure and higher compaction capability. This makes cinder more suitable as filler in asphalt mixtures where high stability and stiffness are required. It achieved a CBR of 35%, slightly outperforming pumice in load resistance, and showed an even lower swell potential of 0.11%, suggesting excellent dimensional stability.

These geotechnical indicators support the conclusion that cinder, due to its higher density, greater bearing strength, and minimal swelling, is more geotechnically favorable as a filler in HMA than pumice. However, pumice can still be considered suitable, particularly when the aim is to reduce mixture weight or when used in blends with stone dust to balance performance traits. Both materials demonstrated acceptable geotechnical behavior, validating their use as sustainable and locally available alternatives to conventional stone dust.

4.6. Summary of Findings

This research examined the use of volcanic ash fillers specifically pumice and cinder as substitutes for conventional stone dust in Hot Mix Asphalt (HMA), utilizing the SUPERPAVE mix design framework. Across all tested mixtures, the incorporation of these alternative fillers resulted in volumetric properties, including Air Voids (AV), Voids in Mineral Aggregate (VMA), and Voids Filled with Asphalt (VFA), that complied with SUPERPAVE specifications. Among the two materials, cinder-modified mixtures produced volumetric values most comparable to the control mix with 100% stone dust, indicating better structural uniformity and compaction. Although pumice slightly increased the air void content due to its porous and lightweight nature, appropriate blending ratios allowed it to remain within acceptable performance thresholds.

In terms of mechanical behavior, both pumice and cinder proved to be structurally reliable. Tensile Strength Ratio (TSR) of all blends was above the required minimum, demonstrating high resistance to moisture. The creep stiffness for all blends was well below the 0.5% specified in the ERA Pavement Design Manual, assuring their performance in resisting permanent deformation by repeated loading. Of the alternate fillers considered, cinder was consistently better performing. Its greater density and lower moisture absorption caused greater stiffness and less strain development compared to pumice, which absorbed more binder and was slightly less stiff particularly in the higher pumice content mixes.

From a geotechnical perspective, laboratory analyses confirmed the suitability of both materials. Pumice and cinder exhibited California Bearing Ratios (CBR) above 30% and very low swell percentages, indicating favorable strength and volumetric stability when used in bituminous mixtures. Cinder, with higher Maximum Dry Density (MDD) and lower Optimum Moisture Content (OMC), was found to be significantly effective in enhancing the mix compaction and stability. Also, ready availability of pumice and cinder provides an opportunity to enhance the sustainable construction practice. Their application as whole or partial replacements for stone dust both achieves environmental objectives through reducing reliance upon quarried materials, while also offering possible economic benefits through cost savings on materials. As a whole, the findings point toward the possibility of volcanic ash or cinder playing a role as an effective and sustainable filler material in asphalt pavement applications.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study investigated the suitability of volcanic ash derivatives pumice and cinder as alternative filler materials in Hot Mix Asphalt (HMA) by evaluating their physical, volumetric, and mechanical effects on asphalt mixtures. The research applied the SUPERPAVE mix design methodology, emphasizing performance-based testing and advanced volumetric parameters.

Based on the results obtained, the following conclusions were drawn:

- ❖ **Physical Characteristics:** Both pumice and cinder, collected from Km 3+900 (RHS) and Km 29+600 (LHS) respectively, exhibited distinct geotechnical properties. Pumice was lightweight with low maximum dry density and high moisture content, while cinder was denser and more compactable. Both materials met the required California Bearing Ratio (CBR) and exhibited minimal swell values, indicating their stability under moisture exposure.
- ❖ **Volumetric Performance:** The incorporation of volcanic fillers influenced key volumetric properties such as Voids in Mineral Aggregate (VMA), Air Voids (AV), Voids Filled with Asphalt (VFA), and specific gravities. Mixes with cinder generally exhibited improved compactability and more promising volumetric properties compared to pumice.
- ❖ **Mechanical Performance:** The creep stiffness of all mixtures remained below the ERA threshold of 0.5%, indicating acceptable resistance to permanent deformation. However, mixtures containing cinder showed better control of accumulated strain compared to those with pumice, affirming cinder's mechanical advantage.
- ❖ **Comparison with Conventional Filler (Stone Dust):** While stone dust performed consistently within standard specifications, certain cinder and pumice blends particularly those with moderate replacement levels achieved comparable or superior results in terms of stiffness and volumetric stability.
- ❖ **Geotechnical Suitability:** Both cinder and pumice structurally exhibited acceptable strength and stability for use in flexible pavement layers. Cinder, however, performed better due to its higher density and lower moisture affinity.

In addition, visual observation at the time of compaction indicated that pumice mixtures were considerably drier than stone dust and cinder mixtures. This was because pumice is light weight and porous and will therefore take up more volume space in the mix. Despite using a uniform bitumen content of 5.4% across all mixtures, the pumice rich blends absorbed more binder internally, leaving less effective binder to coat the aggregates. This behavior led to volumetric inconveniences, such as reduced Voids Filled with Asphalt (VFA) and challenges in achieving optimal compaction. From an economic viewpoint, this implies that the use of pumice as a filler necessitates higher binder content, which increases the cost of materials. Therefore, while pumice is locally available and environmentally friendly, its use must be well optimized to avoid cost inefficiencies through binder usage and other potential performance losses.

5.2. Recommendation

According to the experimental findings and observed behavior of volcanic ash fillers in Hot Mix Asphalt (HMA) in accordance with the SUPERPAVE system, the following are proposed recommendations:

1. **Adjustment of Bitumen Content for Pumice-Modified Mixes:** Due to the high absorptive capacity and low density of pumice, asphalt mixtures incorporating higher percentages of pumice filler exhibited binder starvation and volumetric imbalance. Therefore, it is recommended that increased binder content be considered when using pumice in order to ensure adequate coating of aggregates and to achieve desirable volumetric properties such as Voids Filled with Asphalt (VFA) and Air Voids (AV).
2. **Prioritization of Cinder as a Sustainable Alternative Filler:** Cinder demonstrated favorable volumetric and mechanical characteristics, including better compaction, lower moisture susceptibility, and improved stiffness. As such, it is recommended for use as a partial or full replacement for stone dust in HMA production, particularly in regions where cinder is locally available and cost-effective.
3. **Site Specific Material Testing:** Since volcanic ash materials such as pumice and cinder vary significantly in physical and chemical properties depending on their source, location-specific material testing is required before large-scale application. This includes the determination of specific gravities, absorption, and compatibility with local aggregate and binder types.
4. **Additional Performance Testing under Field Conditions:** Although laboratory testing yields important information, volcanic ash filler long-term performance under actual traffic and environmental conditions must be investigated. Field trials involving rutting, fatigue, and resistance to water would give full validation of their use in flexible pavements.
5. **Integration into National Material Specifications and Guidelines:** Because of the potential of volcanic ash fillers as substitute materials, road authorities and standardizing bodies responsible are encouraged to integrate guidelines for their use into national pavement design guides. This would enable sustainable material use as well as ensure quality control during production of HMA.
6. **Incentives for Sustainable Material Sourcing:** Utilization of volcanic ash materials like pumice and cinder can reduce the consumption of quarried stone dust, thus promoting ecologically friendly practices in road construction. Contractors and agencies must be encouraged to utilize local volcanic ash sources, which can save costs as well as achieve sustainability goals.

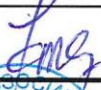
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APPENDIX

Appendix 1 Physical properties of stone dust (Specific gravity and gradation)

CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT  LEA-LASA-UNICONE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)				
SPECIFIC GRAVITY OF FINE VOLCANIC ASH (AASHTO T 100)				
Type of Material	Stone Dust	Date of Sampling	6/2/2025	
Location	Km.29+900 LHS	Date of Testing	10/2/2025	
Proposed Use	Asphalt			
Pycnometer Bottle Number		1		
Weight of Pycnometer (W_f)	(gm)	104.7		
Weight of Pycnometer +Sample (W_2)	(gm)	139.7		
Weight of Oven dry sample (W_o) = ($W_2 - W_f$)	(gm)	35.1		
Weight of Pycnometer +Sample +Water (W_b)	(gm)	367.4		
Any other Desired Temperature (T_x)	($^{\circ}\text{C}$)	28		
Relative Density of Water (D_x)		0.9962652		
Weight of Pycnometer +Water (W_i)	(gm)	347.2		
Weight of Pycnometer +Water (W_a) = $[(D_x/D_i)(W_f - W_i)] + W_f$	(gm)	347.3		
Observed Temperature of Water (T_i)	($^{\circ}\text{C}$)	30		
Relative Density of Water at Temperature (D_i)		0.995678		
Apparent Specific gravity of Filler (S_x) = $W_o / [W_o + (W_a - W_b)]$		2.915		
Remarks :				
Tested by:		Verified by:		
Laboratory Technician		Material and Pavement Engineer		
				





ETHIOPIAN ROAD



LEA-LASA-UNICONE

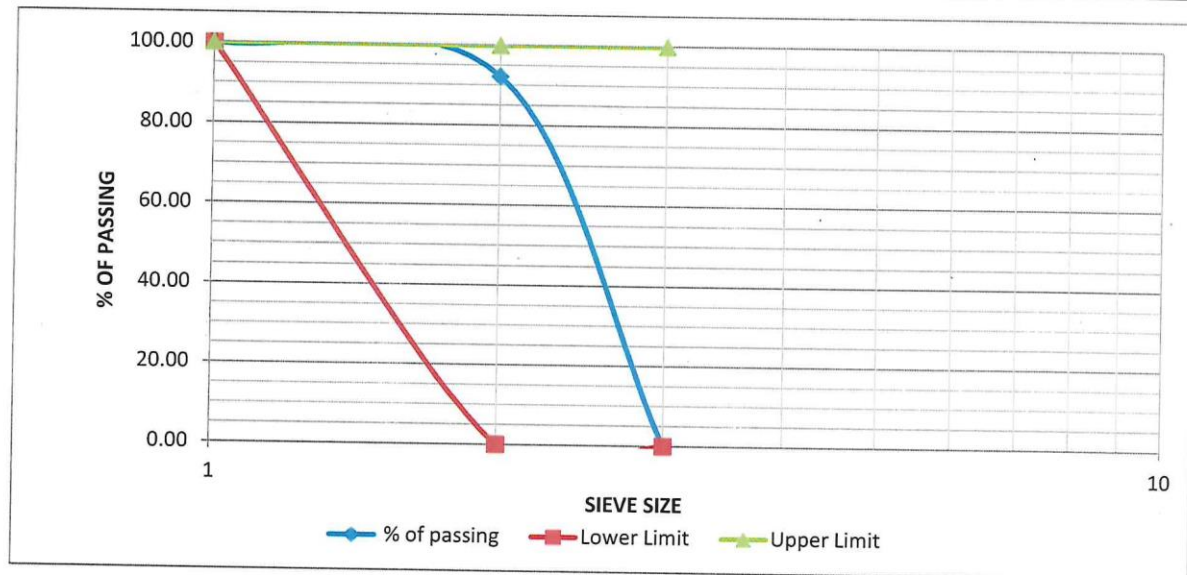


JMC - LRBCL Joint Venture.

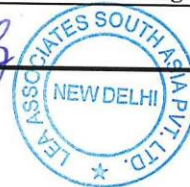
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

GRADATION OF FINE AGGREGATE

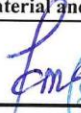
Material Type		Stone Dust		Date of Sampling	6/2/2025	
Sampling Location		Km.29+600 LHS		Date of Testing	10/2/2025	
Weight of Sample: 500 gms.						
Sieves (mm)	Weight Retained (g)	% Retained	Cum % Retained	% of passing	ERA Tech. Spec, Table 8402-2	
					Lower Limit	Upper Limit
0.15	0.0	0.00	0.00	100.00	100	100
0.075	38.8	7.76	7.76	92.24	0	100
Pan	461.2	92.24	100.00	0.00	0	100



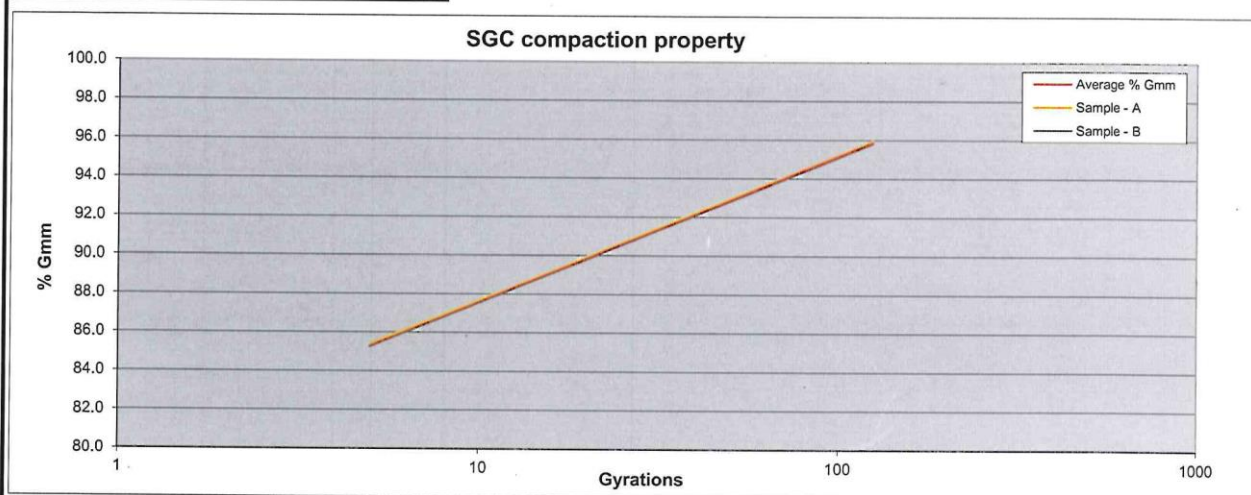
Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer



**Appendix 2 Volumetric properties and Performance
tests of asphalt mixture with 100% Stone Dust of
Filler**

Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor   JMC-LRBCL JOINT VENTURE						
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
Summary of Asphalt Concrete Testing and Approval Record										
Source of Mix		Lab-Mix		Filler	100% SD					
Visual Description		Hot Mix Asphalt Mixture(AC)								
Purpose		AC-60 Binder course								
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT							
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.401	NA							
	AV	4.1	3 - 6							
	VMA(%)	15.2	≥ 14							
	VFB(%)	73.0	65 - 75							
	N _{ini} (%)	87.3	≤ 89							
	N _{ds} (%)	95.9	96% ± 1%							
	N _{max} (%)	96.9	≤ 98%							
MTD	G _{mm}	2.503	NA							
DUST TO BINDER RATIO		1.28	0.8 - 1.6							
EXTRACTION	Bitumen Content/Mix(%)	5.45	± 0.3 Design Binder Content							
Sieve Analysis										
Description	Sieve Size (mm)									
	19	12.5	9.5	4.75	2.36	1.18	0.6	0.30	0.15	0.075
Specimen Grading	100	96.1	77.6	45.6	34.8	25.6	20.1	14.3	9.6	6.3
JMF	100	96.5	78.7	46.8	35.3	26.7	21.0	15.0	10.1	6.7
Tolerance from JMF L. Limit	100	91.5	73.7	42.8	31.3	2.7	17.0	12.0	8.1	5.7
Tolerance from JMF U. Limit	100	100	83.7	50.8	39.3	30.7	25.0	18.0	12.1	7.7
Upper Control Point	100	100	-	-	-	58	-	-	-	10
Lower Control Point	100	90	-	-	-	28	-	-	-	2
REMARK:										
Tested by: Laboratory Technician 						Verified by: Material and Pavement Engineer 				
										

Employer			Consultant		Contractor			
					 			
Ethiopian Roads Administration (ERA)			LEA JV with Unicon P.L.C, Ethiopia		JMC-LRBCL JOINT VENTURE			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	100% SD		Specific Gravity		1.0285			
Date Tested:	25-02-2025		Number of Gyration		125 @ N _{des}			
Mixing Tempreture (°C)		135-165		CompactionTempreture (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.67	85.4	127.736	85.2				
9 [Nini]	124.841	87.3	124.906	87.2				
10	124.347	87.7	124.412	87.5				
20	121.192	90.0	121.255	89.8				
30	119.420	91.3	119.482	91.1				
40	118.194	92.2	118.256	92.1				
50	117.26	93.0	117.321	92.8				
70	115.879	94.1	115.940	93.9				
90	114.869	94.9	114.929	94.7				
110	114.075	95.6	114.134	95.4				
125 [Ndes]	113.575	96.0	113.634	95.8				
	G _{mb} Gyro	2.334	G _{mb} Gyro	2.349			Average G _{mb} Gyro	2.342
	G _{mb}	2.402	G _{mb}	2.399			Average G _{mb}	2.401
	G _{mm}	2.502	G _{mm}	2.504			Average G _{mm}	2.503
	G _{sb}	2.677	G _{sb}	2.677			Average G _{sb}	2.677
	G _{sa}	2.760	G _{sa}	2.760		G _{sa}	2.760	
% AC	5.40		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	94.6		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Gsb	2.677		Sample - A	4734	4743	2772	1971.0	2.402
Pb	1.029		Sample - B	4724	4732	2763	1969.0	2.399
Volumetrics	Value	Spec.						
%Gmm@Ni	87.3	< 89%						
%Gmm@Ndes	95.91							
% Air void	4.1	3-6%						
% VMA	15.17	Min 13%						
%VFA	73.03	65-75						

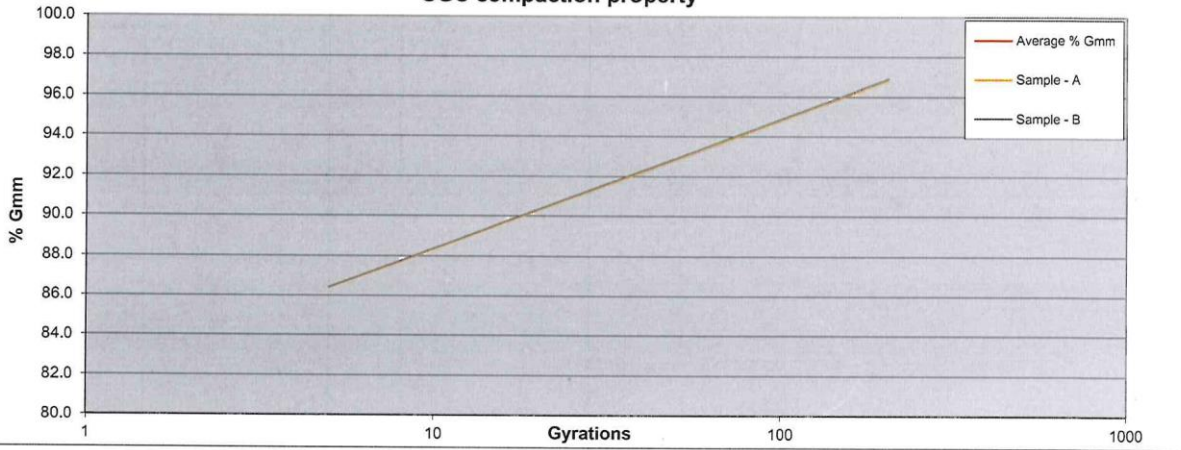


Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer			Consultant			Contractor				
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			  JMC-LRBCL JOINT VENTURE				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS					
Source of Mix	Lab-Mix		Bitumen Grade		40/50					
Filler	100% SD		Specific Gravity		1.0285					
Date Tested:	25-02-2025		Number of Gyration		205 @ N _{max}					
Mixing Temperature (°C)			135-160		Compaction Temperature (°C)		135-150			
Sample - A			Sample - B			Average % Gmm				
No of Gyration	Height	% Gmm	Height	% Gmm						
5	126.415	86.4	126.981	86.4						
9 [Nini]	124.033	88.0	124.589	88.1						
10	123.616	88.3	124.169	88.4						
20	120.938	90.3	121.480	90.3						
30	119.425	91.4	119.959	91.5						
40	118.374	92.2	118.904	92.3						
50	117.571	92.9	118.098	92.9						
70	116.382	93.8	116.903	93.9						
90	115.508	94.5	116.026	94.6						
110	114.821	95.1	115.335	95.1						
125 [Ndes]	114.387	95.5	114.899	95.5						
150	113.774	96.0	114.283	96.0						
175	113.260	96.4	113.767	96.4						
200	112.819	96.8	113.325	96.8						
205 [Nmax]	112.738	96.9	113.243	96.9						
G _{mb} Gyro			2.353		G _{mb} Gyro			2.351		
G _{mb}			2.424		G _{mb}			2.426		
G _{mm}			2.502		G _{mm}			2.504		
G _{sb}			2.677		G _{sb}			2.677		
G _{sa}			2.760		G _{sa}			2.760		
					Average G _{mb} Gyro			2.352		
					Average G _{mb}			2.425		
					Average G _{mm}			2.503		
					Average G _{sb}			2.677		
					G _{sa}			2.760		
% AC			5.4		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.			94.6		Mix Ref.	Wt. air	wax+spe in air	wax+spe in water	Volume	Gmb
Gsb			2.677		Sample - A	4658	4674	2752	1922.0	2.424
Pb			1.029		Sample - B	4624	4629.0	2723	1906.0	2.426
Mix property			Units		Result			Criteria		
% G _{mm} at N _{max}			%		96.9			Max 98		

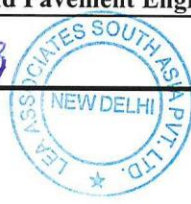
SGC compaction property



Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



Employer	Consultant	Contractor	
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041			
Source of Mix	Lab-Mix	Filler	100% SD
Material Description:	AC-50 Wearing Course	Dated of Testing	27-02-2025
Grade of Bitumen	40/50	Tested By	Jointly
Testing Temp.	25 °c	Bitumen by Wt. of Mix	5.40%
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 5.4			
Test No		Test 1	Test 2
Mass of dry sample in air	A gm.	2367	2341
Mass of container filled with water at test temperature	F gm.	9146.0	9146.0
Mass of container filled with sample and water at test temperature	G gm.	10567	10552
Temperature of test water	T °C	25	25
Correction for thermal expansion of bitumen	H gm.	0.0	0.0
Theoretical Maximum specific gravity at test water temperature	$E = A / [(A+F)-(G-H)]$	2.502	2.504
Correction factor	$R = dw / 0.9970$	1.000	1.000
Corrected Theoretical Maximum Specific Gravity at 25°C	$SG = R \times E$	2.502	2.504
Average Theoretical Maximum Specific Gravity at 25°C	$G_{mm} = (SG\ 1 + SG\ 2)/2$	2.503	
Effective Specific Gravity of Aggregate	G_{se}	2.726	
Effective Specific Gravity of Aggregate [G_{se}] = $(100-P_b) / ((100/G_{mm}) - (P_b/G_b))$ Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³			
Remark:			
Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

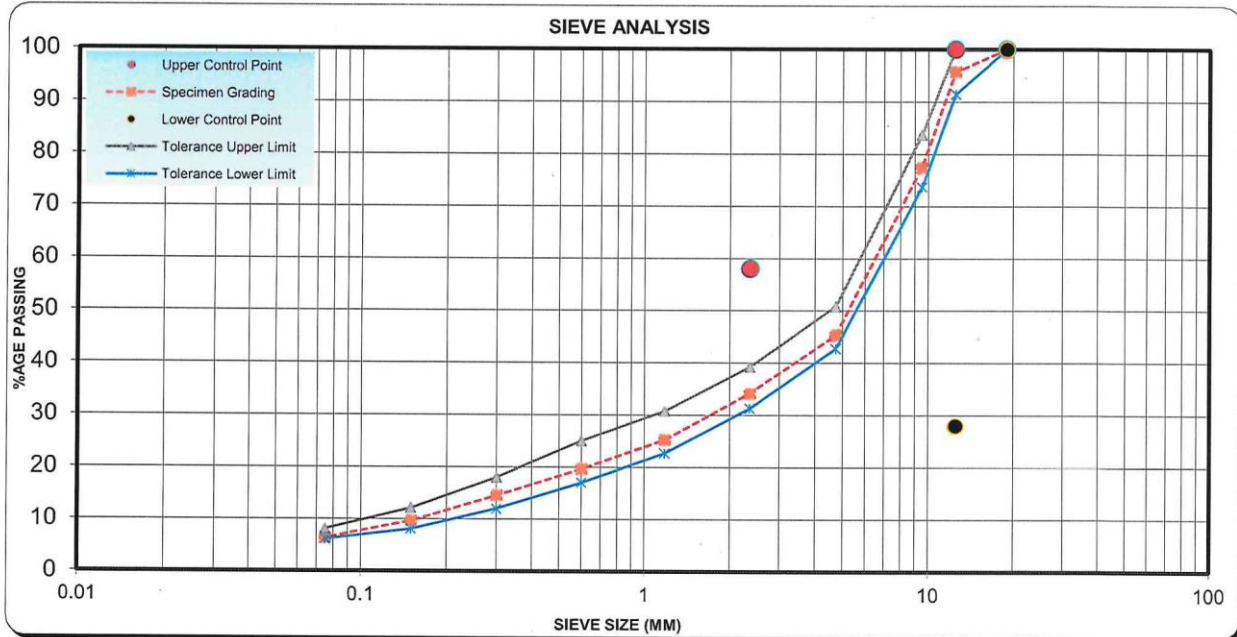
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% SD	Date of Testing	29-02-2025
Proportion:	50:15:30:5		

Trial - A

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION							
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification
							Lower	Upper	
Total Wt. of Mix before test (A) gm	1653	19.0	0.0	0.0	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.1	12.5	65.0	4.2	95.8	96.5	91.5	100	90
Wt. of filter + sediment (C) gm	4	9.50	287.8	18.4	77.4	78.7	73.7	83.7	90
Wt. of Sediment (D) = (C - B) gm	0.9	4.75	501.2	32.1	45.4	46.8	42.8	50.8	-
Wt. of filler after burn (E) gm	18.0	2.36	174.2	11.1	34.2	35.3	31.3	39.3	28
Wt. of Aggregate (F) gm	1544.0	1.18	139.5	8.9	25.3	26.7	22.7	30.7	-
Total Wt. of Aggregate (G) = (D + E+F) gm	1562.9	0.600	88.2	5.6	19.6	21.0	17.0	25.0	-
		0.300	79.6	5.1	14.5	15.0	12.0	18.0	-
Wt. of Bitumen (H) = (A - F) gm	90.1	0.150	75.3	4.8	9.7	10.1	8.1	12.1	-
Bitumen Content	In T.Mix H/A %	5.45	0.075	52.3	3.3	6.4	7.1	6.1	2
	In T. Agg. H/G %	5.76	Pan	99.8	6.4				10



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

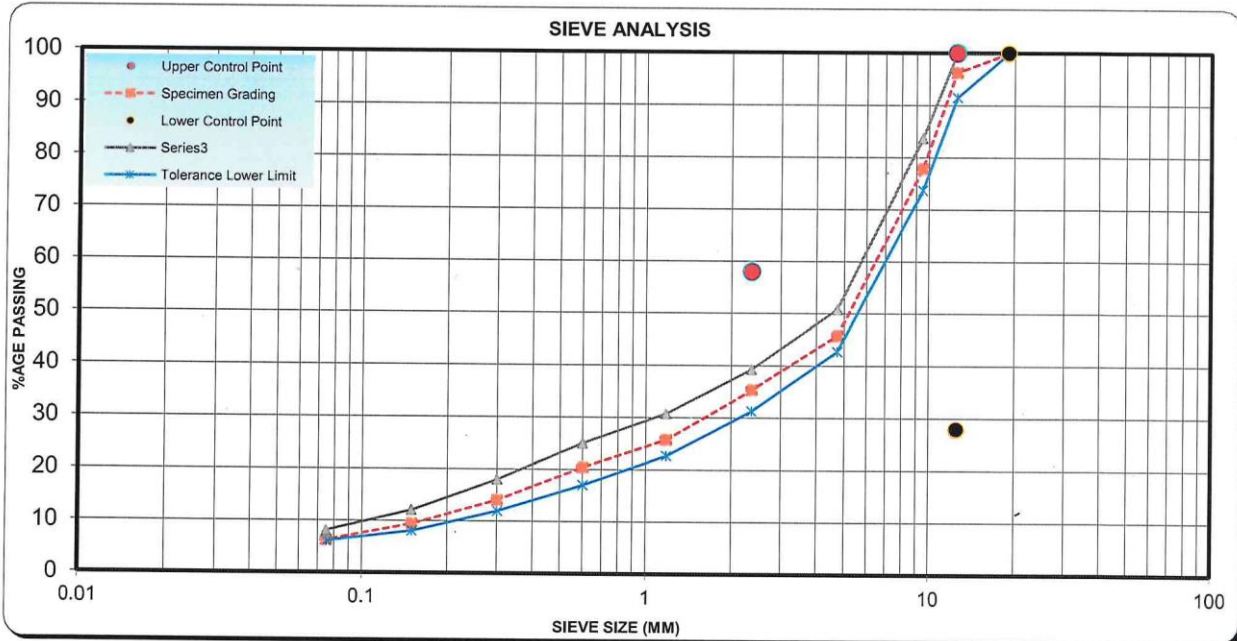
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

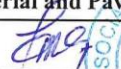
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% SD	Date of Testing	29-02-2025
Proportion:	50:15:30:5		

Trial - B

BITUMEN EXTRACTION TEST			SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
			Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
								Lower	Upper		
Total Wt. of Mix before test (A) gm		1604	19.0	0.0	0.0	100	100	100	100	100	
Wt. of Filter paper before test (B) gm		3.4	12.5	55.5	3.7	96.3	96.5	91.5	100	90	100
Wt. of filter + sediment (C) gm		3.9	9.50	280.2	18.5	77.9	78.7	73.7	83.7		90
Wt. of Sediment (D) = (C – B) gm		0.5	4.75	485.0	32.0	45.9	46.8	42.8	50.8	-	-
Wt. of filler after burn (E) gm		20.0	2.36	158.0	10.4	35.5	35.3	31.3	39.3	28	58
Wt. of Aggregate (F) gm		1496.0	1.18	145.9	9.6	25.8	26.7	22.7	30.7	-	-
Total Wt. of Aggregate (G) = (D + E+F) gm		1516.5	0.600	81.4	5.4	20.5	21.0	17.0	25.0	-	-
			0.300	96.9	6.4	14.1	15.0	12.0	18.0	-	-
Wt. of Bitumen (H) = (A – F) gm		87.5	0.150	69.5	4.6	9.5	10.1	8.1	12.1	-	-
Bitumen Content	In T.Mix H/A %	5.46	0.075	48.6	3.2	6.3	7.1	6.1	8.1	2	10
			Pan	95.5	6.3						
	In T. Agg. H/G %	5.8									



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



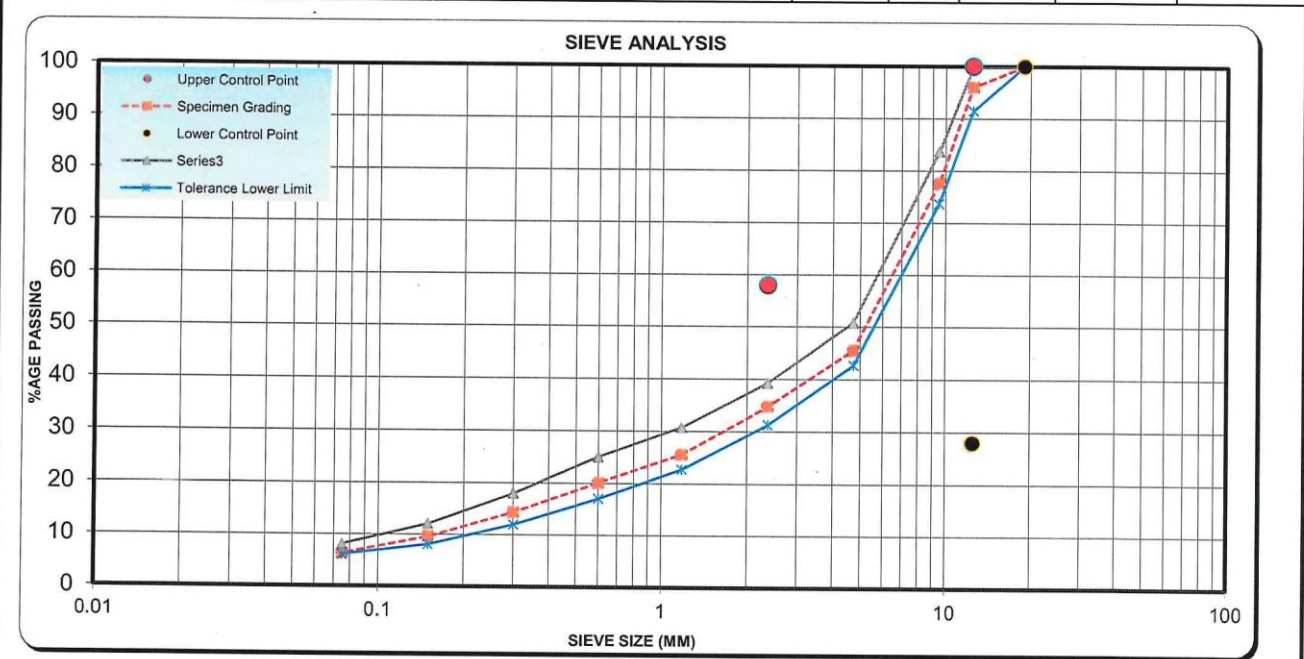
Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE
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ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
 (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% SD	Date of Testing	29-02-2025
Proportion:	50:15:30:5		

Average of Trial A & B											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm	1628.5	19.0	0.0	0.0	100	100	100	100	100		
Wt. of Filter paper before test (B) gm	3.3	12.5	60.3	3.9	96.1	96.5	91.5	100	90	100	
Wt. of filter + sediment (C) gm	4.0	9.50	284.0	18.4	77.6	78.7	73.7	83.7		90	
Wt. of Sediment (D) = (C – B) gm	0.7	4.75	493.1	32.0	45.6	46.8	42.8	50.8	-	-	
Wt. of filler after burn (E) gm	19.0	2.36	166.1	10.8	34.8	35.3	31.3	39.3	28	58	
Wt. of Aggregate (F) gm	1520.0	1.18	142.7	9.3	25.6	26.7	22.7	30.7	-	-	
Total Wt. of Aggregate (G) = (D + E+F) gm	1539.7	0.600	84.8	5.5	20.1	21.0	17.0	25.0	-	-	
		0.300	88.3	5.7	14.3	15.0	12.0	18.0	-	-	
Wt. of Bitumen (H) = (A – F) gm	88.8	0.150	72.4	4.7	9.6	10.1	8.1	12.1	-	-	
Bitumen Content	In T.Mix H/A %	5.45	0.075	50.5	3.3	6.3	7.1	6.1	8.1	2	10
		Pan	97.6	6.3							
	In T. Agg. H/G %	5.8									

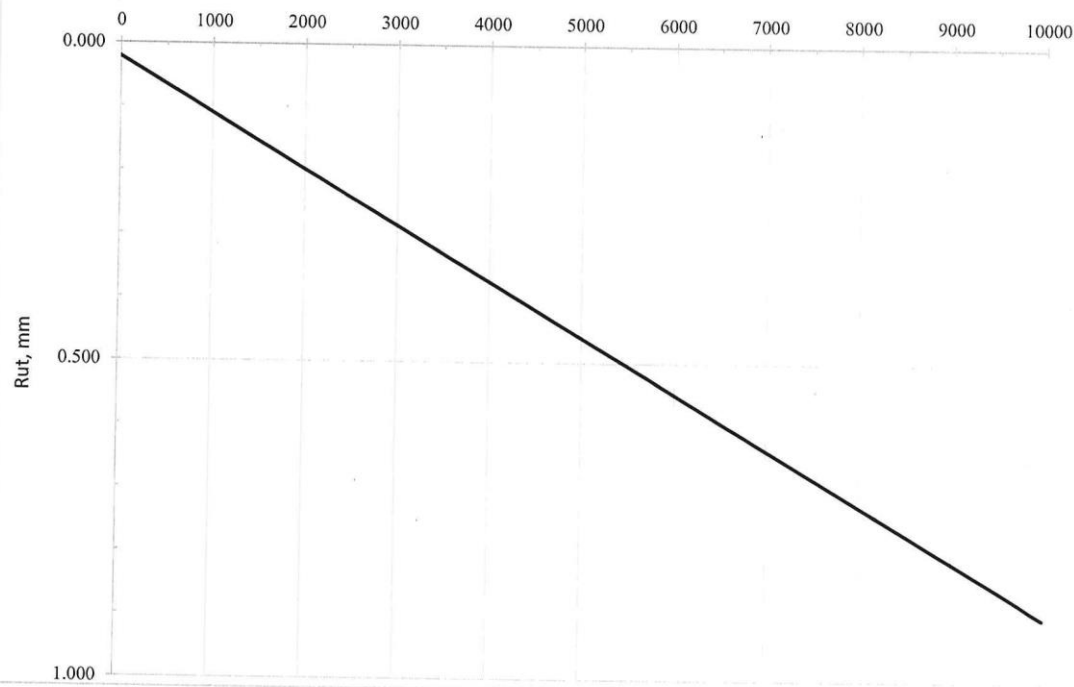
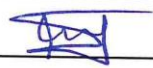


Remarks :

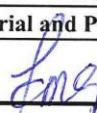
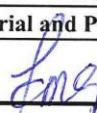
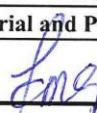
Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	100% Stone Dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,012		
SSD mass	B	gm.	1,015		
Mass in water	C	gm.	573		
Volume	$E = (B-A) - (B - C)$	cm ³	439		
Bulk specific gravity	$G_{mb} = A/E$		2.305		
Maximum specific gravity	G_{mm}		2.492		
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$	%	7.5		
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.23		
Rut at 5,000 passes		mm	0.46		
Rut at 10,000 passes		mm	0.90		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.09		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	1.5		
Maximum Rut depth RD_{Air}		mm	0.9		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
WHEEL-TRACK TESTING EN 12697:22		
Filler	100% Stone Dust	
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)		
Specimen conditioning: In Air		Test temperature: 60 ⁰ C
Conditioning time: +6hr		Test load: 520 N
Passes 		
Remark: _____		
Tested by:		Verified by:
Laboratory Technician		Material & Pavement Engineer
		



Employer	Consultant	Contractor																																				
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE																																				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY) (PHASE-																																						
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283																																						
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs																																						
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa] Saturated 16hrs@ -18°C+ 24hrs @ 60°C+ 2 hrs Duration: 6 min [5 - 10 min] @ 25°C																																						
Filler 100% SD																																						
<table border="1"> <thead> <tr> <th colspan="3">Condition of test specimens</th> <th colspan="3">Saturated/conditioned</th> <th colspan="3">Dry</th> </tr> <tr> <th colspan="3">Sample identification</th> <th>1</th> <th>2</th> <th>3</th> <th>1</th> <th>2</th> <th>3</th> </tr> </thead> <tbody> <tr> <td>Diameter</td> <td>D</td> <td>mm</td> <td>149.0</td> <td>148.6</td> <td>149.3</td> <td>150.0</td> <td>149.7</td> <td>149.8</td> </tr> <tr> <td>Thickness</td> <td>t</td> <td>mm</td> <td>91.3</td> <td>92</td> <td>91.5</td> <td>96.9</td> <td>97.6</td> <td>97.3</td> </tr> </tbody> </table>			Condition of test specimens			Saturated/conditioned			Dry			Sample identification			1	2	3	1	2	3	Diameter	D	mm	149.0	148.6	149.3	150.0	149.7	149.8	Thickness	t	mm	91.3	92	91.5	96.9	97.6	97.3
Condition of test specimens			Saturated/conditioned			Dry																																
Sample identification			1	2	3	1	2	3																														
Diameter	D	mm	149.0	148.6	149.3	150.0	149.7	149.8																														
Thickness	t	mm	91.3	92	91.5	96.9	97.6	97.3																														
VOLUMETRIC																																						
Dry mass in air	A	gm.	3,960	3,897	3,915	3,982	3,922	3,946																														
SSD mass	B	gm.	3,974	3,909	3,920	3,985	3,927	3,950																														
Mass in water	C	gm.	2,281	2,242	2,245	2,295	2,295	2,261																														
Volume	E = B - C	cm ³	1,693	1,667	1,675	1,690	1,632	1,689																														
Bulk specific gravity	G _{mb} = A/E		2.339	2.338	2.337	2.356	2.403	2.336																														
Maximum specific gravity	G _{mm}		2.510	2.510	2.510	2.510	2.510	2.510																														
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%	6.8	6.9	6.9	6.1	4.3	6.9																														
Volume of air voids	V _a = (P _a x E/100)	cm ³	115.3	114.4	115.2	103.5	69.5	116.9																														
TSR																																						
Thickness	t'	mm	91.3	92.0	91.5																																	
SSD mass	B'	gm.	4043	3980	4001																																	
Volume of absorbed water	J' = B' - A	cm ³	83.0	83.0	86.0	-	-	-																														
Saturation	S' = 100 x J'/V _a	%	72.0	72.5	74.6	-	-	-																														
Load	P'	N	22,210.0	20,210.0	21,980.0	27,100.0	28,140.0	26,220.0																														
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa				1,187.0	1,226.1	1,145.2																														
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa	1,039.4	941.1	1,024.3																																	
Average dry strength	Average S ₁	kPa	1,186.1																																			
Average wet strength	Average S ₂	kPa	1,001.6																																			
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%	84.4																																			
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80																																						
Remark:																																						
<table border="1"> <tr> <td> Tested by:  </td> <td> Verified by: Material and Pavement Engineer  </td> </tr> </table>			Tested by: 	Verified by: Material and Pavement Engineer 																																		
Tested by: 	Verified by: Material and Pavement Engineer 																																					



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Data\WC -50\Wearing coarse 3.D003
Template file C:\IPCglobal UTS\003 IT Modulus Test\Templates\UTS003- EHAE ASTM Template.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC-50 Wearing course

Specimen Information

Identification: 100% Stone Dust
Conditioning time: 4
Properties/Comments: AC-50

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	150.0						150.00	
Height (mm)	63.1						63.09	
Cross-sectional area (mm ²): 17671.5								

Test Parameters

Waveshape: Haversine
Loading pulse width (ms): 100
Rest period (ms): 900
Pulse repetition period (ms): 1000
Number of conditioning pulses: 100

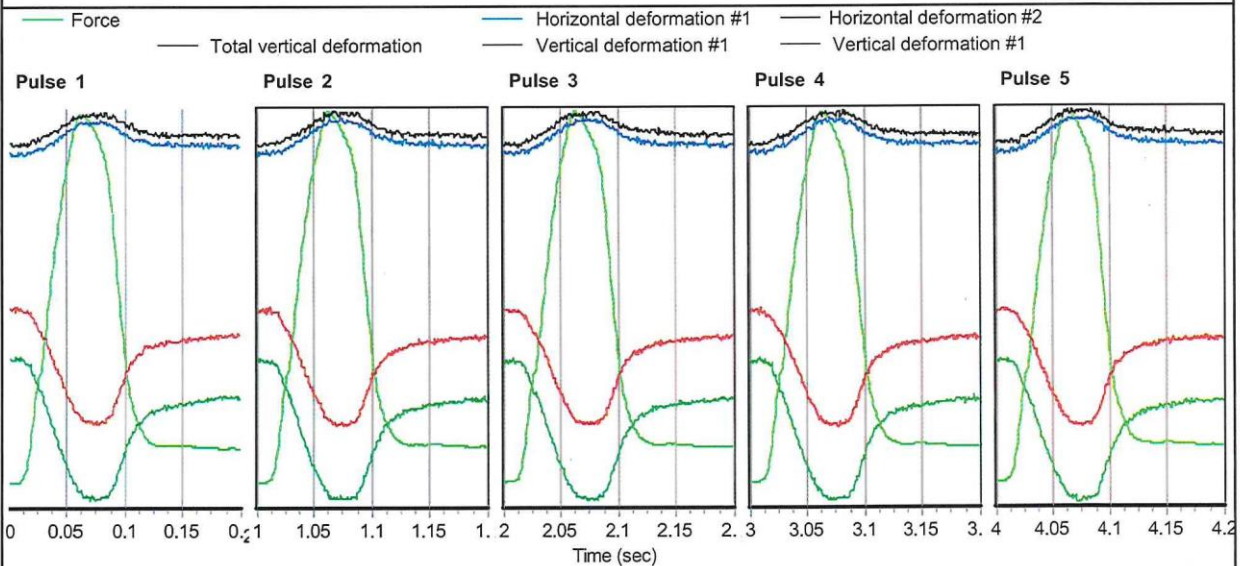
Target temperature (°C): 30
Contact load (N): 50
Peak load (N): 2050

Consta1: 0.233936
I2: -0.780056
I3: 0.307445
I4: -1.069463

Test Results

Test date & time: Saturday, March 29, 2025, at 13:52 Conditioning
pulses: 100
Core temperature (°C): 29.7
Surface temperature (°C): 30.4

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	6390	6453	6580	6381	6454	6452	6452	71.00	1.10
Poisson Ratio #1	0.11	0.13	0.14	0.14	0.14	0.13	0.13	0.01	8.35
Recoverable horizontal deformation #1 (µm)	0.680	0.718	0.710	0.733	0.718	0.712	0.712	0.018	2.461
Recoverable vertical deformation #1 (µm)	-2.340	-2.352	-2.301	-2.367	-2.347	-2.341	-2.341	0.022	-0.947
Resilient Modulus #2 (MPa)	5097	5207	5169	5214	5102	5158	5158	49.82	0.97
Poisson Ratio #2	0.01	0.03	0.03	0.04	0.03	0.03	0.03	0.01	34.52
Recoverable horizontal deformation #2 (µm)	0.643	0.683	0.682	0.686	0.679	0.675	0.675	0.016	2.343
Recoverable vertical deformation #2 (µm)	-2.851	-2.834	-2.841	-2.813	-2.878	-2.844	-2.844	0.021	-0.749
Maximum applied load (N)	855	862	858	856	860	858	858	2.67	0.31
Contact load (N)	48	47	50	48	46	48	48	1.03	2.15



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50 Wearing Coarse
29/03/2025

Specimen Information

Identification: AC -50 Pumice75%-SD25% Dimensions Point 1 Point 2 Point 3 Point 4 Point 5 Point 6 Average Std Dev.
Conditioning time: 2 Diameter (mm) 148.0
Properties/Comments: Height (mm) 63.0
29.03.2025 Cross-sectional area (mm²): 17203.4

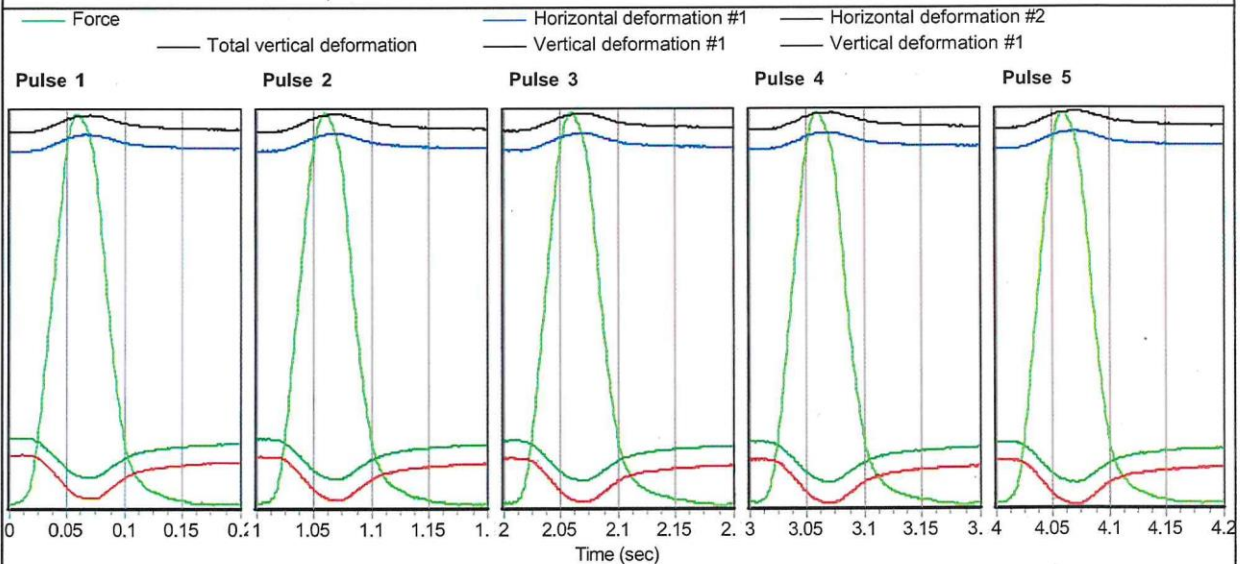
Test Parameters

Waveshape: Haversine Target temperature (°C): 30 Constal1: 0.233936
Loading pulse width (ms): 100 Contact load (N): 50 I2: -0.780056
Rest period (ms): 900 Peak load (N): 1505 I3: 0.307445
Pulse repetition period (ms): 1000 I4: -1.069463
Number of conditioning pulses: 100

Test Results

Test date & time: Friday, February 21, 2025, at 15:35
Conditioning pulses: 100
Core temperature (°C): 31.5
Surface temperature (°C): 27.9

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4595	4600	4547	4550	4573	4573	22.18	0.48	
Poisson Ratio #1	0.28	0.29	0.27	0.27	0.28	0.28	0.01	2.51	
Recoverable horizontal deformation #1 (µm)	2.116	2.136	2.088	2.112	2.125	2.115	0.016	0.758	
Recoverable vertical deformation #1 (µm)	-5.408	-5.412	-5.453	-5.447	-5.433	-5.430	0.018	-0.333	
Resilient Modulus #2 (MPa)	5082	5094	5064	5049	5071	5072	15.62	0.31	
Poisson Ratio #2	0.35	0.34	0.34	0.33	0.35	0.34	0.00	1.41	
Recoverable horizontal deformation #2 (µm)	2.141	2.117	2.140	2.105	2.136	2.128	0.014	0.659	
Recoverable vertical deformation #2 (µm)	-4.979	-4.961	-5.001	-4.988	-4.986	-4.983	0.013	-0.258	
Maximum applied load (N)	1355	1355	1357	1353	1355	1355	1.19	0.09	
Contact load (N)	49	50	51	52	49	50	1.26	2.52	



Stress Strain Test

Data file name: C:\IPCglobal UTS\002 Stress Strain Test\Data\20_03_2025 CI3 -AC-50.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 20/03/2025 16:34:35
Cracking Tolerance Index
100% Stone Dust Project: EHAE
Operator:
Comments: 20-03-2025 CI -AC-50

Specimen Information

Identification:
Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

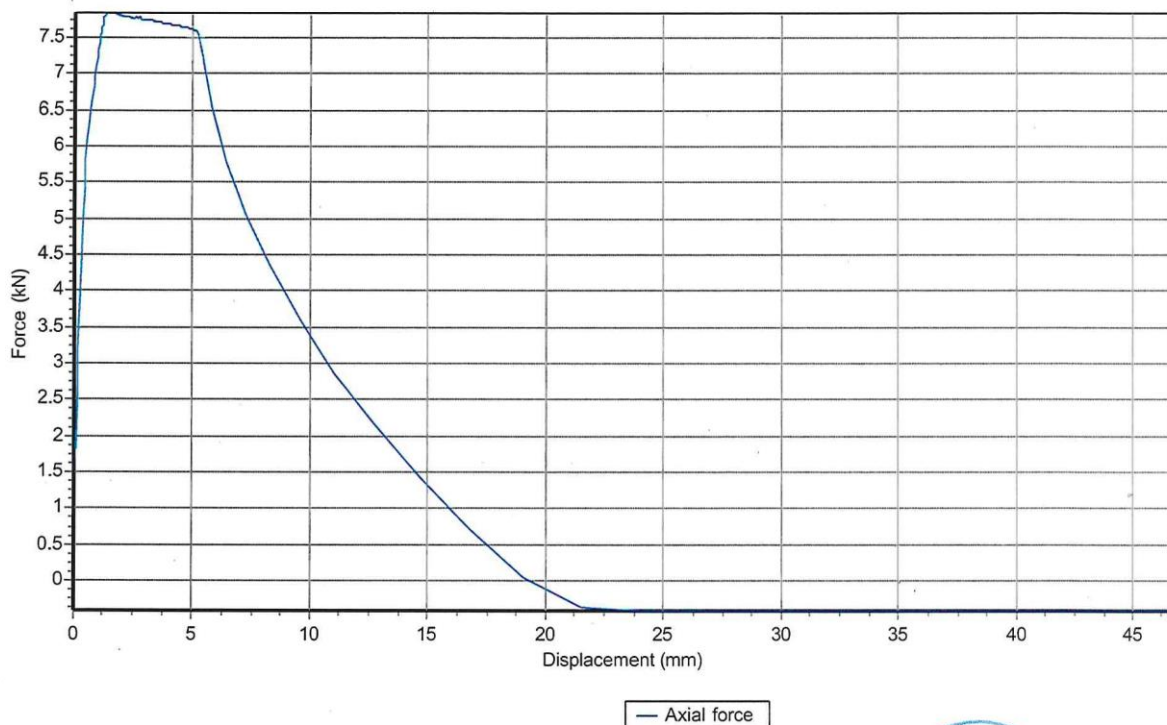
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hh:mm:ss): 00:05:49
Displayed time (hh:mm:ss): 00:05:49
Displayed seconds: 349
Actuator displ. (mm): 46.550
Actuator microstrain: 3.1033E5
Actuator position (mm): 24.478

Axial force (kN): -0.412
Axial stress (kPa): -54.7
Maximum axial force (kN): 7.848
Minimum axial force (kN): 1040.8



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\WC -50 -2.D030
Template file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Templates\UTS030 - EHAE Creep template.P030
Test date & time: 22.03.2025
Project: EHAE
Operator: Ravi
Comments: WC -50 100% Stone Dust

Specimen Information

Identification:
Remarks...

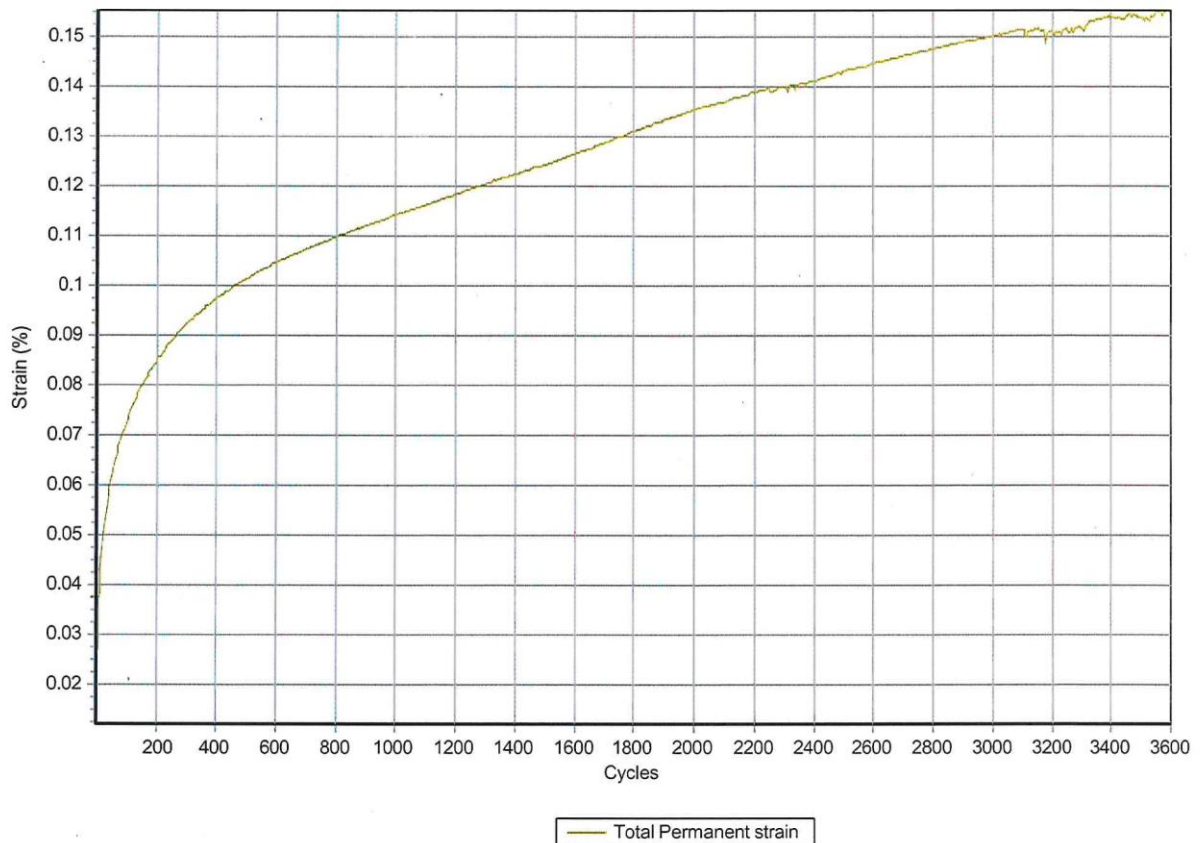
Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	
Cross-sectional area (mm ²): 17671.5								

Set up parameters

Loading function: Square
Target temperature (°C): 50
Upper platen diameter (mm): 96
Preload time (s): 120
Loading pulse width (ms): 1000
Rest period (ms): 1000
Loading cycle width (ms): 2000

Termination cycle count: 3600

	Preload	Axial	Rest period	Permanent deformation limit (mm): 10
Stress (kPa): 10	100	2		
Load (N): 72	724	15		



**Appendix 3 Chemical composition analysis (Complete
silicate analysis), Physical properties and Quality test
of Pumice Volcanic Ash**

	<u>GEOLOGICAL INSTITUTE OF ETHIOPIA</u>			Doc. Number: GLD/F5.10.2	Version No: 1
	<u>Geochemical Laboratory Desk</u>				Page 1 of 1
	<u>Complete Silicate Analysis Report</u>			Effective date:	Nov. 2022
Document Title:-					

Customer Name:- Haimanot Girma

Sample type : - Pumice Volcanic Rock

Sample Preparation:-200 Mesh

Date Submitted ; -06/01/2025

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides.

Analytical Method: LiBO₂ FUSION, HF attack, GRAVIMETRIC, COLORIMETRIC and AAS

Issue Date:-21/01/2025

Request No:- GLD/RQ/785/25

Report No:- GLD/RN/4286/25

Number of Sample: One(01)

Collector's code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	TiO ₂	H ₂ O	LOI	SO ₃	weight of sample
Mermarsa--VA	70.88	8.48	7.80	0.76	0.22	5.14	3.42	0.28	0.04	0.42	0.52	2.49	<0.01	3kg

Note:- This result represent only for the sample submitted to the laboratory.

➤ LOI = Loss on Ignition

Analysts

Fasika Dereje

Abdisa Yohannes

Wedajo Gudisa

Tensae Tarekegn

Bane Abera

Shashe Haile

Checked By



Kindie Kasahun

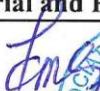
Approved By



Lidet Endeshaw

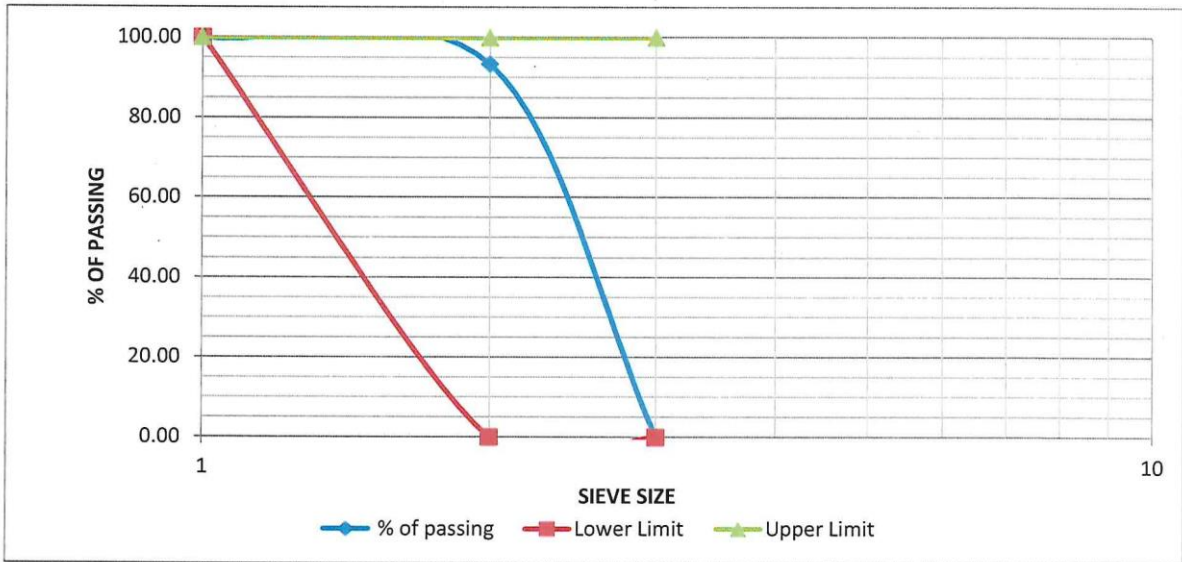


Yohannes Getachew

CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT  LEA-LASA-UNICONE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)				
SPECIFIC GRAVITY OF FINE VOLCANIC ASH (AASHTO T 100)				
Type of Material	Pumice Volcanic Ash	Date of Sampling	4/2/2025	
Location	Km.3+900 RHS	Date of Testing	10/2/2025	
Proposed Use	Asphalt			
Trial No		Trial - 1	Trial - 2	
Pycnometer Bottle Number		1	2	
Weight of Pycnometer (W_f)	(gm)	104.7	104.6	
Weight of Pycnometer +Sample (W_2)	(gm)	139.8	139.7	
Weight of Oven dry sample (W_o) = ($W_2 - W_f$)	(gm)	35.1	35.1	
Weight of Pycnometer +Sample +Water (W_b)	(gm)	367.6	367.7	
Any other Desired Temperature (T_x)	($^{\circ}$ C)	25	25	
Relative Density of Water (D_x)		0.997077	0.997077	
Weight of Pycnometer +Water (W_i)	(gm)	347	347	
Weight of Pycnometer +Water (W_a) = $[(D_x/D_i)(W_i - W_f)] + W_f$	(gm)	347.0	347.0	
Observed Temperature of Water (T_i)	($^{\circ}$ C)	25	25	
Relative Density of Water at Temperature (D_i)		0.997077	0.997077	
Apparent Specific gravity of Filler (S_x) = $W_o / [W_o + (W_a - W_b)]$		2.421	2.429	
Average Apparent Specific Gravity of Stone Filler		2.425		
Remarks :				
Tested by:		Verified by:		
Laboratory Technician		Material and Pavement Engineer		
				



CLIENT  ETHIOPIAN ROAD	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.															
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																	
GRADATION OF FINE AGGREGATE																	
Material Type	Pumice Volcanic Ash	Date of Sampling	4/2/2025														
Sampling Location	Km.3+900 RHS	Date of Testing	10/2/2025														
Weight of Sample: 500 gms.																	
Sieves (mm)	Weight Retained (g)	% Retained	Cum % Retained														
0.15	0.0	0.00	0.00														
0.075	33.4	6.68	6.68														
Pan	466.6	93.32	100.00														
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2">% of passing</th> <th colspan="2">ERA Tech. Spec, Table 8402-2</th> </tr> <tr> <th>Lower Limit</th> <th>Upper Limit</th> </tr> </thead> <tbody> <tr> <td>100.00</td> <td>100</td> <td>100</td> </tr> <tr> <td>93.32</td> <td>0</td> <td>100</td> </tr> <tr> <td>0.00</td> <td>0</td> <td>100</td> </tr> </tbody> </table>				% of passing	ERA Tech. Spec, Table 8402-2		Lower Limit	Upper Limit	100.00	100	100	93.32	0	100	0.00	0	100
% of passing	ERA Tech. Spec, Table 8402-2																
	Lower Limit	Upper Limit															
100.00	100	100															
93.32	0	100															
0.00	0	100															



% OF PASSING

SIEVE SIZE

— % of passing — Lower Limit — Upper Limit

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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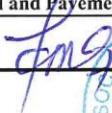


CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR   JMC - LRBCL Joint Venture.	
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway			
SOIL TESTING AND APPROVAL RECORD			
SOURCE	FROM 3+000 to 7+000 FW	SAMPLING DATE	4/2/2025
SAMPLING LOCATION	Km.3+900 RHS		
PURPOSED TO USE	Asphalt		
MATERIAL DESCRIPTION:	Grey Light Weight Vocanic Ash/Pumice		

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	COMPACTION TEST	MDD at 100% 0.670 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557		YES NO ☐ ☐
		OMC 17.3 %			YES NO ☐ ☐
		MDD at 95% 0.637 g/cm ³			YES NO ☐ ☐
2	CBR	CBR at 95% MDD 32.0 %	AASHTO 193/ ASTM D 1883	> 5	YES NO ☒ ☐
		SWELL 0.21 %		< 2	YES NO ☒ ☐
3	SOIL PLASTICITY	LIQUID LIMIT (LL) 0.0 %	AASHTO T-89/90/ ASTM D 4318	< 60	YES NO ☒ ☐
		PLASTIC LIMIT (PL) 0.0 %	AASHTO T-89/90/ ASTM D 4318		YES NO ☐ ☐
		PLASTICITY INDEX(PI) 0.0 %	AASHTO T-89/90/ ASTM D 4318	< 30	YES NO ☒ ☐
4	SOIL CHARACTER	SOIL CLASSIFICATION A-1-b	AASHTO M 145		YES NO ☐ ☐
5	ORGANIC CONTENT	SOIL CLASSIFICATION NA	AASHTO T-267-86	< 3	YES NO ☐ ☐

Note: Attach individual test records and data sheet

Remarks:

Tested by: Laboratory Technician 	Verified by: Material and Payment Engineer 
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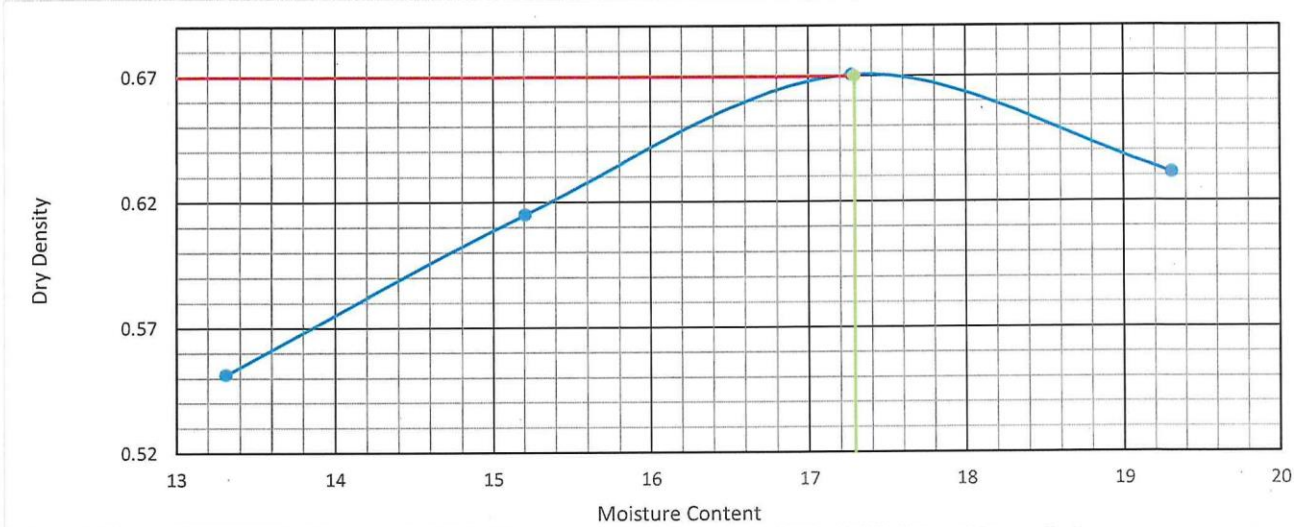


CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR   JMC - LRBCL Joint Venture.
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ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
 (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

MAXIMUM DRY DENSITY AND MOISTURE CONTENT
 (AASTHO T-180)

Source :	FROM 3+000 to 7+000 FW			Propose Used	Asphalt	
Location:	Km.3+900 RHS			Date of Testing:	10/2/2025	
Material Discription	Grey Light Weight Vocanic Ash/Pumice			Date of Sampling:	4/2/2025	
Description	Test I	Test II	Test III	Test IV	Test V	
Density Determination						
Water Added %	10%	12%	14%	16%		
Mass of mould + Wet Soil (g)	7892	8070	8235	8165		
Mass of mould, W5 (g)	6565	6565	6565	6565		
Mass of wet soil, W7=W6-W5 (g)	1327	1505	1670	1600		
Volume of mould, V (cc)	2124	2124	2124	2124		
Bulk density, $y_m = [(W7-W6)/V]$ g/cc	0.625	0.709	0.786	0.753		
Moisture Content Determination					NMC	
Container no	K-60	M-90	T-100	P-30		Z-80
Mass of container + wet soil, W1 (g)	172.60	176.00	169.90	169.70		181.90
Mass of container + oven dry soil, W2 (g)	155.68	156.56	149.00	146.88		177.00
Mass of Water (g) W3=W1-W2	16.92	19.44	20.90	22.82		4.90
Mass of container, W4 (g)	28.60	28.70	28.00	28.70		27.60
Mass of Dry Soil (g) W5 = W2-W4	127.08	127.86	121.00	118.18		149.40
Moisture Content (%) W6= W3/W5*100	13.31	15.20	17.27	19.31		3.28
Dry density, $y_d = y_m/(100+W6)*100$ (g/cc)	0.551	0.615	0.670	0.631		3.28



MDD:	0.670 (gm/cc)	OMC:	17.3 %
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Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBC Joint Venture.
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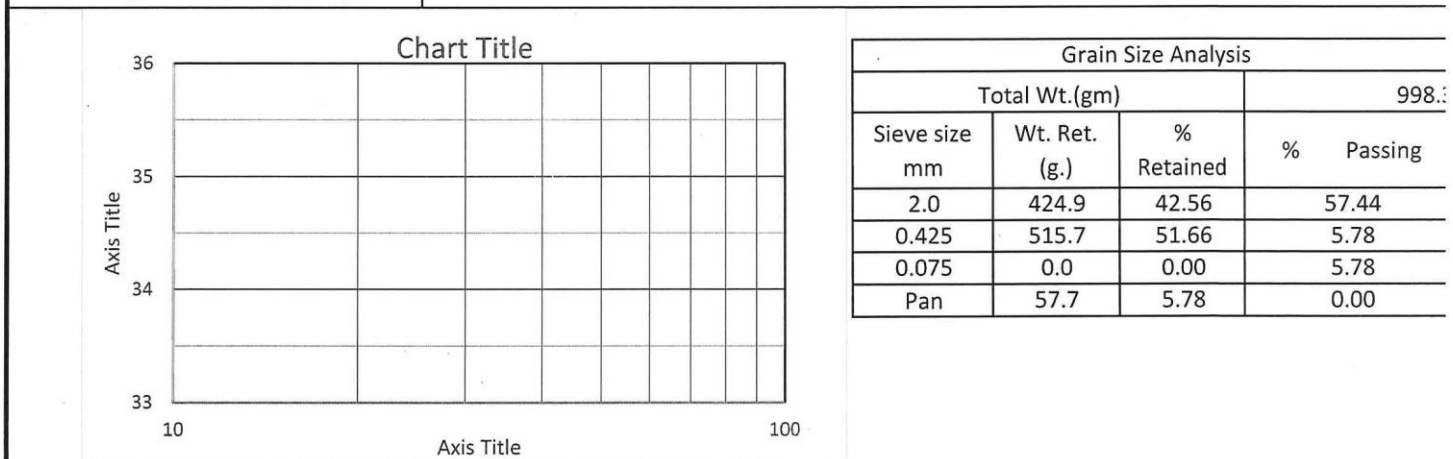
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

ATTERBERG LIMITS

(AASHTO T-89/90)

Source :	FROM 3+000 to 7+000 FW	Date of Sampling:	4/2/2025
Location:	Km.3+900 RHS	Date of Testing:	10/2/2025
Material Discription	Grey Light Weight Vocanic Ash/Pumice	Tested By:	

Description	LIQUID LIMIT				PLASTIC LIMIT		
	Test I	Test II	Test III	Test IV	Test I	Test II	Avg.
No of blows/Penetration (mm)	N/A						
Container No							
Container + Wet soil, W1 (g)							
Container + Dry soil, W2 (g)							
Weight of Container (g)							
Weight of water, W4= W1-W2 (g)							
Weight of oven dry sample, W5=W3 - W1 (g)							
Water content percentage, 100x(W4/W5)							



LL	PL	PI	Soil Class
0.00	0.00	0.00	A-1-b

Comments:-

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT   LEA-LASA-UNICONE		CONTRACTOR   JMC PROJECTS (I) LTD.						
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)										
Source :	FROM 3+000 to 7+000 FW		Date of Sampling:	4/2/2025						
Location:	Km.3+900 RHS		Date of Soaking:	12/2/2025						
Propose Used	Asphalt		Date of Testing:	16/2/2025						
Material Discription	Grey Light Weight Vocanic Ash/Pumice									
DENSITY DETERMINATION										
SOAKING CONDITION	10 Blows		30 Blows		65 Blows					
	Before	After	Before	After	Before After					
MOLD NUMBER	M-13		M-19		M-33					
WEIGHT OF MOLD	6985	6985	6900	6900	7180 7180					
WEIGHT OF SOIL + MOLD	8210	9010	8270	9100	8720 9410					
WEIGHT OF SOIL	1225	2025	1370	2200	1540 2230					
VOLUME OF MOLD	2243	2243	2243	2243	2243 2243					
WET DENSITY OF SOIL	0.55	0.90	0.61	0.98	0.69 0.99					
DRY DENSITY OF SOIL	0.47	0.75	0.52	0.82	0.59 0.83					
MOISTURE DETERMINATION										
CONTAINER NUMBER	Z-88	C-40	T-60	T-60	M-15 T-100					
WET SOIL + CONTAINER (g)	157.40	234.00	144.70	248.60	139.70 211.80					
DRY SOIL + CONTAINER (g)	138.80	198.10	127.10	211.80	123.50 181.10					
WEIGHT OF WATER (g)	18.60	35.90	17.60	36.80	16.20 30.70					
WEIGHT OF CONTAINER (g)	27.20	27.00	28.30	28.30	27.60 28.10					
WEIGHT OF DRY SOIL (g)	111.60	171.10	98.80	183.50	95.90 153.00					
MOISTURE CONTENT (%)	16.67	20.98	17.81	20.05	16.89 20.07					
AVG. MOISTURE CONTENT (%)	18.82		18.93		18.48					
Ring Factor	0.03162									
PENETRATION TEST DATA										
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)
0		0.0	0		0.0	0		0.0	0.0	
0.64		9.0	0.3		13.0	0.4		15.0	0.5	
1.27		21.0	0.7		32.0	1.0		36.0	1.1	
1.96		35.0	1.1		60.0	1.9		65.0	2.1	
2.54	13.54	49.0	1.5	1.7	90.0	2.8	3.2	93.0	2.9	3.4
3.18		61.0	1.9		120.0	3.8		125.0	4.0	
3.81		78.0	2.5		149.0	4.7		155.0	4.9	
4.45		89.0	2.8		175.0	5.5		185.0	5.8	
5.08	20.22	97.0	3.1	2.8	184.0	5.8	5.2	212.0	6.7	5.8
7.62		105.0	3.3		196.0	6.2		223.0	7.1	
10.16		112.0	3.5		204.0	6.5		231.0	7.3	
12.7		121.0	3.8		215.0	6.8		242.0	7.7	
SWELL READING (INITIAL)	0.23		0.22		0.04					
SWELL READING (FINAL)	0.28		0.35		0.60					
PERCENTAGE SWELL	0.04		0.11		0.48					
CBR @ 2.54 mm	12.6		23.6		25.1					
CBR @ 5.08 mm	13.8		25.7		28.7					




CLIENT



ETHIOPIAN ROAD AUTHORITY

CONSULTANT



LEA-LASA-UNICONE

CONTRACTOR



JMC PROJECTS (I) LTD.

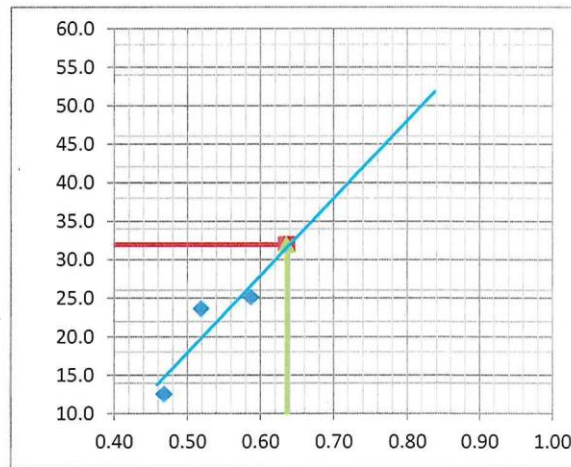
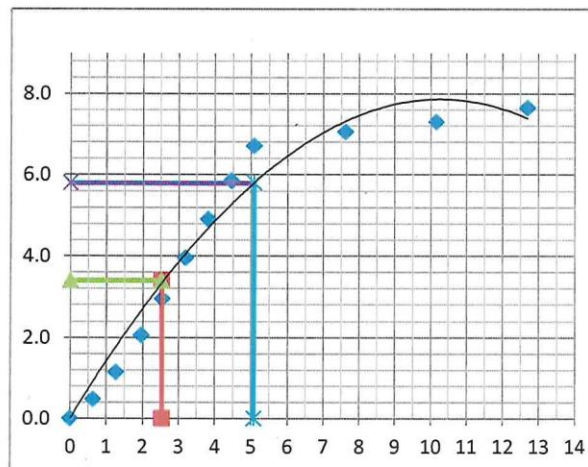
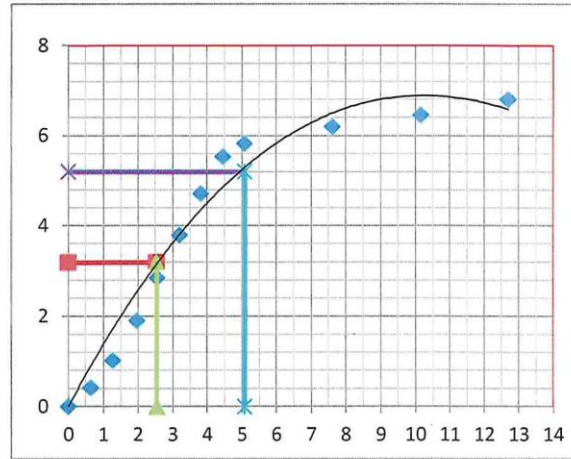
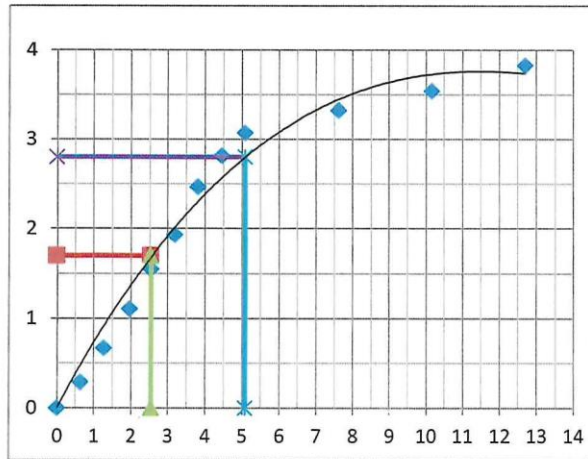
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

CALIFORNIA BEARING RATIO TEST

(AASHTO T 193)

Source :	FROM 3+000 to 7+000 FW	Date of Sampling:	4/2/2025
Location:	Km.3+900 RHS	Date of Soaking:	12/2/2025
Propose Used	Asphalt	Date of Testing:	16/2/2025
Material Discription	Grey Light Weight Vocanic Ash/Pumice		

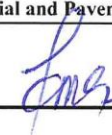
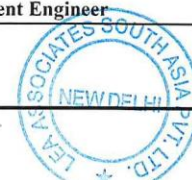
MDD (gm/cc)	0.670	OMC (%)	17.29
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Density @ 95% Compaction (gm/cc)	0.637
CBR @ 95% Compaction (%)	32.0
Swell @ 95% Compaction (%)	0.21

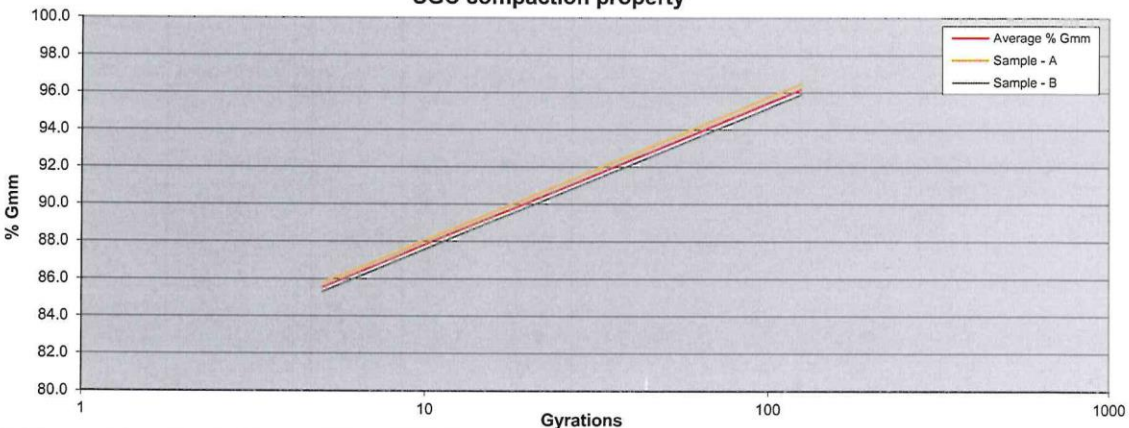


**Appendix 4 Volumetric properties and Performance
tests of asphalt mixture with 25% Pumice and 75%
Stone Dust or Filler**

Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		  JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler	25% PU and 75% SD							
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.395	NA								
	AV	3.8	3 - 6								
	VMA(%)	14.01	≥ 13								
	VFB(%)	72.7	65 - 75								
	N _{ini} (%)	87.5	≤ 89								
	N _{des} (%)	96.2	96% ± 1%								
	N _{max} (%)	97.7	≤ 98%								
MTD	G _{mm}	2.490	NA								
DUST TO BINDER RATIO		1.20	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.95	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075	
Specimen Grading	100.0	97.7	62.2	41.1	31.0	21.1	14.9	10.3	7.0	5.3	
JMF	100.0	98.5	62.1	41.0	31.0	21.0	15.1	10.5	7.3	5.6	
Tolerance from JMF L. Limit	100	93.5	57.1	37	27	17	11.1	7.5	5.3	4.6	
Tolerance from JMF U. Limit	100	100	67.1	45	35	25	19.1	13.5	9.3	6.6	
Upper Control Point	100	100	-	-	49	-	-	5	-	8	
Lower Control Point	100	90	-	-	23	-	-	19	-	2	
REMARK:											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
						 					

Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course			Agg Source	Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix			Bitumen Grade	40/50			
Filler	25% PU and 75% SD			Specific Gravity	1.0285			
Date of Testing	16-02-2025			Number of Gyration	125 @ N _{des}			
Mixing Temperature (°C)		135-165		Compaction Temperature (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.724	85.8	127.853	85.3	85.6			
9 [Nini]	124.894	87.8	125.020	87.2	87.5			
10	124.400	88.1	124.525	87.6	87.8			
20	121.244	90.4	121.366	89.9	90.1			
30	119.471	91.7	119.591	91.2	91.5			
40	118.245	92.7	118.363	92.1	92.4			
50	117.31	93.4	117.428	92.9	93.2			
70	115.929	94.5	116.046	94.0	94.3			
90	114.918	95.4	115.034	94.8	95.1			
110	114.124	96.0	114.239	95.5	95.8			
125 [Ndes]	113.624	96.5	113.738	95.9	96.2			
G _{mb} Gyro		2.339	G _{mb} Gyro		2.334	Average G _{mb} Gyro		2.337
G _{mb}		2.398	G _{mb}		2.392	Average G _{mb}		2.395
G _{mm}		2.486	G _{mm}		2.495	Average G _{mm}		2.490
G _{sb}		2.654	G _{sb}		2.654	Average G _{sb}		2.654
G _{sa}		2.736	G _{sa}		2.736	G _{sa}		2.736
% AC	4.70							
Aggreg. Frac.	95.3		Determination of measured Bulk Specific Gravity					
Gsb	2.654		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Pb	1.029		Sample - A	4618	4627	2701	1926.0	2.398
Volumetrics	Value	Spec.	Sample - B	4607	4618.0	2692	1926.0	2.392
%Gmm@Ni	87.5	< 89%						
%Gmm@Ndes	96.17							
% Air void	3.8	3-6%						
% VMA	14.01	Min 13%						
%VFA	72.67	65-75						

SGC compaction property

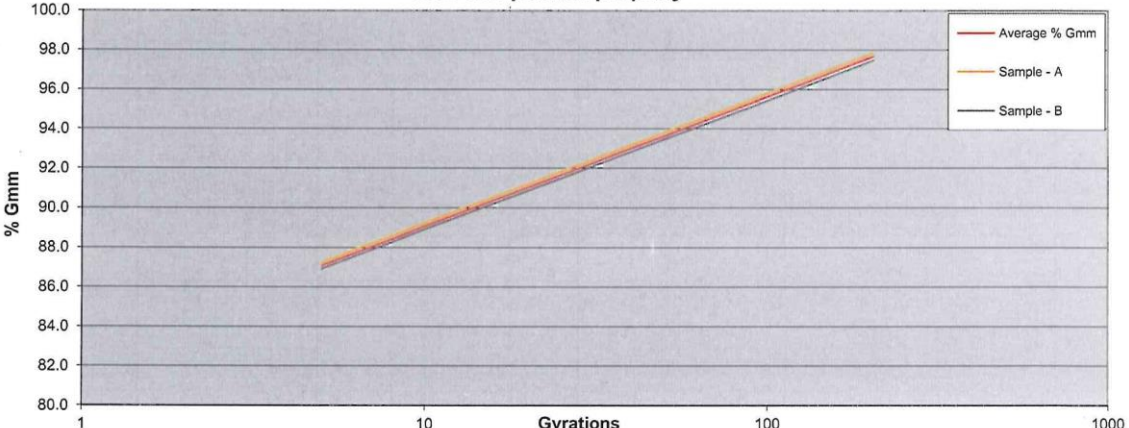


Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	

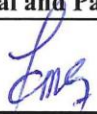


Employer			Consultant			Contractor																																		
 Ethiopian Roads Administration (ERA)			  LEA JV with Unicon P.L.C, Ethiopia			  JMC-LRBCL JOINT VENTURE																																		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																																								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS																																			
Source of Mix	Lab-Mix		Bitumen Grade		40/50																																			
Filler	25% PU and 75% SD		Specific Gravity		1.0285																																			
Date of Testing	16-02-2025		Number of Gyration		205 @ N _{max}																																			
Mixing Temperature (°C)		135-160		Compaction Temperature (°C)		135-150																																		
Sample - A			Sample - B			Average % Gmm																																		
No of Gyration	Height	% Gmm		Height	% Gmm																																			
5	126.071	87.3		126.065	86.9			87.1																																
9 [Nini]	123.696	88.9		123.690	88.6			88.8																																
10	123.280	89.2		123.273	88.9			89.1																																
20	120.609	91.2		120.603	90.9			91.0																																
30	119.100	92.4		119.094	92.0			92.2																																
40	118.052	93.2		118.046	92.8			93.0																																
50	117.251	93.8		117.246	93.5			93.6																																
70	116.065	94.8		116.059	94.4			94.6																																
90	115.194	95.5		115.188	95.1			95.3																																
110	114.508	96.1		114.503	95.7			95.9																																
125 [Ndes]	114.076	96.4		114.070	96.1			96.3																																
150	113.464	97.0		113.458	96.6			96.8																																
175	112.952	97.4		112.947	97.0			97.2																																
200	112.513	97.8		112.507	97.4			97.6																																
205 [Nmax]	112.432	97.9		112.426	97.5			97.7																																
	G _{mb} Gyro	2.345		G _{mb} Gyro	2.350		Average G _{mb} Gyro	2.348																																
	G _{mb}	2.433		G _{mb}	2.431		Average G _{mb}	2.432																																
	G _{mm}	2.486		G _{mm}	2.495		Average G _{mm}	2.490																																
	G _{sb}	2.654		G _{sb}	2.654		Average G _{sb}	2.654																																
	G _{sa}	2.736		G _{sa}	2.736		G _{sa}	2.736																																
<table border="1"> <thead> <tr> <th colspan="2">% AC</th> <th colspan="6">Determination of measured Bulk Specific Gravity</th> </tr> <tr> <th>Aggreg. Frac.</th> <th></th> <th>Mix Ref.</th> <th>Wt. air</th> <th>wax+ spc in air</th> <th>wax+spc in water</th> <th>Volume</th> <th>Gmb</th> </tr> </thead> <tbody> <tr> <td>Gsb</td> <td>2.654</td> <td>Sample - A</td> <td>4595</td> <td>4600</td> <td>2711</td> <td>1889.0</td> <td>2.433</td> </tr> <tr> <td>Pb</td> <td>1.029</td> <td>Sample - B</td> <td>4583</td> <td>4589.0</td> <td>2704</td> <td>1885.0</td> <td>2.431</td> </tr> </tbody> </table>									% AC		Determination of measured Bulk Specific Gravity						Aggreg. Frac.		Mix Ref.	Wt. air	wax+ spc in air	wax+spc in water	Volume	Gmb	Gsb	2.654	Sample - A	4595	4600	2711	1889.0	2.433	Pb	1.029	Sample - B	4583	4589.0	2704	1885.0	2.431
% AC		Determination of measured Bulk Specific Gravity																																						
Aggreg. Frac.		Mix Ref.	Wt. air	wax+ spc in air	wax+spc in water	Volume	Gmb																																	
Gsb	2.654	Sample - A	4595	4600	2711	1889.0	2.433																																	
Pb	1.029	Sample - B	4583	4589.0	2704	1885.0	2.431																																	
Mix property		Units	Result			Criteria																																		
% G _{mm} at N _{max}		%	97.7			Max 98																																		

SGC compaction property



Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer  
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Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041					
Source of Mix	Lab-Mix	Filler	25% PU and 75% SD		
Material Description:	AC-60 Binder course	Bitumen by Wt. of Mix	5.40%		
Grade of Bitumen	40/50	Date of Testing	17-02-2025		
Testing Temp.	25 °c				
SG of Asphalt binder [G_b] = 1.0285 % of binder from extraction [P_{bo}], % = 4.7					
Test No			Test 1	Test 2	
Mass of dry sample in air	A	gm.	2262	2325	
Mass of container filled with water at test temperature	F	gm.	9138.0	9138.0	
Mass of container filled with sample and water at test temperature	G	gm.	10490	10531	
Temperature of test water	T	°C	25	25	
Correction for thermal expansion of bitumen	H	gm.	0.0	0.0	
Theoretical Maximum specific gravity at test water temperature	$E = A / [(A+F)-(G-H)]$		2.486	2.495	
Correction factor	$R = d_w / 0.9970$		1.000	1.000	
Corrected Theoretical Maximum Specific Gravity at 25°C	$SG = R \times E$		2.486	2.495	
Average Theoretical Maximum Specific Gravity at 25°C	$G_{mm} = (SG\ 1 + SG\ 2)/2$		2.490		
Effective Specific Gravity of Aggregate	G_{se}		2.678		
Effective Specific Gravity of Aggregate [G_{sc}] = $(100-P_b) / ((100/G_{mm}) - (P_b/G_b))$ Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen d_w - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³					
Remark: 					
Tested by:			Verified by:		
Laboratory Technician			Material and Pavement Engineer		
			 		

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBL JOINT VENTURE

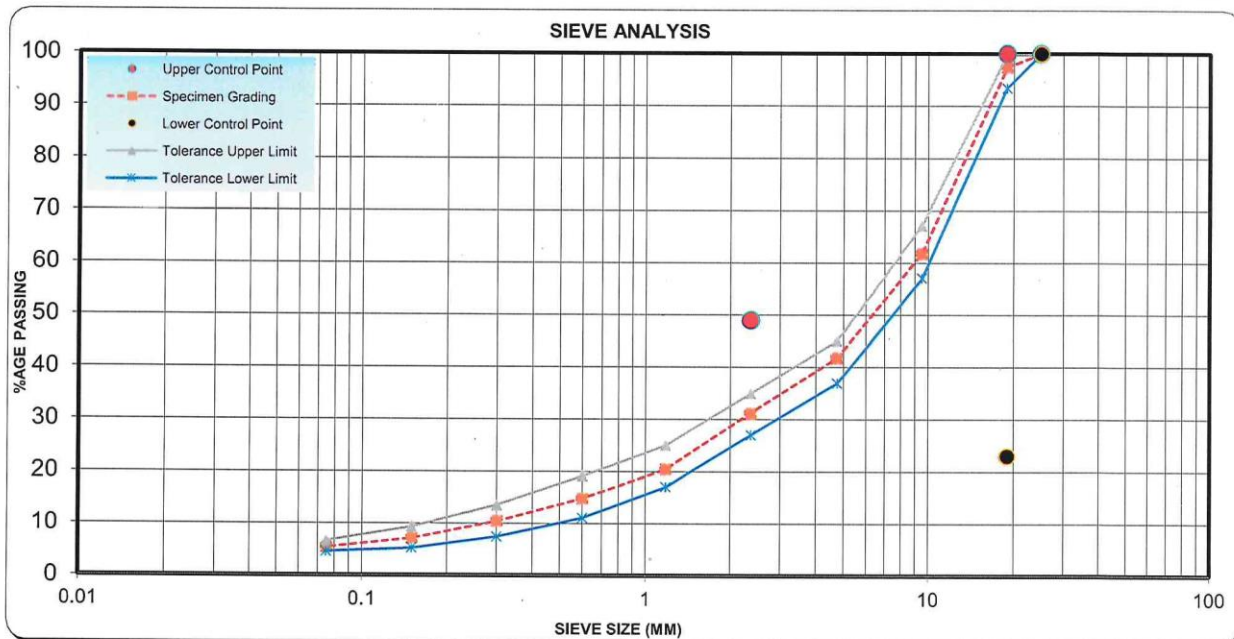
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Sampled by	Jointly	Filler	25% PU and 75% SD
Proportion:	25:32:8.32:3	Date of Testing	16-02-2025

Trial - A

BITUMEN EXTRACTION TEST			SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
			Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
								Lower	Upper		
Total Wt. of Mix before test (A) gm		1693.4	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		13.2	19.0	40.3	2.5	97.5	98.5	93.5	100	90	100
Wt. of filter + sediment (C) gm		13.9	9.50	574.2	35.7	61.8	62.1	57.1	67.1		
Wt. of Sediment (D) = (C – B) gm		0.7	4.75	322.3	20.0	41.8	41.0	37.0	45.0	-	-
Wt. of filler after burn (E) gm		10.0	2.36	170.6	10.6	31.2	31.0	27.0	35.0	23	49
Wt. of Aggregate (F) gm		1599.3	1.18	173.6	10.8	20.4	21.0	17.0	25.0	-	-
Total Wt. of Aggregate (G) = (D + E+F) gm		1610.0	0.600	90.7	5.6	14.8	15.1	11.1	19.1	-	-
			0.300	70.3	4.4	10.4	10.5	7.5	13.5	5	19
Wt. of Bitumen (H) = (A – F) gm		83.4	0.150	52.4	3.3	7.2	7.3	5.3	9.3	-	-
Bitumen Content	In T.Mix H/A %	4.93	0.075	28.3	1.8	5.4	5.6	4.6	6.6	2	8
			Pan	87.3	5.4						
	In T. Agg. H/F %	5.2									



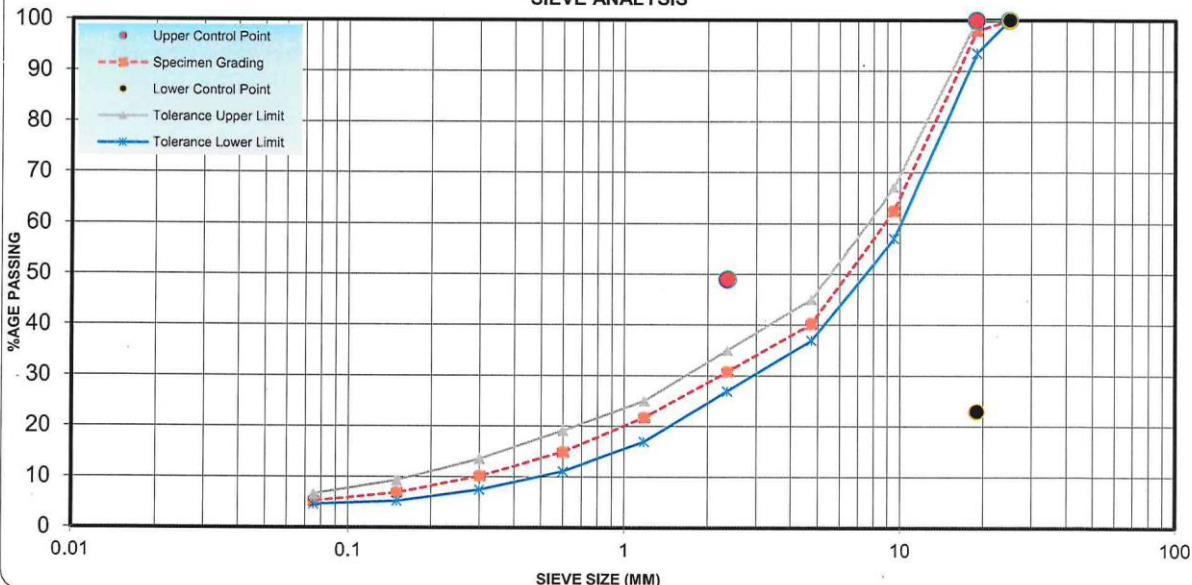
Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor  JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164											
Source of Mix		Lab-Mix		Source of Material							
Material Description		Hot Mix Asphalt Binder Course Mixture		Grade of Bitumen							
Sampled by		Jointly		Filler							
Proportion:		25:32:8:32.3		Date of Testing							
				20-02-2025							
Trial - B											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm	1666.8	25.0	0.0	0.0	100	100	100	100	100	100	
Wt. of Filter paper before test (B) gm	13.1	19.0	32.5	2.1	97.9	98.5	93.5	100	90	100	
Wt. of filter + sediment (C) gm	13.9	9.50	561.1	35.4	62.5	62.1	57.1	67.1			
Wt. of Sediment (D) = (C - B) gm	0.8	4.75	352.2	22.2	40.3	41.0	37.0	45.0	-	-	
Wt. of filler after burn (E) gm	12.0	2.36	149.5	9.4	30.9	31.0	27.0	35.0	23	49	
Wt. of Aggregate (F) gm	1571.2	1.18	144.4	9.1	21.7	21.0	17.0	25.0	-	-	
Total Wt. of Aggregate (G) = (D + E + F) gm	1584.0	0.600	107.6	6.8	14.9	15.1	11.1	19.1	-	-	
		0.300	75.1	4.7	10.2	10.5	7.5	13.5	5	19	
Wt. of Bitumen (H) = (A - F) gm	82.8	0.150	52.2	3.3	6.9	7.3	5.3	9.3	-	-	
Bitumen Content	In T.Mix H/A %	4.97	0.075	26.5	1.7	5.2	5.6	4.6	6.6	2	8
			Pan	82.9	5.2						
	In T. Agg. H/F %	5.3									

SIEVE ANALYSIS



Remarks :

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

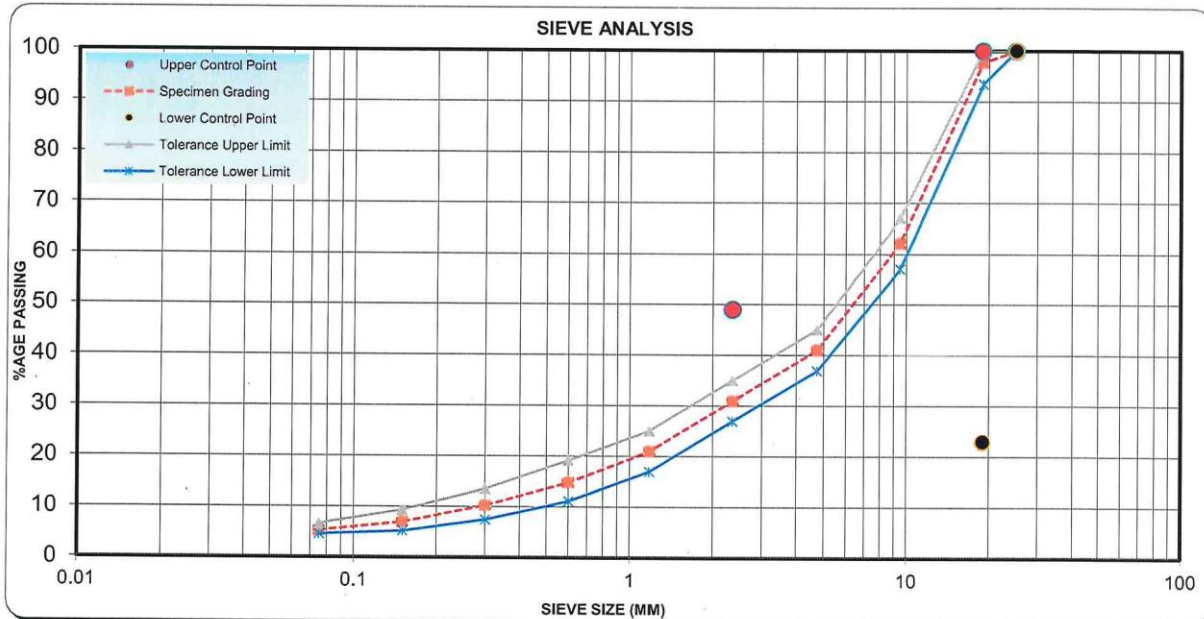
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

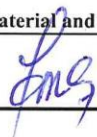
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Sampled by	Jointly	Filler	25% PU and 75% SD
Proportion:	25:32:8.32:3	Date of Testing	20-02-2025

Average of Trial A & B

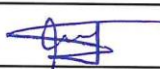
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm	1680.1	25.0	0.0	0.0	100	100	100	100	100	100	
Wt. of Filter paper before test (B) gm	13.15	19.0	36.4	2.3	97.7	98.5	93.5	100	90	100	
Wt. of filter + sediment (C) gm	13.9	9.50	567.7	35.5	62.2	62.1	57.1	67.1			
Wt. of Sediment (D) = (C – B) gm	0.75	4.75	337.3	21.1	41.1	41.0	37.0	45.0	-	-	
Wt. of filler after burn (E) gm	11	2.36	160.1	10.0	31.0	31.0	27.0	35.0	23	49	
Wt. of Aggregate (F) gm	1585.25	1.18	159.0	10.0	21.1	21.0	17.0	25.0	-	-	
Total Wt. of Aggregate (G) = (D + E+F) gm	1597.0	0.600	99.2	6.2	14.9	15.1	11.1	19.1	-	-	
		0.300	72.7	4.6	10.3	10.5	7.5	13.5	5	19	
Wt. of Bitumen (H) = (A – F) gm	83.1	0.150	52.3	3.3	7.0	7.3	5.3	9.3	-	-	
Bitumen Content	In T.Mix H/A %	4.95	0.075	27.4	1.7	5.3	5.6	4.6	6.6	2	8
		Pan	85.1	5.3							
	In T. Agg. H/F %	5.2									

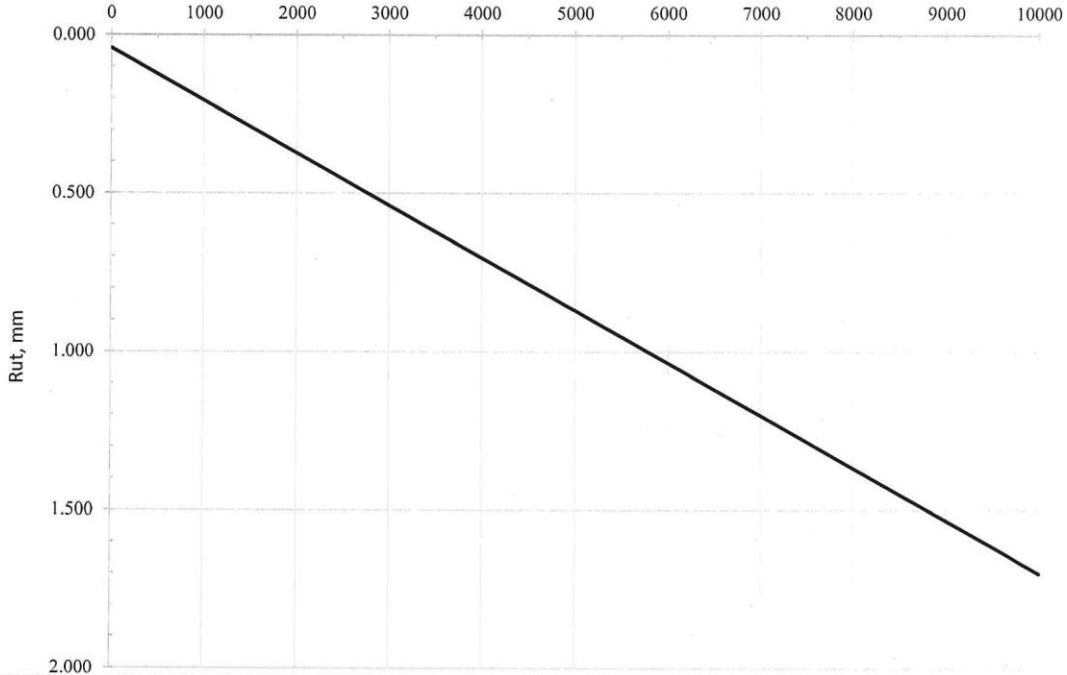
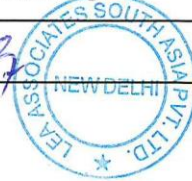


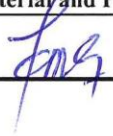
Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	25% Pumice Mix with 75% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,032		
SSD mass	B	gm.	1,036		
Mass in water	C	gm.	587		
Volume	$E = (B - A) - (B - C)$		cm ³	445	
Bulk specific gravity	$G_{mb} = A/E$			2.319	
Maximum specific gravity	G_{mm}			2.490	
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$		%	6.9	
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.43		
Rut at 5,000 passes		mm	0.87		
Rut at 10,000 passes		mm	1.70		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.17		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	2.8		
Maximum Rut depth RD_{Air}		mm	1.7		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
WHEEL-TRACK TESTING EN 12697:22		
Filler	25% Pumice Mix with 75% Stone dust	
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)		
Specimen conditioning: In Air		Test temperature: 60°C
Conditioning time: +6hr		Test load: 520 N
Passes  Remark:		
Tested by:		Verified by:
Laboratory Technician		Material & Pavement Engineer
		 

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283		
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs		
Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa]		
Specimen conditioning: Saturated 16hrs@ -18°C+ 24hrs @ 60°C +2 hrs @ 25°C Duration: 6 min [5 - 10 min]		
Filler 25% Pumice Mix with 75% Stone dust		
Condition of test specimens		
Sample identification		
Diameter	D	mm
Thickness	t	mm
Saturated/conditioned		
1 2 3		
Diameter	149.6	149.0
Thickness	94.1	95.2
Dry		
1 2 3		
Diameter	150.0	149.7
Thickness	95.2	93.6
VOLUMETRIC		
Dry mass in air	A	gm.
SSD mass	B	gm.
Mass in water	C	gm.
Volume	E = B - C	cm³
Bulk specific gravity	G _{mb} = A/E	
Maximum specific gravity	G _{mm}	
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%
Volume of air voids	V _a = (P _a x E/100)	cm³
TSR		
Thickness	t'	mm
SSD mass	B'	gm.
Volume of absorbed water	J' = B' - A	cm³
Saturation	S' = 100 x J'/V _a	%
Load	P'	N
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa
Average dry strength	Average S ₁	kPa
Average wet strength	Average S ₂	kPa
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80		
Remark:		
Tested by:		Verified by:
Tested by:		Material and Pavement Engineer
		



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50
Wearing coarse
21.02.2025.

Specimen Information

Identification: AC -50 Pumice 25%-SD75%	Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Conditioning time: 2	Diameter (mm)	148.0						148.00	
Properties/Comments: Sample -1	Height (mm)	63.0						63.00	
21.02.2025									

Cross-sectional area (mm²): 17203.4

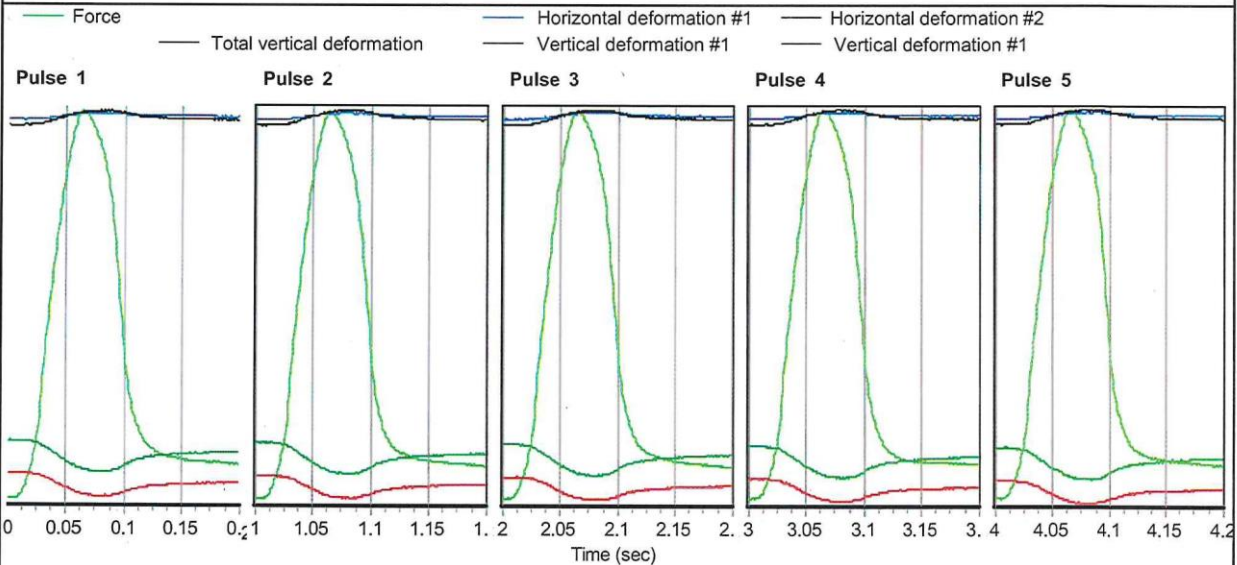
Test Parameters

Waveshape: Haversine	Target temperature (°C): 30	nts
Loading pulse width (ms): 100	Contact load (N): 50	Consta I1: 0.233936
Rest period (ms): 900	Peak load (N): 1550	I2: -0.780056
Pulse repetition period (ms): 1000		I3: 0.307445
Number of conditioning pulses: 100		I4: -1.069463

Test Results

Test date & time: Friday, February 21, 2025, at 14:43
Conditioning pulses: 100
Core temperature (°C): 31.6
Surface temperature (°C): 27.4

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4075	4079	4015	4107	4038	4063	32.54	0.80	
Poisson Ratio #1	0.11	0.13	0.11	0.13	0.12	0.12	0.01	8.52	
Recoverable horizontal deformation #1 (µm)	0.655	0.688	0.653	0.676	0.674	0.669	0.013	1.950	
Recoverable vertical deformation #1 (µm)	-2.247	-2.255	-2.275	-2.244	-2.276	-2.259	0.013	-0.596	
Resilient Modulus #2 (MPa)	3150	3163	3131	3127	3149	3144	13.02	0.41	
Poisson Ratio #2	0.43	0.44	0.42	0.44	0.43	0.43	0.00	0.98	
Recoverable horizontal deformation #2 (µm)	1.509	1.501	1.496	1.525	1.503	1.507	0.010	0.676	
Recoverable vertical deformation #2 (µm)	-3.168	-3.150	-3.176	-3.198	-3.170	-3.172	0.015	-0.485	
Maximum applied load (N)	523	522	522	524	523	523	0.71	0.14	
Contact load (N)	49	49	50	50	51	50	0.73	1.47	



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

Wearing Course

21.02.2025

Specimen Information

Identification: AC -50 Pumice 25%-SD75%

Conditioning time: 2

Properties/Comments: Sample -2
21.02.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm²): 17203.4								

Test Parameters

Waveshape: Haversine
Loading pulse width (ms): 100
Rest period (ms): 900
Pulse repetition period (ms): 1000
Number of conditioning pulses: 100

Target temperature (°C): 30
Contact load (N): 50
Peak load (N): 1550

nts
Consta I1: 0.233936
I2: -0.780056
I3: 0.307445
I4: -1.069463

Test Results

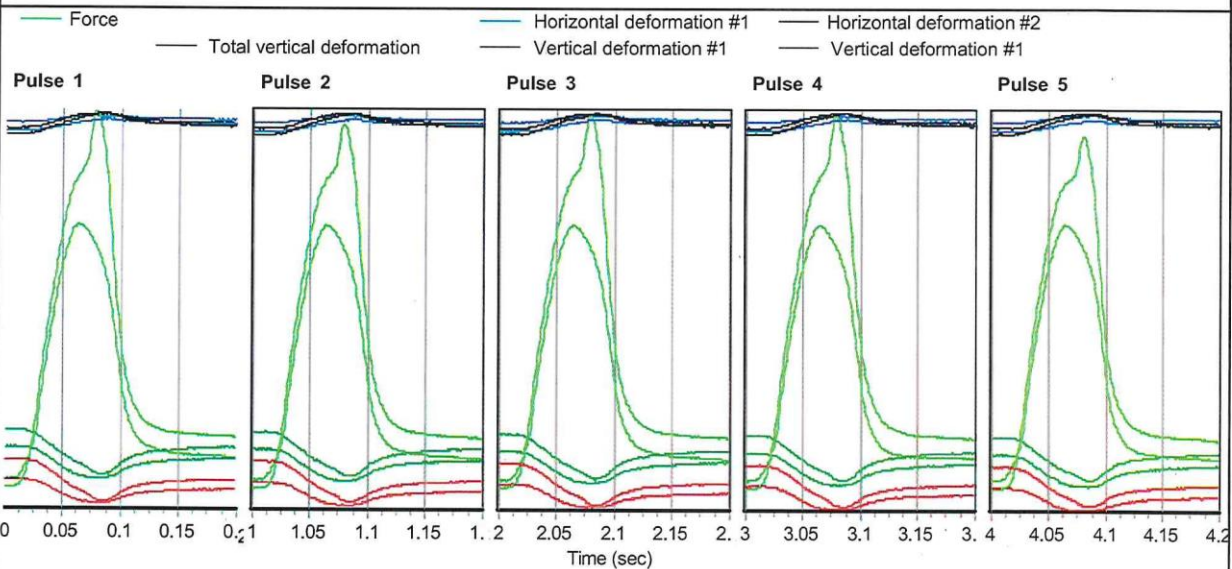
Test date & time: Friday, February 21, 2025, at 14:46

Conditioning pulses: 100

Core temperature (°C): 31.6

Surface temperature (°C): 27.5

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	3218	3265	3217	3225	3182	3221	3221	26.45	0.82
Poisson Ratio #1	0.11	0.13	0.12	0.12	0.12	0.12	0.12	0.01	5.36
Recoverable horizontal deformation #1 (µm)	1.221	1.224	1.249	1.232	1.182	1.221	1.221	0.022	1.815
Recoverable vertical deformation #1 (µm)	-4.189	-4.028	-4.178	-4.163	-3.986	-4.109	-4.109	0.085	-2.057
Resilient Modulus #2 (MPa)	3216	3194	3207	3237	3183	3207	3207	18.41	0.57
Poisson Ratio #2	0.44	0.43	0.45	0.44	0.45	0.44	0.44	0.01	1.83
Recoverable horizontal deformation #2 (µm)	2.180	2.104	2.207	2.175	2.102	2.154	2.154	0.043	1.986
Recoverable vertical deformation #2 (µm)	-4.569	-4.454	-4.567	-4.521	-4.348	-4.492	-4.492	0.083	-1.853
Maximum applied load (N)	769	746	764	764	722	753	753	17.40	2.31
Contact load (N)	33	32	34	33	33	33	33	0.90	2.72



Stress Strain Test

Data file name: C:\IPCglobal UTS\002 Stress Strain Test\Data\CT Index 21.03.25 .D002 Template file
name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 21/03/2025 14:31:16
Project: EHAE
Operator:
Comments: 21.03.2025 25% Pumice and 75% Stone Dust Cracking Tolerance Index

Specimen Information

Identification:
Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	95.0						95.0	
Diameter (mm)	150.0						150.0	
Cross-sectional area (mm ²): 17671.5								

Setup Parameters

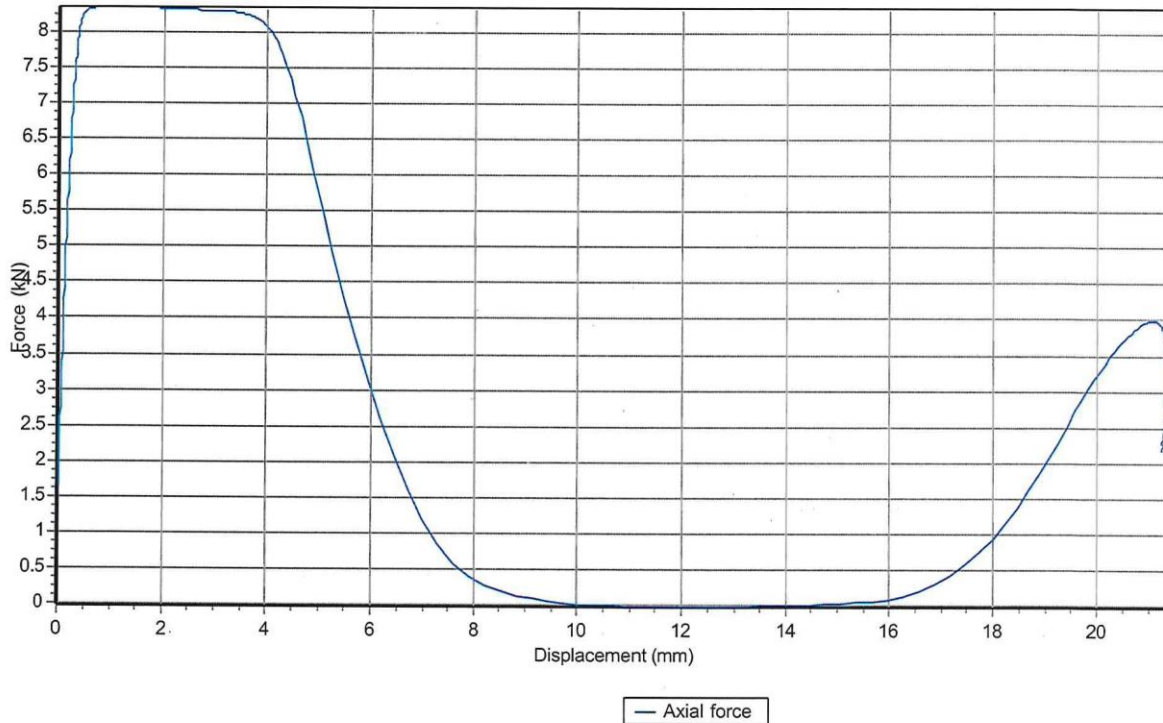
Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hhmmss): 00:00:27
Displayed time (hhmmss): 00:00:27
Displayed seconds: 27
Actuator displ. (mm): 21.287
Actuator microstrain: 1.4191E5
Actuator position (mm): 19.547
Axial force (kN): 2.162
Axial stress (kPa): 181.1
Maximum axial force (kN): 8.348
Minimum axial force (kN): 699.3



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\WC -50 -2.D030

Template file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Templates\UTS030 - EHAE Creep template.P030

Test date & time: 21.03.2025 25% Pumice and 75% Stone Dust, at 12:11 PM

Project: EHAE

Operator: Ravi

Comments: Creep Modulus

Specimen Information

Identification: 25% Pumice and 75% Stone Dust

Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

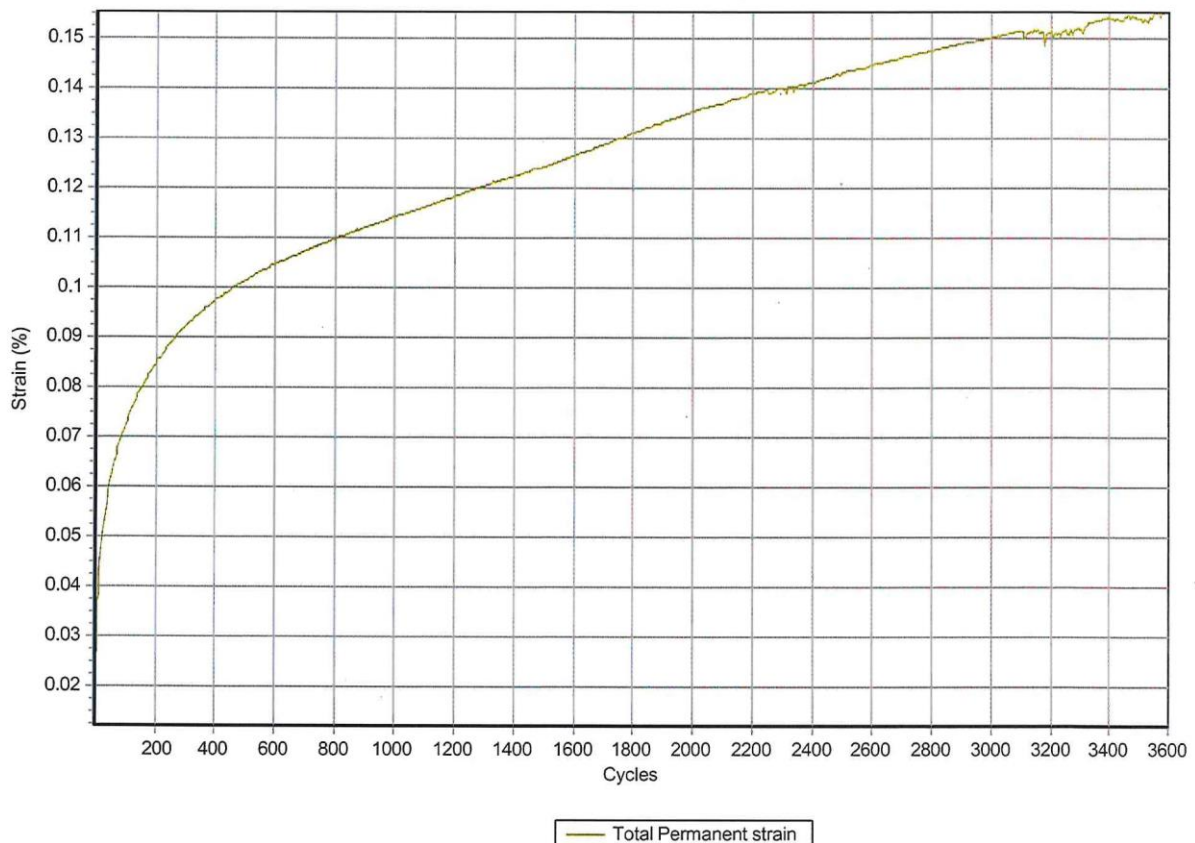
Rest period (ms): 1000

Loading cycle width (ms): 2000

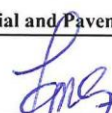
Termination cycle count: 3600

Permanent deformation limit (mm): 10

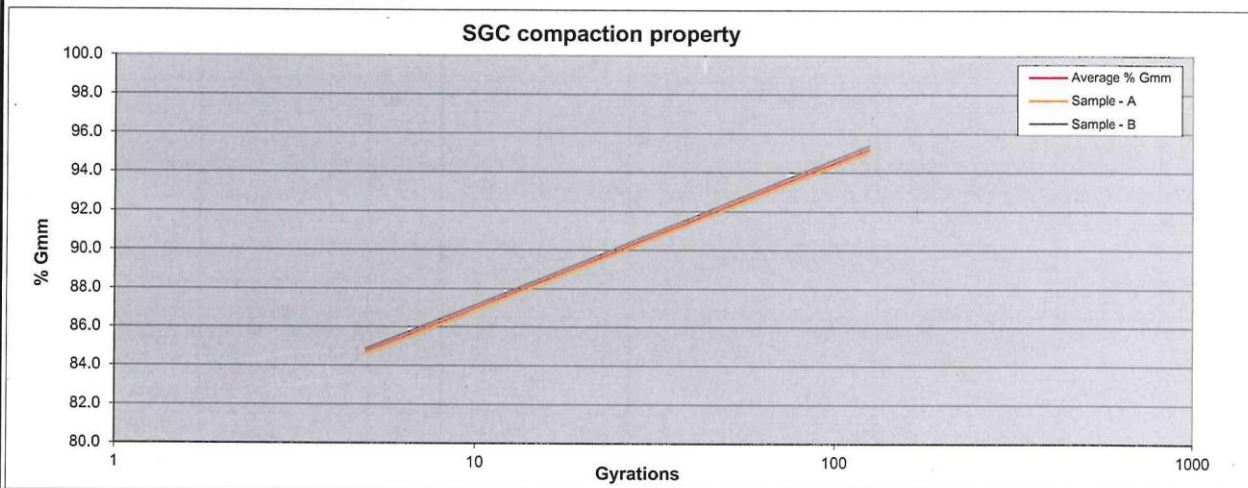
	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	



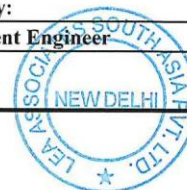
**Appendix 5 Volumetric properties and Performance
tests of asphalt mixture with 50% Pumice and 50%
Stone Dust of Filler**

Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		  JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler	50% PU and 50% SD							
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.377	NA								
	AV	4.8	3 - 6								
	VMA(%)	14.7	≥ 13								
	VFB(%)	67.5	65 - 75								
	N _{ini} (%)	86.6	≤ 89								
	N _{des} (%)	95.2	96% ± 1%								
	N _{max} (%)	96.2	≤ 98%								
MTD	G _{mm}	2.495	NA								
DUST TO BINDER RATIO		1.14	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.72	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	12.5	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100.0	97.0	71.2	59.4	38.6	29.7	19.7	14.6	9.4	6.3	4.8
JMF	100	96.5	73.0	61.6	40.6	31.6	20.4	14.7	9.7	6.8	5.4
Tolerance from JMF L. Limit	100	88.5	66	54.6	33.6	25.6	15.4	9.7	4.7	3.8	2.4
Tolerance from JMF U. Limit	100	100	80	68.6	47.6	37.6	25.4	19.7	14.7	9.8	8.4
Upper Control Point	100	100	-	-	-	49	-	-	-	-	8
Lower Control Point	100	90	-	-	-	23	-	-	-	-	2
REMARK: _____											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
						 					

Employer			Consultant		Contractor			
					 			
Ethiopian Roads Administration (ERA)			LEA JV with Unicon P.L.C, Ethiopia		JMC-LRBCL JOINT VENTURE			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	50% PU and 50% SD		Specific Gravity		1.0285			
Date Tested:	17-02-2025		Number of Gyration		125 @ N _{des}			
Mixing Tempreture (°C)		135-165		CompactionTempreture (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.67	84.6	127.736	84.9				
9 [Nini]	124.841	86.5	124.906	86.8				
10	124.347	86.8	124.412	87.1				
20	121.192	89.1	121.255	89.4				
30	119.420	90.4	119.482	90.7				
40	118.194	91.4	118.256	91.7				
50	117.26	92.1	117.321	92.4				
70	115.879	93.2	115.940	93.5				
90	114.869	94.0	114.929	94.3				
110	114.075	94.7	114.134	95.0				
125 [Ndes]	113.575	95.1	113.634	95.4				
	G _{mb} Gyro	2.334	G _{mb} Gyro	2.349		Average G _{mb} Gyro	2.342	
	G _{mb}	2.372	G _{mb}	2.381		Average G _{mb}	2.377	
	G _{mm}	2.495	G _{mm}	2.496		Average G _{mm}	2.495	
	G _{sb}	2.654	G _{sb}	2.654		Average G _{sb}	2.654	
	G _{sa}	2.736	G _{sa}	2.736		G _{sa}	2.736	
% AC	4.70		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Gsb	2.654		Sample - A	4569	4591	2665	1926.0	2.372
Pb	1.029		Sample - B	4607	4625.0	2690	1935.0	2.381
Volumetrics	Value	Spec.						
%Gmm@Ni	86.6	< 89%						
%Gmm@Ndes.	95.24							
% Air void	4.8	3-6%						
% VMA	14.66	Min 13%						
%VFA	67.54	65-75						

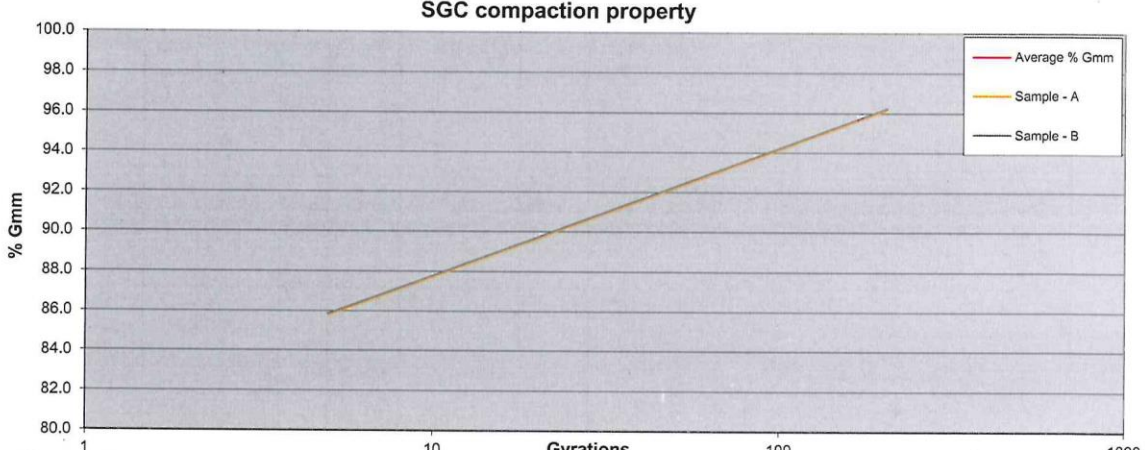


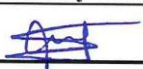
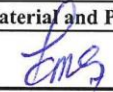
Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



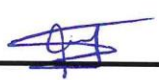
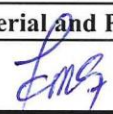
Employer			Consultant			Contractor			
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)									
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS				
Source of Mix	Lab-Mix		Bitumen Grade		40/50				
Filler	50% PU and 50% SD		Specific Gravity		1.0285				
Date Tested:	17-02-2025		Number of Gyration		205 @ N _{max}				
Mixing Temperature (°C)		135-160		Compaction Temperature (°C)		135-150			
Sample - A			Sample - B			Average % Gmm			
No of Gyration	Height	% Gmm	Height	% Gmm					
5	126.415	85.8	126.981	85.8				85.8	
9 [Nini]	124.033	87.4	124.589	87.5				87.5	
10	123.616	87.7	124.169	87.8				87.8	
20	120.938	89.7	121.480	89.7				89.7	
30	119.425	90.8	119.959	90.9				90.8	
40	118.374	91.6	118.904	91.7				91.6	
50	117.571	92.2	118.098	92.3				92.3	
70	116.382	93.2	116.903	93.2				93.2	
90	115.508	93.9	116.026	93.9				93.9	
110	114.821	94.4	115.335	94.5				94.5	
125 [Ndes]	114.387	94.8	114.899	94.9				94.8	
150	113.774	95.3	114.283	95.4				95.3	
175	113.260	95.7	113.767	95.8				95.8	
200	112.819	96.1	113.325	96.2				96.1	
205 [Nmax]	112.738	96.2	113.243	96.2				96.2	
		G _{mb} Gyro	2.353	G _{mb} Gyro	2.351	Average G _{mb} Gyro			2.352
		G _{mb}	2.400	G _{mb}	2.402	Average G _{mb}			2.401
		G _{mm}	2.495	G _{mm}	2.496	Average G _{mm}			2.495
		G _{sb}	2.654	G _{sb}	2.654	Average G _{sb}			2.654
		G _{sa}	2.736	G _{sa}	2.736	G _{sa}			2.736
% AC	4.7		Determination of measured Bulk Specific Gravity						
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	wax+ spc in air	wax+spc In water	Volume	Gmb	
Gsb	2.654		Sample - A	4579	4595	2687	1908.0	2.400	
Pb	1.029		Sample - B	4583	4598.0	2690	1908.0	2.402	
Mix property	Units		Result			Criteria			
% G _{mm} at N _{max}	%		96.2			Max 98			

SGC compaction property



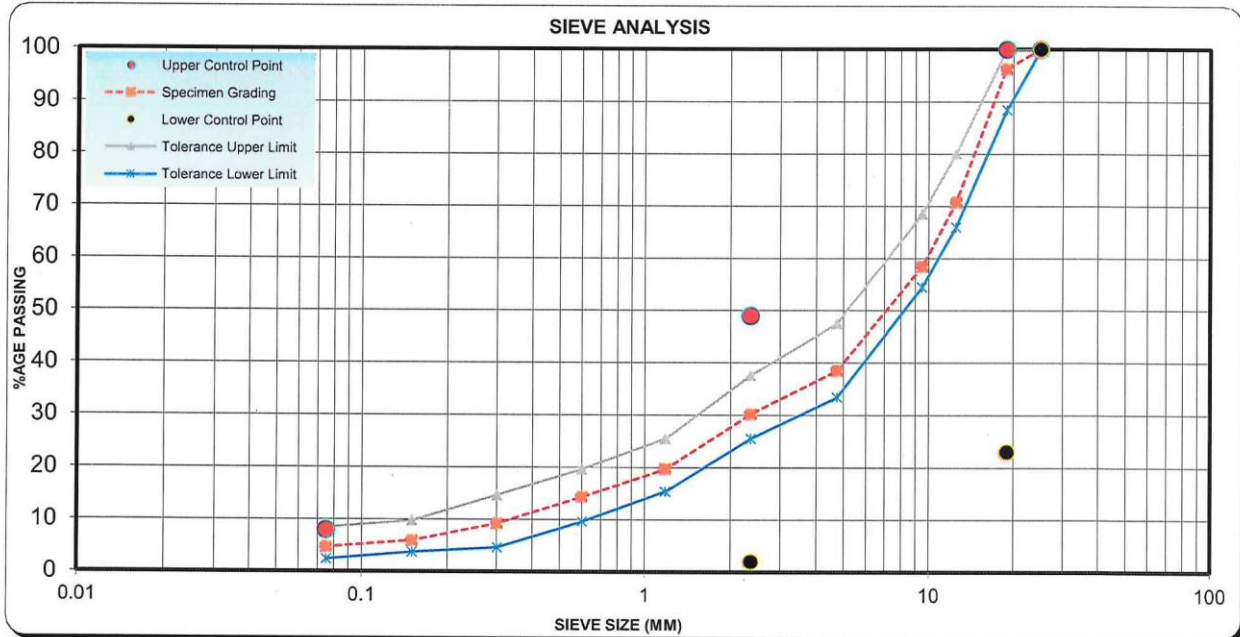
Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



Employer	Consultant	Contractor		
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)				
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041				
Source of Mix	Lab-Mix	Filler	50% PU and 50% SD	
Material Description:	AC-60 Binder course	Date of Testing	18-02-2025	
Grade of Bitumen	40/50	Bitumen by Wt. of Mix	5.40%	
Testing Temp.	25 °C			
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7				
Test No		Test 1	Test 2	
Mass of dry sample in air	A	gm.	2218	2346
Mass of container filled with water at test temperature	F	gm.	9138.0	9138.0
Mass of container filled with sample and water at test temperature	G	gm.	10467	10544
Temperature of test water	T	°C	25	25
Correction for thermal expansion of bitumen	H	gm.	0.0	0.0
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]		2.495	2.496
Correction factor	R = dw / 0.9970		1.000	1.000
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E		2.495	2.496
Average Theoretical Maximum Specific Gravity at 25°C	G _{mm} = (SG 1 + SG 2)/2		2.495	
Effective Specific Gravity of Aggregate	G _{se}		2.684	
Effective Specific Gravity of Aggregate [G_{se}] = (100-P_b) / ((100/G_{mm}) - (P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³				
Remark: _____				
Tested by:		Verified by:		
Laboratory Technician		Material and Pavement Engineer		
				



Employer			Consultant					Contractor			
											
Ethiopian Roads Administration (ERA)			LEA JV with Unicon P.L.C, Ethiopia					JMC-LRBCL JOINT VENTURE			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164											
Source of Mix		Lab-Mix			Source of Material		Km.29+600 LHS Quarry				
Material Description		Hot Mix Asphalt Binder Course Mixture			Grade of Bitumen		40/50				
Sampled by		Jointly			Filler		50% PU and 50% SD				
Proportion:		25:32:8.32.3			Date of Testing		22-02-2025				
Trial - A (Morning)											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm		1794.6	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		3.2	19.0	62.5	3.7	96.3	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm		3.7	12.50	436.6	25.5	70.8	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C – B) gm		0.5	9.50	210.4	12.3	58.5	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm		10.0	4.75	339.4	19.9	38.6	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm		1698.9	2.36	142.1	8.3	30.3	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm		1709.4	1.18	180.2	10.5	19.8	20.4	15.4	25.4	-	-
			0.600	92.3	5.4	14.4	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A – F) gm		85.2	0.300	88.4	5.2	9.2	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.75	0.150	55.5	3.2	6.0	6.8	3.8	9.8	-	-
			0.075	22.3	1.3	4.7	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.0	Pan	79.7	4.7						



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE
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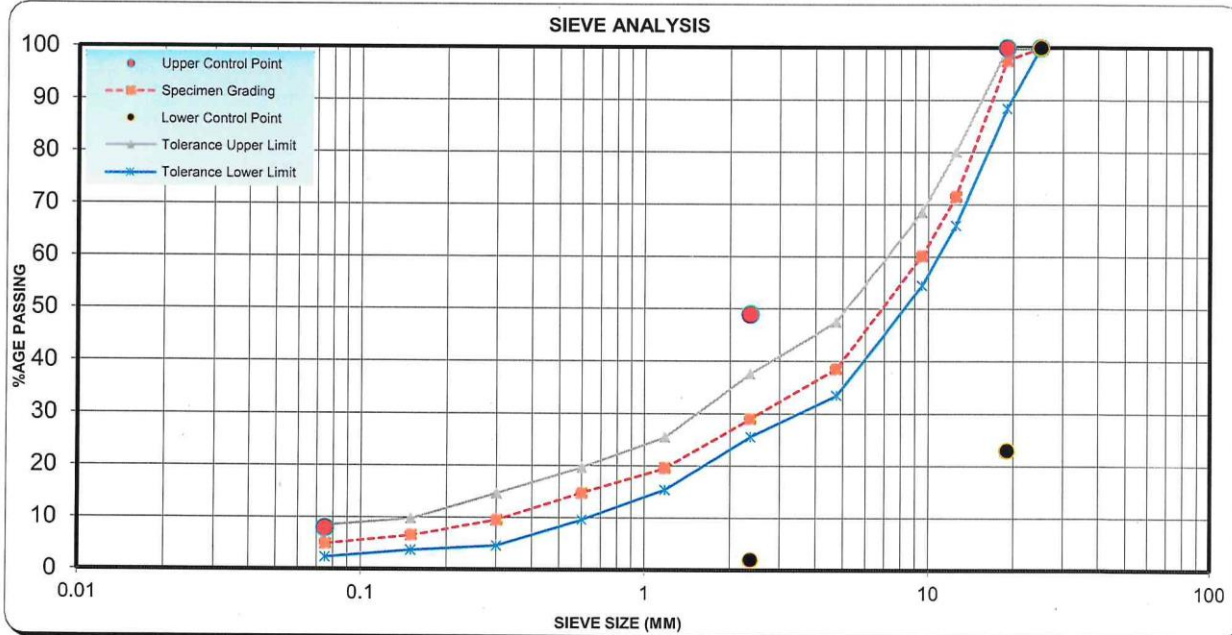
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Sampled by	Jointly	Filler	50% PU and 50% SD
Proportion:	25:32:8.32.3	Date of Testing	22-02-2025

Trial - B (Morning)

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm		1777.5	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		3.0	19.0	40.1	2.4	97.6	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm		3.5	12.50	441.2	26.0	71.6	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C – B) gm		0.5	9.50	192.6	11.4	60.2	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm		8.5	4.75	365.2	21.6	38.7	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm		1685.0	2.36	162.5	9.6	29.1	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm		1694.0	1.18	160.4	9.5	19.6	20.4	15.4	25.4	-	-
			0.600	81.2	4.8	14.8	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A – F) gm		83.5	0.300	88.2	5.2	9.6	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.70	0.150	50.2	3.0	6.6	6.8	3.8	9.8	-	-
			0.075	28.5	1.7	5.0	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.0	Pan	83.9	5.0						

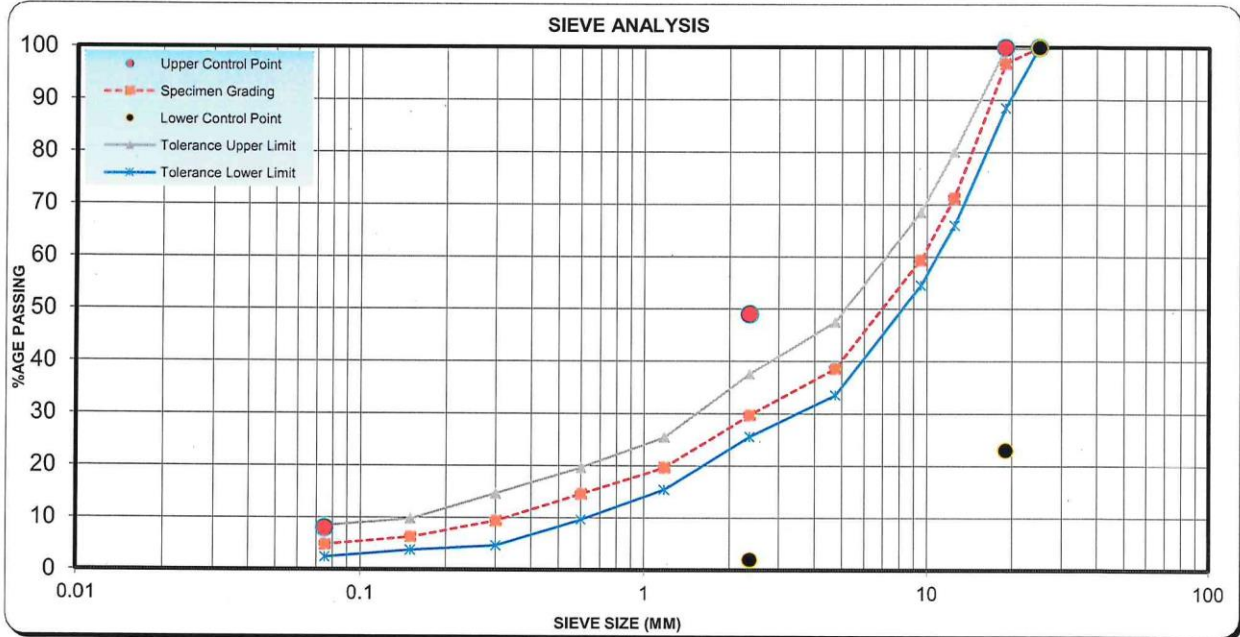


Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer			Consultant					Contractor			
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia					 JMC-LRBCL JOINT VENTURE			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164											
Source of Mix		Lab-Mix			Source of Material			Km.29+600 LHS Quarry			
Material Description		Hot Mix Asphalt Binder Course Mixture			Grade of Bitumen			40/50			
Sampled by		Jointly			Filler			50% PU and 50% SD			
Proportion:		25:32:8.32.3			Date of Testing			22-02-2025			
Average (Morning & Afternoon)											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm		1786.05	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		3.1	19.0	51.3	3.0	97.0	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm		3.6	12.50	438.9	25.8	71.2	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C – B) gm		0.5	9.50	201.5	11.8	59.4	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm		9.3	4.75	352.3	20.7	38.6	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm		1692.0	2.36	152.3	8.9	29.7	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm		1701.7	1.18	170.3	10.0	19.7	20.4	15.4	25.4	-	-
			0.600	86.8	5.1	14.6	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A – F) gm		84.3	0.300	88.3	5.2	9.4	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.72	0.150	52.9	3.1	6.3	6.8	3.8	9.8	-	-
			0.075	25.4	1.5	4.8	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.0	Pan	81.8	4.8						



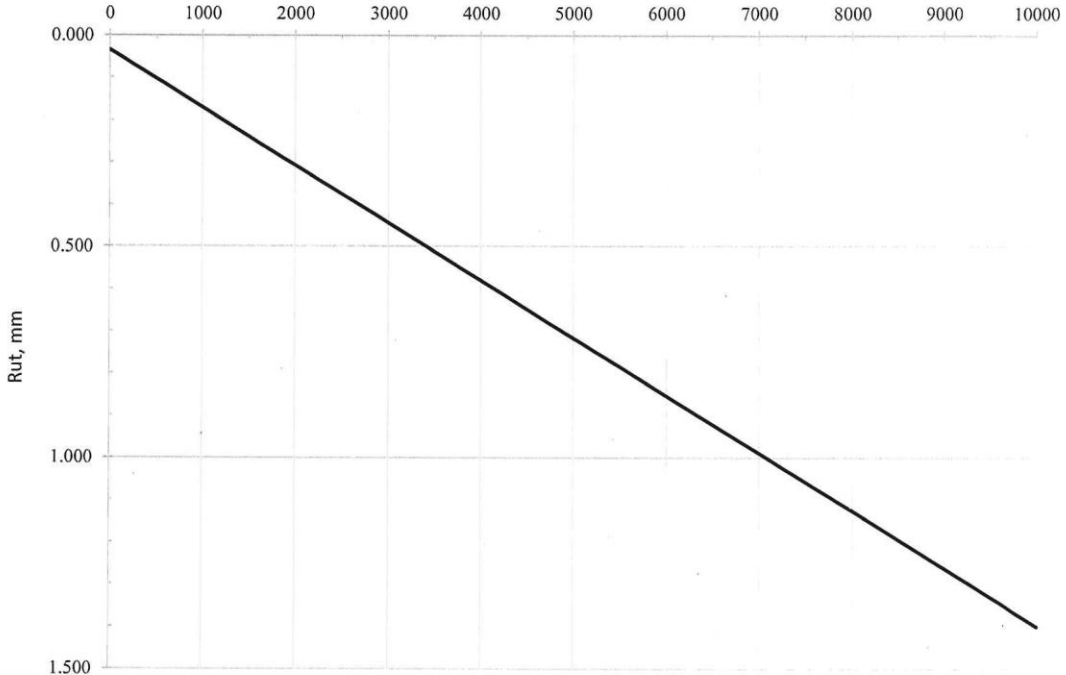
Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	

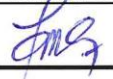


Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	50% Pumice Mix with 50% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60 ⁰ C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,021		
SSD mass	B	gm.	1,024		
Mass in water	C	gm.	581		
Volume	$E = (B - A) - (B - C)$		cm ³	440	
Bulk specific gravity	$G_{mb} = A/E$			2.320	
Maximum specific gravity	G_{mm}			2.495	
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$		%	7.0	
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.35		
Rut at 5,000 passes		mm	0.72		
Rut at 10,000 passes		mm	1.40		
Maximum Wheel Tracking Slope WTS _{Air} (d ₁₀₀₀₀ -d ₅₀₀₀)/5		mm/1k cycl	0.14		
Maximum Proportional Rut Depth PRD _{Air} 100 (d _n -d ₀)/h		%	2.3		
Maximum Rut depth RD _{Air}		mm	1.4		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by: Laboratory Technician 			Verified by: Material & Pavement Engineer 		



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	50% Pumice Mix with 50% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Passes 					
Remark: _____					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
					



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283		
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs		
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa] Saturated 16hrs@ -18°C+ 24hrs @ 60°C +2 hrs Duration: 6 min [5 - 10 min] @ 25°C		
Filler 50% Pumice Mix with 50% Stone dust		
Condition of test specimens		
Saturated/conditioned		
Dry		
Sample identification		
Diameter	D	mm
Thickness	t	mm
VOLUMETRIC		
Dry mass in air	A	gm.
SSD mass	B	gm.
Mass in water	C	gm.
Volume	E = B - C	cm ³
Bulk specific gravity	G _{mb} = A/E	
Maximum specific gravity	G _{mm}	
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%
Volume of air voids	V _a = (P _a x E/100)	cm ³
TSR		
Thickness	t'	mm
SSD mass	B'	gm.
Volume of absorbed water	J' = B' - A	cm ³
Saturation	S' = 100 x J'/V _a	%
Load	P'	N
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa
Average dry strength	Average S ₁	kPa
Average wet strength	Average S ₂	kPa
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80		
Remark:		
Tested by:		Verified by:
Tested by:		Material and Pavement Engineer
		



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50
Wearing Coarse
21.02.2025

Specimen Information

Identification: AC -50 Pumice 50%-SD50% Dimensions Point 1 Point 2 Point 3 Point 4 Point 5 Point 6 Average Std Dev.
Conditioning time: 2 Diameter (mm) 148.0
Properties/Comments: Sample -1 Height (mm) 63.0
21.02.2025 Cross-sectional area (mm²): 17203.4

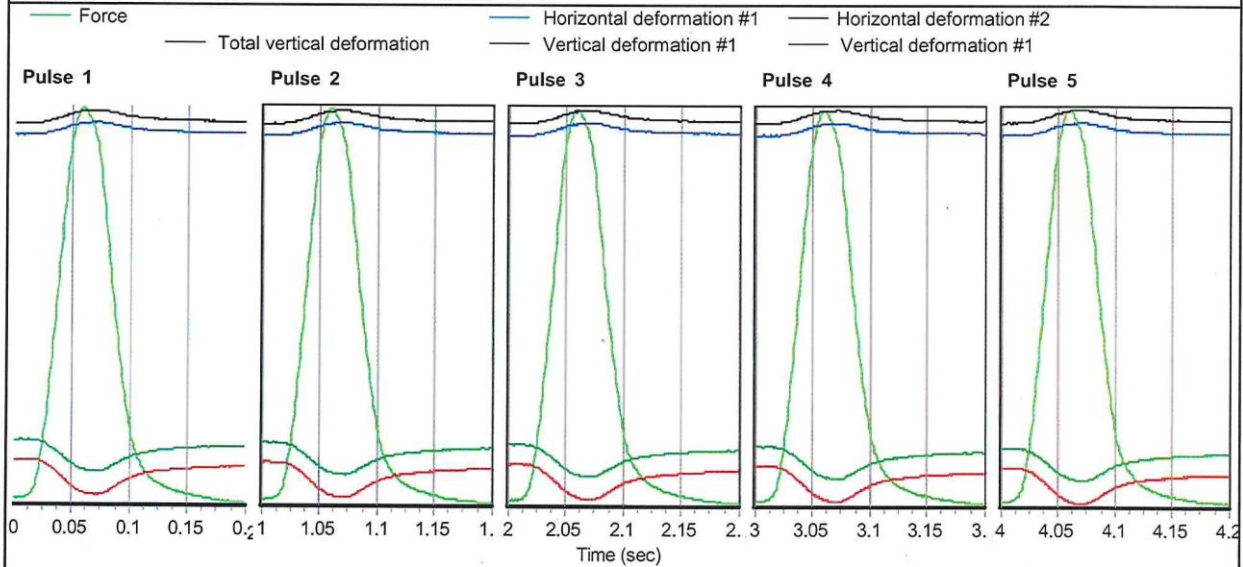
Test Parameters

Waveshape: Haversine Target temperature (°C): 30
Loading pulse width (ms): 100 Contact load (N): 50
Rest period (ms): 900 Peak load (N): 1505
Pulse repetition period (ms): 1000
Number of conditioning pulses: 100

Test Results

Test date & time: Friday, February 21, 2025, at 15:23
Conditioning pulses: 100
Core temperature (°C): 31.6
Surface temperature (°C): 27.7

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4309	4305	4354	4334	4368	4334	24.45	0.56	
Poisson Ratio #1	0.22	0.22	0.23	0.22	0.23	0.23	0.01	2.62	
Recoverable horizontal deformation #1 (µm)	2.008	2.004	2.043	2.008	2.025	2.018	0.015	0.720	
Recoverable vertical deformation #1 (µm)	-5.626	-5.629	-5.597	-5.595	-5.578	-5.605	0.020	-0.350	
Resilient Modulus #2 (MPa)	4989	4948	4955	5007	5002	4980	24.31	0.49	
Poisson Ratio #2	0.32	0.31	0.32	0.33	0.33	0.32	0.01	2.21	
Recoverable horizontal deformation #2 (µm)	2.075	2.057	2.090	2.095	2.104	2.084	0.017	0.792	
Recoverable vertical deformation #2 (µm)	-4.994	-5.021	-5.034	-4.983	-5.003	-5.007	0.018	-0.363	
Maximum applied load (N)	1343	1343	1345	1342	1346	1344	1.40	0.10	
Contact load (N)	51	51	50	50	49	50	1.00	1.98	



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

Wearing Coarse

21.02.2025

Specimen Information

Identification: AC -50 Pumice 50%-SD50%

Conditioning time: 2

Properties/Comments: Sample -2

21.02.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm ²): 17203.4								

Test Parameters

Waveshape: Haversine

Loading pulse width (ms): 100

Rest period (ms): 900

Pulse repetition period (ms): 1000

Number of conditioning pulses: 100

Target temperature (°C): 30

Contact load (N): 50

Peak load (N): 1505

nts
Consta I1: 0.233936

I2: -0.780056

I3: 0.307445

I4: -1.069463

Test Results

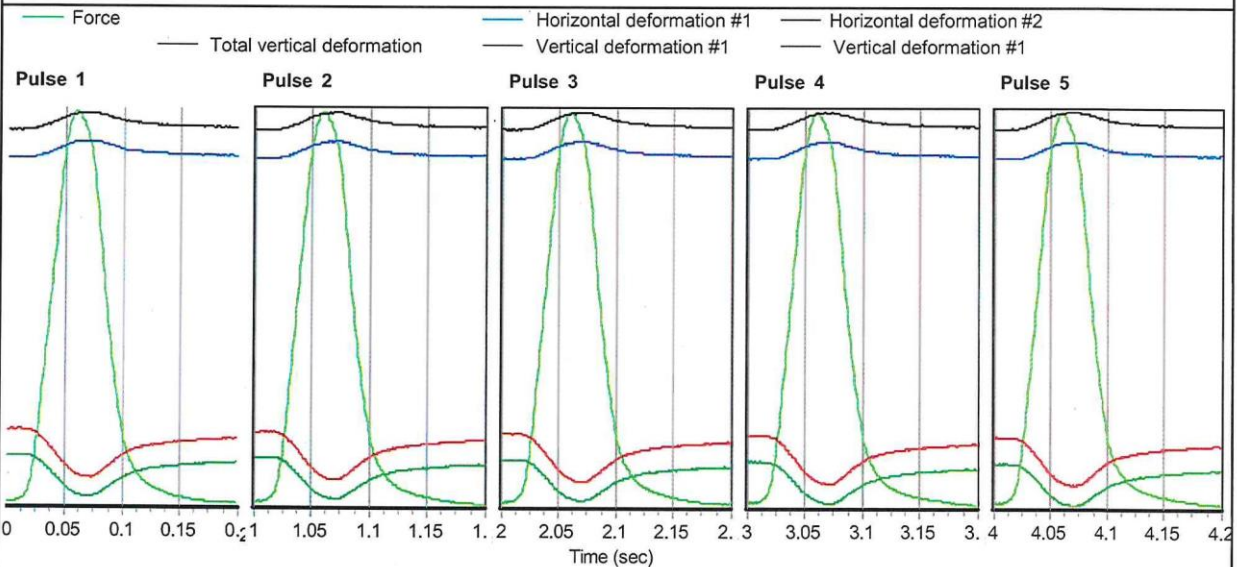
Test date & time: Friday, February 21, 2025, at 15:26

Conditioning pulses: 100

Core temperature (°C): 31.6

Surface temperature (°C): 27.7

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4199	4175	4169	4161	4170	4175	4175	13.10	0.31
Poisson Ratio #1	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.00	1.01
Recoverable horizontal deformation #1 (µm)	2.087	2.080	2.086	2.094	2.079	2.085	2.085	0.005	0.262
Recoverable vertical deformation #1 (µm)	-5.778	-5.801	-5.809	-5.833	-5.824	-5.809	-5.809	0.019	-0.325
Resilient Modulus #2 (MPa)	5062	5034	4980	4967	4985	5005	5005	36.09	0.72
Poisson Ratio #2	0.33	0.33	0.32	0.32	0.33	0.32	0.32	0.00	1.12
Recoverable horizontal deformation #2 (µm)	2.055	2.077	2.065	2.079	2.089	2.073	2.073	0.012	0.569
Recoverable vertical deformation #2 (µm)	-4.921	-4.951	-4.989	-5.015	-5.009	-4.977	-4.977	0.036	-0.718
Maximum applied load (N)	1342	1341	1340	1343	1345	1342	1342	1.73	0.13
Contact load (N)	49	50	51	51	50	50	50	0.57	1.14



Stress Strain Test

Data file name: C:\IPCglobal UTS\002 Stress Strain Test\Data\CT index 21.03.25 .D002 Template file
name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 21/03/2025 14:21:21
Project: EHAE
Operator:
Comments: 21.03.2025 50% Pumice and 50% Stone Dust Cracking Tolerance Index -AC-50

Specimen Information

Identification:

Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	95.0						95.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

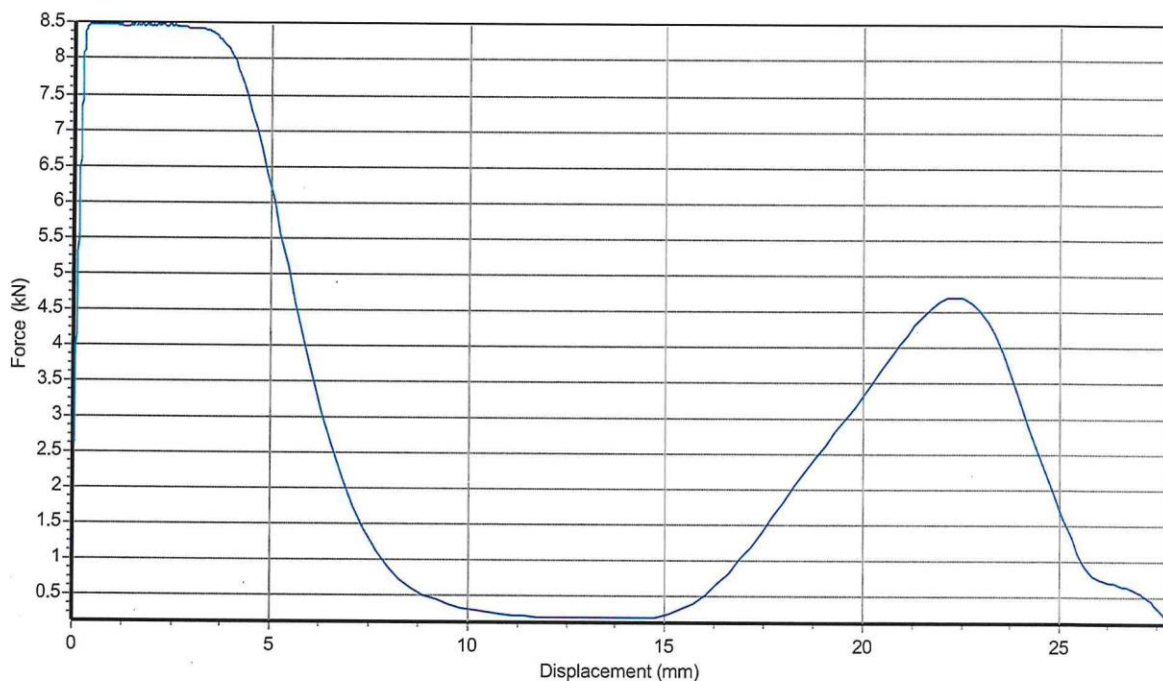
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hhmmss): 00:00:34
Displayed time (hhmmss): 00:00:34
Displayed seconds: 34
Actuator displ. (mm): 27.685
Actuator microstrain: 1.8457E5
Actuator position (mm): 13.692

Axial force (kN): 0.126
Axial stress (kPa): 10.5
Maximum axial force (kN): 8.525
Minimum axial force (kN): 714.1



— Axial force



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\Creep -2.D030

Template file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Templates\UTS030 - EHAE Creep template.P030

Test date & time: 21.03.2025 50% Pumice and 50% Stone Dust, at 2:30 PM

Project: Adama Awash km 60

Operator: Ravi

Comments: Creep Modulus

Specimen Information

Identification: 50% Pumice and 50% Stone Dust

Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

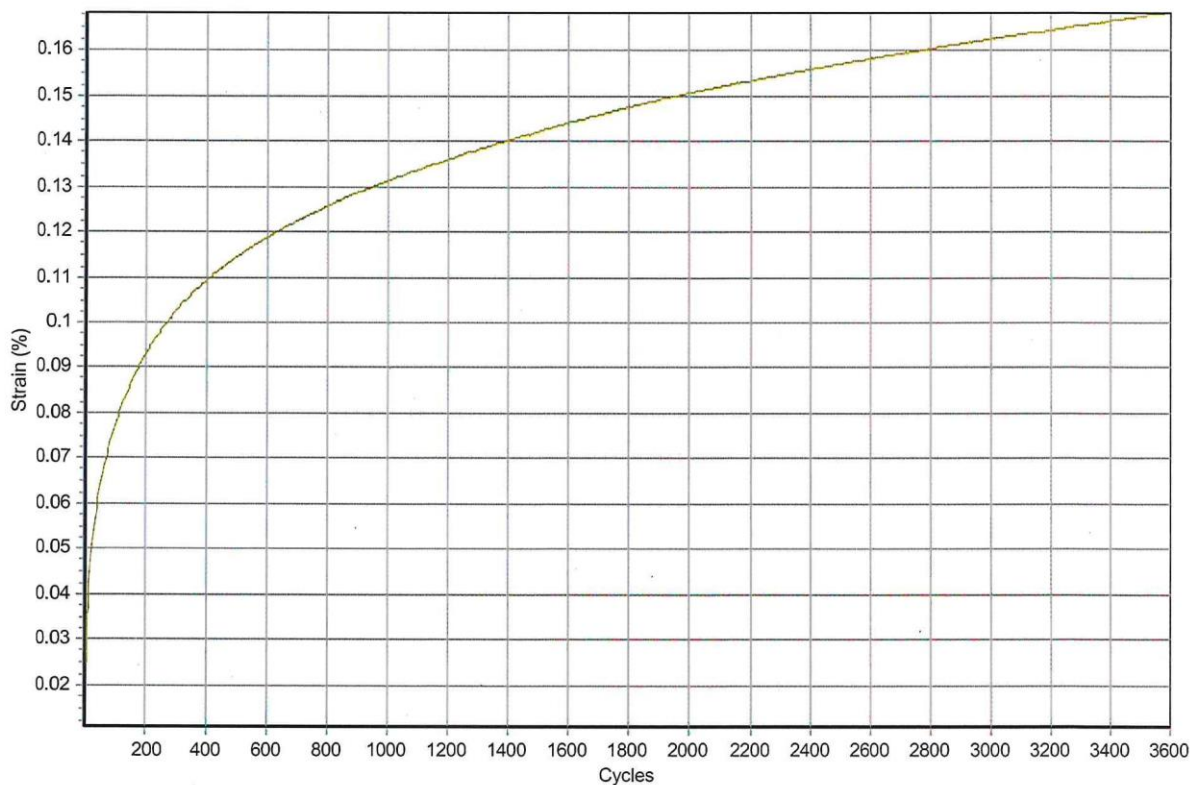
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 10

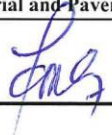
	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	



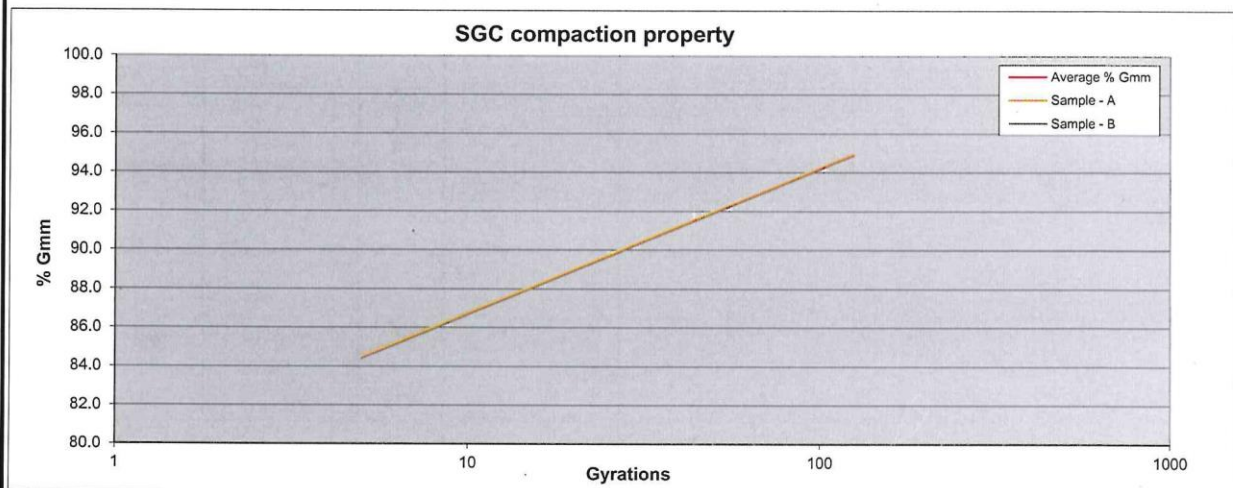
— Total Permanent strain



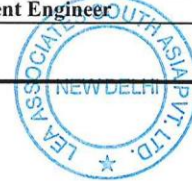
**Appendix 6 Volumetric properties and Performance
tests of asphalt mixture with 75% Pumice and 25%
Stone Dust or Filler**

Employer		Consultant		Contractor						
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE						
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
Summary of Asphalt Concrete Testing and Approval Record										
Source of Mix	Lab-Mix		Filler	75% PU and 25% SD						
Visual Description	Hot Mix Asphalt Mixture(AC)									
Purpose	AC-60 Binder course									
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT							
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.367	NA							
	AV	5.1	3 - 6							
	VMA(%)	15.01	≥ 13							
	VFB(%)	66.3	65 - 75							
	N _{ini} (%)	86.4	≤ 89							
	N _{des} (%)	94.9	96% ± 1%							
	N _{max} (%)	95.2	≤ 98%							
MTD	G _{mm}	2.493	NA							
DUST TO BINDER RATIO		1.33	0.8 - 1.6							
EXTRACTION	Bitumen Content/Mix(%)	4.95	± 0.3 Design Binder Content							
Sieve Analysis										
Description	Sieve Size (mm)									
	25	19	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100.0	97.4	61.9	41.3	30.8	21.1	15.6	10.1	7.5	5.9
JMF	100.0	98.5	62.1	41.0	31.0	21.0	15.1	10.5	7.3	5.6
Tolerance from JMF L. Limit	100	93.5	57.1	37	27	17	11.1	7.5	5.3	4.6
Tolerance from JMF U. Limit	100	100	67.1	45	35	25	19.1	13.5	9.3	6.6
Upper Control Point	100	100	-	-	49	-	-	5	-	8
Lower Control Point	100	90	-	-	23	-	-	19	-	2
REMARK:										
Tested by:						Verified by:				
Laboratory Technician						Material and Pavement Engineer				
						 				

Employer			Consultant			Contractor		
								
Ethiopian Roads Administration (ERA)			LEA JV with Unicon P.L.C, Ethiopia			JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course			Agg Source		Quarry @ KM 29+600LHS		
Source of Mix	Lab-Mix			Bitumen Grade		40/50		
Filler	75% PU and 25% SD			Specific Gravity		1.0285		
Date Tested:	23-02-2025			Number of Gyration		125 @ N _{des}		
Mixing Tempreture (°C)		135-165			CompactionTempreture (°C)		135-150	
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.811	84.5	127.625	84.4				
9 [Nini]	124.979	86.4	124.797	86.3				
10	124.484	86.8	124.304	86.7				
20	121.327	89.0	121.150	88.9				
30	119.552	90.4	119.379	90.2				
40	118.325	91.3	118.153	91.2				
50	117.39	92.0	117.219	91.9				
70	116.008	93.1	115.839	93.0				
90	114.996	93.9	114.829	93.8				
110	114.201	94.6	114.035	94.5				
125 [Ndes]	113.701	95.0	113.535	94.9				
	G _{mb} Gyro	2.339	G _{mb} Gyro	2.334	Average G _{mb} Gyro			2.337
	G _{mb}	2.368	G _{mb}	2.366	Average G _{mb}			2.367
	G _{mm}	2.493	G _{mm}	2.493	Average G _{mm}			2.493
	G _{sb}	2.654	G _{sb}	2.654	Average G _{sb}			2.654
	G _{sa}	2.736	G _{sa}	2.736	G _{sa}			2.736
% AC	4.70		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Gsb	2.654		Sample - A	4592	4612	2673	1939.0	2.368
Pb	1.029		Sample - B	4568	4592.0	2661	1931.0	2.366
Volumetrics	Value	Spec.						
%Gmm@Ni	86.4	< 89%						
%Gmm@Ndes	94.95							
% Air void	5.1	3-6%						
% VMA	15.01	Min 13%						
%VFA	66.33	65-75						

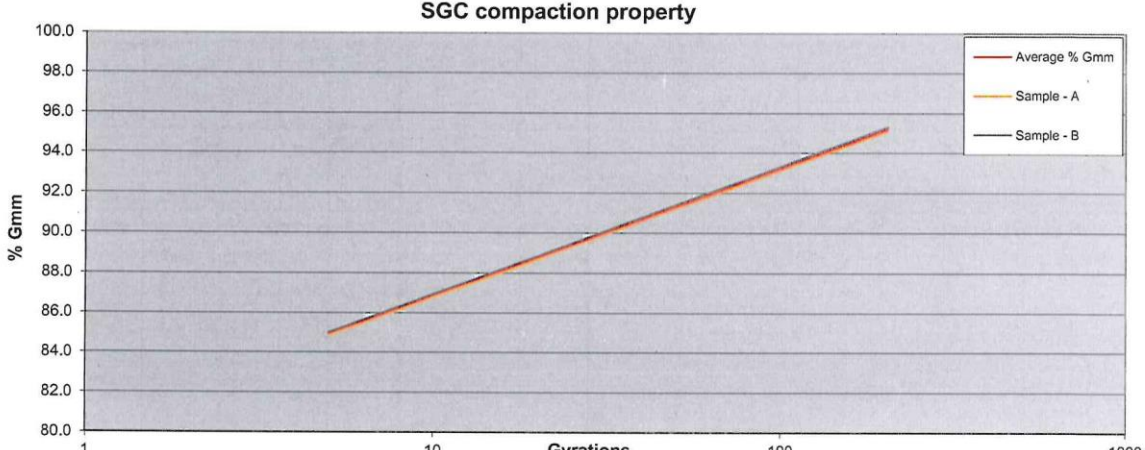


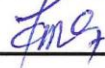
Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	75% PU and 25% SD		Specific Gravity		1.0285			
Date Tested:	23-02-2025		Number of Gyration		205 @ N _{max}			
Mixing Temperature (°C)		135-160		Compaction Temperature (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.103	84.8	126.959	85.0				84.9
9 [Nini]	124.709	86.5	124.567	86.6				86.6
10	124.289	86.8	124.148	86.9				86.8
20	121.597	88.7	121.459	88.9				88.8
30	120.075	89.8	119.939	90.0				89.9
40	119.018	90.6	118.883	90.8				90.7
50	118.211	91.2	118.077	91.4				91.3
70	117.015	92.2	116.882	92.3				92.2
90	116.137	92.9	116.006	93.0				92.9
110	115.446	93.4	115.315	93.6				93.5
125 [Ndes]	115.010	93.8	114.879	93.9				93.9
150	114.393	94.3	114.263	94.4				94.4
175	113.877	94.7	113.748	94.9				94.8
200	113.434	95.1	113.305	95.2				95.2
205 [Nmax]	113.352	95.1	113.223	95.3				95.2
		G _{mb} Gyro	2.345	G _{mb} Gyro	2.350	Average G _{mb} Gyro		2.348
		G _{mb}	2.371	G _{mb}	2.376	Average G _{mb}		2.374
		G _{mm}	2.493	G _{mm}	2.493	Average G _{mm}		2.493
		G _{sb}	2.654	G _{sb}	2.654	Average G _{sb}		2.654
		G _{sa}	2.736	G _{sa}	2.736	G _{sa}		2.736
Determination of measured Bulk Specific Gravity								
% AC	4.7		Mix Ref.	Wt. air	wax+ spc in air	wax+spc In water	Volume	Gmb
Aggreg. Frac.	95.3		Sample - A	4565	4592	2667	1925.0	2.371
Gsb	2.654		Sample - B	4572	4602.0	2678	1924.0	2.376
Pb	1.029							
Mix property	Units		Result			Criteria		
% G _{mm} at N _{max}	%		95.2			Max 98		

SGC compaction property



Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



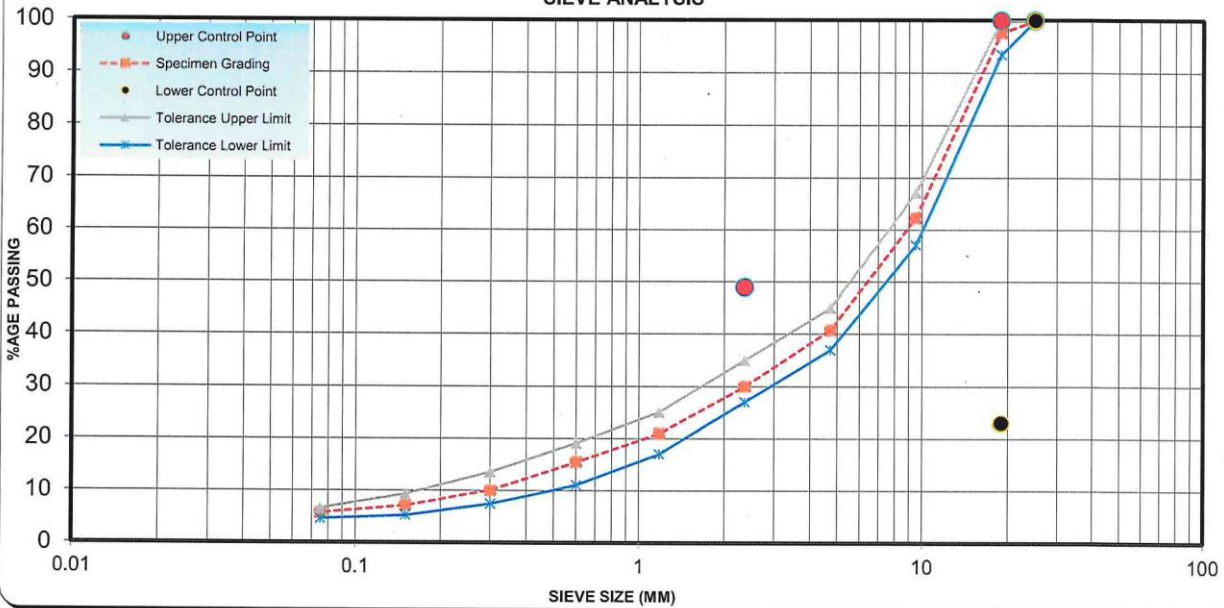
Employer	Consultant	Contractor	
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041			
Source of Mix	Lab-Mix	Filler	75% PU and 25% SD
Material Description:	AC-60 Binder course	Date of Testing	26-02-2025
Grade of Bitumen	40/50	Bitumen by Wt. of Mix	5.40%
Testing Temp.	25 °C		
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7			
Test No		Test 1	Test 2
Mass of dry sample in air	A	gm.	2226
Mass of container filled with water at test temperature	F	gm.	9138.0
Mass of container filled with sample and water at test temperature	G	gm.	10471
Temperature of test water	T	°C	25
Correction for thermal expansion of bitumen	H	gm.	0.0
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]		2.493
Correction factor	R = dw / 0.9970		1.000
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E		2.493
Average Theoretical Maximum Specific Gravity at 25°C	G _{mm} = (SG 1 + SG 2)/2		2.493
Effective Specific Gravity of Aggregate	G _{se}		2.681
Effective Specific Gravity of Aggregate [G_{se}] = (100-P_b) / ((100/G_{mm}) - (P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³			
Remark: _____			
Tested by: Laboratory Technician		Verified by: Material and Pavement Engineer	
			



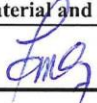
Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164			
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	75% PU and 25% SD	Date of Testing	28-02-2025
Proportion:	25:32:8.32.3		

Trial - A											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm	1709.5	25.0	0.0	0.0	100	100	100	100	100	100	
Wt. of Filter paper before test (B) gm	13	19.0	37.2	2.3	97.7	98.5	93.5	100	90	100	
Wt. of filter + sediment (C) gm	13.8	9.50	576.0	35.5	62.3	62.1	57.1	67.1			
Wt. of Sediment (D) = (C - B) gm	0.8	4.75	348.3	21.4	40.8	41.0	37.0	45.0	-	-	
Wt. of filler after burn (E) gm	9.0	2.36	175.8	10.8	30.0	31.0	27.0	35.0	23	49	
Wt. of Aggregate (F) gm	1615.0	1.18	147.1	9.1	21.0	21.0	17.0	25.0	-	-	
Total Wt. of Aggregate (G) = (D + E+F) gm	1624.8	0.600	87.9	5.4	15.5	15.1	11.1	19.1	-	-	
		0.300	88.5	5.4	10.1	10.5	7.5	13.5	5	19	
Wt. of Bitumen (H) = (A - F) gm	84.7	0.150	46.9	2.9	7.2	7.3	5.3	9.3	-	-	
Bitumen Content	In T.Mix H/A %	4.95	0.075	23.9	1.5	5.7	5.6	4.6	6.6	2	8
			Pan	93.2	5.7						
	In T. Agg. H/F %	5.2									

SIEVE ANALYSIS



Remarks :

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE
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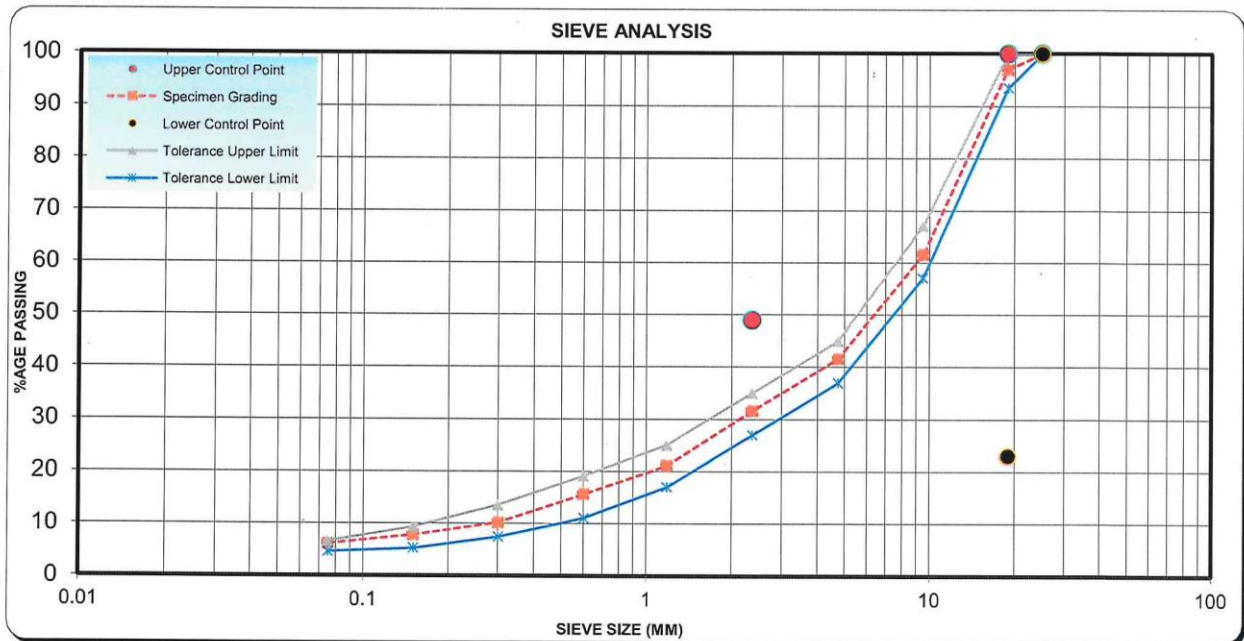
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	75% PU and 25% SD	Date of Testing	28-02-2025
Proportion:	25:32:8.32.3		

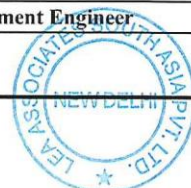
Trial - B

BITUMEN EXTRACTION TEST			SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION							
			Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification
								Lower	Upper	
Total Wt. of Mix before test (A) gm	1699.2		25.0	0.0	0.0	100	100	100	100	100
Wt. of Filter paper before test (B) gm	13		19.0	47.6	2.9	97.1	98.5	93.5	100	90
Wt. of filter + sediment (C) gm	13.7		9.50	573.0	35.5	61.6	62.1	57.1	67.1	
Wt. of Sediment (D) = (C - B) gm	0.7		4.75	321.2	19.9	41.7	41.0	37.0	45.0	-
Wt. of filler after burn (E) gm	6.0		2.36	162.0	10.0	31.7	31.0	27.0	35.0	23
Wt. of Aggregate (F) gm	1608.4		1.18	169.5	10.5	21.2	21.0	17.0	25.0	-
Total Wt. of Aggregate (G) = (D + E+F) gm	1615.1		0.600	89.1	5.5	15.6	15.1	11.1	19.1	-
			0.300	88.2	5.5	10.2	10.5	7.5	13.5	5
Wt. of Bitumen (H) = (A - F) gm	84.1		0.150	38.2	2.4	7.8	7.3	5.3	9.3	-
Bitumen Content	In T.Mix H/A %	4.95	0.075	27.3	1.7	6.1	5.6	4.6	6.6	2
	In T. Agg. H/F %	5.2	Pan	99.0	6.1					8



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

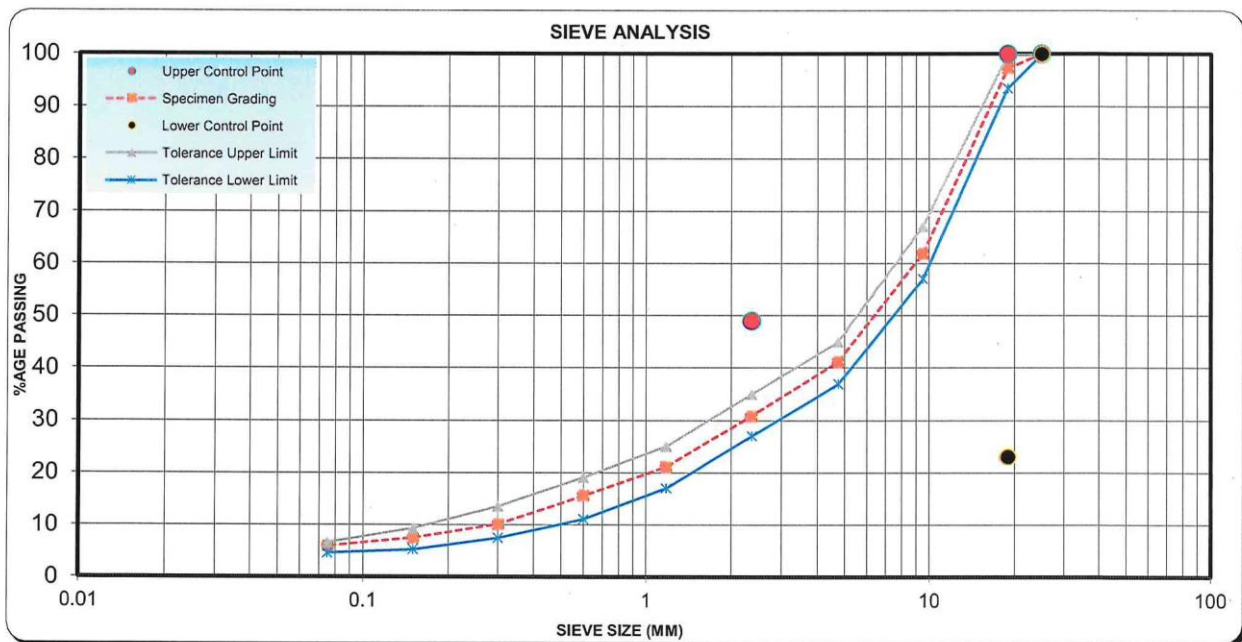
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

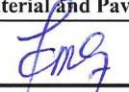
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	75% PU and 25% SD	Date of Testing	28-02-2025
Proportion:	25:32:8.32.3		

Average of Trial A & B

BITUMEN EXTRACTION TEST			SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
			Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
								Lower	Upper		
Total Wt. of Mix before test (A) gm		1704.35	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		13	19.0	42.4	2.6	97.4	98.5	93.5	100	90	100
Wt. of filter + sediment (C) gm		13.75	9.50	574.5	35.5	61.9	62.1	57.1	67.1		
Wt. of Sediment (D) = (C – B) gm		0.75	4.75	334.8	20.7	41.3	41.0	37.0	45.0	-	-
Wt. of filler after burn (E) gm		7.5	2.36	168.9	10.4	30.8	31.0	27.0	35.0	23	49
Wt. of Aggregate (F) gm		1611.7	1.18	158.3	9.8	21.1	21.0	17.0	25.0	-	-
Total Wt. of Aggregate (G) = (D + E+F) gm		1620.0	0.600	88.5	5.5	15.6	15.1	11.1	19.1	-	-
			0.300	88.4	5.5	10.1	10.5	7.5	13.5	5	19
Wt. of Bitumen (H) = (A – F) gm		84.4	0.150	42.6	2.6	7.5	7.3	5.3	9.3	-	-
Bitumen Content	In T.Mix H/A %	4.95	0.075	25.6	1.6	5.9	5.6	4.6	6.6	2	8
			Pan	96.1	5.9						
	In T. Agg. H/F %	5.2									

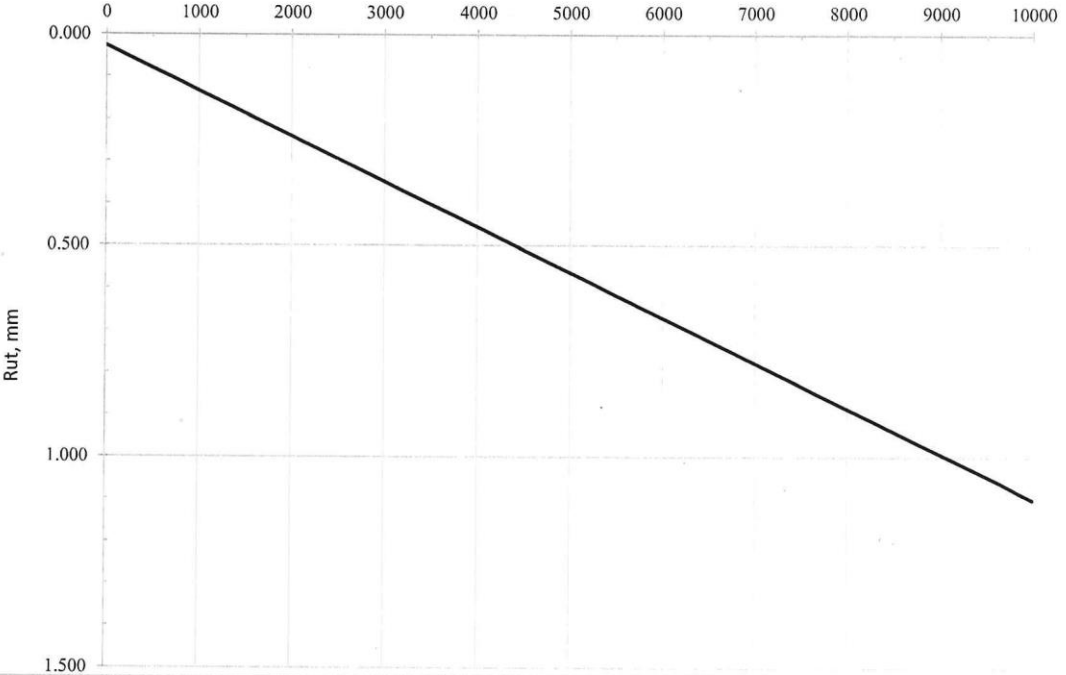
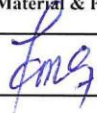


Remarks :

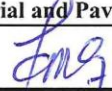
Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	

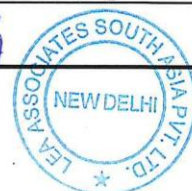


Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	75% Pumice Mix with 25% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,026		
SSD mass	B	gm.	1,029		
Mass in water	C	gm.	584		
Volume	$E = (B - A) - (B - C)$	cm ³	442		
Bulk specific gravity	$G_{mb} = A/E$		2.321		
Maximum specific gravity	G_{mm}		2.493		
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$	%	6.9		
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.28		
Rut at 5,000 passes		mm	0.56		
Rut at 10,000 passes		mm	1.10		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.11		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	1.8		
Maximum Rut depth RD_{Air}		mm	1.1		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	75% Pumice Mix with 25% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60 ⁰ C		
Conditioning time: +6hr			Test load: 520 N		
Passes 					
Remark: _____					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
					



Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE- I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283								
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa]								
Specimen conditioning: Saturated 16hrs@ -18°C+ 24hrs @ 60°C +2 hrs @ 25°C Duration: 6 min [5 - 10 min]								
Filler 75% Pumice Mix with 25% Stone dust								
Condition of test specimens			Saturated/conditioned			Dry		
Sample identification			1	2	3	1	2	3
Diameter	D	mm	149.3	149.2	149.8	149.7	149.2	149.0
Thickness	t	mm	96.2	95.5	95	95.6	97.5	94.8
VOLUMETRIC								
Dry mass in air	A	gm.	3,975	3,988	3,966	4,005	3,996	3,981
SSD mass	B	gm.	4,001	4,014	3,992	4,031	4,026	4,003
Mass in water	C	gm.	2,348	2,336	2,340	2,350	2,354	2,339
Volume	$E = B - C$	cm ³	1,653	1,678	1,652	1,681	1,672	1,664
Bulk specific gravity	$G_{mb} = A/E$		2.405	2.377	2.401	2.383	2.390	2.392
Maximum specific gravity	G_{mm}		2.493	2.493	2.493	2.493	2.493	2.493
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$	%	3.5	4.7	3.7	4.4	4.1	4.0
Volume of air voids	$V_a = (P_a \times E/100)$	cm ³	58.5	78.3	61.1	74.5	69.1	67.1
TSR								
Thickness	t'	mm	96.2	95.5	95			
SSD mass	B'	gm.	4,018.0	4,047.0	4,010.0			
Volume of absorbed water	$J' = B' - A$	cm ³	43.0	59.0	44.0	-	-	-
Saturation	$S' = 100 \times J'/V_a$	%	73.5	75.3	72.0	-	-	-
Load	P'	N	25,590.0	25,320.0	24,020.0	27,820.0	28,000.0	28,980.0
Dry strength	$S_1 = 2000 \times P/(\pi \times t \times D)$	kPa				1,237.5	1,225.4	1,306.1
Wet strength	$S_2 = 2000 \times P/(\pi \times t' \times D)$	kPa	1,134.3	1,131.3	1,074.5			
Average dry strength	Average S_1	kPa	1,256.3					
Average wet strength	Average S_2	kPa	1,113.4					
Tensile Strength Ratio	$TSR = \text{Average } S_2 / \text{Average } S_1$	%	88.6					
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80								
Remark:								
Tested by:			Verified by:					
Tested by:			Material and Pavement Engineer					
								



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

Wearing Course

21.02.2025

Specimen Information

Identification: AC -50 Pumice 75 % -SD25%	Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Conditioning time: 2	Diameter (mm)	148.0						148.00	
Properties/Comments: Sample -1	Height (mm)	63.0						63.00	
21.02.2025									

Cross-sectional area (mm²): 17203.4

Test Parameters

Waveshape: Haversine	Target temperature (°C): 30	nts
Loading pulse width (ms): 100	Contact load (N): 50	Consta I1: 0.233936
Rest period (ms): 900	Peak load (N): 1505	I2: -0.780056
Pulse repetition period (ms): 1000		I3: 0.307445
Number of conditioning pulses: 100		I4: -1.069463

Test Results

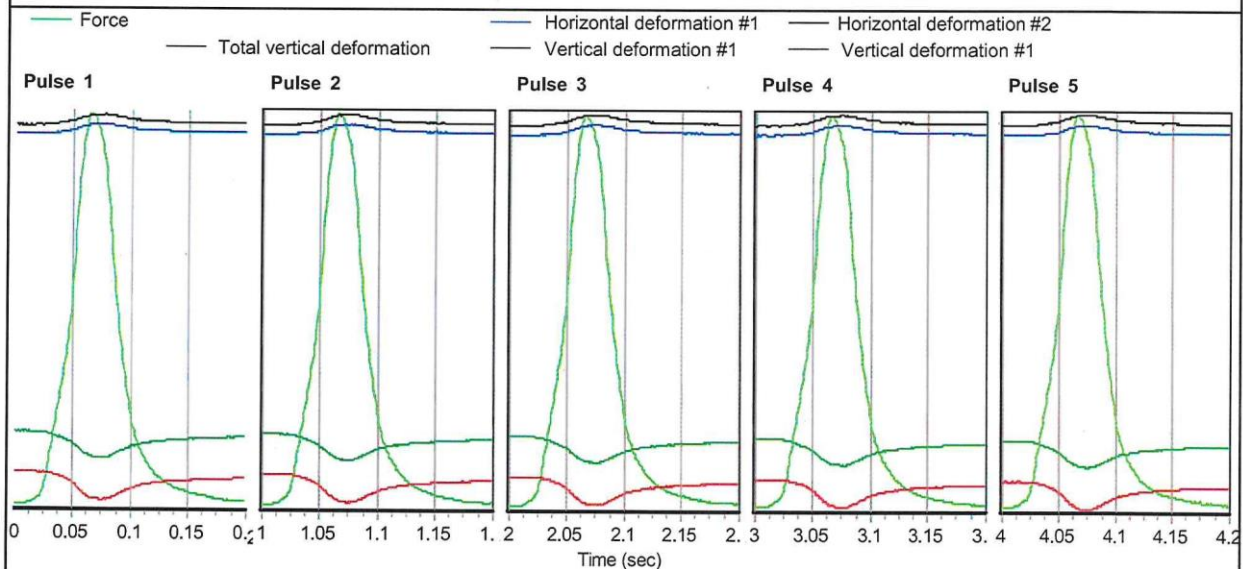
Test date & time: Friday, February 21, 2025, at 15:19

Conditioning pulses: 100

Core temperature (°C): 31.5

Surface temperature (°C): 27.4

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4784	4810	4764	4729	4758	4769	27.01	0.57	
Poisson Ratio #1	0.22	0.24	0.22	0.22	0.23	0.23	0.01	4.47	
Recoverable horizontal deformation #1 (µm)	1.553	1.623	1.553	1.575	1.587	1.578	0.026	1.636	
Recoverable vertical deformation #1 (µm)	-4.364	-4.373	-4.375	-4.414	-4.407	-4.387	0.020	-0.457	
Resilient Modulus #2 (MPa)	5142	5192	5131	5129	5142	5147	23.29	0.45	
Poisson Ratio #2	0.31	0.33	0.32	0.32	0.32	0.32	0.01	1.79	
Recoverable horizontal deformation #2 (µm)	1.698	1.727	1.739	1.730	1.737	1.726	0.015	0.869	
Recoverable vertical deformation #2 (µm)	-4.159	-4.139	-4.179	-4.179	-4.184	-4.168	0.017	-0.403	
Maximum applied load (N)	1157	1158	1156	1156	1160	1157	1.45	0.13	
Contact load (N)	50	50	50	50	50	50	0.13	0.25	



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

Wearing Coarse

21.02.2025

Specimen Information

Identification: AC -50 Pumice75%-SD25%	Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Conditioning time: 2	Diameter (mm)	148.0						148.00	
Properties/Comments: Sample -2	Height (mm)	63.0						63.00	
21.02.2025	Cross-sectional area (mm ²): 17203.4								

Test Parameters

Waveshape: Haversine	Target temperature (°C): 30	Consta ^{nts} I1: 0.233936
Loading pulse width (ms): 100	Contact load (N): 50	I2: -0.780056
Rest period (ms): 900	Peak load (N): 1505	I3: 0.307445
Pulse repetition period (ms): 1000		I4: -1.069463
Number of conditioning pulses: 100		

Test Results

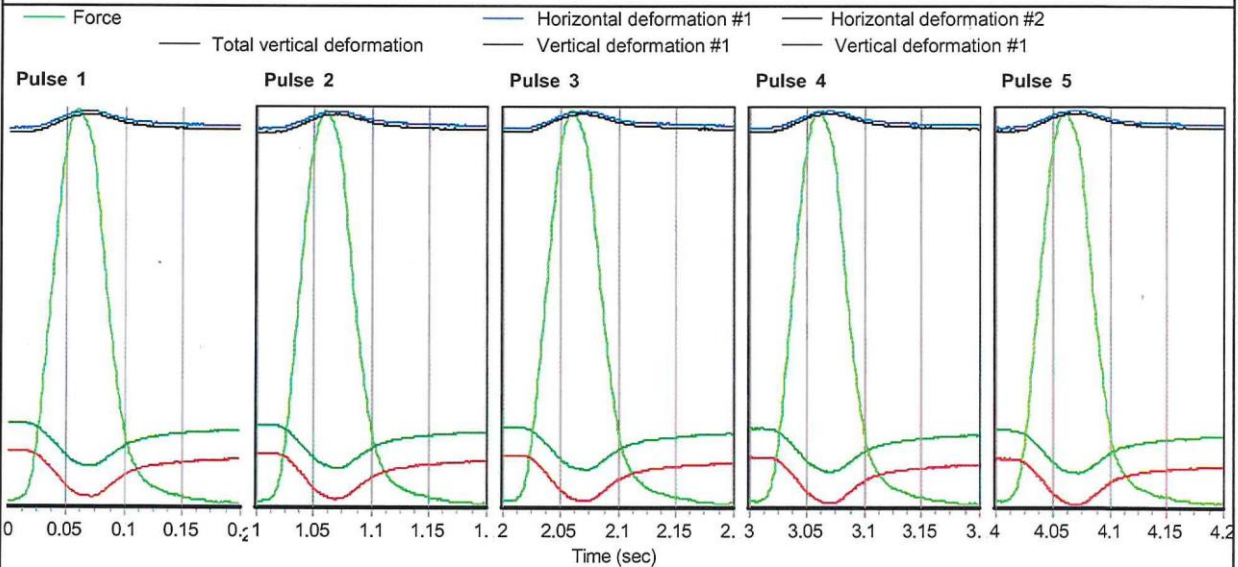
Test date & time: Friday, February 21, 2025, at 15:32

Conditioning pulses: 100

Core temperature (°C): 31.5

Surface temperature (°C): 27.6

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4530	4540	4540	4540	4539	4529	4536	5.24	0.12
Poisson Ratio #1	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.00	0.48
Recoverable horizontal deformation #1 (µm)	2.070	2.055	2.053	2.055	2.049	2.056	2.056	0.007	0.340
Recoverable vertical deformation #1 (µm)	-5.444	-5.426	-5.423	-5.429	-5.420	-5.428	-5.428	0.008	-0.156
Resilient Modulus #2 (MPa)	4967	4941	4919	4846	4942	4923	4923	41.28	0.84
Poisson Ratio #2	0.34	0.34	0.33	0.33	0.35	0.34	0.34	0.01	2.30
Recoverable horizontal deformation #2 (µm)	2.158	2.182	2.152	2.167	2.190	2.170	2.170	0.014	0.658
Recoverable vertical deformation #2 (µm)	-5.072	-5.102	-5.107	-5.181	-5.090	-5.110	-5.110	0.037	-0.728
Maximum applied load (N)	1352	1351	1350	1352	1346	1350	1350	1.93	0.14
Contact load (N)	48	49	52	51	50	50	50	1.23	2.46



Stress Strain Test

Data file name: C:\IPCglobal UTS\002 Stress Strain Test\Data\21_03_2025 crack index.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 21/03/2025 09:03:56
Project: EHAE
Operator:
Comments: 21.03.2025 75% Pumice and 25% Stone Dust Cracking Tolerance Index -AC-50

Specimen Information

Identification:
Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	95.0						95.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

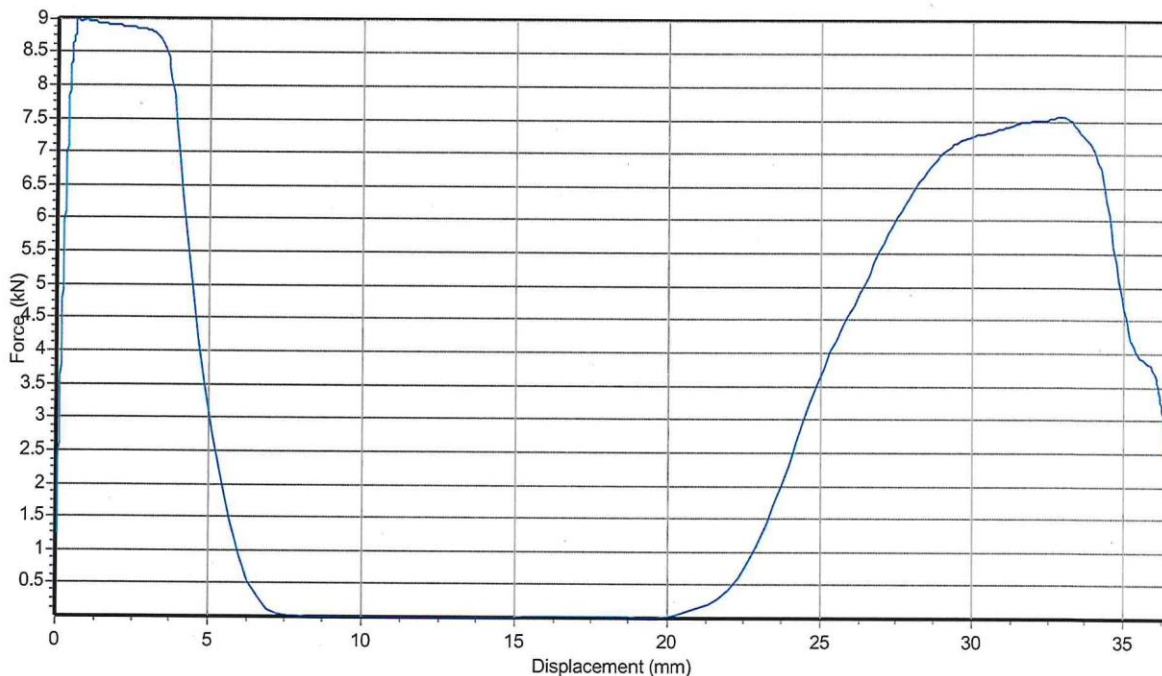
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hh:mm:ss): 00:00:45
Displayed time (hh:mm:ss): 00:00:45
Displayed seconds: 45
Actuator displ. (mm): 36.423
Actuator microstrain: 2.4282E5
Actuator position (mm): 17.759

Axial force (kN): 2.450
Axial stress (kPa): 205.3
Maximum axial force (kN): 9.022
Minimum axial force (kN): 755.7



— Axial force



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\Creep .D030

Template file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Templates\UTS030 - EHAE Creep template.P030

Test date & time: 21.03.2025 75% Pumice and 25% Stone Dust, at 7:15 AM

Project: Adama Awash km 60

Operator: Ravi

Comments: Creep Modules

Specimen Information

Identification: 75% Pumice and 25% Stone Dust

Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

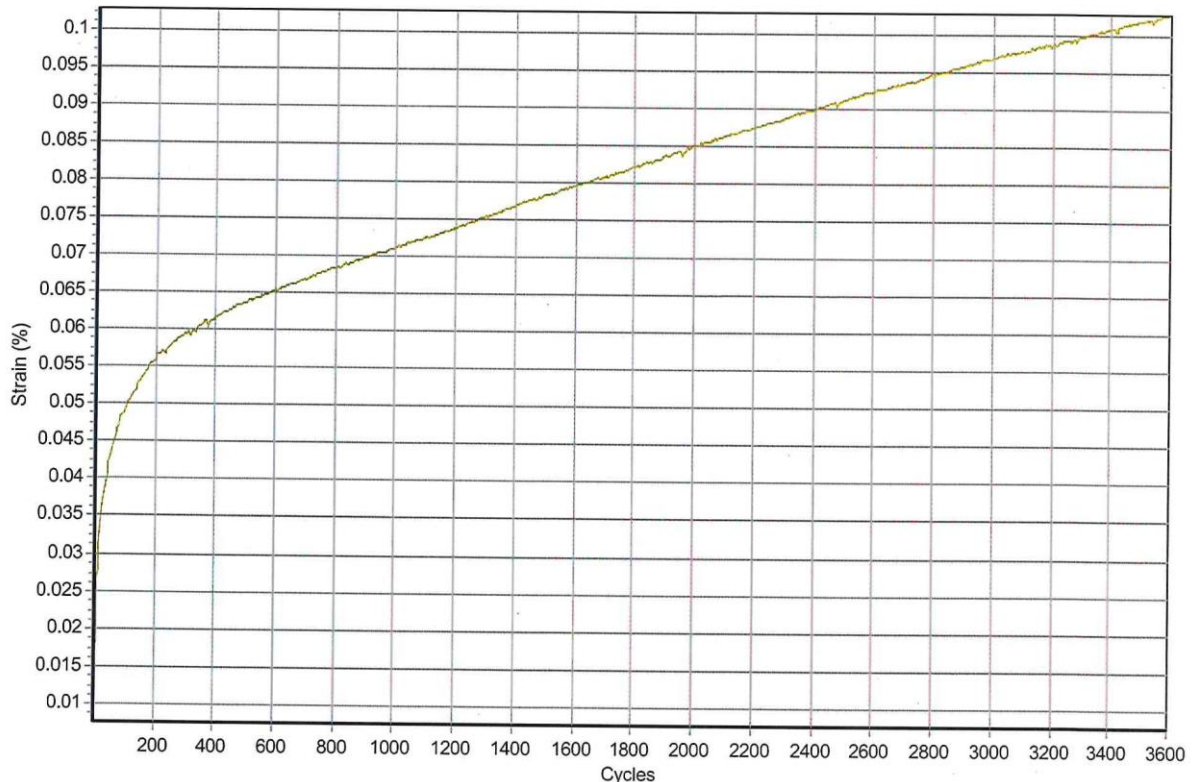
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 10

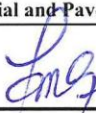
	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	



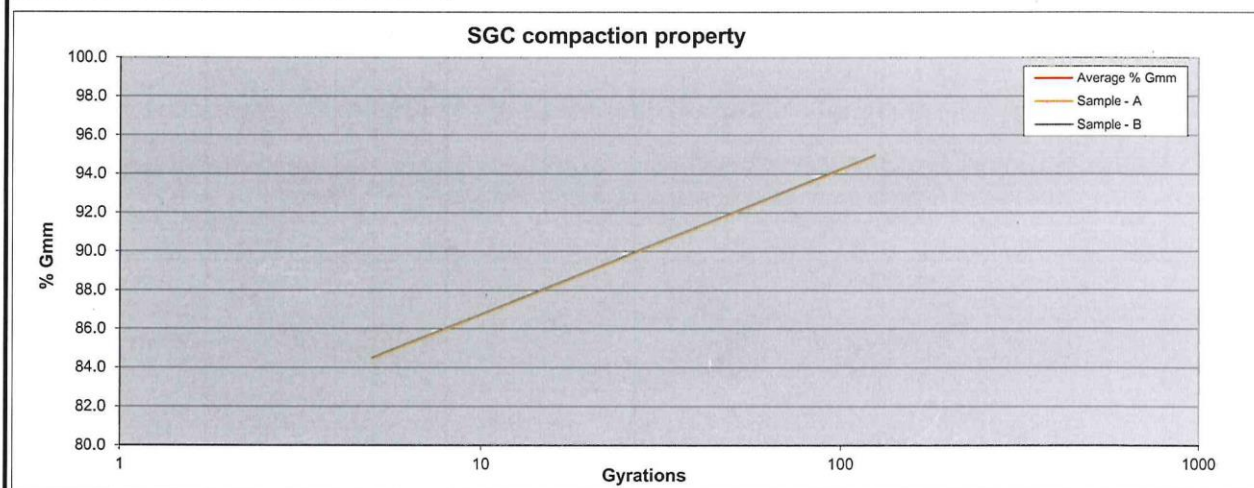
— Total Permanent strain



**Appendix 7 Volumetric properties and Performance
tests of asphalt mixture with 100% Pumice**

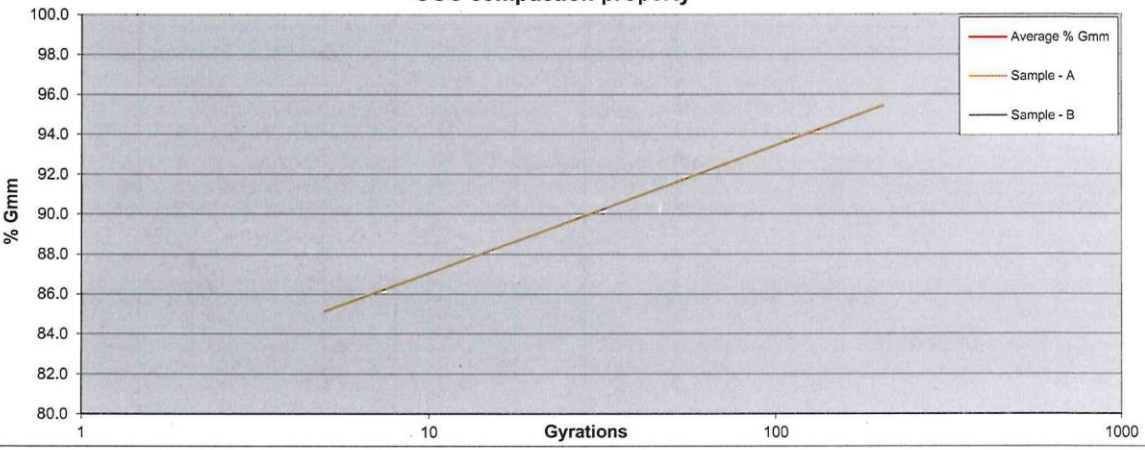
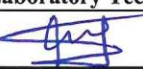
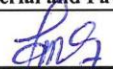
Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		  JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler		100% Pumice						
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.367	NA								
	AV	5.1	3 - 6								
	VMA(%)	15.0	≥ 13								
	VFB(%)	66.4	65 - 75								
	N _{ini} (%)	86.4	≤ 89								
	N _{des} (%)	94.9	96% ± 1%								
	N _{max} (%)	95.5	≤ 98%								
MTD	G _{mm}	2.492	NA								
DUST TO BINDER RATIO		1.14	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.77	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	12.5	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100.0	97.5	72.5	60.1	39.3	29.8	19.4	14.4	9.7	6.6	4.9
JMF	100	96.5	73.0	61.6	40.6	31.6	20.4	14.7	9.7	6.8	5.4
Tolerance from JMF L. Limit	100	88.5	66	54.6	33.6	25.6	15.4	9.7	4.7	3.8	2.4
Tolerance from JMF U. Limit	100	100	80	68.6	47.6	37.6	25.4	19.7	14.7	9.8	8.4
Upper Control Point	100	100	-	-	-	49	-	-	-	-	8
Lower Control Point	100	90	-	-	-	23	-	-	-	-	2
REMARK:											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
						 					

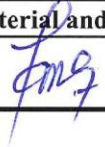
Employer			Consultant		Contractor			
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia		  JMC-LRBCL JOINT VENTURE			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:		AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS		
Source of Mix		Lab-Mix		Bitumen Grade		40/50		
Filler		100% Pumice		Specific Gravity		1.0285		
Date Tested:		25-02-2025		Number of Gyration		125 @ N _{des}		
Mixing Tempreture (°C)			135-165		CompactionTempreture (°C)		135-150	
Sample - A				Sample - B			Average % Gmm	
No of Gyration	Height	% Gmm		Height	% Gmm			
5	127.67	84.4		127.736	84.5		84.5	
9 [Nini]	124.841	86.4		124.906	86.4		86.4	
10	124.347	86.7		124.412	86.7		86.7	
20	121.192	89.0		121.255	89.0		89.0	
30	119.420	90.3		119.482	90.3		90.3	
40	118.194	91.2		118.256	91.3		91.2	
50	117.26	91.9		117.321	92.0		92.0	
70	115.879	93.0		115.940	93.1		93.1	
90	114.869	93.9		114.929	93.9		93.9	
110	114.075	94.5		114.134	94.6		94.5	
125 [Ndes]	113.575	94.9		113.634	95.0		94.9	
	G _{mb} Gyro	2.334		G _{mb} Gyro	2.349		Average G _{mb} Gyro	2.342
	G _{mb}	2.364		G _{mb}	2.369		Average G _{mb}	2.367
	G _{mm}	2.490	G _{mm}	2.495	Average G _{mm}	2.492		
	G _{sb}	2.654	G _{sb}	2.654	Average G _{sb}	2.654		
	G _{sa}	2.736	G _{sa}	2.736	G _{sa}	2.736		
% AC	4.70		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Gsb	2.654		Sample - A	4607	4635	2686	1949.0	2.364
Pb	1.029		Sample - B	4573	4599.0	2669	1930.0	2.369
Volumetrics	Value	Spec.						
%Gmm@Ni	86.4	< 89%						
%Gmm@Ndes.	94.95							
% Air void	5.1	3-6%						
% VMA	15.02	Min 13%						
%VFA	66.38	65-75						



Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	100% Pumice		Specific Gravity		1.0285			
Date Tested:	25-02-2025		Number of Gyration		205 @ N _{max}			
Mixing Temperature (°C)		135-160		Compaction Temperature (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	126.415	85.2	126.981	85.1	85.1			
9 [Nini]	124.033	86.8	124.589	86.7	86.8			
10	123.616	87.1	124.169	87.0	87.1			
20	120.938	89.0	121.480	89.0	89.0			
30	119.425	90.1	119.959	90.1	90.1			
40	118.374	90.9	118.904	90.9	90.9			
50	117.571	91.6	118.098	91.5	91.5			
70	116.382	92.5	116.903	92.4	92.5			
90	115.508	93.2	116.026	93.1	93.2			
110	114.821	93.8	115.335	93.7	93.7			
125 [Ndes]	114.387	94.1	114.899	94.1	94.1			
150	113.774	94.6	114.283	94.6	94.6			
175	113.260	95.1	113.767	95.0	95.0			
200	112.819	95.4	113.325	95.4	95.4			
205 [Nmax]	112.738	95.5	113.243	95.4	95.5			
G_{mb} Gyro		2.353	G_{mb} Gyro		2.351	Average G_{mb} Gyro		2.352
G_{mb}		2.378	G_{mb}		2.381	Average G_{mb}		2.379
G_{mm}		2.490	G_{mm}		2.495	Average G_{mm}		2.492
G_{sb}		2.654	G_{sb}		2.654	Average G_{sb}		2.654
G_{sa}		2.736	G_{sa}		2.736	G_{sa}		2.736
Determination of measured Bulk Specific Gravity								
% AC	4.7		Mix Ref.	Wt. air	wax+ spc in air	wax+spc In water	Volume	Gmb
Aggreg. Frac.	95.3		Sample - A	4575	4599	2675	1924.0	2.378
Gsb	2.654		Sample - B	4581	4606.0	2682	1924.0	2.381
Pb	1.029							
Mix property	Units		Result			Criteria		
% G_{mm} at N_{max}	%		95.5			Max 98		
SGC compaction property 								
Tested by:				Verified by:				
Laboratory Technician				Material and Pavement Engineer				
								

Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041					
Source of Mix	Lab-Mix	Filler	100% Pumice		
Material Description:	AC-60 Binder course	Dated of Testing	27-02-2025		
Grade of Bitumen	40/50	Tested By	Jointly		
Testing Temp.	25 °c	Bitumen by Wt. of Mix	4.70%		
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7					
Test No				Test 1	Test 2
Mass of dry sample in air	A	gm.	2388	2183	
Mass of container filled with water at test temperature	F	gm.	9138.0	9138.0	
Mass of container filled with sample and water at test temperature	G	gm.	10567	10446	
Temperature of test water	T	°C	25	25	
Correction for thermal expansion of bitumen	H	gm.	0.0	0.0	
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]		2.490	2.495	
Correction factor	R = dw /0.9970		1.000	1.000	
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E		2.490	2.495	
Average Theoretical Maximum Specific Gravity at 25°C	G_{mm} = (SG 1 + SG 2)/2		2.492		
Effective Specific Gravity of Aggregate	G_{se}		2.680		
Effective Specific Gravity of Aggregate[G_{sc}] = (100-P_b)/((100/G_{mm})-(P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³					
Remark:					
Tested by:			Verified by:		
Laboratory Technician			Material and Pavement Engineer		
			 		

Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE
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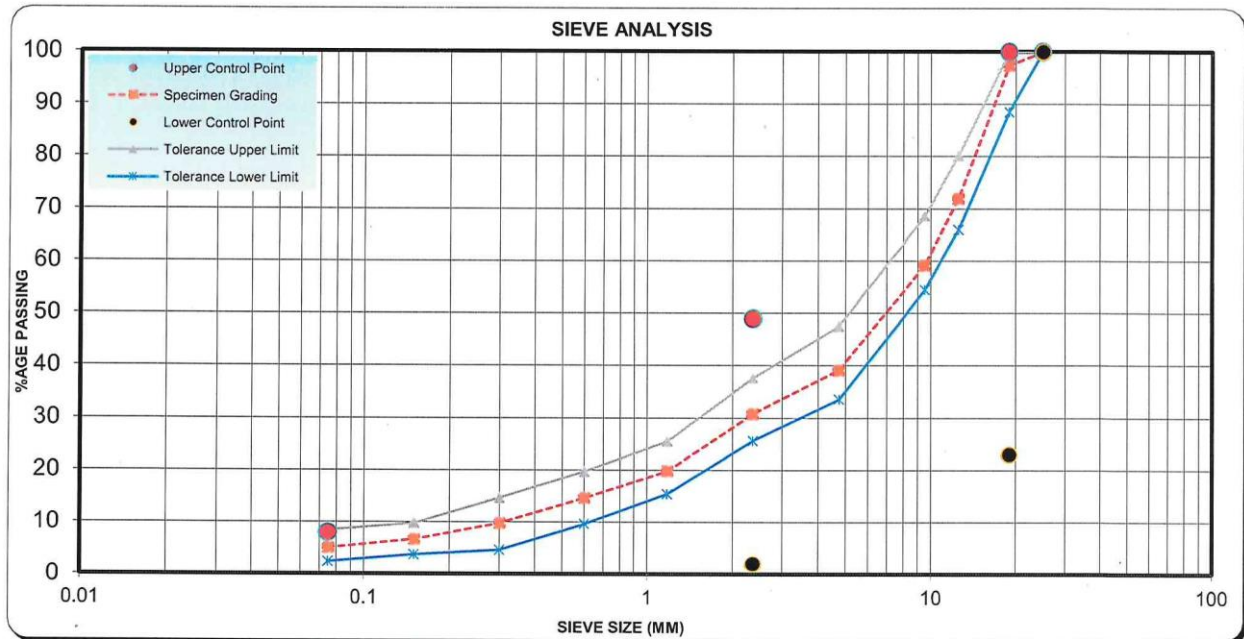
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% Pumice	Date of Testing	29-02-2025
Proportion:	25:32:8.32.3		

Trial - A (Morning)

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1732.6	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.2	19.0	42.2	2.6	97.4	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.8	12.50	420.3	25.5	72.0	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.6	9.50	210.3	12.7	59.2	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	9.2	4.75	331.4	20.1	39.1	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1640.3	2.36	137.5	8.3	30.8	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1650.1	1.18	181.3	11.0	19.8	20.4	15.4	25.4	-	-
		0.600	85.2	5.2	14.7	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	82.5	0.300	80.1	4.9	9.8	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.76	0.150	51.0	3.1	6.7	6.8	3.8	9.8	-
			0.075	27.7	1.7	5.0	5.4	2.4	8.4	2
	In T. Agg. H/F %	5.0	Pan	83.1	5.0					8



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE
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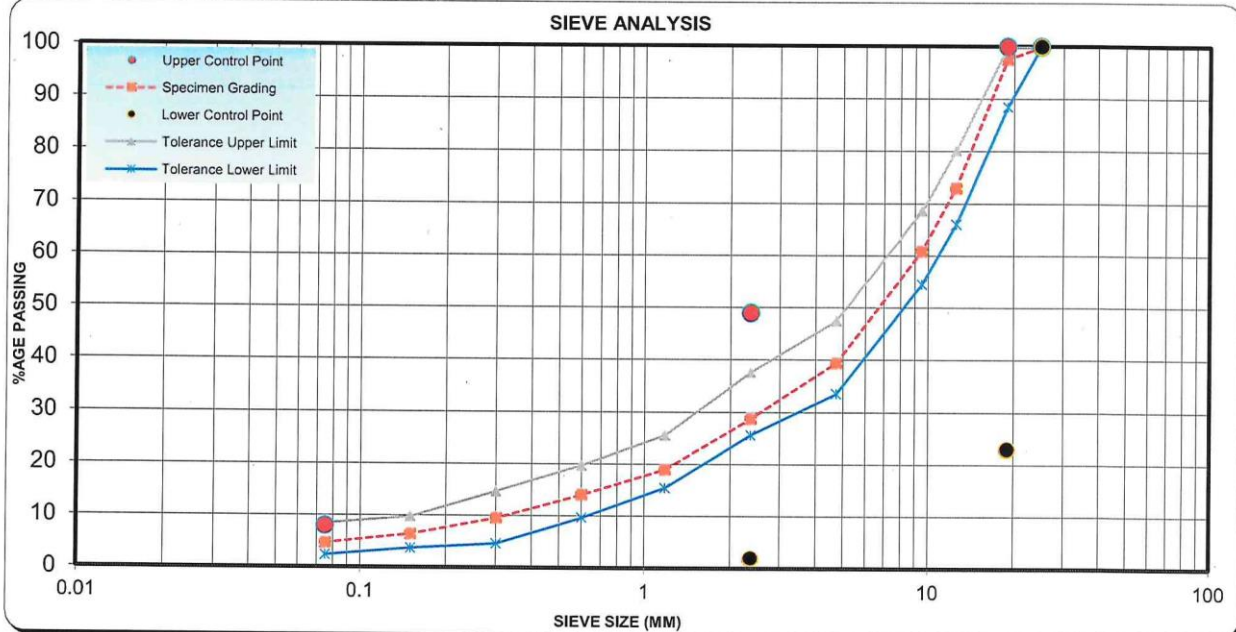
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% Pumice	Date of Testing	29-02-2025
Proportion:	25:32:8.32.3		

Trial - B (Morning)

BITUMEN EXTRACTION TEST			SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
			Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
								Lower	Upper		
Total Wt. of Mix before test (A) gm		1744.7	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		2.9	19.0	39.0	2.3	97.7	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm		3.5	12.50	410.4	24.7	73.0	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C – B) gm		0.6	9.50	200.1	12.0	60.9	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm		8.8	4.75	355.4	21.4	39.5	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm		1652.0	2.36	178.6	10.7	28.8	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm		1661.4	1.18	162.2	9.8	19.0	20.4	15.4	25.4	-	-
			0.600	80.5	4.8	14.2	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A – F) gm		83.3	0.300	75.2	4.5	9.6	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.77	0.150	51.1	3.1	6.6	6.8	3.8	9.8	-	-
			0.075	30.3	1.8	4.7	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.0	Pan	78.6	4.7						



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

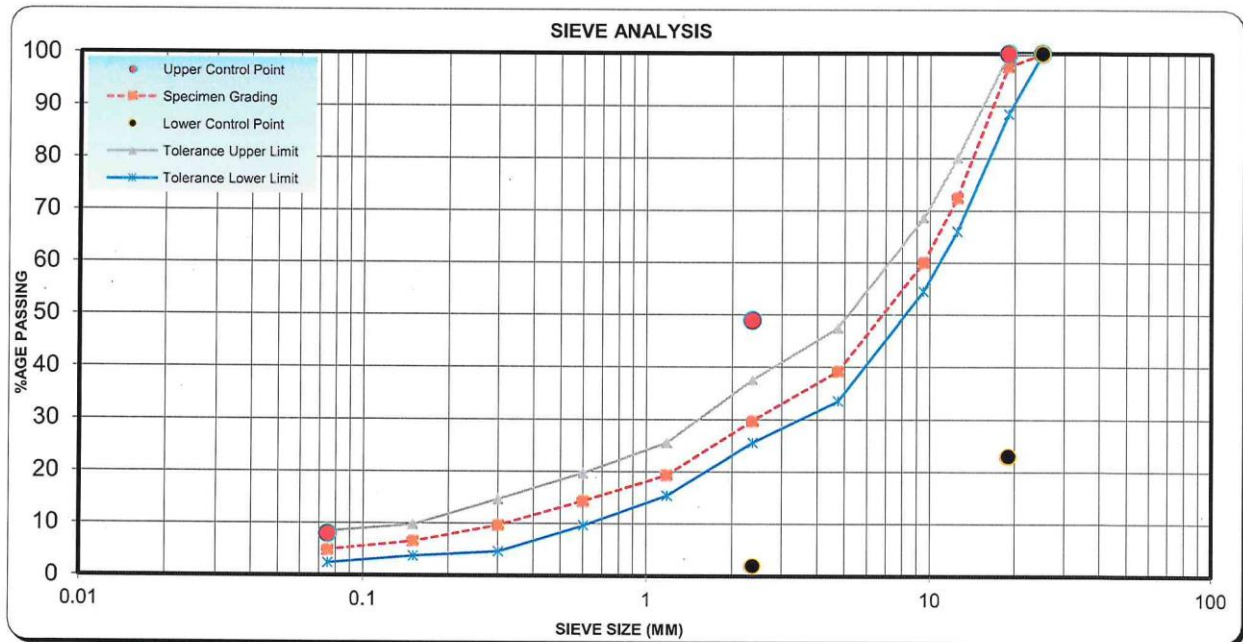
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

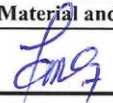
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% Pumice	Date of Testing	29-02-2025
Proportion:	25:32:8.32.3		

Average (Morning & Afternoon)

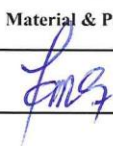
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1738.65	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.05	19.0	40.6	2.5	97.5	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.65	12.50	415.4	25.1	72.5	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.6	9.50	205.2	12.4	60.1	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	9.0	4.75	343.4	20.7	39.3	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1646.2	2.36	158.1	9.5	29.8	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1655.8	1.18	171.8	10.4	19.4	20.4	15.4	25.4	-	-
		0.600	82.9	5.0	14.4	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	82.9	0.300	77.7	4.7	9.7	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.77	0.150	51.1	3.1	6.6	6.8	3.8	9.8	-
			0.075	29.0	1.8	4.9	5.4	2.4	8.4	2
	In T. Agg. H/F %	5.0	Pan	80.9	4.9					8

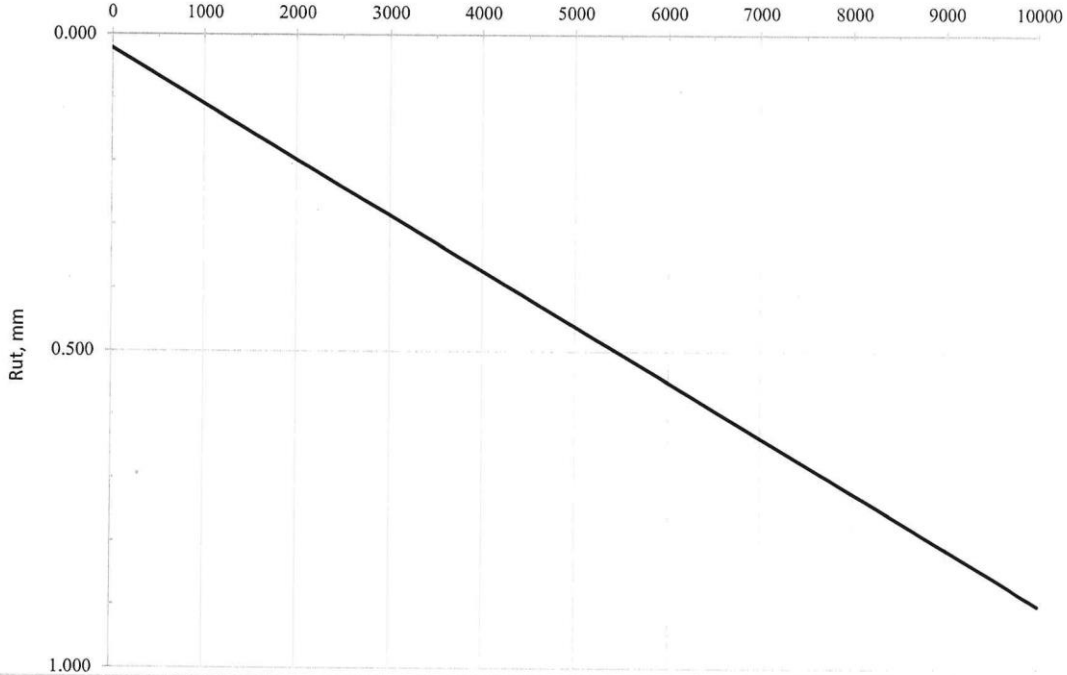
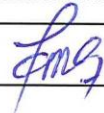


Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	100% Pumice				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,010		
SSD mass	B	gm.	1,013		
Mass in water	C	gm.	573		
Volume	$E = (B - A) - (B - C)$		cm ³	437	
Bulk specific gravity	$G_{mb} = A/E$			2.311	
Maximum specific gravity	G_{mm}			2.492	
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$		%	7.3	
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.23		
Rut at 5,000 passes		mm	0.46		
Rut at 10,000 passes		mm	0.90		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.09		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	1.5		
Maximum Rut depth RD_{Air}		mm	0.9		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	100% Pumice				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Passes 					
Remark: _____					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
					



Employer	Consultant	Contractor																																				
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE																																				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE- I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																																						
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283																																						
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs																																						
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa]																																						
Saturated 16hrs @ -18°C + 24hrs @ 60°C + 2 hrs @ 25°C Duration: 6 min [5 - 10 min]																																						
Filler 100% Pumice																																						
Condition of test specimens																																						
<table border="1"> <thead> <tr> <th colspan="3">Sample identification</th> <th colspan="3">Saturated/conditioned</th> <th colspan="3">Dry</th> </tr> <tr> <th></th> <th></th> <th></th> <th>1</th> <th>2</th> <th>3</th> <th>1</th> <th>2</th> <th>3</th> </tr> </thead> <tbody> <tr> <td>Diameter</td> <td>D</td> <td>mm</td> <td>150.1</td> <td>149.0</td> <td>149.4</td> <td>150.0</td> <td>149.9</td> <td>149.8</td> </tr> <tr> <td>Thickness</td> <td>t</td> <td>mm</td> <td>93.6</td> <td>97.5</td> <td>96.8</td> <td>95.9</td> <td>94.8</td> <td>96.5</td> </tr> </tbody> </table>			Sample identification			Saturated/conditioned			Dry						1	2	3	1	2	3	Diameter	D	mm	150.1	149.0	149.4	150.0	149.9	149.8	Thickness	t	mm	93.6	97.5	96.8	95.9	94.8	96.5
Sample identification			Saturated/conditioned			Dry																																
			1	2	3	1	2	3																														
Diameter	D	mm	150.1	149.0	149.4	150.0	149.9	149.8																														
Thickness	t	mm	93.6	97.5	96.8	95.9	94.8	96.5																														
VOLUMETRIC																																						
Dry mass in air	A	gm.	3,951	3,905	3,935	3,954	3,984	3,962																														
SSD mass	B	gm.	3,966	3,916	3,966	3,966	3,998	3,974																														
Mass in water	C	gm.	2,305	2,272	2,316	2,295	2,300	2,288																														
Volume	E = B - C	cm ³	1,661	1,644	1,650	1,671	1,698	1,686																														
Bulk specific gravity	G _{mb} = A/E		2.379	2.375	2.385	2.366	2.346	2.350																														
Maximum specific gravity	G _{mm}		2.492	2.492	2.492	2.492	2.492	2.492																														
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%	4.5	4.7	4.3	5.0	5.8	5.7																														
Volume of air voids	V _a = (P _a x E/100)	cm ³	75.5	77.0	70.9	84.3	99.3	96.1																														
TSR																																						
Thickness	t'	mm	93.6	97.5	96.8																																	
SSD mass	B'	gm.	4008	3962	3989																																	
Volume of absorbed water	J' = B' - A	cm ³	57.0	57.0	54.0	-	-	-																														
Saturation	S' = 100 x J'/V _a	%	75.5	74.0	76.1	-	-	-																														
Load	P'	N	26,070.0	26,510.0	25,950.0	28,560.0	29,540.0	29,120.0																														
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa				1,263.9	1,323.4	1,282.4																														
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa	1,181.3	1,161.7	1,142.3																																	
Average dry strength	Average S ₁	kPa	1,289.9																																			
Average wet strength	Average S ₂	kPa	1,161.8																																			
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%	90.1																																			
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80																																						
Remark:																																						
<table border="1"> <tr> <td> Tested by:  </td> <td> Verified by: Material and Pavement Engineer  </td> </tr> </table>			Tested by: 	Verified by: Material and Pavement Engineer 																																		
Tested by: 	Verified by: Material and Pavement Engineer 																																					



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50 Wearing Course
21.02.2025

Specimen Information

Identification: AC -50 100% pumice
Conditioning time: 2
Properties/Comments: Sample -1
21.02.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm ²): 17203.4								

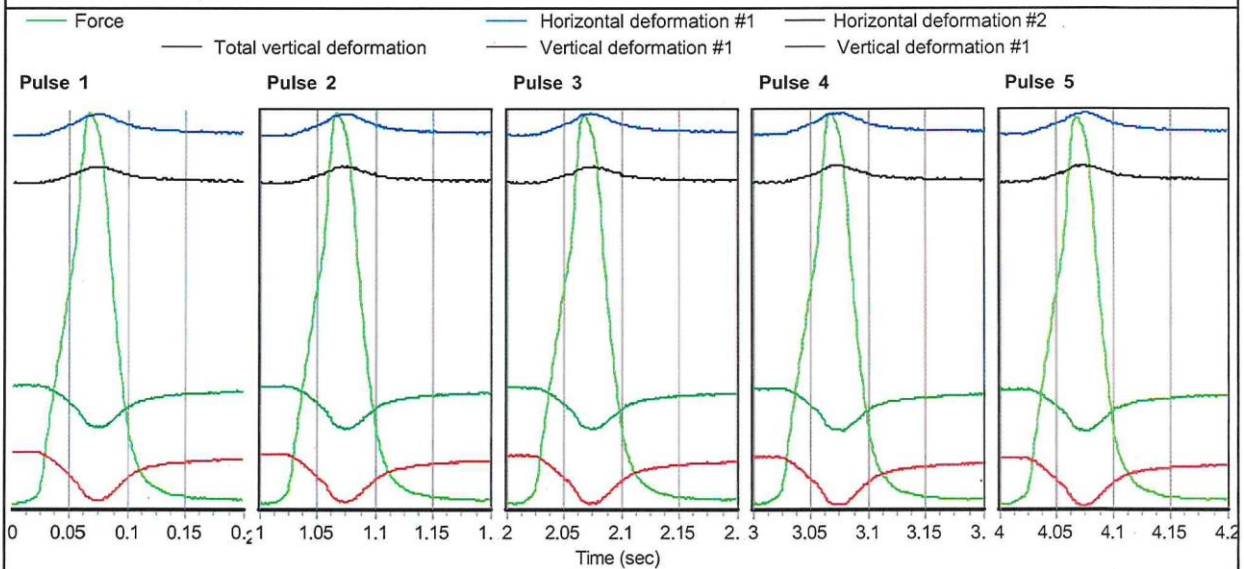
Test Parameters

Waveshape: Haversine
Loading pulse width (ms): 100
Rest period (ms): 900
Pulse repetition period (ms): 1000
Number of conditioning pulses: 100
Target temperature (°C): 30
Contact load (N): 50
Peak load (N): 1550
Consta₁₁: 0.233936
I2: -0.780056
I3: 0.307445
I4: -1.069463

Test Results

Test date & time: Friday, February 21, 2025, at 10:59
Conditioning pulses: 100
Core temperature (°C): 31.9
Surface temperature (°C): 26.3

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	6294	6248	6173	6339	6248	6260	55.38	0.88	
Poisson Ratio #1	0.40	0.38	0.39	0.42	0.39	0.40	0.01	3.52	
Recoverable horizontal deformation #1 (µm)	1.626	1.569	1.619	1.635	1.572	1.604	0.028	1.728	
Recoverable vertical deformation #1 (µm)	-3.531	-3.527	-3.556	-3.506	-3.493	-3.523	0.022	-0.622	
Resilient Modulus #2 (MPa)	7038	6945	7084	7011	7010	7018	44.93	0.64	
Poisson Ratio #2	0.30	0.31	0.32	0.30	0.31	0.31	0.01	2.45	
Recoverable horizontal deformation #2 (µm)	1.245	1.269	1.261	1.238	1.253	1.253	0.011	0.878	
Recoverable vertical deformation #2 (µm)	-3.076	-3.116	-3.040	-3.075	-3.054	-3.072	0.026	-0.842	
Maximum applied load (N)	1173	1171	1161	1169	1157	1166	6.13	0.53	
Contact load (N)	49	50	51	50	50	50	0.66	1.32	



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHA ASTM Template Binder Course.P003

Project: Adama-Awash km 50

Operator: Ravi

Comments: AC -50

Wearing coarse

21.02.2025

Specimen Information

Identification: AC -50 100 % pumice

Conditioning time: 2

Properties/Comments: sample 3 21.02.2025

Dimensions

Diameter (mm)

Height (mm)

Point 1

Point 2

Point 3

Point 4

Point 5

Point 6

Average

Std Dev.

148.00

63.00

148.00

63.00

148.00

63.00

148.00

63.00

148.00

63.00

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63.00

148.00

63.00

148.00

63.00

Cross-sectional area (mm²): 17203.4

Test Parameters

Waveshape: Haversine

Loading pulse width (ms): 100

Rest period (ms): 900

Pulse repetition period (ms): 1000

Number of conditioning pulses: 100

Target temperature (°C): 30

Contact load (N): 50

Peak load (N): 1550

nts
Consta I1: 0.233936

I2: -0.780056

I3: 0.307445

I4: -1.069463

Test Results

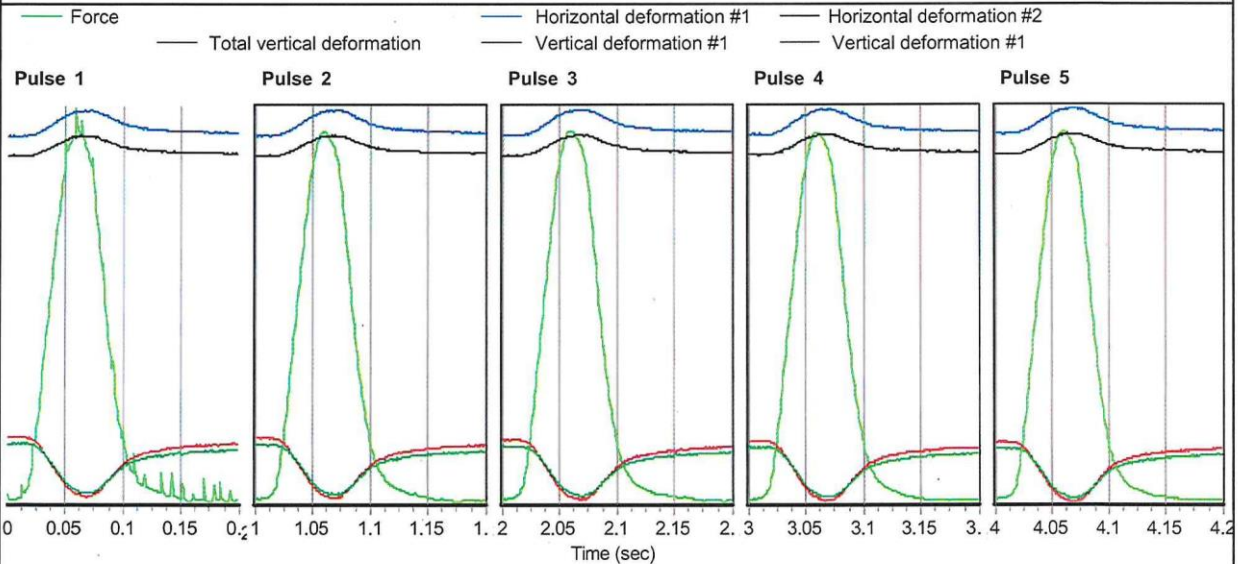
Test date & time: Friday, February 21, 2025, at 11:25

Conditioning pulses: 100

Core temperature (°C): 31.6

Surface temperature (°C): 27.0

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	5973	5674	5671	5647	5708	5735	5735	120.76	2.11
Poisson Ratio #1	0.35	0.34	0.35	0.34	0.35	0.35	0.35	0.00	1.26
Recoverable horizontal deformation #1 (µm)	2.003	1.970	2.000	1.982	1.995	1.990	1.990	0.012	0.616
Recoverable vertical deformation #1 (µm)	-4.664	-4.615	-4.643	-4.640	-4.604	-4.633	-4.633	0.021	-0.461
Resilient Modulus #2 (MPa)	7254	6817	6856	6746	6770	6889	6889	186.51	2.71
Poisson Ratio #2	0.34	0.33	0.33	0.31	0.33	0.33	0.33	0.01	3.59
Recoverable horizontal deformation #2 (µm)	1.641	1.611	1.599	1.567	1.610	1.606	1.606	0.024	1.485
Recoverable vertical deformation #2 (µm)	-3.837	-3.830	-3.819	-3.847	-3.853	-3.837	-3.837	0.012	-0.318
Maximum applied load (N)	1492	1404	1409	1405	1405	1423	1423	34.60	2.43
Contact load (N)	53	51	50	49	50	51	51	1.55	3.05



Stress Strain Test

Data file name: C:\IPCglobal UTS\002 Stress Strain Test\Data\21-03-25 CI -AC-50.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 21/03/2025 16:26:41
Project: EHAE
Operator:
Comments: 21-03-25 Cracking Tolerance Index 100% Pumice

Specimen Information

Identification:
Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

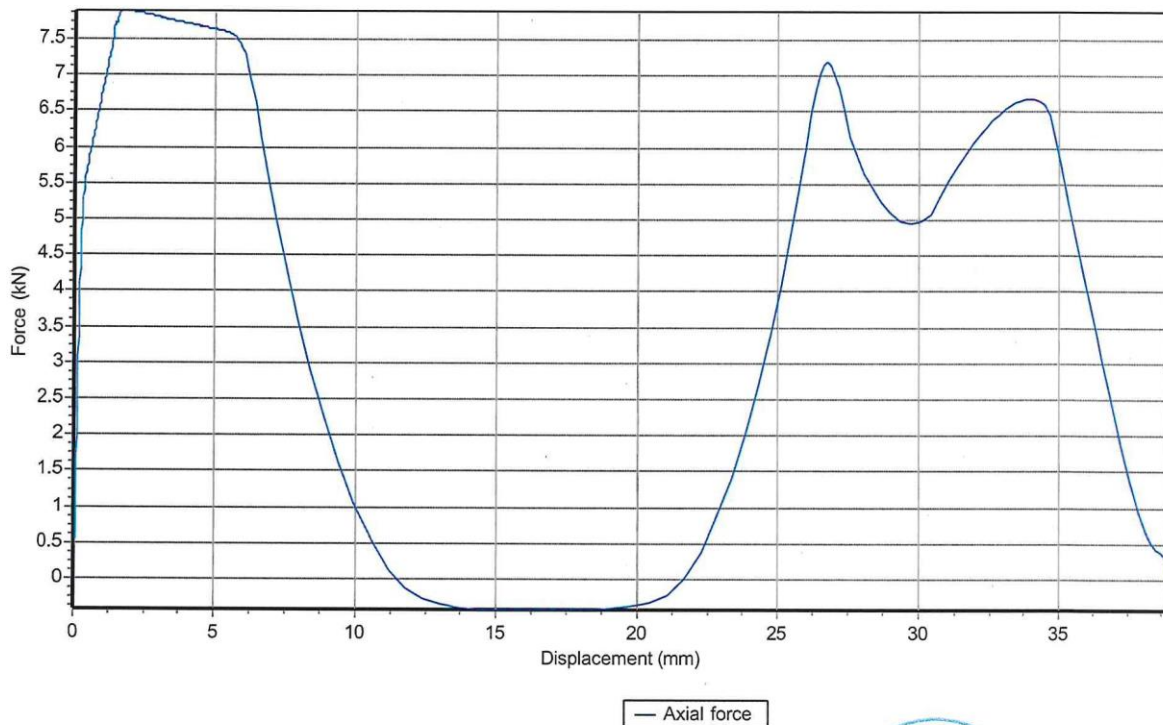
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hh:mm:ss): 00:01:23
Displayed time (hh:mm:ss): 00:01:23
Displayed seconds: 83
Actuator displ. (mm): 38.948
Actuator microstrain: 2.5966E5
Actuator position (mm): 24.473

Axial force (kN): 0.106
Axial stress (kPa): 14.1
Maximum axial force (kN): 7.907
Minimum axial force (kN): 1048.7



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\Creep test sample -1.D030

Template file name: C:\Users\IPC GLOBAL\Desktop\UTS030 - EHAE Creep template AC 50.P030

Test date & time: 21-03-25 100% Pumice, at 2:52 PM

Project: Adama Awash km 60

Operator: Ravi

Comments: Creep Modulus

Specimen Information

Identification: 100% Pumice

Remarks...

AC -50

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

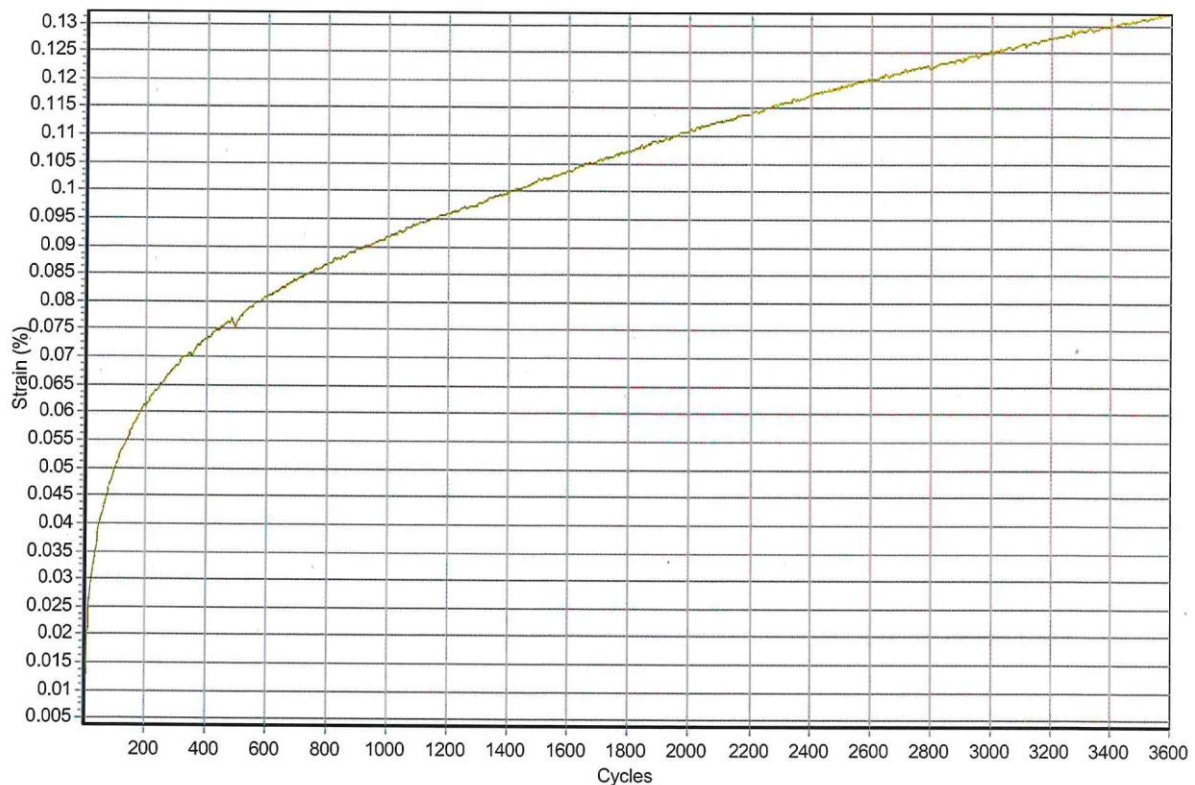
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 10

	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	



— Total Permanent strain



Appendix 8 Chemical composition analysis (Complete silicate analysis), Physical properties and Quality test of Red Volcanic Ash Cinder

	GEOLOGICAL INSTITUTE OF ETHIOPIA		Doc. Number: GLD/F5.10.2	Version No: 1
	Geochemical Laboratory Desk			Page 1 of 1
	Complete Silicate Analysis Report		Effective date: Nov. 2022	
Document Title:-				

Customer Name:- Haimanot Girma

Sample type :- Red Volcanic Ash Cinder

Sample Preparation:-200 Mesh

Date Submitted ; - 06/03/2025

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides.

Analytical Method: LiBO₂ FUSION, HF attack, GRAVIMETRIC, COLORIMETRIC and AAS

Issue Date:- 18/03/2025

Request No:- GLD/RQ/1055/25

Report No:- GLD/RN/4559/25

Number of Sample: One(01)

Collector's code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	TiO ₂	H ₂ O	LOI	weight Of sample
RVAC-1	52.68	16.28	11.34	10.12	4.96	2.58	0.64	0.18	0.96	0.10	0.16	0.51	1kg

Note:- This result represent only for the sample submitted to the laboratory.

➤ LOI = Loss on Ignition

Analysts

Fasika Dereje

Abdisa Yohannes

Wedajo Gudisa

Tensae Tarekegn

Bane Abera

Shashe Haile

Checked By


Kindte Kasahun

Approved By


Lidet Endeshaw



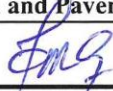
Yohannes Getachew

CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT  LEA-LASA-UNICONE		 
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)				
<u>SPECIFIC GRAVITY OF VOLCANIC ASH</u> (AASHTO T 100)				
Type of Material	Red Volcanic Ash Cinder	Date of Sampling	5/3/2025	
Location	Km.34+000 RHS	Date of Testing	10/3/2025	
Proposed Use	Asphalt			
Trial No		Trial - 1	Trial - 2	
Pycnometer Bottle Number		1	2	
Weight of Pycnometer (W_f)	(gm)	104.7	104.6	
Weight of Pycnometer +Sample (W_2)	(gm)	204.7	204.6	
Weight of Oven dry sample (W_o) = ($W_2 - W_f$)	(gm)	100	100	
Weight of Pycnometer +Sample +Water (W_b)	(gm)	413.4	413.3	
Any other Desired Temperature (T_x)	($^{\circ}\text{C}$)	25	25	
Relative Density of Water (D_x)		0.9965451	0.9965451	
Weight of Pycnometer +Water (W_i)	(gm)	347.5	347.5	
Weight of Pycnometer +Water (W_a) = $[(D_x/D_i)(W_i - W_f)] + W_f$	(gm)	347.5	347.5	
Observed Temperature of Water (T_i)	($^{\circ}\text{C}$)	27	25	
Relative Density of Water at Temperature (D_i)		0.9965451	0.9965451	
Apparent Specific gravity of Filler (S_x) = $W_o / [W_o + (W_a - W_b)]$		2.933	2.924	
Average Apparent Specific Gravity of Stone Filler		2.928		
Remarks :				
Tested by:		Verified by:		
Laboratory Technician		Material and Pavement Engineer		
		 		

CLIENT  ETHIOPIAN ROAD	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBC Joint Venture.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
GRADATION OF FINE AGGREGATE			
Material Type	Red Ash	Date of Sampling	5/3/2025
Source Of Material	Km. 29+600 LHS	Date of Testing	13/3/2025
Propose use	Asphalt	Weight of Sample: 500	gms.
Sieves (mm)	Weight Retained (g)	% Retained	Cum % Retained
0.15	0.0	0.00	0.00
0.075	92.6	18.52	18.52
Pan	407.4	81.48	100.00
		% of passing	ERA Tech. Spec, Table 8402-2
			Lower Limit Upper Limit
			100 100
			0 100
			0 100

SIEVE SIZE

—●— % of passing
 —■— Lower Limit
 —▲— Upper Limit

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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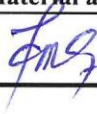
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCCL Joint Venture
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Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway

SOURCE	Borrow Area @34+000 RHS	SAMPLEING DATE	5/3/2025
SAMPLING LOCATION	Km.34+000 RHS		
PURPOSED TO USE	Asphalt		
MATERIAL DESCRIPTION:	Red Volcanic Ash Cinder		

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA
1	COMPACTION TEST	MDD at 100%	AASHTO T-180 Method D/ ASTM D 1557	
		OMC		
		MDD at 95%		
2	CBR	CBR at 95% MDD	AASHTO 193/ ASTM D 1883	> 5
		SWELL		< 2
3	SOIL PLASTICITY	LIQUID LIMIT (LL)	AASHTO T-89/90/ ASTM D 4318	< 60
		PLASTIC LIMIT (PL)	AASHTO T-89/90/ ASTM D 4318	
		PLASTICITY INDEX(PI)	AASHTO T-89/90/ ASTM D 4318	< 30
4	SOIL CHARACTER	SOIL CLASSIFICATION	A -1-b(0)	AASHTO M 145

Note: Attach individual test records and data sheet

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRCL Joint Venture.
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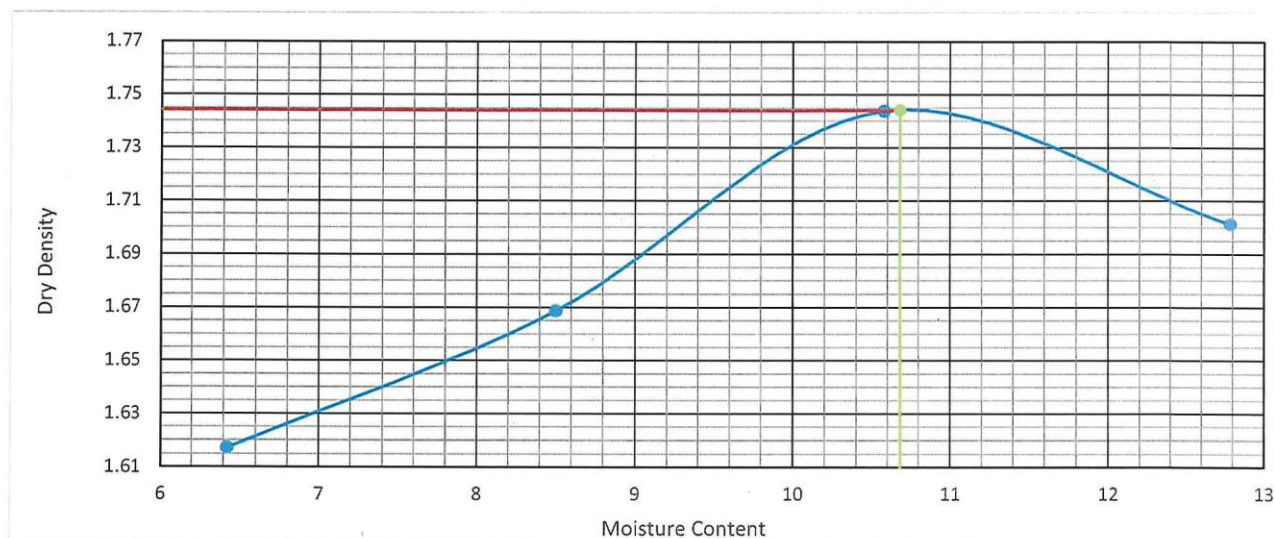
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT

(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

MAXIMUM DRY DENSITY AND MOISTURE CONTENT

(AASHTO T-180)

Source :	Borrow Area @34+000 RHS			Date of Sampling:	5/3/2025	
Propose Used	Asphalt			Date of Testing:	9/3/2025	
Material Discription	Red Volcanic Ash Cinder					
Description	Test I	Test II	Test III	Test IV	Test V	
Density Determination						
Water Added %	4%	6%	8%	10%		
Mass of mould + Wet Soil (g)	9100	9290	9540	9520		
Mass of mould, W5 (g)	5440	5440	5440	5440		
Mass of wet soil, W7=W6-W5 (g)	3660	3850	4100	4080		
Volume of mould, V (cc)	2124	2124	2124	2124		
Bulk density, $y_m = [(W7-W6)/V]$ g/cc	1.723	1.813	1.930	1.921		NMC
Moisture Content Determination						
Container no	B-15	B-1	B-9	B-6		A-12
Mass of container + wet soil, W1 (g)	256.10	280.50	269.90	279.90		395.20
Mass of container + oven dry soil, W2 (g)	242.40	260.90	247.00	251.40		386.60
Mass of Water (g) W3=W1-W2	13.70	19.60	22.90	28.50		8.60
Mass of container, W4 (g)	29.10	30.40	30.50	28.50		47.70
Mass of Dry Soil (g) W5 = W2-W4	213.30	230.50	216.50	222.90		338.90
Moisture Content (%) W6= W3/W5*100	6.42	8.50	10.58	12.79		2.54
Dry density, $y_d = y_m/(100+W6)*100$ (g/cc)	1.619	1.671	1.746	1.703		2.54



MDD: 1.746 (gm/cc)

OMC: 10.7 %

Tested by:

Laboratory Technician



Verified by:

Material and Pavement Engineer




CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBC Joint Venture.			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
ATTERBERG LIMITS (AASHTO T-89/90)					
Source :	Borrow Area @34+000 RHS	Date of Sampling:	5/3/2025		
Propose Used	Asphalt	Date of Testing:	9/3/2025		
Material Discription	Red Volcanic Ash Cinder				
Description	LIQUID LIMIT		PLASTIC LIMIT		
	Test I	Test II	Test III		
	Test IV	Test I	Test II		
			Avg.		
No of blows/Penetration (mm)	NP				
Container No					
Container + Wet soil, W1 (g)					
Container + Dry soil, W2 (g)					
Weight of Container (g)					
Weight of water, W4= W1-W2 (g)					
Weight of oven dry sample, W5=W3 - W1 (g)					
Water content percentage, 100x(W4/W5)					
NP		Grain Size Analysis			
		Total Wt.(gm)		780.6	
		Sieve size mm	Wt. Ret. (g.)	% Retained	% Passing
		2.0	488.1	62.53	37.47
		0.425	195.0	24.98	12.49
		0.075	38.8	4.97	7.52
		Pan	58.7	7.52	0.00
LL	PL	PI	Soil Class		
Np	NP	NP	A -1-b(0)		
Tested by:		Verified by:			
Laboratory Technician		Material and Pavement Engineer			
					



CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Source :	Borrow Area @34+000 RHS	Date of Sampling:	5/3/2025
Location:	Km.34+000 RHS	Date of Soaking:	12/3/2025
Propose Used	Asphalt	Date of Testing:	16/3/2025
Material Discription	Red Volcanic Ash Cinder		
DENSITY DETERMINATION			
SOAKING CONDITION	10 Blows		30 Blows
	Before	After	Before After
MOLD NUMBER	M-36		M-19
WEIGHT OF MOLD	7480	7480	7700 7700
WEIGHT OF SOIL + MOLD	11040	11415	11700 11970
WEIGHT OF SOIL	3560	3935	4000 4270
VOLUME OF MOLD	2124	2124	2124 2124
WET DENSITY OF SOIL	1.68	1.85	1.88 2.01
DRY DENSITY OF SOIL	1.52	1.60	1.70 1.76
MOISTURE DETERMINATION			
CONTAINER NUMBER	A-6	B-10	A-8 B-6 A-3 B-8
WET SOIL + CONTAINER (g)	364.90	313.44	335.20 293.60 291.60 310.63
DRY SOIL + CONTAINER (g)	336.21	274.92	308.44 260.24 268.42 279.30
WEIGHT OF WATER (g)	28.69	38.52	26.76 33.36 23.18 31.33
WEIGHT OF CONTAINER (g)	65.50	31.17	56.00 28.56 49.70 30.68
WEIGHT OF DRY SOIL (g)	270.71	243.75	252.44 231.68 218.72 248.62
MOISTURE CONTENT (%)	10.60	15.80	10.60 14.40 10.60 12.60
AVG. MOISTURE CONTENT (%)	13.20		12.50 11.60
Ring Factor	0.19752		
PENETRATION TEST DATA			
PENETRATION (mm)	Std. Load	Dial reading	Load (kn) Cor. Load (kn)
0		0.0	0
0.64		1.4	0.3
1.27		4.0	0.8
1.96		6.2	1.2
2.54	13.54	9.0	1.8 1.9
3.18		11.8	2.3
3.81		14.0	2.8
4.45		16.0	3.2
5.08	20.22	17.4	3.4 3.3
7.62		19.6	3.9
10.16		21.7	4.3
12.7		23.8	4.7
SWELL READING (INITIAL)		5.34 3.42 4.77	
SWELL READING (FINAL)		5.43 3.57 4.90	
PERCENTAGE SWELL		0.08 0.13 0.11	
CBR @ 2.54 mm		14.2 29.5 73.8	
CBR @ 5.08 mm		16.1 33.6 80.1	
Tested by: 			
Verified by: 			

CLIENT



ETHIOPIAN ROAD AUTHORITY

CONSULTANT



LEA-LASA-UNICONE

CONTRACTOR



JMC PROJECTS (I) LTD.

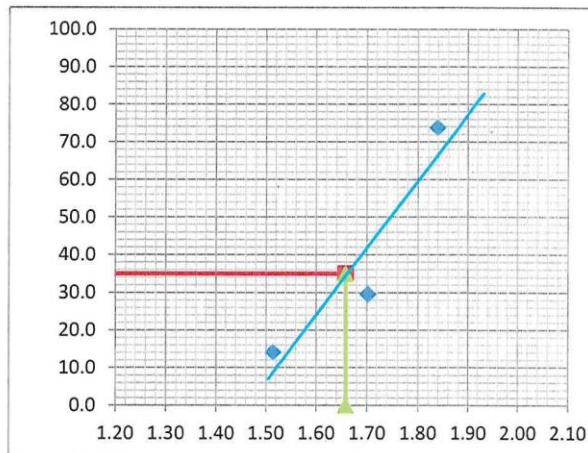
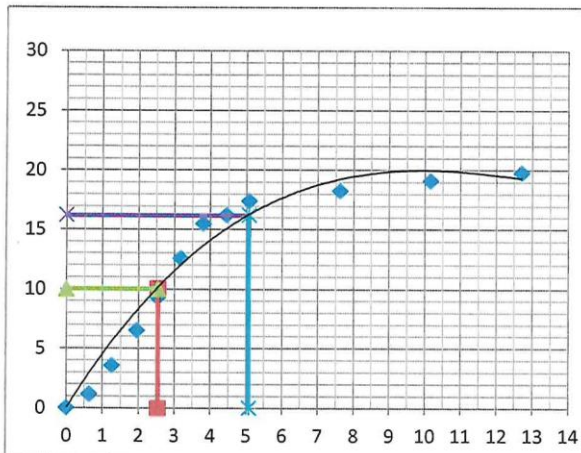
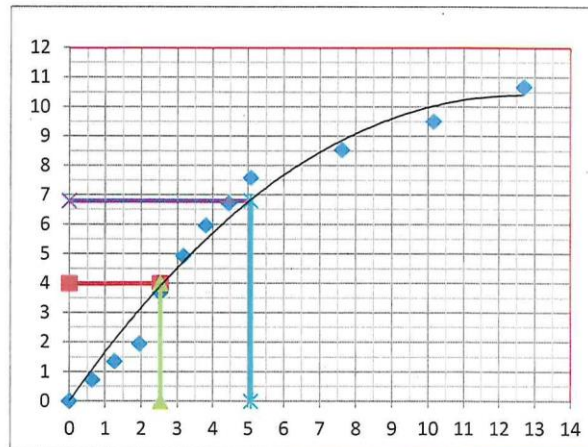
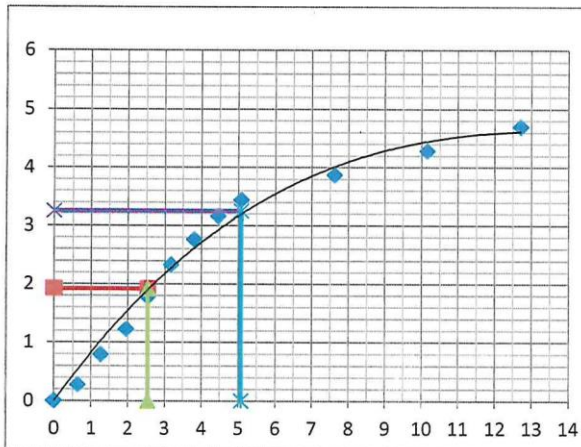
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

CALIFORNIA BEARING RATIO TEST

(AASHTO T 193)

Source :	Borrow Area @34+000 RHS	Date of Sampling:	5/3/2025
Location:	Km.34+000 RHS	Date of Soaking:	12/3/2025
Propose Used	Asphalt	Date of Testing:	16/3/2025
Material Discription	Red Volcanic Ash Cinder		

MDD (gm/cc)	1.746	OMC (%)	10.68
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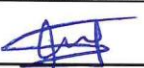
Density @ 95% Compaction (gm/cc)	1.659
CBR @ 95% Compaction (%)	35.0
Swell @ 95% Compaction (%)	0.11

Tested by:

Verified by:

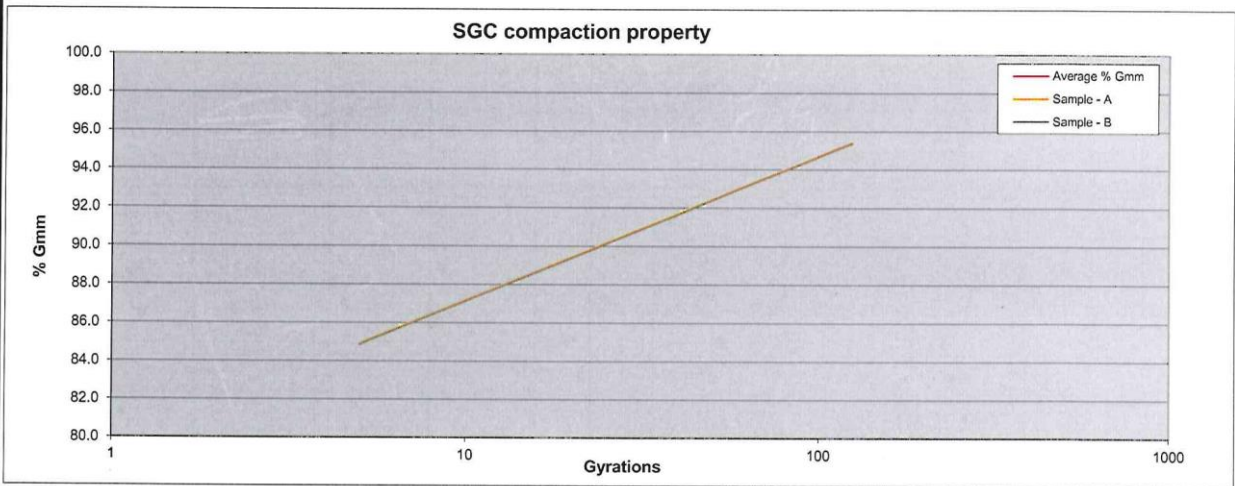


**Appendix 9 Volumetric properties and Performance
tests of asphalt mixture with 25% Red Volcanic Ash
Cinder and 75% Stone Dust of Filler**

Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT											
ADAMA-Km 60 EXPRESSWAY											
(PHASE-I: DESIGN BUILD OF											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler	25% RA and 75% SD							
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.394	NA								
	Av	4.6	3 - 6								
	VMA(%)	14.0	≥ 13								
	VFB(%)	67.4	65 - 75								
	N _{ini} (%)	86.8	≤ 89								
	N _{des} (%)	95.4	96% ± 1%								
	N _{max} (%)	96.4	≤ 98%								
MTD	G _{mm}	2.509	NA								
DUST TO BINDER RATIO		1.58	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.72	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	12.5	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100	96.7	73.0	61.7	40.3	32.3	21.6	16.2	11.3	8.5	7.1
JMF	100	96.5	73.0	61.6	40.6	31.6	20.4	14.7	9.7	6.8	5.4
Tolerance from JMF L. Limit	100	88.5	66	54.6	33.6	25.6	15.4	9.7	4.7	3.8	2.4
Tolerance from JMF U. Limit	100	100	80	68.6	47.6	37.6	25.4	19.7	14.7	9.8	8.4
Upper Control Point	100	100	-	-	-	49	-	-	-	-	8
Lower Control Point	100	90	-	-	-	23	-	-	-	-	2
REMARK:											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
											



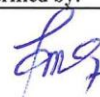
Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course			Agg Source	Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix			Bitumen Grade	40/50			
Filler	25% RA and 75% SD			Specific Gravity	1.0285			
Date Tested:	10-Mar-25			Number of Gyration	125 @ N _{des}			
Mixing Temperature (°C)	135-165			Compaction Temperature (°C)	135-150			
Sample - A			Sample - B			Average % Gmm Average G _{mb} Gyro Average G _{mb} Average G _{mm} Average G _{sb} G _{sa}		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.868	84.9	128.084	84.9				
9 [Nini]	125.034	86.8	125.245	86.8				
10	124.539	87.2	124.750	87.1				
20	121.38	89.5	121.585	89.4				
30	119.605	90.8	119.807	90.7				
40	118.377	91.7	118.577	91.7				
50	117.442	92.5	117.640	92.4				
70	116.059	93.6	116.255	93.5				
90	115.047	94.4	115.242	94.3				
110	114.252	95.0	114.445	95.0				
125 [Ndes]	113.751	95.5	113.943	95.4				
G _{mb} Gyro			G _{mb} Gyro					
G _{mb}			G _{mb}					
G _{mm}			G _{mm}					
G _{sb}			G _{sb}					
G _{sa}			G _{sa}					
% AC	4.70		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Gsb	2.654		Sample - A	4436.2	4453.1	2600.6	1852.5	2.395
Pb	1.029		Sample - B	4435.5	4457.9	2605.2	1852.7	2.394
Volumetrics	Value	Spec.						
%Gmm@Ni	86.8	< 89%						
%Gmm@Ndes	95.43							
% Air void	4.6	3-6%						
% VMA	14.02	Min 12%						
% VFA	67.41	65-75						



Tested by:

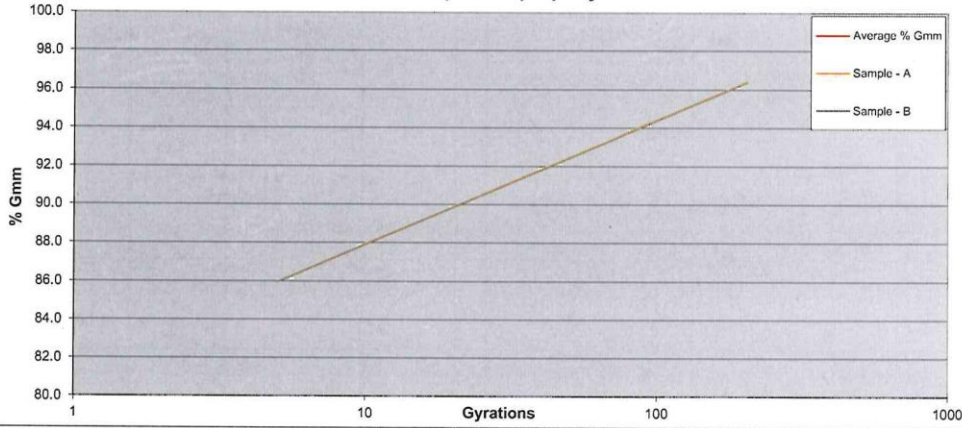


Verified by:




Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	25% RA and 75% SD		Specific Gravity		1.0285			
Date Tested:	10-Mar-25		Number of Gyration		205 @ N _{max}			
Mixing Tempreture (°C)		135-160		Compaction Tempreture (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.123	86.0	126.900	86.0	Average G _{mb} Gyro Average G _{mb} Average G _{mm} Average G _{sb} G _{sa}	86.0		
9 [Nini]	124.728	87.7	124.509	87.6		87.6		
10	124.308	87.9	124.090	87.9		87.9		
20	121.615	89.9	121.402	89.9		89.9		
30	120.094	91.0	119.883	91.0		91.0		
40	119.037	91.8	118.828	91.8		91.8		
50	118.230	92.5	118.022	92.4		92.5		
70	117.033	93.4	116.828	93.4		93.4		
90	116.155	94.1	115.952	94.1		94.1		
110	115.464	94.7	115.261	94.6		94.7		
125 [Ndes]	115.027	95.0	114.826	95.0		95.0		
150	114.411	95.6	114.210	95.5		95.5		
175	113.895	96.0	113.695	96.0		96.0		
200	113.451	96.4	113.252	96.3		96.3		
205 [Nmax]	113.370	96.4	113.171	96.4		96.4		
G _{mb} Gyro		2.353	G _{mb} Gyro			2.351	2.352	
G _{mb}		2.419	G _{mb}		2.419	2.419		
G _{mm}		2.509	G _{mm}		2.510	2.509		
G _{sb}		2.654	G _{sb}		2.654	2.654		
G _{sa}		2.736	G _{sa}		2.736	2.736		
% AC			4.7			Determination of measured Bulk Specific Gravity		
Aggreg. Frac.			95.3			Mix Ref.	Wt. air	wax+ spc in air
Gsb			2.654			Sample - A	4419.7	4435.6
Pb			1.029			Sample - B	4464.3	4477.0
wax+spc in water			2608.6			Volume	1827.0	Gmb
wax+spc in water			2631.6			1845.4	2.419	
Mix property		Units	Result		Criteria			
% G _{mm} at N _{max}		%	96.4		Max 98			

SGC compaction property



The graph plots % Gmm (Y-axis, 80.0 to 100.0) against Gyration (X-axis, 1 to 1000 on a log scale). Three data series are shown: Average % Gmm (red line), Sample - A (blue line), and Sample - B (green line). All three series follow a very similar linear trend, starting around 86% Gmm at 5 gyrations and reaching approximately 96.4% Gmm at 205 gyrations.

Tested by:



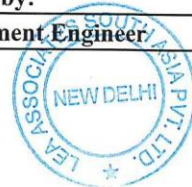
Verified by:





Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041		
Source of Mix	Lab-Mix	Filler
		25% RA and 75% SD
Material Description:	AC-60 Binder course	Dated of Testing
		13-Mar-2025
Grade of Bitumen	60/70	Bitumen by Wt. of Mix
		: 5.40%
Testing Temp.	25 °C	
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7		
Test No		Test 1
		Test 2
Mass of dry sample in air	A	gm.
		2675.6
Mass of container filled with water at test temperature	F	gm.
		9124.0
Mass of container filled with sample and water at test temperature	G	gm.
		10733
Temperature of test water	T	°C
		25
Correction for thermal expansion of bitumen	H	gm.
		0.0
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]	
	2.509	
Correction factor	R = dw/0.9970	
	1.000	
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E	
	2.509	
Average Theoretical Maximum Specific Gravity at 25°C	G_{mm} = (SG 1 + SG 2)/2	2.509
Effective Specific Gravity of Aggregate	G_{se}	2.701
Effective Specific Gravity of Aggregate[G_{se}] = (100-P_b)/((100/G_{mm})-(P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³		
Remark:		
Tested by: Laboratory Technician		Verified by: Material and Pavement Engineer





Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

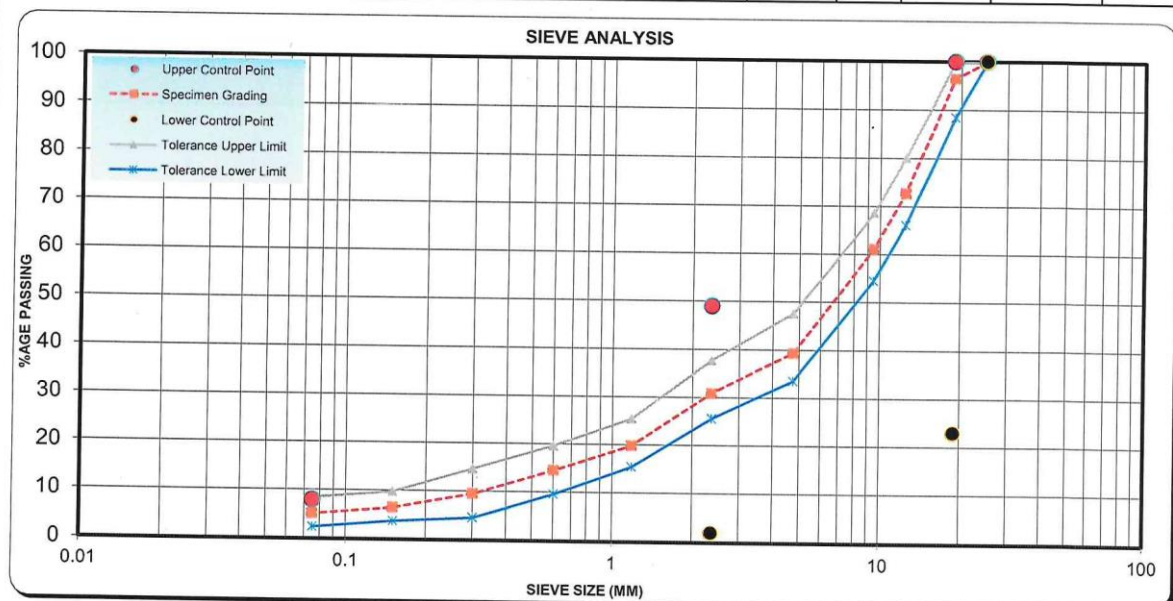
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	25% RA and 75% SD	Date of Testing	17-Mar-2025
Proportion:	25:32:8.32.3		

Trial - A

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1583.6	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.2	19.0	52.4	3.5	96.5	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.5	12.50	358.7	23.8	72.8	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.3	9.50	174.6	11.6	61.2	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	10.6	4.75	328.6	21.8	39.4	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1497.8	2.36	127.8	8.5	30.9	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1508.7	1.18	165.5	11.0	20.0	20.4	15.4	25.4	-	-
		0.600	80.3	5.3	14.6	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	74.9	0.300	76.6	5.1	9.6	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.73	0.150	44.5	2.9	6.6	6.8	3.8	9.8	-
			0.075	21.1	1.4	5.2	5.4	2.4	8.4	2
	In T. Agg. H/F %	5.0	Pan	78.6	5.2					8



Remarks :

Tested by:

Verified by:



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

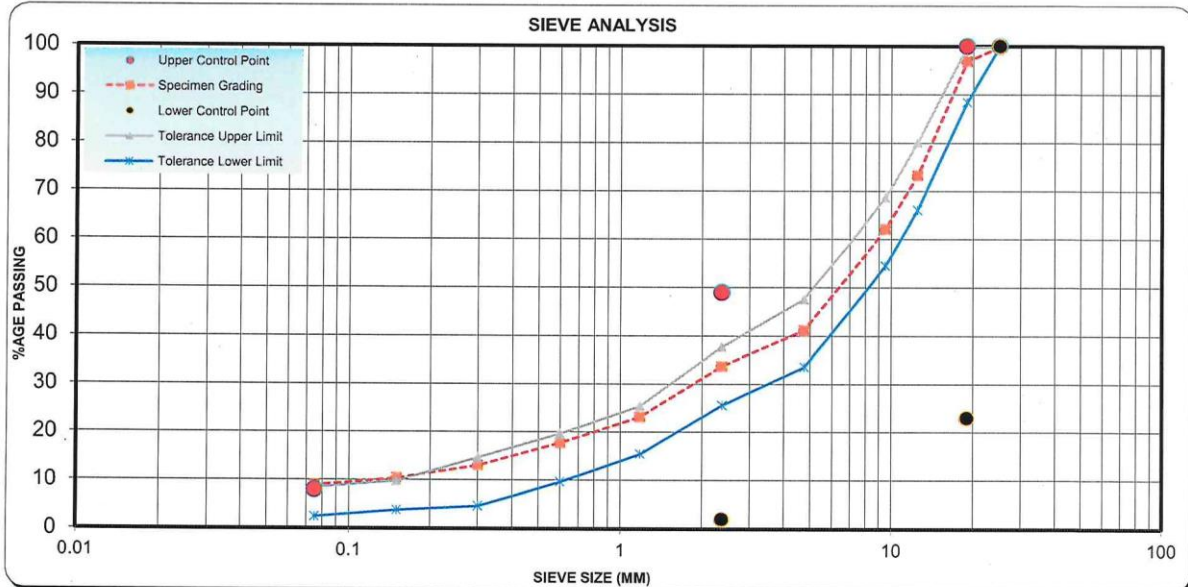
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	25% RA and 75% SD	Date of Testing	17-Mar-2025
Proportion:	25:32:8:32:3		

Trial - B

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1606.9	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.2	19.0	47.4	3.1	96.9	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.6	12.50	361.4	23.6	73.3	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.4	9.50	169.7	11.1	62.2	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	11.2	4.75	321.4	21.0	41.2	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1519.6	2.36	114.6	7.5	33.7	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1531.2	1.18	161.6	10.6	23.2	20.4	15.4	25.4	-	-
		0.600	83.2	5.4	17.8	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	75.7	0.300	71.9	4.7	13.1	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.71	0.150	40.6	2.7	10.4	6.8	9.8	-	-
			0.075	22.2	1.4	9.0	5.4	8.4	2	8
	In T. Agg. H/F %	5.0	Pan	137.2	9.0					



Remarks :

Tested by:

[Signature]

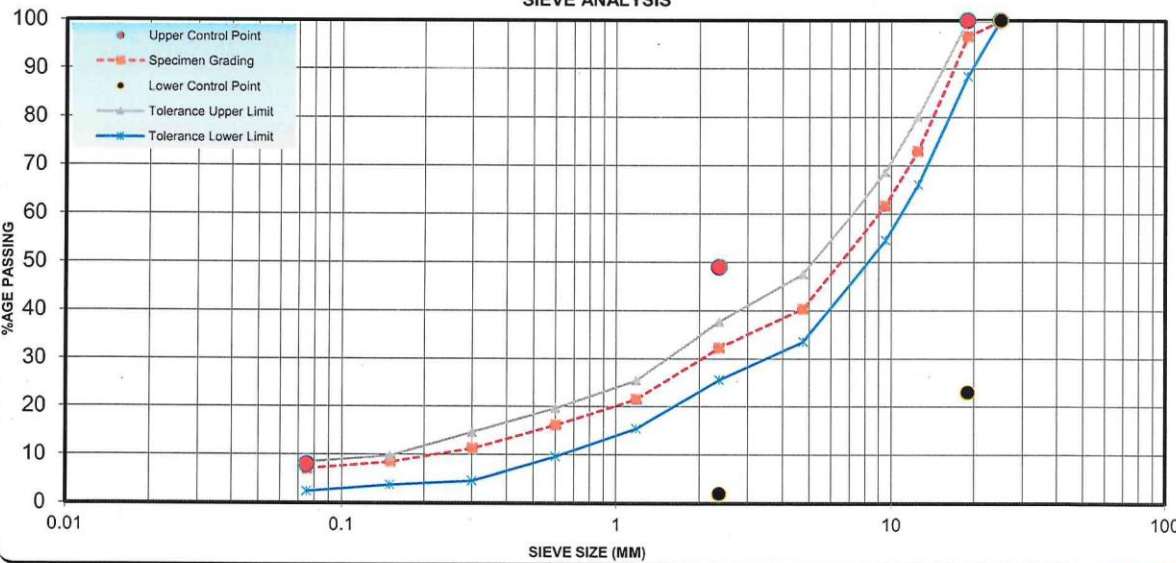
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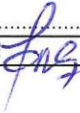


Employer		Consultant				Contractor						
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia				 JMC-LRBCL JOINT VENTURE						
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)												
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164												
Source of Mix		Lab-Mix		Source of Material		Km.29+600 LHS Quarry						
Material Description		Hot Mix Asphalt Binder Course Mixture				Grade of Bitumen		40/50				
Filler		25% RA and 75% SD				Date of Testing		17-Mar-2025				
Proportion:		25:32:8.32.3										
Average of 2 Trials												
BITUMEN EXTRACTION TEST			SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
			Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
								Lower	Upper			
Total Wt. of Mix before test (A) gm			1595.25	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm			3.2	19.0	49.9	3.3	96.7	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm			3.55	12.50	360.1	23.7	73.0	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm			0.4	9.50	172.2	11.3	61.7	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm			10.9	4.75	325.0	21.4	40.3	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm			1508.7	2.36	121.2	8.0	32.3	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm			1520.0	1.18	163.6	10.8	21.6	20.4	15.4	25.4	-	-
				0.600	81.8	5.4	16.2	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm			75.3	0.300	74.3	4.9	11.3	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.72	0.150	42.6	2.8	8.5	6.8	3.8	9.8	-	-	
			0.075	21.7	1.4	7.1	5.4	2.4	8.4	2	8	
		In T. Agg. H/F %	5.0	Pan	107.9	7.1						

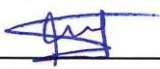
SIEVE ANALYSIS



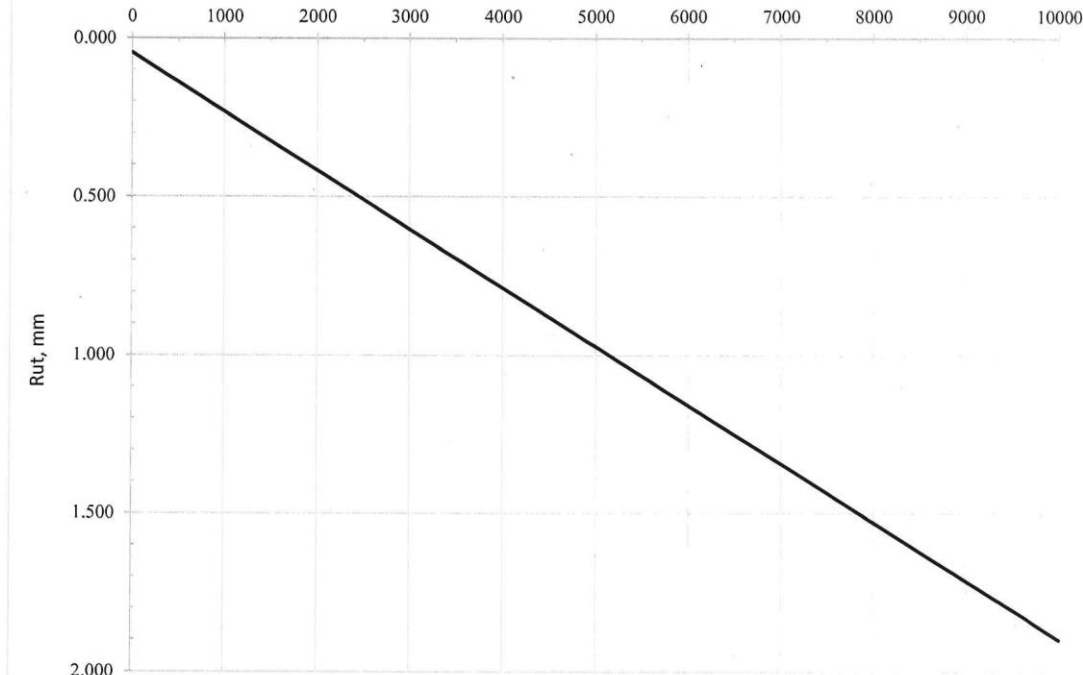
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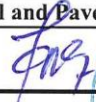
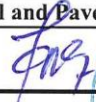
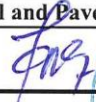
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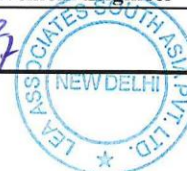


Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	25% Red ash Mix with 75% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60 ⁰ C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,006		
SSD mass	B	gm.	1,036		
Mass in water	C	gm.	574		
Volume	$E = (B - A) - (B - C)$		cm ³	432	
Bulk specific gravity	$G_{mb} = A/E$			2.329	
Maximum specific gravity	G_{mm}			2.509	
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$		%	7.2	
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.48		
Rut at 5,000 passes		mm	0.97		
Rut at 10,000 passes		mm	1.90		
Maximum Wheel Tracking Slope WTS _{Air} (d ₁₀₀₀₀ -d ₅₀₀₀)/5		mm/1k cycl	0.19		
Maximum Proportional Rut Depth PRD _{Air} 100 (d _n -d ₀)/h		%	3.1		
Maximum Rut depth RD _{Air}		mm	1.9		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
					



Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBC JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
WHEEL-TRACK TESTING EN 12697:22		
Filler	25% Red ash Mix with 75% Stone dust	
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)		
Specimen conditioning: In Air	Test temperature: 60 ⁰ C	
Conditioning time: +6hr	Test load: 520 N	
Passes  Remark:		
Page 2 of 2		
Tested by:	Verified by:	
Laboratory Technician	Material & Pavement Engineer	
	 	

Employer	Consultant	Contractor																																				
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE																																				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE- I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																																						
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283																																						
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs																																						
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa] Saturated 16hrs @ -18°C + 24hrs @ 60°C + 2 hrs @ 25°C Duration: 6 min [5 - 10 min]																																						
Filler 25% Red ash Mix with 75% Stone dust																																						
Condition of test specimens																																						
<table border="1"> <thead> <tr> <th colspan="3">Sample identification</th> <th colspan="3">Saturated/conditioned</th> <th colspan="3">Dry</th> </tr> <tr> <th></th> <th></th> <th></th> <th>1</th> <th>2</th> <th>3</th> <th>1</th> <th>2</th> <th>3</th> </tr> </thead> <tbody> <tr> <td>Diameter</td> <td>D</td> <td>mm</td> <td>150.0</td> <td>149.1</td> <td>148.9</td> <td>149.5</td> <td>150.0</td> <td>149.2</td> </tr> <tr> <td>Thickness</td> <td>t</td> <td>mm</td> <td>96.8</td> <td>94.8</td> <td>95.2</td> <td>96.7</td> <td>97.5</td> <td>96</td> </tr> </tbody> </table>			Sample identification			Saturated/conditioned			Dry						1	2	3	1	2	3	Diameter	D	mm	150.0	149.1	148.9	149.5	150.0	149.2	Thickness	t	mm	96.8	94.8	95.2	96.7	97.5	96
Sample identification			Saturated/conditioned			Dry																																
			1	2	3	1	2	3																														
Diameter	D	mm	150.0	149.1	148.9	149.5	150.0	149.2																														
Thickness	t	mm	96.8	94.8	95.2	96.7	97.5	96																														
VOLUMETRIC																																						
Dry mass in air	A	gm.	4,010	3,993	4,001	3,988	3,985	3,994																														
SSD mass	B	gm.	4,032	4,021	4,034	4,021	4,013	4,024																														
Mass in water	C	gm.	2,352	2,345	2,362	2,332	2,336	2,345																														
Volume	E = B - C	cm³	1,680	1,676	1,672	1,689	1,677	1,679																														
Bulk specific gravity	G _{mb} = A/E		2.387	2.382	2.393	2.361	2.376	2.379																														
Maximum specific gravity	G _{mm}		2.509	2.509	2.509	2.509	2.509	2.509																														
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%	4.9	5.0	4.6	5.9	5.3	5.2																														
Volume of air voids	V _a = (P _a x E/100)	cm³	81.8	84.5	77.3	99.5	88.7	87.1																														
TSR																																						
Thickness	t'	mm	96.8	94.8	95.2																																	
SSD mass	B'	gm.	4,069	4,055	4,059																																	
Volume of absorbed water	J' = B' - A	cm³	59.0	62.0	58.0	-	-	-																														
Saturation	S' = 100 x J'/V _a	%	72.2	73.3	75.0	-	-	-																														
Load	P'	N	18,250.0	20,880.0	19,950.0	24,020.0	24,310.0	23,080.0																														
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa				1,057.8	1,058.2	1,025.8																														
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa	800.2	940.4	896.0																																	
Average dry strength	Average S ₁	kPa	1,047.3																																			
Average wet strength	Average S ₂	kPa	878.9																																			
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%	83.9																																			
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80																																						
Remark:																																						
<table border="1"> <tr> <td> Tested by:  </td> <td> Verified by: Material and Pavement Engineer  </td> </tr> </table>			Tested by: 	Verified by: Material and Pavement Engineer 																																		
Tested by: 	Verified by: Material and Pavement Engineer 																																					



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

28.03.2025

Specimen Information

Identification: AC -50 25% RA-75% SD Dimensions | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 | Point 6 | Average | Std Dev.
Conditioning time: 2 Diameter (mm) 148.0
Properties/Comments: Sample 1 Height (mm) 63.0
28.03.2025 Cross-sectional area (mm²): 17203.4

Test Parameters

Waveshape: Haversine Target temperature (°C): 30 Const₁: 0.233936
Loading pulse width (ms): 100 Contact load (N): 50 I2: -0.780056
Rest period (ms): 900 Peak load (N): 1550 I3: 0.307445
Pulse repetition period (ms): 1000 I4: -1.069463
Number of conditioning pulses: 100

Test Results

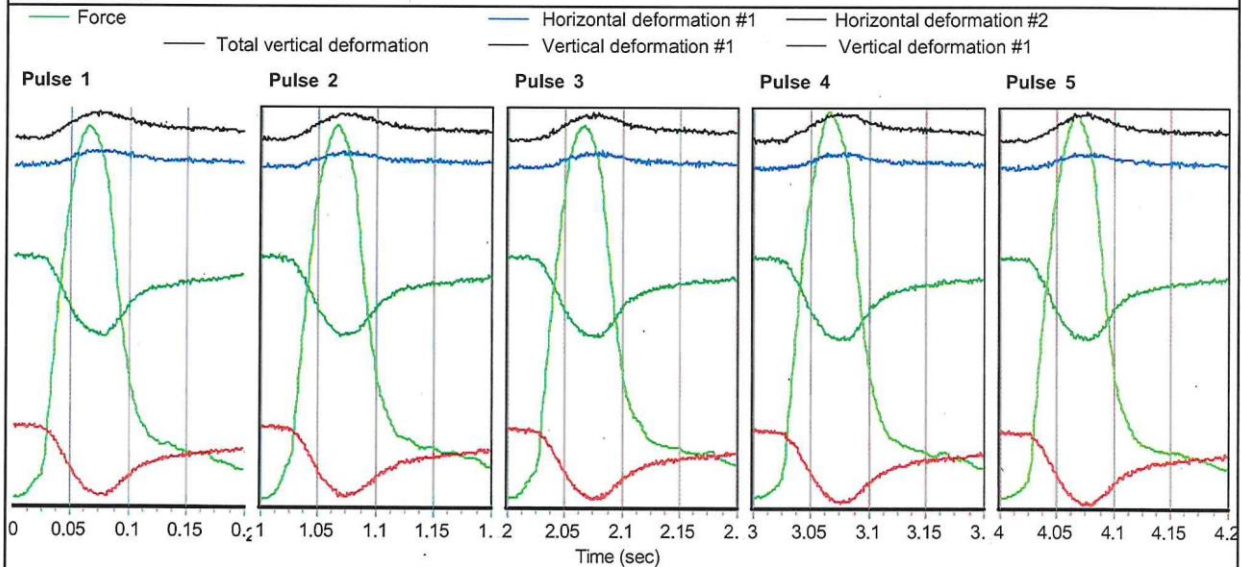
Test date & time: Friday , March 28, 2025, at 10:02

Conditioning pulses: 100

Core temperature (°C): 35.7

Surface temperature (°C): 30.3

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	6156	6277	6179	6178	6016	6161	83.82	1.36	
Poisson Ratio #1	0.02	0.03	0.04	0.00	-0.02	0.01	0.02	151.58	
Recoverable horizontal deformation #1 (µm)	0.385	0.394	0.412	0.376	0.359	0.385	0.018	4.612	
Recoverable vertical deformation #1 (µm)	-1.665	-1.655	-1.677	-1.717	-1.744	-1.691	0.034	-1.989	
Resilient Modulus #2 (MPa)	5497	5666	5661	5672	5733	5646	78.98	1.40	
Poisson Ratio #2	0.18	0.19	0.22	0.18	0.22	0.20	0.02	8.38	
Recoverable horizontal deformation #2 (µm)	0.650	0.656	0.682	0.658	0.698	0.669	0.018	2.719	
Recoverable vertical deformation #2 (µm)	-1.951	-1.920	-1.922	-1.969	-1.956	-1.943	0.019	-0.999	
Maximum applied load (N)	600	607	603	625	621	611	9.90	1.62	
Contact load (N)	48	46	49	51	50	49	1.79	3.68	



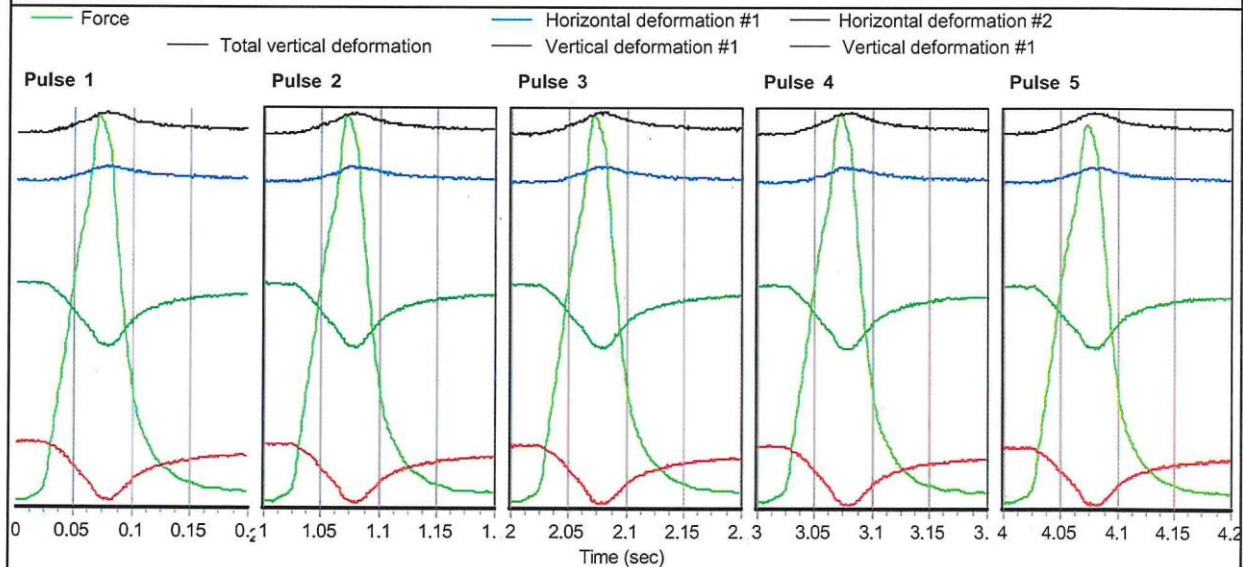
Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50
28.03.2025

Identification: AC -50 25% RA-75% SD	Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Conditioning time: 2	Diameter (mm)	148.0						148.00	
Properties/Comments: Sample 2	Height (mm)	63.0						63.00	
28.03.2025								Cross-sectional area (mm²): 17203.4	

Waveshape: Haversine	Target temperature (°C): 30	Consta ₁ : 0.233936
Loading pulse width (ms): 100	Contact load (N): 50	I2: -0.780056
Rest period (ms): 900	Peak load (N): 1550	I3: 0.307445
Pulse repetition period (ms): 1000		I4: -1.069463
Number of conditioning pulses: 100		

Test date & time: Friday, March 28, 2025, at 10:12 Conditioning
pulses: 100
Core temperature (°C): 35.2
Surface temperature (°C): 29.8

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	6137	6042	6012	6041	6040	6054	42.99	0.71	
Poisson Ratio #1	0.08	0.09	0.08	0.07	0.07	0.08	0.01	10.21	
Recoverable horizontal deformation #1 (µm)	0.702	0.740	0.723	0.709	0.686	0.712	0.019	2.613	
Recoverable vertical deformation #1 (µm)	-2.600	-2.660	-2.658	-2.675	-2.596	-2.638	0.033	-1.260	
Resilient Modulus #2 (MPa)	5590	5606	5621	5693	5564	5615	43.48	0.77	
Poisson Ratio #2	0.18	0.17	0.20	0.18	0.17	0.18	0.01	5.68	
Recoverable horizontal deformation #2 (µm)	0.971	0.956	1.005	0.979	0.943	0.971	0.021	2.153	
Recoverable vertical deformation #2 (µm)	-2.933	-2.929	-2.934	-2.928	-2.896	-2.924	0.014	-0.487	
Maximum applied load (N)	919	923	920	933	905	920	8.81	0.96	
Contact load (N)	51	50	50	49	49	50	0.53	1.07	



Stress Strain Test

Data file name: C:\IPCglobal UTS\002 Stress Strain Test\Data\CI SAMPLE 1.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 22/03/2025 16:10:52
Project: EHAE
Operator:
Comments: 22.03.2025 25% Red Ash and 75% Stone Dust Cracking Tolerance Index -AC-50

Specimen Information

Identification:
Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

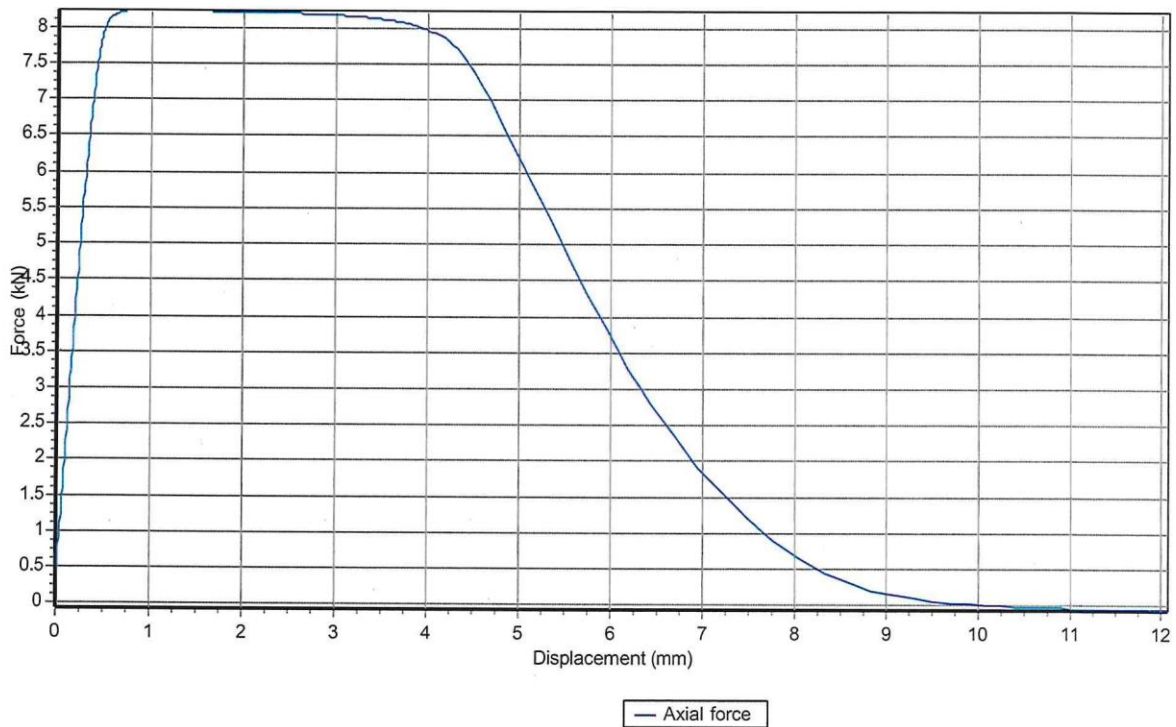
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hh:mm:ss): 00:00:16
Displayed time (hh:mm:ss): 00:00:16
Displayed seconds: 16
Actuator displ. (mm): 11.915
Actuator microstrain: 79,434.0
Actuator position (mm): 7.189

Axial force (kN): -0.067
Axial stress (kPa): -8.9
Maximum axial force (kN): 8.243
Minimum axial force (kN): 1093.3



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\Creep test .D030

Template file name: C:\Users\IPC GLOBAL\Desktop\UTS030 - EHAE Creep template AC 50.P03

Test date & time: 22.03.2025 25% Red Ash and 75% Stone Dust, at 5:10 PM

Project: Adama Awash km 60

Operator: Ravi

Comments: Creep Modulus

Specimen Information

Identification: 25% Red Ash and 75% Stone Dust

Remarks...

AC -50

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

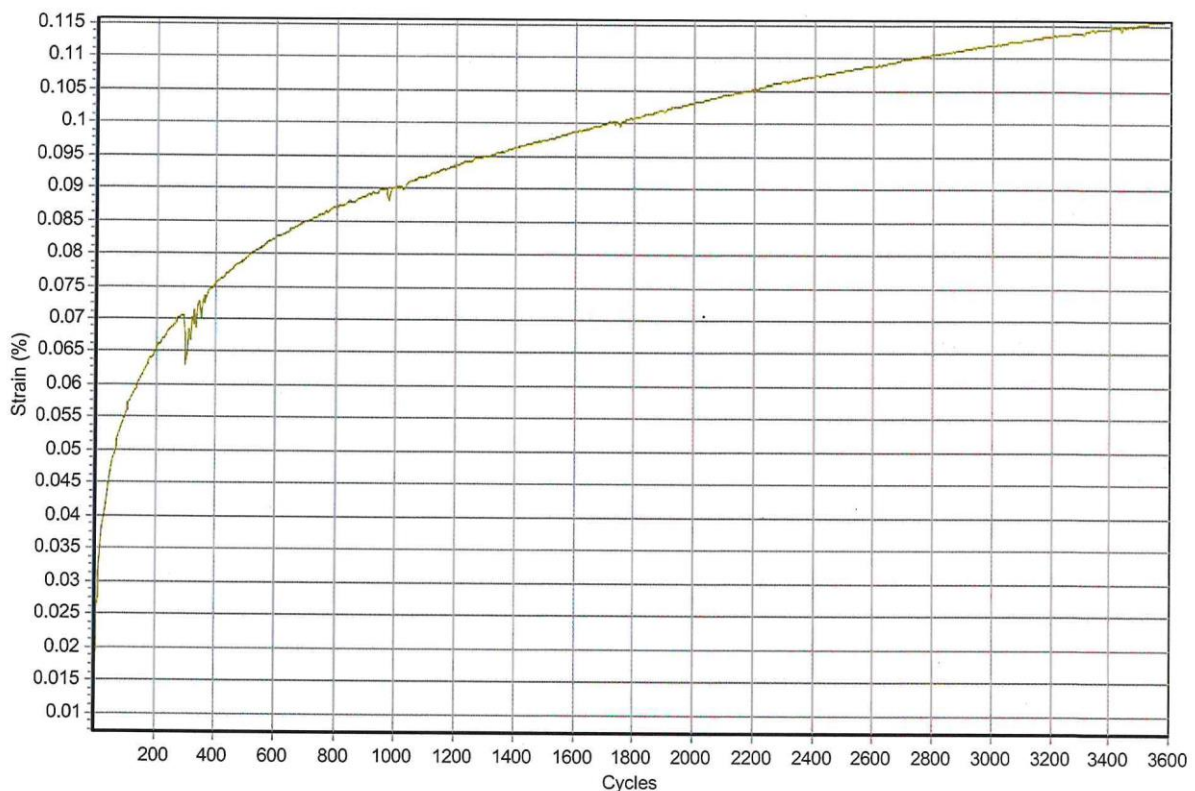
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 10

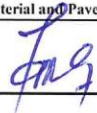
	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	

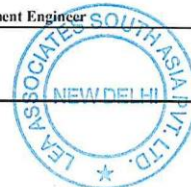


— Total Permanent strain



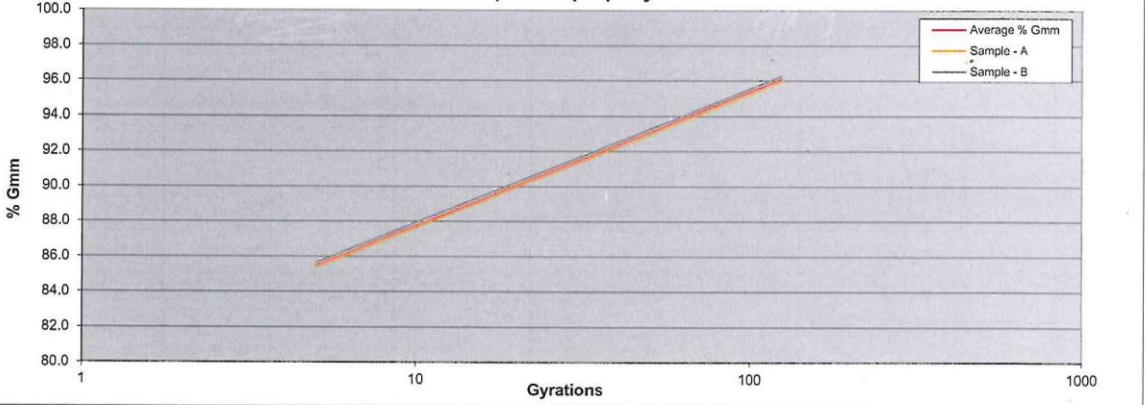
**Appendix 10 Volumetric properties and Performance
tests of asphalt mixture with 50% Red Volcanic Ash
Cinder and 50% Stone Dust of Filler**

Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler	50% RA and 50% SD							
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.414	NA								
	Av	3.9	3 - 6								
	VMA(%)	13.3	≥ 13								
	VFB(%)	71.0	65 - 75								
	N _{mi} (%)	87.5	≤ 89								
	N _{dec} (%)	96.1	96% ± 1%								
	N _{max} (%)	97.7	≤ 98%								
MTD	G _{mm}	2.511	NA								
DUST TO BINDER RATIO		1.38	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.84	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	12.5	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100	94.9	70.7	59.5	39.9	30.7	21.3	15.5	10.6	7.8	6.4
JMF	100	96.5	73.0	61.6	40.6	31.6	20.4	14.7	9.7	6.8	5.4
Tolerance from JMF L. Limit	100	88.5	66	54.6	33.6	25.6	15.4	9.7	4.7	3.8	2.4
Tolerance from JMF U. Limit	100	100	80	68.6	47.6	37.6	25.4	19.7	14.7	9.8	8.4
Upper Control Point	100	100	-	-	-	49	-	-	-	-	8
Lower Control Point	100	90	-	-	-	23	-	-	-	-	2
REMARK:											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
											



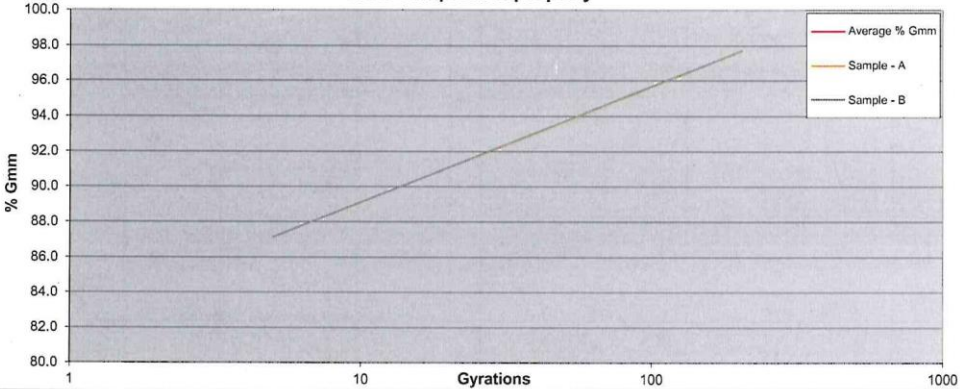
Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course			Agg Source	Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix			Bitumen Grade	40/50			
Filler	50% RA and 50% SD			Specific Gravity	1.0285			
Date Tested:	17-Mar-25			Number of Gyration	125 @ N _{des}			
Mixing Temperature (°C)	135-165			Compaction Temperature (°C)	135-150			
Sample - A			Sample - B					
No of Gyration	Height	% Gmm		Height	% Gmm	Average % Gmm		
5	128.158	85.4		128.512	85.6	85.5		
9 [Nini]	125.318	87.3		125.664	87.6	87.5		
10	124.822	87.7		125.167	87.9	87.8		
20	121.655	90.0		121.991	90.2	90.1		
30	119.876	91.3		120.208	91.6	91.4		
40	118.646	92.2		118.973	92.5	92.4		
50	117.708	93.0		118.033	93.2	93.1		
70	116.322	94.1		116.643	94.4	94.2		
90	115.308	94.9		115.626	95.2	95.1		
110	114.511	95.6		114.827	95.8	95.7		
125 [Ndes]	114.009	96.0		114.324	96.3	96.1		
	G _{mb} Gyro	2.304		G _{mb} Gyro	2.319	Average G _{mb} Gyro 2.312		
	G _{mb}	2.413		G _{mb}	2.415	Average G _{mb} 2.414		
	G _{mm}	2.513		G _{mm}	2.508	Average G _{mm} 2.511		
	G _{sb}	2.654		G _{sb}	2.654	Average G _{sb} 2.654		
	G _{sa}	2.736		G _{sa}	2.736	G _{sa} 2.736		
% AC	4.70		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc in water	Volume	Gmb
Gsb	2.654		Sample - A	4418.1	4430	2598.7	1831.3	2.413
Pb	1.029		Sample - B	4402.2	4413.4	2590.4	1823.0	2.415
Volumetrics	Value	Spec.						
%Gmm@Ni	87.5	< 89%						
%Gmm@Ndes	96.13							
% Air void	3.9	3-6%						
% VMA	13.33	Min 13%						
%VFA	70.99	65-75						

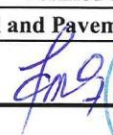
SGC compaction property



Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with UNICONE Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	50% RA and 50% SD		Specific Gravity		1.0285			
Date Tested:	17-Mar-25		Number of Gyration		205 @ N _{max}			
Mixing Temperature (°C)		135-160		Compaction Temperature (°C)		135-150		
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	128.174	87.1	128.193	87.1	87.1			
9 [Nini]	125.759	88.8	125.778	88.8	88.8			
10	125.336	89.1	125.354	89.1	89.1			
20	122.621	91.1	122.639	91.1	91.1			
30	121.087	92.2	121.104	92.2	92.2			
40	120.021	93.0	120.038	93.1	93.1			
50	119.207	93.7	119.225	93.7	93.7			
70	118.001	94.6	118.018	94.7	94.6			
90	117.116	95.4	117.133	95.4	95.4			
110	116.418	95.9	116.435	95.9	95.9			
125 [Ndes]	115.979	96.3	115.995	96.3	96.3			
150	115.357	96.8	115.374	96.8	96.8			
175	114.836	97.3	114.853	97.3	97.3			
200	114.389	97.6	114.406	97.6	97.6			
205 [Nmax]	114.307	97.7	114.324	97.7	97.7			
G_{mb} Gyro		2.353	G_{mb} Gyro		2.351	Average G_{mb} Gyro		2.352
G_{mb}		2.455	G_{mb}		2.451	Average G_{mb}		2.453
G_{mm}		2.513	G_{mm}		2.508	Average G_{mm}		2.511
G_{sb}		2.654	G_{sb}		2.654	Average G_{sb}		2.654
G_{sa}		2.736	G_{sa}		2.736	G_{sa}		2.736
Determination of measured Bulk Specific Gravity								
% AC	4.7		Mix Ref.	Wt. air	wax+ spc in air	wax+spc In water	Volume	Gmb
Aggreg. Frac.	95.3		Sample - A	4385.6	4387.5	2601.3	1786.2	2.455
Gsb	2.654		Sample - B	4381.2	4386.2	2598.8	1787.4	2.451
Pb	1.029							
Mix property	Units	Result		Criteria				
% G_{mm} at N_{max}	%	97.7		Max 98				
SGC compaction property 								
Tested by:				Verified by:				
Laboratory Technician				Material and Pavement Engineer				
								

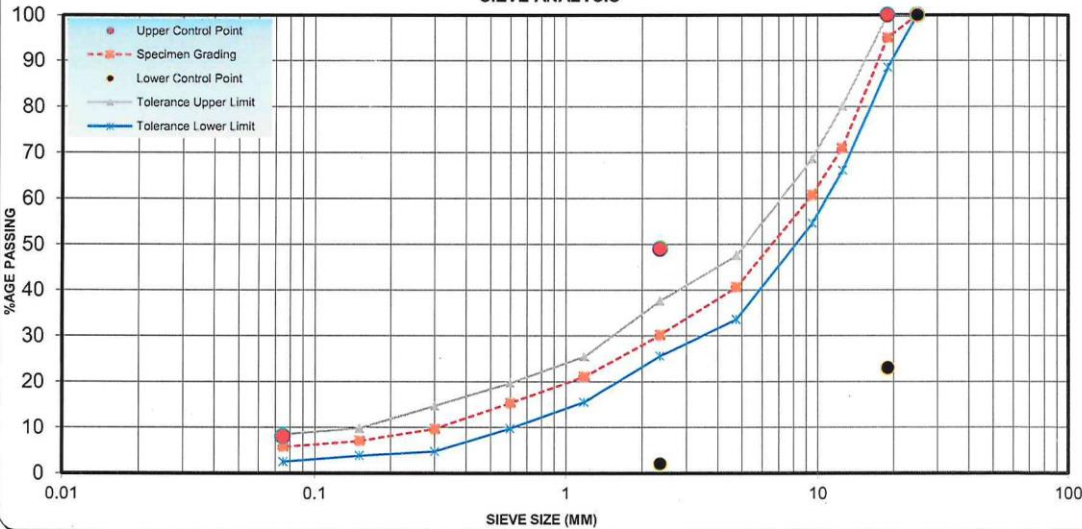
Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor   JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041					
Source of Mix	Lab-Mix	Filler	50% RA and 50% SD		
Material Description:	AC-60 Binder course	Dated of Testing	18-Mar-2025		
Grade of Bitumen	40/50	Bitumen by Wt. of Mix	:	5.40%	
Testing Temp.	25 °C				
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7					
Test No			Test 1	Test 2	
Mass of dry sample in air	A	gm.	2626.4	2541.1	
Mass of container filled with water at test temperature	F	gm.	9129.1	9129.1	
Mass of container filled with sample and water at test temperature	G	gm.	10710.4	10657.2	
Temperature of test water	T	°C	25	25	
Correction for thermal expansion of bitumen	H	gm.	0.0	0.0	
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]		2.513	2.508	
Correction factor	R = d _w /0.9970		1.000	1.000	
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E		2.513	2.508	
Average Theoretical Maximum Specific Gravity at 25°C	G _{mm} = (SG 1 + SG 2)/2		2.511		
Effective Specific Gravity of Aggregate	G _{se}		2.703		
Effective Specific Gravity of Aggregate [G_{se}] = (100-P_b)/((100/G_{mm})-(P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen d_w - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³					
Remark:					
Tested by: Laboratory Technician 			Verified by: Material and Pavement Engineer 		



Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164			
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	50% RA and 50% SD	Date of Testing	20-Mar-2025
Proportion:	25:32:8.32.3		

Trial - A											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm	1902	25.0	0.0	0.0	100	100	100	100	100	100	
Wt. of Filter paper before test (B) gm	3.1	19.0	90.6	5.0	95.0	96.5	88.5	100	90	100	
Wt. of filter + sediment (C) gm	4	12.50	435.7	24.1	70.9	73.0	66.0	80.0	-	-	
Wt. of Sediment (D) = (C - B) gm	0.9	9.50	185.4	10.2	60.7	61.6	54.6	68.6	-	-	
Wt. of filler after burn (E) gm	12.0	4.75	363.4	20.1	40.6	40.6	33.6	47.6	-	-	
Wt. of Aggregate (F) gm	1797.0	2.36	189.0	10.4	30.2	31.6	25.6	37.6	23	49	
Total Wt. of Aggregate (G) = (D + E + F) gm	1809.9	1.18	164.2	9.1	21.1	20.4	15.4	25.4	-	-	
		0.600	104.5	5.8	15.3	14.7	9.7	19.7	-	-	
Wt. of Bitumen (H) = (A - F) gm	92.1	0.300	102.6	5.7	9.6	9.7	4.7	14.7	-	-	
Bitumen Content	In T.Mix H/A %	4.84	0.150	47.6	2.6	7.0	6.8	3.8	9.8	-	-
			0.075	23.6	1.3	5.7	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.1	Pan	103.3	5.7						

SIEVE ANALYSIS



Remarks :

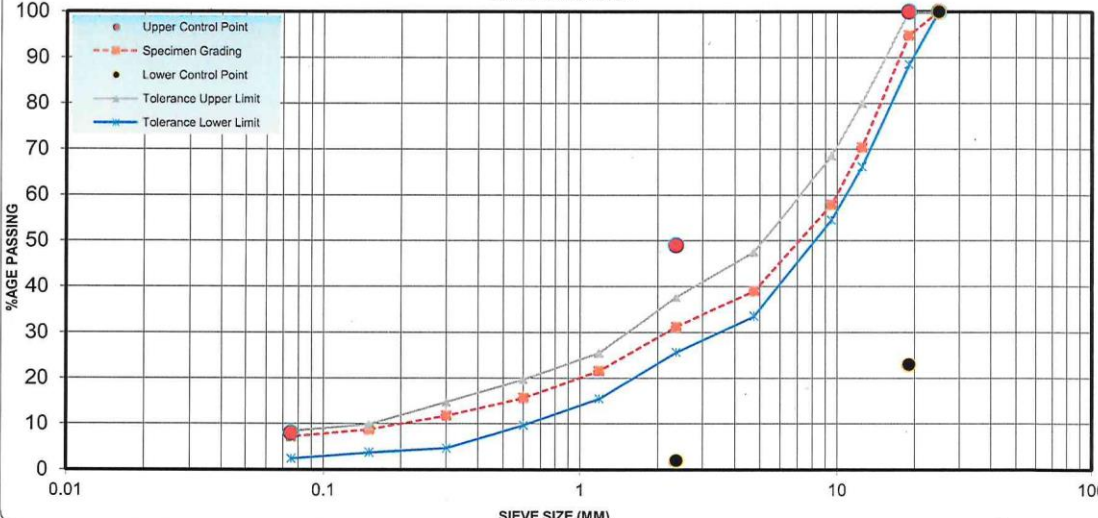
Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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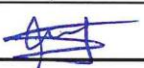
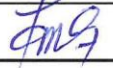
Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164			
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	50% RA and 50% SD	Date of Testing	20-Mar-2025
Proportion:	25:32:8.32.3		

Trial - B										
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1434.3	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.2	19.0	71.5	5.2	94.8	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.5	12.50	333.3	24.4	70.3	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.3	9.50	169.9	12.4	57.9	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	5.5	4.75	257.5	18.9	39.0	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1359.0	2.36	105.3	7.7	31.3	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1364.8	1.18	131.6	9.6	21.7	20.4	15.4	25.4	-	-
		0.600	81.5	6.0	15.7	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	69.5	0.300	53.0	3.9	11.8	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.85	0.150	41.2	3.0	8.8	6.8	3.8	9.8	-
			0.075	21.5	1.6	7.2	5.4	2.4	8.4	2
	In T. Agg. H/F %	5.1	Pan	98.5	7.2					

SIEVE ANALYSIS



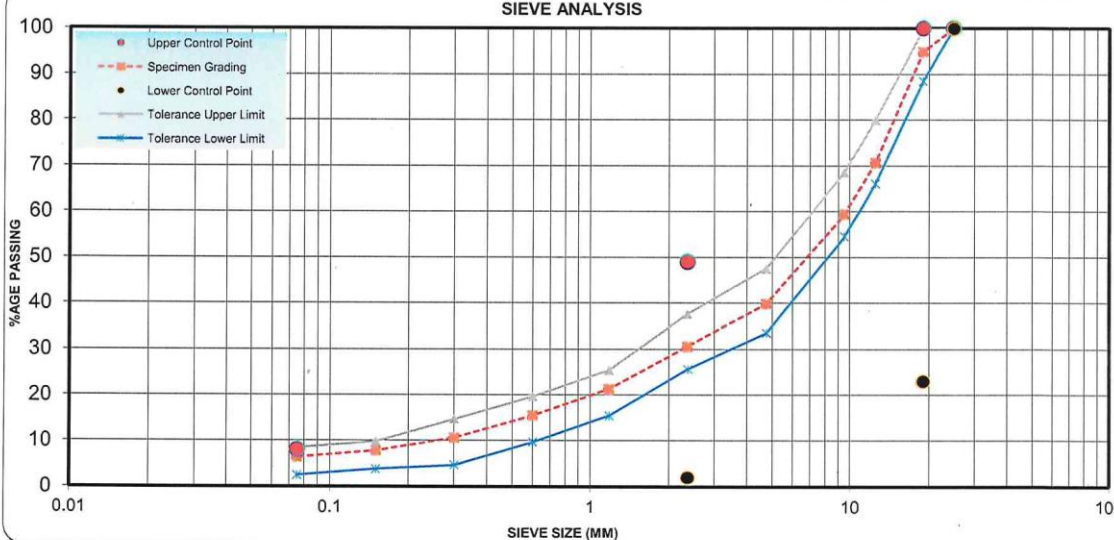
Remarks :

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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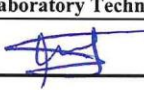


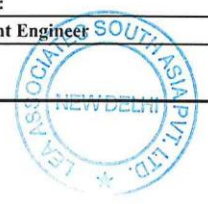
Employer		Consultant				Contractor				
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia				 JMC-LRBCL JOINT VENTURE				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164										
Source of Mix	Lab-Mix			Source of Material	Km.29+600 LHS Quarry					
Material Description	Hot Mix Asphalt Binder Course Mixture			Grade of Bitumen	40/50					
Filler	50% RA and 50% SD			Date of Testing	20-Mar-2025					
Proportion:	25:32:8.32.3									
Average of 2 Trials										
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
			Lower	Upper						
Total Wt. of Mix before test (A) gm	1668.15	25.0	0.0	0.0	100	100	100	100	100	
Wt. of Filter paper before test (B) gm	3.15	19.0	81.1	5.1	94.9	96.5	88.5	100	90	
Wt. of filter + sediment (C) gm	3.75	12.50	384.5	24.2	70.7	73.0	66.0	80.0	-	
Wt. of Sediment (D) = (C - B) gm	0.6	9.50	177.7	11.2	59.5	61.6	54.6	68.6	-	
Wt. of filler after burn (E) gm	8.75	4.75	310.5	19.6	39.9	40.6	33.6	47.6	-	
Wt. of Aggregate (F) gm	1578	2.36	147.2	9.3	30.7	31.6	25.6	37.6	23	
Total Wt. of Aggregate (G) = (D + E + F) gm	1587.4	1.18	147.9	9.3	21.3	20.4	15.4	25.4	-	
		0.600	93.0	5.9	15.5	14.7	9.7	19.7	-	
Wt. of Bitumen (H) = (A - F) gm	80.8	0.300	77.8	4.9	10.6	9.7	4.7	14.7	-	
Bitumen Content	In T.Mix H/A %	4.84	0.150	44.4	2.8	7.8	6.8	3.8	9.8	-
			0.075	22.6	1.4	6.4	5.4	2.4	8.4	2
			Pan	100.9	6.4					8
	In T. Agg. H/F %	5.1								

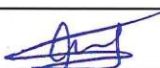
SIEVE ANALYSIS

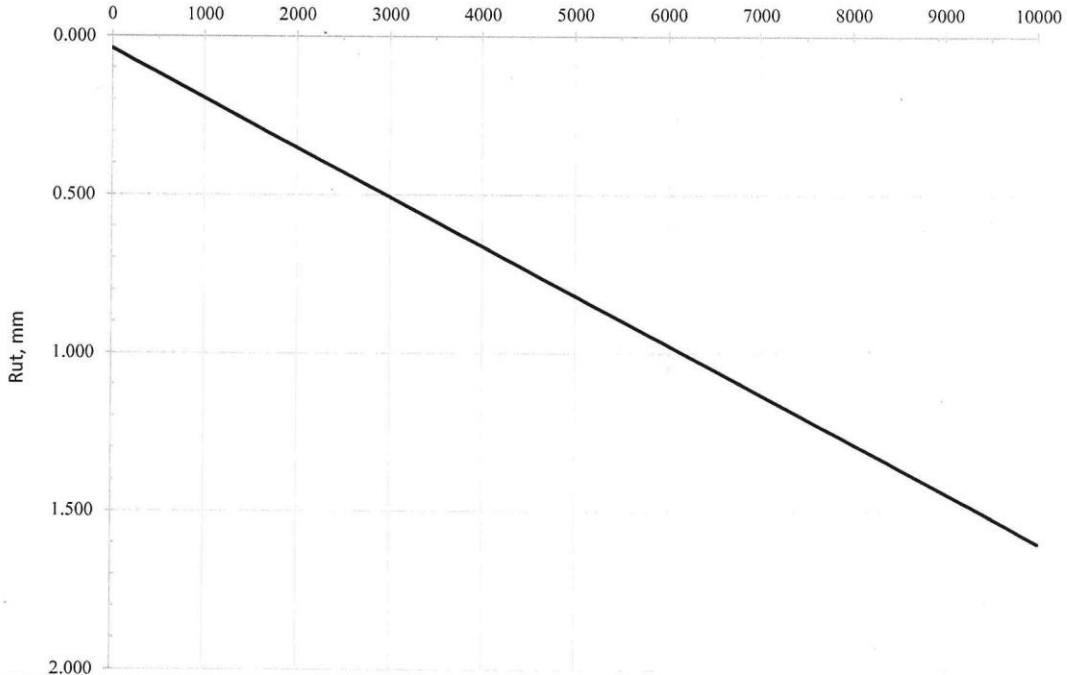


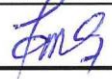
Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	50% Red ash Mix with 50% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60 ⁰ C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	996		
SSD mass	B	gm.	1,000		
Mass in water	C	gm.	570		
Volume	$E = (B-A) - (B - C)$		cm ³	426	
Bulk specific gravity	$G_{mb} = A/E$			2.338	
Maximum specific gravity	G_{mm}			2.511	
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$		%	6.9	
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.40		
Rut at 5,000 passes		mm	0.82		
Rut at 10,000 passes		mm	1.60		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.16		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	2.6		
Maximum Rut depth RD_{Air}		mm	1.6		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
WHEEL-TRACK TESTING EN 12697:22		
Filler	50% Red ash Mix with 50% Stone dust	
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)		
Specimen conditioning: In Air		Test temperature: 60 ⁰ C
Conditioning time: +6hr		Test load: 520 N
Passes  Remark:		
Tested by:		Verified by:
Laboratory Technician		Material & Pavement Engineer
		 

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283		
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs		
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa]		
Saturated 16hrs @ -18°C + 24hrs @ 60°C + 2 hrs @ 25°C Duration: 6 min [5 - 10 min]		
Filler 50% Red ash Mix with 50% Stone dust		
Condition of test specimens		
Saturated/conditioned Dry		
Sample identification		
Diameter D mm 149.6 149.2 149.0 149.3 149.4 150.0		
Thickness t mm 94 94.3 94.2 96.7 95.1 95.9		
VOLUMETRIC		
Dry mass in air A gm. 3,992 3,964 3,956 3,949 3,983 3,994		
SSD mass B gm. 4,026 3,998 3,989 3,978 4,018 4,031		
Mass in water C gm. 2,358 2,330 2,341 2,326 2,319 2,352		
Volume E = B - C cm³ 1,668 1,668 1,648 1,652 1,699 1,679		
Bulk specific gravity G _{mb} = A/E 2.393 2.376 2.400 2.390 2.344 2.379		
Maximum specific gravity G _{mm} 2.511 2.511 2.511 2.511 2.511 2.511		
Air voids P _a = [100(G _{mm} - G _{mb})/G _{mm}] % 4.7 5.4 4.4 4.8 6.6 5.3		
Volume of air voids V _a = (P _a x E/100) cm³ 78.2 89.3 72.5 79.3 112.8 88.4		
TSR		
Thickness t' mm 94 94 94		
SSD mass B' gm. 4048 4029 4008		
Volume of absorbed water J' = B' - A cm³ 56.0 65.0 52.0 - - -		
Saturation S' = 100 x J'/V _a % 71.6 72.8 71.7 - - -		
Load P' N 20,250.0 19,780.0 19,990.0 24,110.0 23,740.0 23,950.0		
Dry strength S ₁ = 2000 x P/(π x t x D) kPa 1,063.1 1,063.7 1,059.9		
Wet strength S ₂ = 2000 x P/(π x t' x D) kPa 916.7 895.0 906.7		
Average dry strength Average S ₁ kPa 1,062.3		
Average wet strength Average S ₂ kPa 906.1		
Tensile Strength Ratio TSR = Average S ₂ /Average S ₁ % 85.3		
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80		
Remark:		
Tested by: Verified by:		
Tested by: Material and Pavement Engineer		
 		



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50
28.03.2025

Specimen Information

Identification: AC -50 50% RA and 50% SD
Conditioning time: 2
Properties/Comments: Sample -1
28.03.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm ²): 17203.4								

Test Parameters

Waveshape: Haversine
Loading pulse width (ms): 100
Rest period (ms): 900
Pulse repetition period (ms): 1000
Number of conditioning pulses: 100

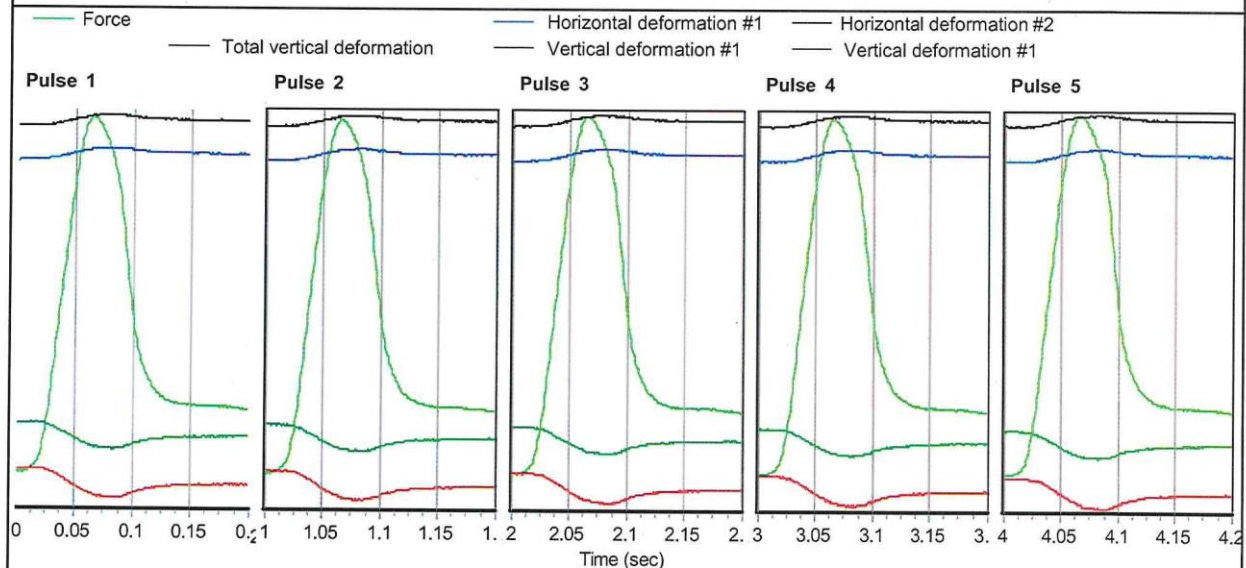
Target temperature (°C): 30
Contact load (N): 50
Peak load (N): 1456

Consta₁: 0.233936
I2: -0.780056
I3: 0.307445
I4: -1.069463

Test Results

Test date & time: Friday, March 28, 2025, at 15:39
Conditioning pulses: 100
Core temperature (°C): 30.5
Surface temperature (°C): 28.6

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4204	4326	4310	4261	4190	4258	54.67	1.28	
Poisson Ratio #1	0.31	0.33	0.35	0.33	0.33	0.33	0.01	4.22	
Recoverable horizontal deformation #1 (µm)	1.087	1.080	1.142	1.106	1.146	1.112	0.028	2.477	
Recoverable vertical deformation #1 (µm)	-2.660	-2.587	-2.640	-2.640	-2.724	-2.650	0.044	-1.676	
Resilient Modulus #2 (MPa)	4682	4695	4697	4675	4783	4707	39.12	0.83	
Poisson Ratio #2	0.34	0.31	0.35	0.32	0.35	0.33	0.01	4.28	
Recoverable horizontal deformation #2 (µm)	1.019	0.976	1.040	0.995	1.030	1.012	0.024	2.343	
Recoverable vertical deformation #2 (µm)	-2.405	-2.375	-2.420	-2.401	-2.397	-2.400	0.014	-0.598	
Maximum applied load (N)	605	603	609	605	614	607	3.87	0.64	
Contact load (N)	46	45	46	46	46	46	0.40	0.88	



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test
Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003
Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003
Project: Adama-Awash km 60
Operator: Ravi
Comments: AC -50
28.03.2025

Specimen Information

Identification: AC -50 50% RA and 50% SD
Conditioning time: 2
Properties/Comments: Sample -2
28.03.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm ²): 17203.4								

Test Parameters

Waveshape: Haversine
Loading pulse width (ms): 100
Rest period (ms): 900
Pulse repetition period (ms): 1000
Number of conditioning pulses: 100

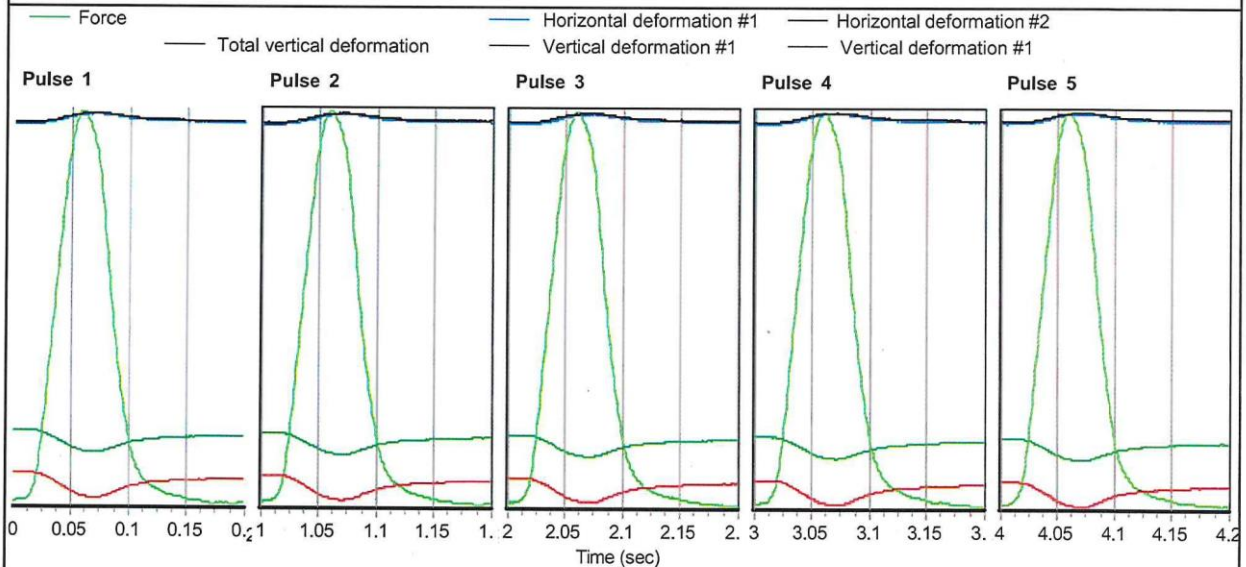
Target temperature (°C): 30
Contact load (N): 50
Peak load (N): 1456

Const_{r1}: 0.233936
I2: -0.780056
I3: 0.307445
I4: -1.069463

Test Results

Test date & time: Friday, March 28, 2025, at 15:44
Conditioning pulses: 100
Core temperature (°C): 30.3
Surface temperature (°C): 28.7

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4623	4665	4606	4658	4641	4639	21.67	0.47	
Poisson Ratio #1	0.34	0.33	0.33	0.33	0.33	0.33	0.00	1.27	
Recoverable horizontal deformation #1 (µm)	2.237	2.203	2.205	2.204	2.204	2.211	0.013	0.592	
Recoverable vertical deformation #1 (µm)	-5.262	-5.223	-5.277	-5.236	-5.248	-5.249	0.019	-0.361	
Resilient Modulus #2 (MPa)	5180	5161	5124	5169	5156	5158	18.81	0.36	
Poisson Ratio #2	0.33	0.32	0.32	0.34	0.34	0.33	0.01	1.96	
Recoverable horizontal deformation #2 (µm)	1.978	1.958	1.965	1.996	2.004	1.980	0.018	0.884	
Recoverable vertical deformation #2 (µm)	-4.689	-4.708	-4.737	-4.722	-4.732	-4.718	0.017	-0.364	
Maximum applied load (N)	1306	1309	1309	1311	1310	1309	1.94	0.15	
Contact load (N)	51	51	50	49	49	50	1.01	2.03	



Stress Strain Test

Data file name: C:\Users\IPC GLOBAL\Desktop\CT index AC-50 -22.03.2025.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 22/03/2025 10:12:52
Project: EHAE
Operator:
Comments: 50% Red Ash and 50% Stone Dust Cracking Tolerance Index -AC-50
22.03.2025

Specimen Information

Identification: CTindex
Remarks...
AC -50

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	95.0						95.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

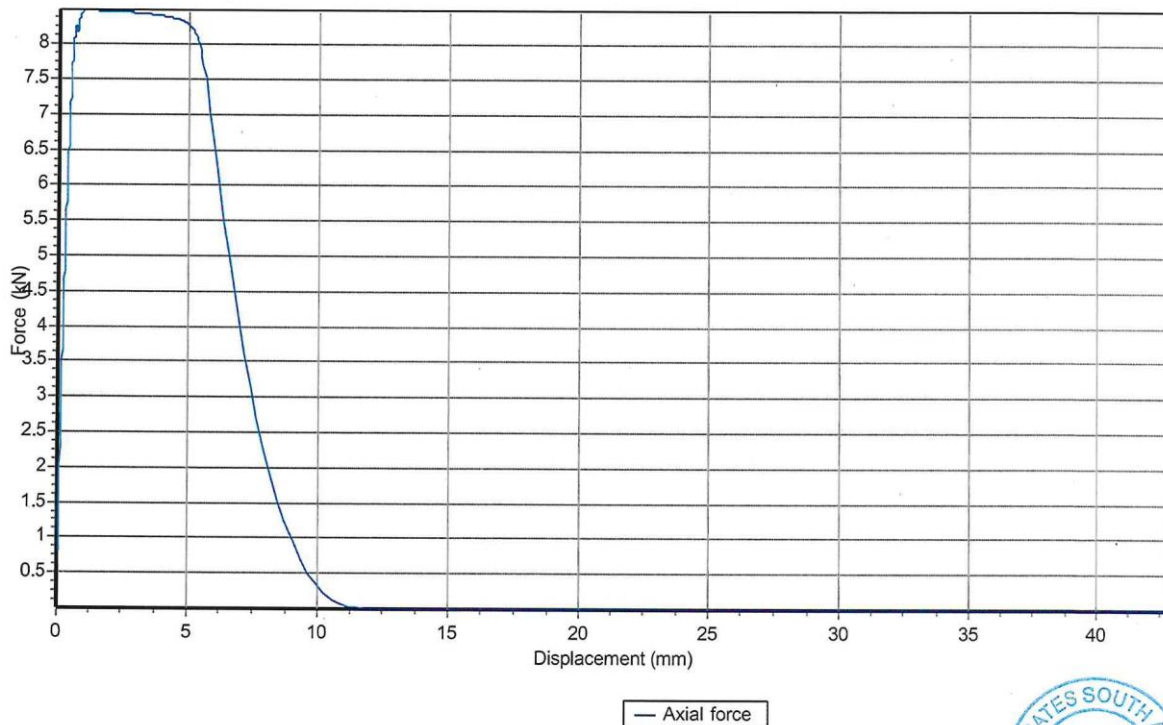
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hh:mm:ss): 00:00:52
Displayed time (hh:mm:ss): 00:00:52
Displayed seconds: 52
Actuator displ. (mm): 42.762
Actuator microstrain: 2.8508E5
Actuator position (mm): 23.325

Axial force (kN): 0.002
Axial stress (kPa): 0.2
Maximum axial force (kN): 8.486
Minimum axial force (kN): 710.8



[Handwritten signature]



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\Creep test.D030

Template file name: C:\Users\IPC GLOBAL\Desktop\UTS030 - EHAE Creep template AC 50.P030

Test date & time: 22.03.2025 50% Red Ash and 50% Stone Dust, at 8:36 AM

Project: Adama Awash km 60

Operator: Ravi

Comments: Creep Modulus

Specimen Information

Identification: 50% Red Ash and 50% Stone Dust

Remarks...

AC -50

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

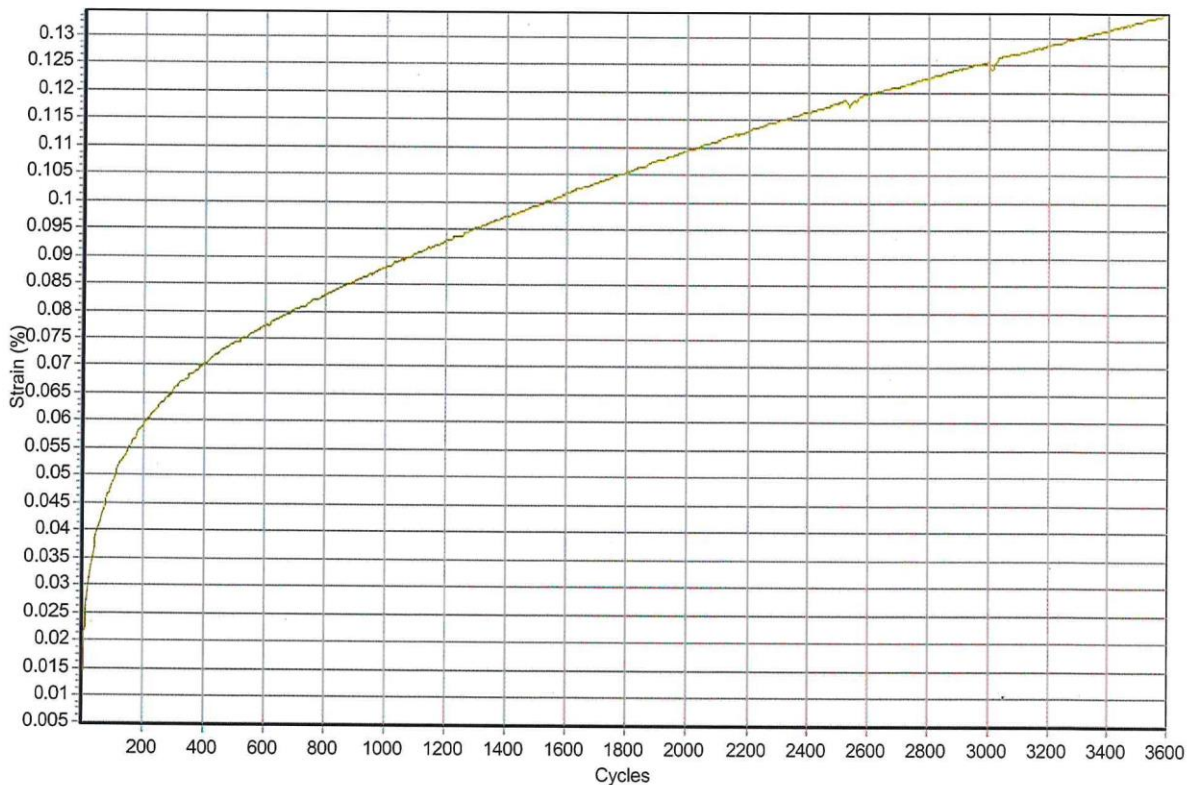
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 10

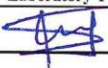
	Preload	Axial	Rest period
Stress (kPa):	10	100	2
Load (N):	72	724	15



— Total Permanent strain



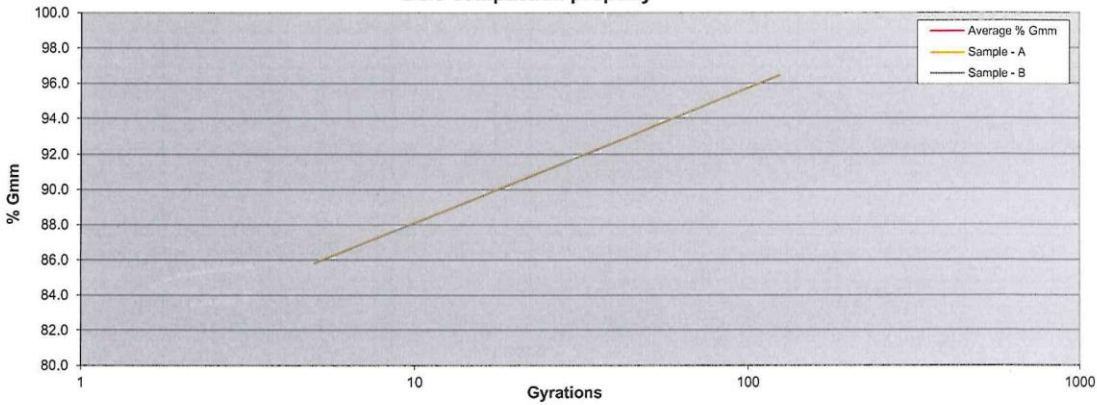
**Appendix 11 Volumetric properties and Performance
tests of asphalt mixture with 75% Red Volcanic Ash
Cinder and 25% Stone Dust of Filler**

Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C. Ethiopia		 JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler	75% RA and 25% SD							
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.415	NA								
	Av	3.5	3 - 6								
	VMA(%)	13.3	≥ 13								
	VFB(%)	73.4	65 - 75								
	N _{mf} (%)	87.8	≤ 89								
	N _{ds} (%)	96.5	96% ± 1%								
	N _{ms} (%)	97.5	≤ 98%								
MTD	G _{mm}	2.504	NA								
DUST TO BINDER RATIO		1.08	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.74	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	12.5	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100	96.7	71.6	60.9	40.5	29.7	19.3	12.4	9.0	5.8	4.5
JMF	100	96.5	73.0	61.6	40.6	31.6	20.4	14.7	9.7	6.8	5.4
Tolerance from JMF L. Limit	100	88.5	66	54.6	33.6	25.6	15.4	9.7	4.7	3.8	2.4
Tolerance from JMF U. Limit	100	100	80	68.6	47.6	37.6	25.4	19.7	14.7	9.8	8.4
Upper Control Point	100	100	-	-	-	49	-	-	-	-	8
Lower Control Point	100	90	-	-	-	23	-	-	-	-	2
REMARK:											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
											



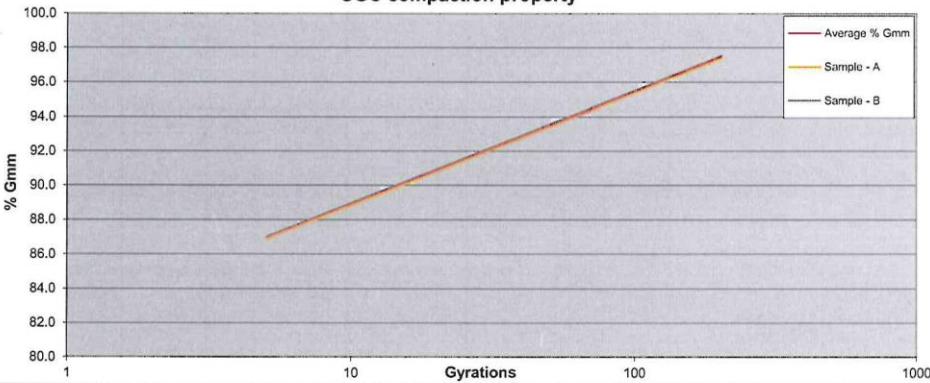
Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course			Agg Source	Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix			Bitumen Grade	40/50			
Filler	75% RA and 25% SD			Specific Gravity	1.0285			
Date Tested:	20-Mar-25			Number of Gyration	125 @ N _{des}			
Mixing Temperature (°C)	135-165			Compaction Temperature (°C)	135-150			
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	128.802	85.8	128.759	85.8	Average G _{mb} Gyro 2.312 Average G _{mb} 2.415 Average G _{mm} 2.504 Average G _{sb} 2.654 G _{sa} 2.736			
9 [Nini]	125.948	87.8	125.906	87.7				
10	125.45	88.1	125.408	88.1				
20	122.267	90.4	122.226	90.4				
30	120.479	91.8	120.439	91.7				
40	119.242	92.7	119.202	92.7				
50	118.3	93.5	118.260	93.4				
70	116.907	94.6	116.868	94.5				
90	115.888	95.4	115.849	95.4				
110	115.087	96.1	115.048	96.0				
125 [Ndes]	114.582	96.5	114.544	96.5				
	G _{mb} Gyro	2.304	G _{mb} Gyro	2.319				
	G _{mb}	2.415	G _{mb}	2.416				
	G _{mm}	2.503	G _{mm}	2.505				
	G _{sb}	2.654	G _{sb}	2.654				
	G _{sa}	2.736	G _{sa}	2.736				
% AC	4.70		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb
Gsb	2.654		Sample - A	4542.1	4551	2670	1881.0	2.415
Pb	1.029		Sample - B	4441.3	4448.4	2610	1838.4	2.416
Volumetrics	Value	Spec.						
%Gmm@Ni	87.8	< 89%						
%Gmm@Ndes	96.47							
% Air void	3.5	3-6%						
% VMA	13.27	Min 13%						
%VFA	73.38	65-75						

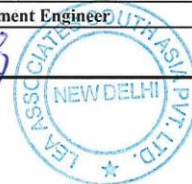
SGC compaction property

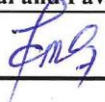


Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	75% RA and 25% SD		Specific Gravity		1.0285			
Date Tested:	20-Mar-25		Number of Gyration		205 @ N_{max}			
Mixing Temperature (°C)	135-160		Compaction Temperature (°C)		135-150			
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm	Height	% Gmm				
5	127.359	86.9	127.484	87.0				86.9
9 [Nini]	124.959	88.5	125.082	88.7				88.6
10	124.539	88.8	124.661	89.0				88.9
20	121.841	90.8	121.961	90.9				90.9
30	120.316	91.9	120.435	92.1				92.0
40	119.257	92.8	119.375	92.9				92.8
50	118.449	93.4	118.566	93.5				93.5
70	117.250	94.3	117.366	94.5				94.4
90	116.371	95.1	116.485	95.2				95.1
110	115.678	95.6	115.792	95.8				95.7
125 [Ndes]	115.241	96.0	115.354	96.1				96.1
150	114.623	96.5	114.736	96.7				96.6
175	114.106	96.9	114.218	97.1				97.0
200	113.661	97.3	113.774	97.5				97.4
205 [Nmax]	113.580	97.4	113.692	97.5				97.5
G _{mb} Gyro			G _{mb} Gyro			Average G _{mb} Gyro		
2.353			2.351			2.352		
G _{mb}			G _{mb}			Average G _{mb}		
2.438			2.443			2.440		
G _{mm}			G _{mm}			Average G _{mm}		
2.503			2.505			2.504		
G _{sb}			G _{sb}			Average G _{sb}		
2.654			2.654			2.654		
G _{sa}			G _{sa}			G _{sa}		
2.736			2.736			2.736		
Determination of measured Bulk Specific Gravity								
% AC	4.7		Mix Ref.	Wt. air	wax+ spc in air	wax+spc In water	Volume	Gmb
Aggreg. Frac.	95.3		Sample - A	4508.9	4515.8	2666	1849.8	2.438
Gsb	2.654		Sample - B	4475.1	4483.6	2652	1831.6	2.443
Pb	1.029							
Mix property	Units		Result				Criteria	
% G _{mm} at N_{max}	%		97.5				Max 98	
SGC compaction property								
								
Tested by:				Verified by:				
Laboratory Technician				Material and Pavement Engineer				
								



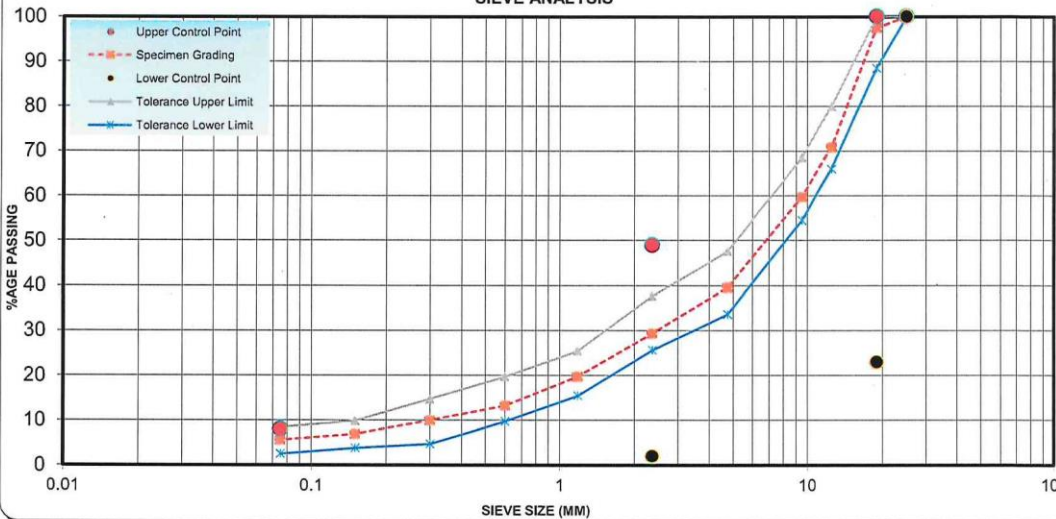
Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041					
Source of Mix	Lab-Mix	Filler	75% RA and 25% SD		
Material Description:	AC-60 Binder course	Dated of Testing	21-Mar-2025		
Grade of Bitumen	40/50	Bitumen by Wt. of Mix	:	5.40%	
Testing Temp.	25 °c				
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7					
Test No				Test 1	Test 2
Mass of dry sample in air	A	gm.		2786.3	2770.5
Mass of container filled with water at test temperature	F	gm.		9125.7	9125.7
Mass of container filled with sample and water at test temperature	G	gm.		10798.7	10790.1
Temperature of test water	T	°C		25	25
Correction for thermal expansion of bitumen	H	gm.		0.0	0.0
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]			2.503	2.505
Correction factor	R = dw / 0.9970			1.000	1.000
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E			2.503	2.505
Average Theoretical Maximum Specific Gravity at 25°C	G_{mm} = (SG 1 + SG 2)/2			2.504	
Effective Specific Gravity of Aggregate	G_{se}			2.695	
Effective Specific Gravity of Aggregate[G_{se}] = (100-P_b)/((100/G_{mm})-(P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³					
Remark:					
Tested by:			Verified by:		
Laboratory Technician			Material and Pavement Engineer		
					



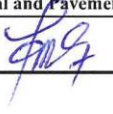
Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164			
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	75% RA and 25% SD	Date of Testing	23-Mar-2025
Proportion:	25:32:8.32:3		

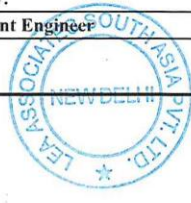
Trial - A										
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1836.5	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3	19.0	42.9	2.5	97.5	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.2	12.50	466.9	26.7	70.9	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.2	9.50	193.5	11.1	59.8	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	11.0	4.75	353.7	20.2	39.6	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1738.6	2.36	177.7	10.2	29.4	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1749.8	1.18	169.3	9.7	19.8	20.4	15.4	25.4	-	-
		0.600	114.1	6.5	13.2	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	86.7	0.300	57.8	3.3	9.9	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.72	0.150	53.2	3.0	6.9	6.8	3.8	9.8	-
			0.075	23.3	1.3	5.6	5.4	2.4	8.4	2
	In T. Agg. H/F %	5.0	Pan	97.4	5.6					

SIEVE ANALYSIS



Remarks :

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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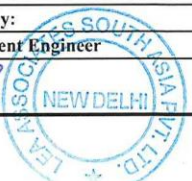


Employer  Ethiopian Roads Administration (ERA)	Consultant  LEA JV with Unicon P.L.C, Ethiopia	Contractor  JMC-LRBCL JOINT VENTURE								
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164										
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry							
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50							
Filler	75% RA and 25% SD	Date of Testing	23-Mar-2025							
Proportion:	25:32:8.32.3									
Trial - B										
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1540	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.1	19.0	62.1	4.2	95.8	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	3.4	12.50	342.2	23.3	72.4	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	0.3	9.50	149.5	10.2	62.2	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	5.5	4.75	304.0	20.7	41.5	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1461.0	2.36	167.4	11.4	30.1	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E + F) gm	1466.8	1.18	167.3	11.4	18.7	20.4	15.4	25.4	-	-
		0.600	105.7	7.2	11.5	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	73.2	0.300	52.2	3.6	7.9	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.75	0.150	51.8	3.5	4.4	6.8	3.8	9.8	-
			0.075	17.8	1.2	3.2	5.4	2.4	8.4	2
	In T. Agg. H/F %	5.0	Pan	46.8	3.2					

SIEVE ANALYSIS



Remarks :

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer  
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Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBL JOINT VENTURE

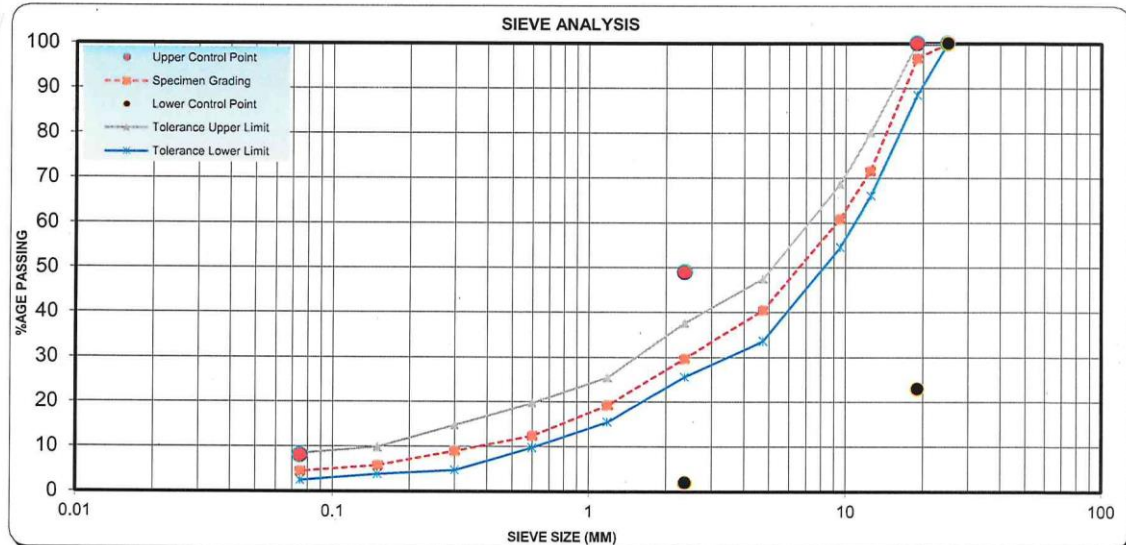
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

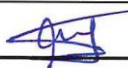
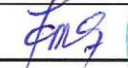
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	75% RA and 25% SD	Date of Testing	23-Mar-2025
Proportion:	25:32:8.32.3		

Average of 2 Trials

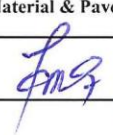
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION							
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification
							Lower	Upper	
Total Wt. of Mix before test (A) gm	1688.25	25.0	0.0	0.0	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.05	19.0	52.5	3.3	96.7	96.5	88.5	100	90
Wt. of filter + sediment (C) gm	3.3	12.50	404.6	25.2	71.6	73.0	66.0	80.0	-
Wt. of Sediment (D) = (C - B) gm	0.3	9.50	171.5	10.7	60.9	61.6	54.6	68.6	-
Wt. of filler after burn (E) gm	8.25	4.75	328.9	20.4	40.5	40.6	33.6	47.6	-
Wt. of Aggregate (F) gm	1599.8	2.36	172.6	10.7	29.7	31.6	25.6	37.6	23
Total Wt. of Aggregate (G) = (D + E + F) gm	1608.3	1.18	168.3	10.5	19.3	20.4	15.4	25.4	-
		0.600	109.9	6.8	12.4	14.7	9.7	19.7	-
Wt. of Bitumen (H) = (A - F) gm	80.0	0.300	55.0	3.4	9.0	9.7	4.7	14.7	-
Bitumen Content	In T.Mix H/A %	4.74	0.150	52.5	3.3	5.8	6.8	3.8	9.8
			0.075	20.6	1.3	4.5	5.4	2.4	8.4
	In T. Agg. H/F %	5.0	Pan	72.1	4.5				

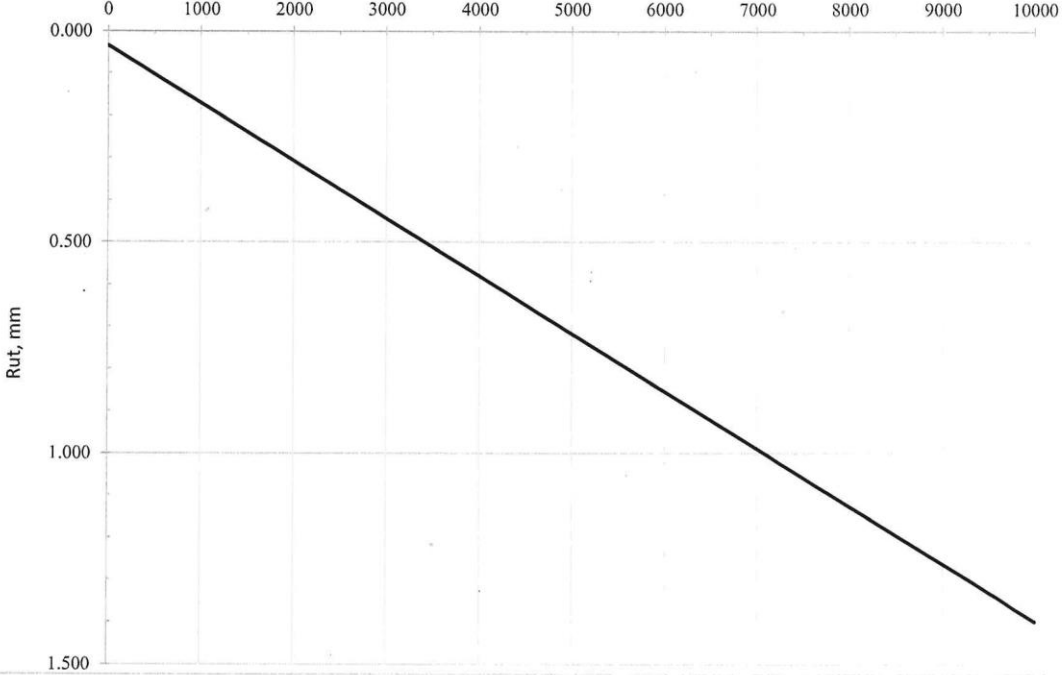
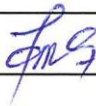


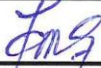
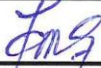
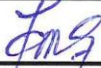
Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	75% Red ash Mix with 25% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,012		
SSD mass	B	gm.	1,016		
Mass in water	C	gm.	579		
Volume	$E = (B - A) - (B - C)$		cm ³	433	
Bulk specific gravity	$G_{mb} = A/E$			2.337	
Maximum specific gravity	G_{mm}			2.504	
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$		%	6.7	
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.35		
Rut at 5,000 passes		mm	0.72		
Rut at 10,000 passes		mm	1.40		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.14		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	2.3		
Maximum Rut depth RD_{Air}		mm	1.4		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	75% Red ash Mix with 25% Stone dust				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60 ⁰ C		
Conditioning time: +6hr			Test load: 520 N		
Passes 					
Remark: _____					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer	Consultant	Contractor																																				
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE																																				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																																						
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283																																						
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs																																						
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa] Saturated 16hrs @ -18°C + 24hrs @ 60°C + 2 hrs @ 25°C Duration: 6 min [5 - 10 min]																																						
Filler 75% Red ash Mix with 25% Stone dust																																						
Condition of test specimens																																						
<table border="1"> <thead> <tr> <th colspan="3">Sample identification</th> <th colspan="3">Saturated/conditioned</th> <th colspan="3">Dry</th> </tr> <tr> <th colspan="3"></th> <th>1</th> <th>2</th> <th>3</th> <th>1</th> <th>2</th> <th>3</th> </tr> </thead> <tbody> <tr> <td>Diameter</td> <td>D</td> <td>mm</td> <td>149.9</td> <td>149.3</td> <td>149.8</td> <td>149.7</td> <td>149.2</td> <td>149.0</td> </tr> <tr> <td>Thickness</td> <td>t</td> <td>mm</td> <td>96</td> <td>94.7</td> <td>95.2</td> <td>95</td> <td>96</td> <td>96.4</td> </tr> </tbody> </table>			Sample identification			Saturated/conditioned			Dry						1	2	3	1	2	3	Diameter	D	mm	149.9	149.3	149.8	149.7	149.2	149.0	Thickness	t	mm	96	94.7	95.2	95	96	96.4
Sample identification			Saturated/conditioned			Dry																																
			1	2	3	1	2	3																														
Diameter	D	mm	149.9	149.3	149.8	149.7	149.2	149.0																														
Thickness	t	mm	96	94.7	95.2	95	96	96.4																														
VOLUMETRIC																																						
Dry mass in air	A	gm.	3,963	3,999	4,008	3,975	3,984	3,960																														
SSD mass	B	gm.	3,994	4,028	4,034	4,000	4,017	3,990																														
Mass in water	C	gm.	2,333	2,346	2,354	2,325	2,354	2,328																														
Volume	E = B - C	cm ³	1,661	1,682	1,680	1,675	1,663	1,662																														
Bulk specific gravity	G _{mb} = A/E		2.386	2.378	2.386	2.373	2.396	2.383																														
Maximum specific gravity	G _{mm}		2.504	2.504	2.504	2.504	2.504	2.504																														
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%	4.7	5.1	4.7	5.2	4.3	4.8																														
Volume of air voids	V _a = (P _a x E/100)	cm ³	78.3	85.0	79.4	87.5	71.9	80.5																														
TSR																																						
Thickness	t'	mm	96	94.7	95.2																																	
SSD mass	B'	gm.	4,020	4,064	4,066																																	
Volume of absorbed water	J' = B' - A	cm ³	57.0	65.0	58.0	-	-	-																														
Saturation	S' = 100 x J'/V _a	%	72.8	76.5	73.1	-	-	-																														
Load	P'	N	20,960.0	21,850.0	21,340.0	24,050.0	23,870.0	25,870.0																														
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa				1,076.6	1,060.9	1,146.6																														
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa	927.3	983.8	952.6																																	
Average dry strength	Average S ₁	kPa	1,094.7																																			
Average wet strength	Average S ₂	kPa	954.6																																			
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%	87.2																																			
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80																																						
Remark:																																						
<table border="1"> <thead> <tr> <th>Tested by:</th> <th>Verified by:</th> </tr> </thead> <tbody> <tr> <td>  </td> <td>  </td> </tr> <tr> <td> Tested by: </td> <td> Material and Pavement Engineer </td> </tr> </tbody> </table>			Tested by:	Verified by:			Tested by:	Material and Pavement Engineer																														
Tested by:	Verified by:																																					
																																						
Tested by:	Material and Pavement Engineer																																					



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

29.03..2025

Specimen Information

Identification: 75% RA-25% SD

Conditioning time:2

Properties/Comments:AC-50 Sample -1

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	96.0						96.00	
Height (mm)	38.0						38.00	
Cross-sectional area (mm²): 7238.2								

Test Parameters

Waveshape: Haversine

Target temperature (°C): 30

Consta I1: 0.233936

Loading pulse width (ms): 100

Contact load (N): 50

r12: -0.780056

Rest period (ms): 900

Peak load (N): 478

I3: 0.307445

Pulse repetition period (ms): 1000

I4: -1.069463

Number of conditioning pulses: 100

Test Results

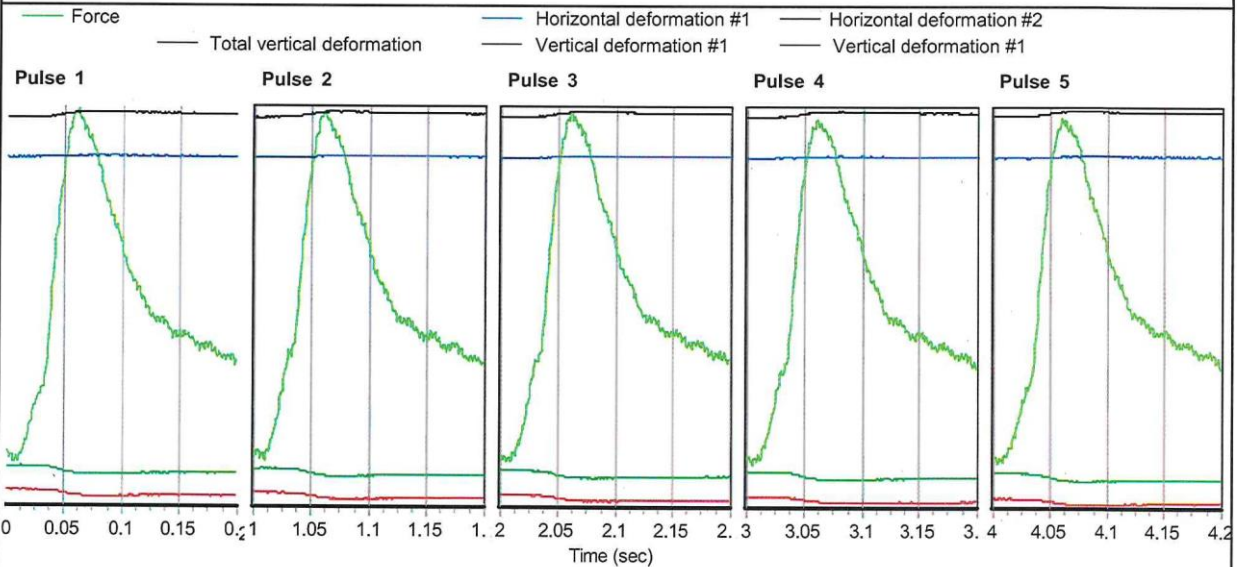
Test date & time: Saturday, March 29, 2025, at 15:16 Conditioning

pulses: 100

Core temperature (°C): 31.6

Surface temperature (°C): 31.4

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	5612	5222	5470	4913	5557	5355	5355	258.30	4.82
Poisson Ratio #1	0.28	0.27	0.32	0.23	0.26	0.27	0.27	0.03	10.61
Recoverable horizontal deformation #1 (µm)	0.286	0.296	0.312	0.295	0.273	0.292	0.292	0.013	4.402
Recoverable vertical deformation #1 (µm)	-0.729	-0.768	-0.751	-0.807	-0.720	-0.755	-0.755	0.031	-4.104
Resilient Modulus #2 (MPa)	4466	4759	4247	4361	4760	4519	4519	208.65	4.62
Poisson Ratio #2	0.94	1.16	0.92	1.03	1.10	1.03	1.03	0.09	8.91
Recoverable horizontal deformation #2 (µm)	0.768	0.833	0.787	0.826	0.800	0.803	0.803	0.024	3.006
Recoverable vertical deformation #2 (µm)	-1.077	-1.043	-1.119	-1.104	-1.030	-1.075	-1.075	0.034	-3.179
Maximum applied load (N)	134	132	134	132	132	133	133	0.96	0.72
Contact load (N)	50	52	50	49	50	50	50	0.87	1.72



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

29.03.2025

Specimen Information

Identification: 75% RA-25% SD

Conditioning time:2

Properties/Comments:AC-50 Sample -2

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	96.0						96.00	
Height (mm)	38.0						38.00	
Cross-sectional area (mm ²): 7238.2								

Test Parameters

Waveshape: Haversine

Target temperature (°C): 30

Consta-I1: 0.233936

Loading pulse width (ms): 100

Contact load (N): 50

nt2: -0.780056

Rest period (ms): 900

Peak load (N): 478

I3: 0.307445

Pulse repetition period (ms): 1000

I4: -1.069463

Number of conditioning pulses: 100

Test Results

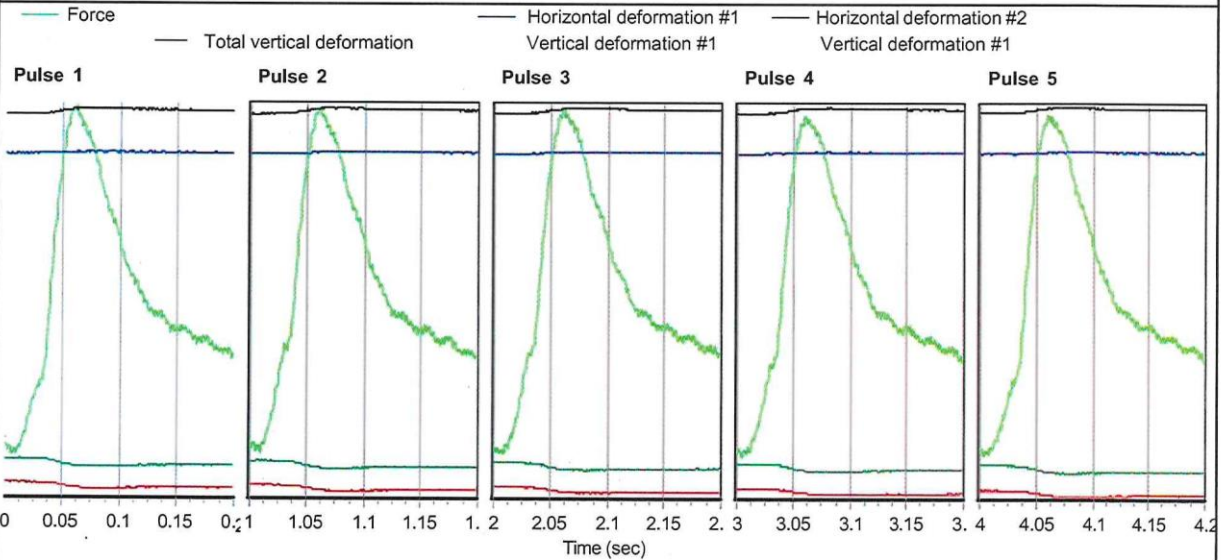
Test date & time: Saturday, March 29, 2025, at 15:16

Conditioning pulses: 100

Core temperature (°C): 31.6

Surface temperature (°C): 31.4

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	5612	5222	5470	4913	5557	5355	5355	258.30	4.82
Poisson Ratio #1	0.28	0.27	0.32	0.23	0.26	0.27	0.27	0.03	10.61
Recoverable horizontal deformation #1 (µm)	0.286	0.296	0.312	0.295	0.273	0.292	0.292	0.013	4.402
Recoverable vertical deformation #1 (µm)	-0.729	-0.768	-0.751	-0.807	-0.720	-0.755	-0.755	0.031	-4.104
Resilient Modulus #2 (MPa)	4466	4759	4247	4361	4760	4519	4519	208.65	4.62
Poisson Ratio #2	0.94	1.16	0.92	1.03	1.10	1.03	1.03	0.09	8.91
Recoverable horizontal deformation #2 (µm)	0.768	0.833	0.787	0.826	0.800	0.803	0.803	0.024	3.006
Recoverable vertical deformation #2 (µm)	-1.077	-1.043	-1.119	-1.104	-1.030	-1.075	-1.075	0.034	-3.179
Maximum applied load (N)	134	132	134	132	132	133	133	0.96	0.72
Contact load (N)	50	52	50	49	50	50	50	0.87	1.72



Stress Strain Test

Data file name: C:\Users\IPC GLOBAL\Desktop\CT index -AC-50, 22.03.2025.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 22/03/2025 10:02:32
Project: EHAE
Operator:
Comments: 75% Red Ash and 25% Stone dust Cracking Tolerance Index AC-50
22.03.2025

Specimen Information

Identification: CT index
Remarks...
AC 50 CT index

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	95.0						95.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Setup Parameters

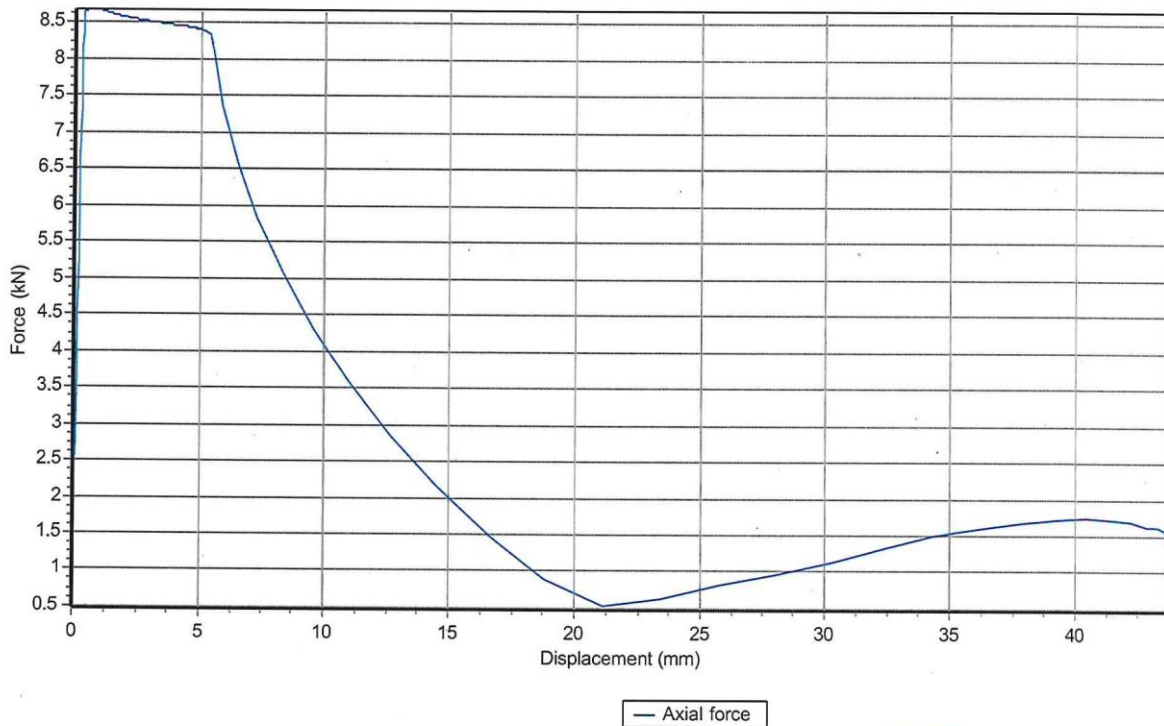
Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hhmmss): 00:05:51
Displayed time (hhmmss): 00:05:51
Displayed seconds: 351
Actuator displ. (mm): 43.738
Actuator microstrain: 2.9159E5
Actuator position (mm): 24.473
Axial force (kN): 1.332
Axial stress (kPa): 111.5
Maximum axial force (kN): 8.683
Minimum axial force (kN): 727.3



EN12697-25 Cyclic Compression Test

Data file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Data\WC -50 1.D030

Template file name: C:\IPCglobal UTS\030 Cyclic Compression Test\Templates\UTS030 - EHAE Creep template.P030

Test date & time: 22.03.2025 75% Red Ash and 25% Stone dust, at 10:40 AM

Project: EHAE

Operator: Ravi

Comments: WC -50

Specimen Information

Identification: 75% Red Ash and 25% Stone dust

Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

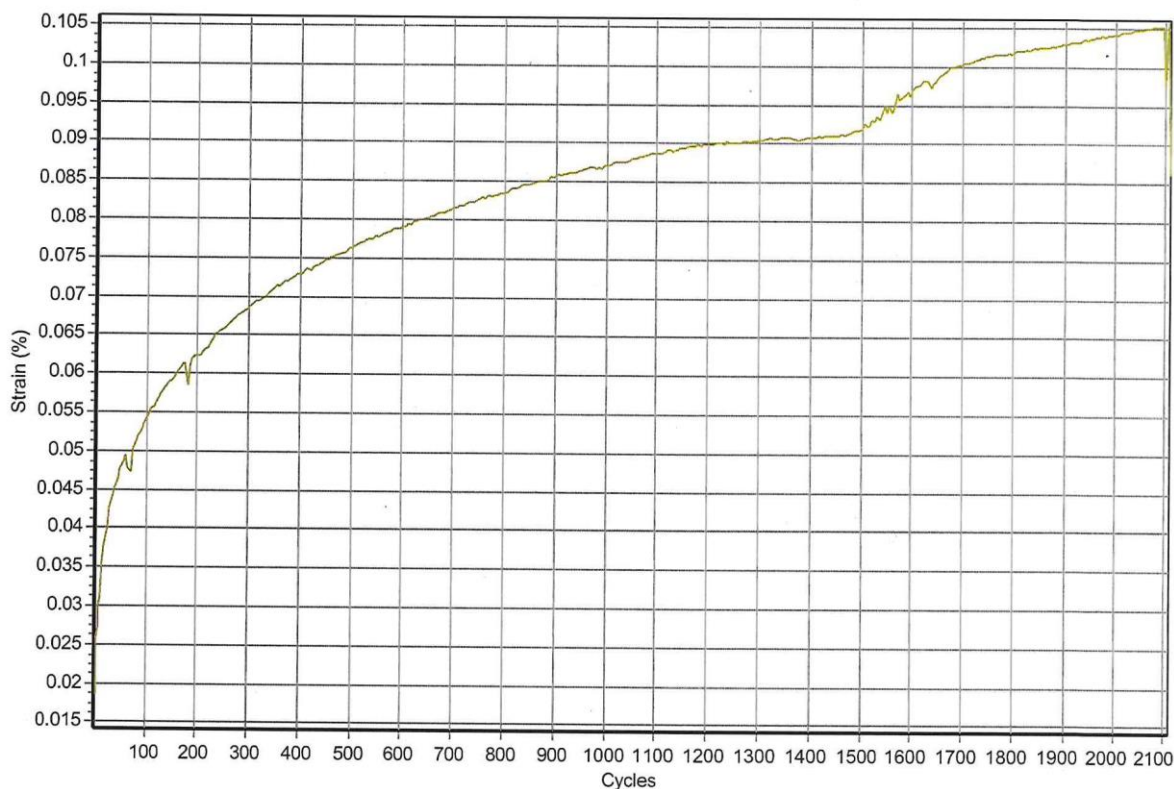
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 5

	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	



— Total Permanent strain



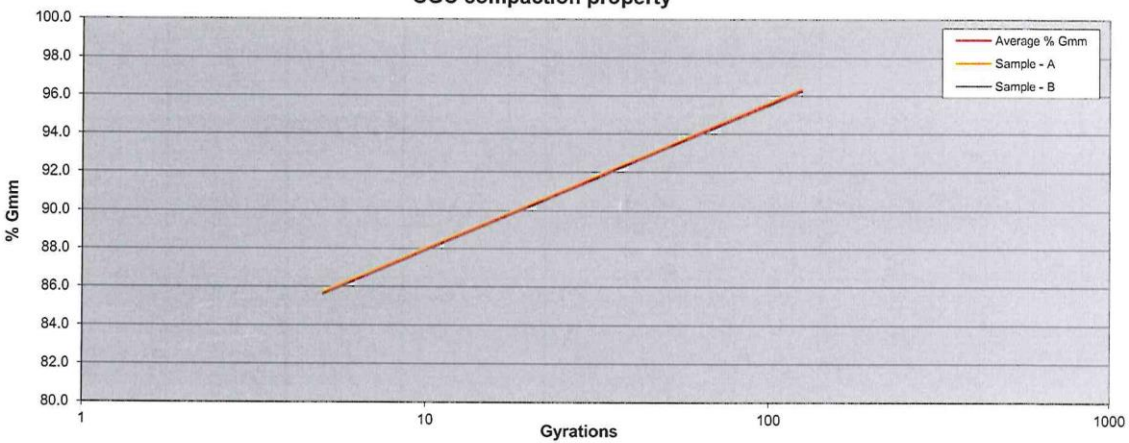
**Appendix 12 Volumetric properties and Performance
tests of asphalt mixture with 100% Red Volcanic Ash
Cinder**

Employer		Consultant		Contractor							
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
Summary of Asphalt Concrete Testing and Approval Record											
Source of Mix	Lab-Mix		Filler	100% Red-Ash							
Visual Description	Hot Mix Asphalt Mixture(AC)										
Purpose	AC-60 Binder course										
TYPE OF TEST CONDUCTED	PROPERTIES	VALUES	SPECIFICATION LIMIT								
SUPERPAVE PROPERTIES OF BITUMEN MIXTURE	Bulk S.G of Compacted mix	2.410	NA								
	Av	3.7	3 - 6								
	VMA(%)	13.4	≥ 13								
	VFB(%)	72.7	65 - 75								
	N _{ini} (%)	87.6	≤ 89								
	N _{des} (%)	96.3	96% ± 1%								
	N _{max} (%)	96.7	≤ 98%								
MTD	G _{mm}	2.502	NA								
DUST TO BINDER RATIO		1.01	0.8 - 1.6								
EXTRACTION	Bitumen Content/Mix(%)	4.81	± 0.3 Design Binder Content								
Sieve Analysis											
Description	Sieve Size (mm)										
	25	19	12.5	9.5	4.75	2.36	1.18	0.60	0.30	0.150	0.075
Specimen Grading	100	96.2	72.6	60.5	39.6	31.0	19.5	14.1	10.0	6.3	4.6
JMF	100	96.5	73.0	61.6	40.6	31.6	20.4	14.7	9.7	6.8	5.4
Tolerance from JMF L. Limit	100	88.5	66	54.6	33.6	25.6	15.4	9.7	4.7	3.8	2.4
Tolerance from JMF U. Limit	100	100	80	68.6	47.6	37.6	25.4	19.7	14.7	9.8	8.4
Upper Control Point	100	100	-	-	-	49	-	-	-	-	8
Lower Control Point	100	90	-	-	-	23	-	-	-	-	2
REMARK:											
Tested by:						Verified by:					
Laboratory Technician						Material and Pavement Engineer					
											



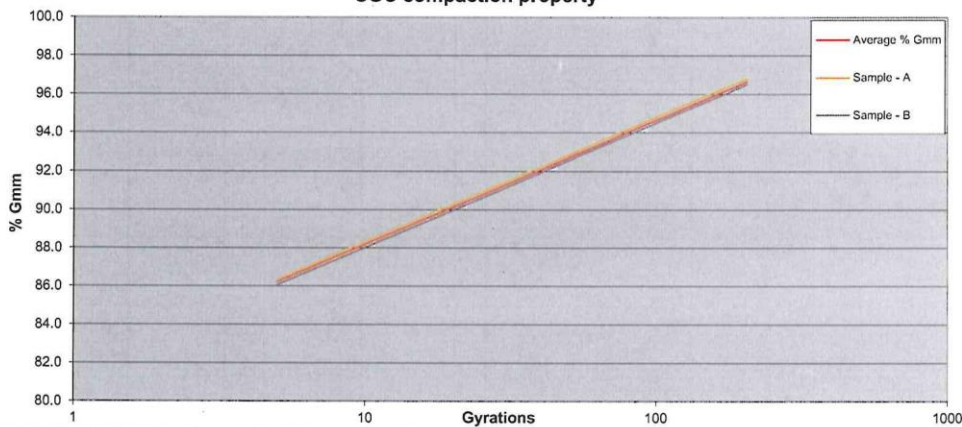
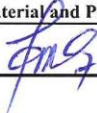
Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course			Agg Source	Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix			Bitumen Grade	40/50			
Filler	100% Red-Ash			Specific Gravity	1.0285			
Date Tested:	24-Mar-25			Number of Gyration	125 @ N _{des}			
Mixing Temperature (°C)	135-165			Compaction Temperature (°C)	135-150			
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm		Height	% Gmm			
5	127.868	85.8		128.084	85.6			85.7
9 [Nini]	125.034	87.7		125.245	87.5			87.6
10	124.539	88.1		124.750	87.9			88.0
20	121.38	90.4		121.585	90.2			90.3
30	119.605	91.7		119.807	91.5			91.6
40	118.377	92.7		118.577	92.5			92.6
50	117.442	93.4		117.640	93.2			93.3
70	116.059	94.5		116.255	94.3			94.4
90	115.047	95.3		115.242	95.1			95.2
110	114.252	96.0		114.445	95.8			95.9
125 [Ndes]	113.751	96.4		113.943	96.2			96.3
	G _{mb} Gyro	2.304		G _{mb} Gyro	2.319		Average G _{mb} Gyro	2.312
	G _{mb}	2.412		G _{mb}	2.409		Average G _{mb}	2.410
	G _{mm}	2.501		G _{mm}	2.504		Average G _{mm}	2.502
	G _{sb}	2.654		G _{sb}	2.654		Average G _{sb}	2.654
	G _{sa}	2.736		G _{sa}	2.736		G _{sa}	2.736
% AC	4.70							
Aggreg. Frac.	95.3							
Csb	2.654							
Pb	1.029							
Volumetrics	Value	Spec.						
%Gmm@Ni	87.6	< 89%						
%Gmm@Ndes	96.33							
% Air void	3.7	3-6%						
% VMA	13.45	Min 13%						
%VFA	72.70	65-75						
			Determination of measured Bulk Specific Gravity					
	Mix Ref.	Wt. air	Wax + spc in air	Wax + spc In water	Volume	Gmb		
	Sample - A	4444.6	4459.6	2616.7	1842.9	2.412		
	Sample - B	4460.1	4471.3	2620	1851.3	2.409		

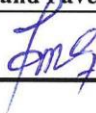
SGC compaction property



Tested by:		Verified by:	
Laboratory Technician		Material and Pavement Engineer	
			



Employer			Consultant			Contractor		
 Ethiopian Roads Administration (ERA)			 LEA JV with Unicon P.L.C, Ethiopia			 JMC-LRBCL JOINT VENTURE		
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)								
Description:	AC-60 Binder course		Agg Source		Quarry @ KM 29+600LHS			
Source of Mix	Lab-Mix		Bitumen Grade		40/50			
Filler	100% Red-Ash		Specific Gravity		1.0285			
Date Tested:	24-Mar-25		Number of Gyration		205 @ N _{max}			
Mixing Temperature (°C)	135-160		Compaction Temperature (°C)		135-150			
Sample - A			Sample - B			Average % Gmm		
No of Gyration	Height	% Gmm		Height	% Gmm			
5	127.123	86.4		126.900	86.1			86.2
9 [Nini]	124.728	88.0		124.509	87.7			87.9
10	124.308	88.3		124.090	88.0			88.2
20	121.615	90.3		121.402	90.0			90.1
30	120.094	91.4		119.883	91.1			91.3
40	119.037	92.3		118.828	91.9			92.1
50	118.230	92.9		118.022	92.5			92.7
70	117.033	93.8		116.828	93.5			93.7
90	116.155	94.5		115.952	94.2			94.4
110	115.464	95.1		115.261	94.8			94.9
125 [Ndes]	115.027	95.5		114.826	95.1			95.3
150	114.411	96.0		114.210	95.6			95.8
175	113.895	96.4		113.695	96.1			96.2
200	113.451	96.8		113.252	96.4			96.6
205 [Nmax]	113.370	96.9		113.171	96.5			96.7
	G _{mb} Gyro	2.353		G _{mb} Gyro	2.351		Average G _{mb} Gyro	2.352
	G _{mb}	2.423		G _{mb}	2.416		Average G _{mb}	2.419
	G _{mm}	2.501		G _{mm}	2.504		Average G _{mm}	2.502
	G _{sb}	2.654		G _{sb}	2.654		Average G _{sb}	2.654
	G _{sa}	2.736		G _{sa}	2.736		G _{sa}	2.736
% AC	4.7		Determination of measured Bulk Specific Gravity					
Aggreg. Frac.	95.3		Mix Ref.	Wt. air	wax+ spc in air	wax+spc in water	Volume	Gmb
Gsb	2.654		Sample - A	4454	4463.5	2625	1838.5	2.423
Pb	1.029		Sample - B	4477.6	4488.1	2635	1853.1	2.416
Mix property	Units		Result			Criteria		
% G _{mm} at N _{max}	%		96.7			Max 98		
SGC compaction property 								
Tested by:			Verified by:					
Laboratory Technician			Material and Pavement Engineer					
			 					

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
THEORETICAL MAXIMUM SPECIFIC GRAVITY AASHTO T 209/ASTM D 2041		
Source of Mix	Lab-Mix	Filler
		100% Red-Ash
Material Description:	AC-60 Binder course	Dated of Testing
		24-Mar-2025
Grade of Bitumen	40/50	Bitumen by Wt. of Mix
		: 5.40%
Testing Temp.	25 °C	
SG of Asphalt binder [G _b] = 1.0285 % of binder from extraction [P _{bo}], % = 4.7		
Test No		Test 1 Test 2
Mass of dry sample in air	A	gm. 2708.2 2741.6
Mass of container filled with water at test temperature	F	gm. 9129.1 9129.1
Mass of container filled with sample and water at test temperature	G	gm. 10754.5 10775.6
Temperature of test water	T	°C 25 25
Correction for thermal expansion of bitumen	H	gm. 0.0 0.0
Theoretical Maximum specific gravity at test water temperature	E = A/[(A+F)-(G-H)]	2.501 2.504
Correction factor	R = dw/0.9970	1.000 1.000
Corrected Theoretical Maximum Specific Gravity at 25°C	SG = R x E	2.501 2.504
Average Theoretical Maximum Specific Gravity at 25°C	G_{mm} = (SG 1 + SG 2)/2	2.502
Effective Specific Gravity of Aggregate	G_{se}	2.692
Effective Specific Gravity of Aggregate[G_{se}] = (100-P_b)/((100/G_{mm})-(P_b/G_b)) Where: P_b - Percentage of Asphalt binder by Weight of Total Mix P_s - Aggregate content, percent by Weight of Total Mix G_{mm} - Average Theoretical Maximum Specific Gravity at 25°C G_b - Specific Gravity of Bitumen dw - density of water at test temperature 0.9970 - density of water at 25°C, Mg/m³		
Remark:		
Tested by:	Verified by:	
Laboratory Technician	Material and Pavement Engineer	
	 	

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

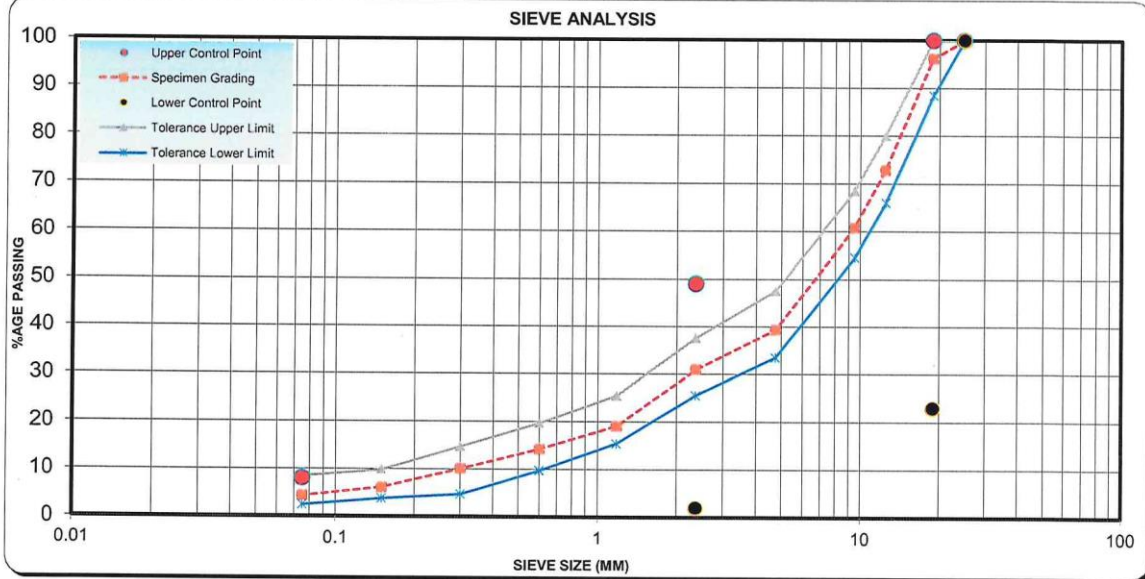
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

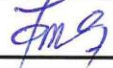
Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% Red-Ash	Date of Testing	25-Mar-2025
Proportion:	25:32:8.32.3		

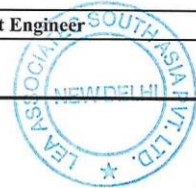
Trial - A

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION								
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification	
							Lower	Upper		
Total Wt. of Mix before test (A) gm	1396	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm	3.3	19.0	50.0	3.8	96.2	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm	4.3	12.50	310.5	23.4	72.9	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm	1.0	9.50	159.9	12.0	60.8	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm	6.0	4.75	285.0	21.5	39.4	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm	1321.5	2.36	110.7	8.3	31.0	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm	1328.5	1.18	157.8	11.9	19.2	20.4	15.4	25.4	-	-
		0.600	65.2	4.9	14.3	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm	67.5	0.300	55.0	4.1	10.1	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	0.150	52.0	3.9	6.2	6.8	3.8	9.8	-	-
		0.075	24.0	1.8	4.4	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.1	Pan	58.4	4.4					



Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE

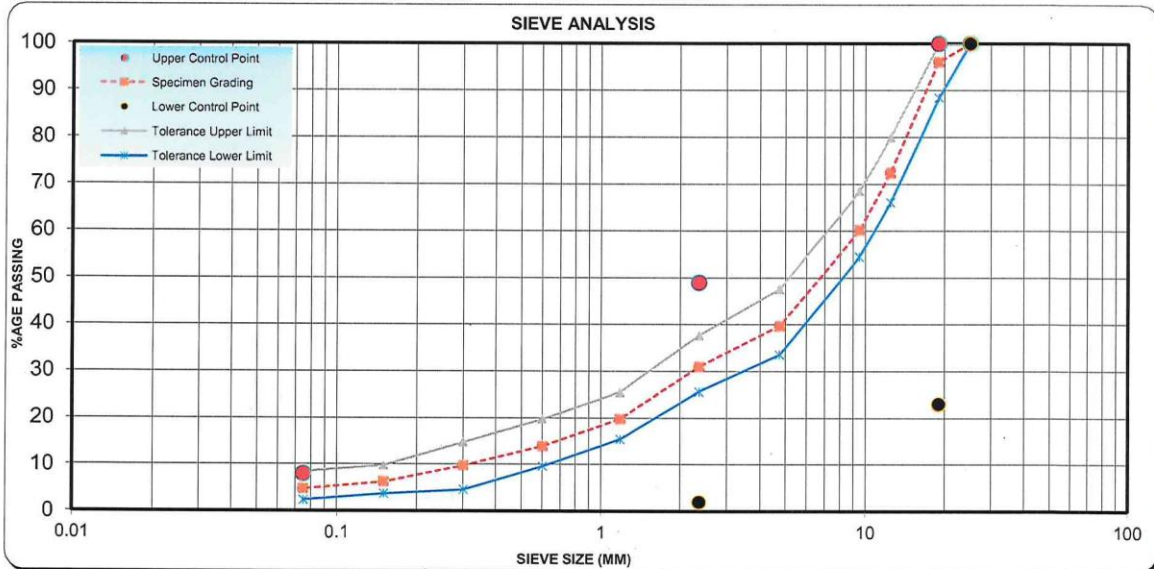
**ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT
(PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)**

BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164

Source of Mix	Lab-Mix	Source of Material	Km.29+600 LHS Quarry
Material Description	Hot Mix Asphalt Binder Course Mixture	Grade of Bitumen	40/50
Filler	100% Red-Ash	Date of Testing	25-Mar-2025
Proportion:	25:32:8.32.3		

Trial - B

BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm	1512	25.0	0.0	0.0	100	100	100	100	100	100	
Wt. of Filter paper before test (B) gm	3.3	19.0	56.1	3.9	96.1	96.5	88.5	100	90	100	
Wt. of filter + sediment (C) gm	3.5	12.50	340.9	23.7	72.4	73.0	66.0	80.0	-	-	
Wt. of Sediment (D) = (C - B) gm	0.2	9.50	175.9	12.2	60.2	61.6	54.6	68.6	-	-	
Wt. of filler after burn (E) gm	6.0	4.75	295.0	20.5	39.7	40.6	33.6	47.6	-	-	
Wt. of Aggregate (F) gm	1433.5	2.36	125.4	8.7	31.0	31.6	25.6	37.6	23	49	
Total Wt. of Aggregate (G) = (D + E+F) gm	1439.7	1.18	160.6	11.2	19.9	20.4	15.4	25.4	-	-	
		0.600	84.2	5.8	14.0	14.7	9.7	19.7	-	-	
Wt. of Bitumen (H) = (A - F) gm	72.3	0.300	60.0	4.2	9.8	9.7	4.7	14.7	-	-	
Bitumen Content	In T.Mix H/A %	4.78	0.150	49.9	3.5	6.4	6.8	3.8	9.8	-	-
			0.075	22.6	1.6	4.8	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.0	Pan	69.1	4.8						



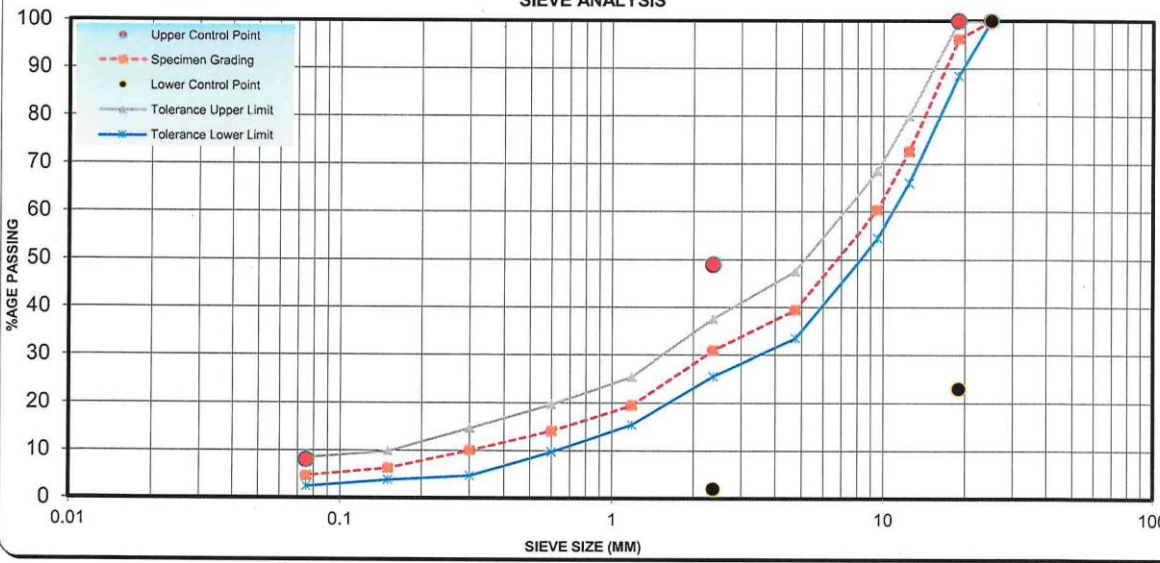
Remarks :

Tested by:	Verified by:
Laboratory Technician	Material and Pavement Engineer
	



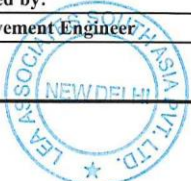
Employer  Ethiopian Roads Administration (ERA)		Consultant  LEA JV with Unicon P.L.C, Ethiopia		Contractor  JMC-LRBCL JOINT VENTURE							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
BINDER CONTENT AND GRADATION OF BITUMINOUS MIX AASHTO T-164											
Source of Mix		Lab-Mix		Source of Material							
Material Description		Hot Mix Asphalt Binder Course Mixture		Km.29+600 LHS Quarry							
Filler		100% Red-Ash		Date of Testing							
Proportion:		25:32:8.32.3		25-Mar-2025							
Average of 2 Trials											
BITUMEN EXTRACTION TEST		SIEVE ANALYSIS OF AGGREGATE AFTER EXTRACTION									
		Sieve Size (mm)	Weight Retained (gm)	Weight Retained (%)	Percent Passing %	JMF	Acceptable Limits		Specification		
							Lower	Upper			
Total Wt. of Mix before test (A) gm		1454	25.0	0.0	0.0	100	100	100	100	100	100
Wt. of Filter paper before test (B) gm		3.3	19.0	53.1	3.8	96.2	96.5	88.5	100	90	100
Wt. of filter + sediment (C) gm		3.9	12.50	325.7	23.5	72.6	73.0	66.0	80.0	-	-
Wt. of Sediment (D) = (C - B) gm		0.6	9.50	167.9	12.1	60.5	61.6	54.6	68.6	-	-
Wt. of filler after burn (E) gm		6	4.75	290.0	21.0	39.6	40.6	33.6	47.6	-	-
Wt. of Aggregate (F) gm		1377.5	2.36	118.1	8.5	31.0	31.6	25.6	37.6	23	49
Total Wt. of Aggregate (G) = (D + E+F) gm		1384.1	1.18	159.2	11.5	19.5	20.4	15.4	25.4	-	-
			0.600	74.7	5.4	14.1	14.7	9.7	19.7	-	-
Wt. of Bitumen (H) = (A - F) gm		69.9	0.300	57.5	4.2	10.0	9.7	4.7	14.7	-	-
Bitumen Content	In T.Mix H/A %	4.81	0.150	51.0	3.7	6.3	6.8	3.8	9.8	-	-
			0.075	23.3	1.7	4.6	5.4	2.4	8.4	2	8
	In T. Agg. H/F %	5.1	Pan	63.8	4.6						

SIEVE ANALYSIS

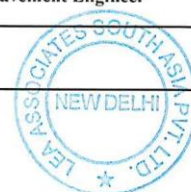


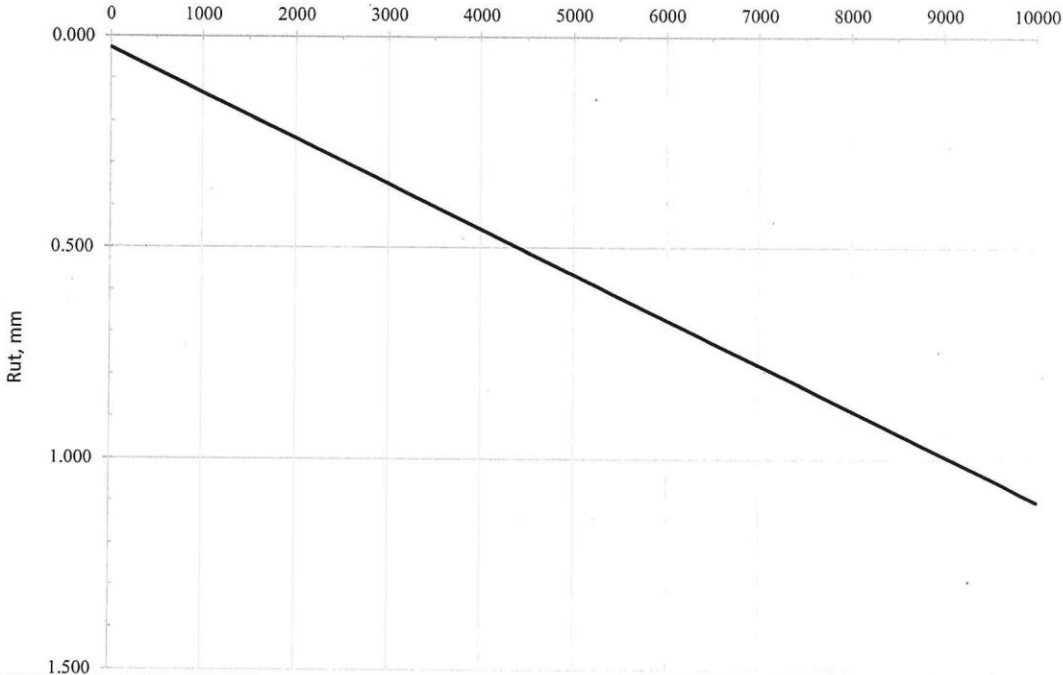
Remarks :

Tested by: Laboratory Technician 	Verified by: Material and Pavement Engineer 
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Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	100% Red ash				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Sample Identification				A	
Length	L	mm	300.0		
Thickness	t	mm	60.0		
VOLUMETRIC					
Dry mass in air	A	gm.	1,018		
SSD mass	B	gm.	1,021		
Mass in water	C	gm.	580		
Volume	$E = (B - A) - (B - C)$	cm ³	438		
Bulk specific gravity	$G_{mb} = A/E$		2.324		
Maximum specific gravity	G_{mm}		2.502		
Air voids	$P_a = [100(G_{mm} - G_{mb})/G_{mm}]$	%	7.1		
HWT					
Sample Identification				A-1	
Rut at 2,340 passes (after 45 minute)		mm	0.28		
Rut at 5,000 passes		mm	0.56		
Rut at 10,000 passes		mm	1.10		
Maximum Wheel Tracking Slope WTS_{Air} ($d_{10000} - d_{5000}$)/5		mm/1k cycl	0.11		
Maximum Proportional Rut Depth PRD_{Air} 100 ($d_n - d_0$)/h		%	1.8		
Maximum Rut depth RD_{Air}		mm	1.1		
As per ERA Flexible Pavement Design Manual-2013 (Max) ≤ 7mm					
Remark: _____ Page 1 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
					



Employer		Consultant		Contractor	
 Ethiopian Roads Administration (ERA)		 LEA JV with Unicon P.L.C, Ethiopia		 JMC-LRBCL JOINT VENTURE	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
WHEEL-TRACK TESTING EN 12697:22					
Filler	100% Red ash				
Mixture conditioning: At compaction temperature for 4hours (short-term conditioning)					
Specimen conditioning: In Air			Test temperature: 60°C		
Conditioning time: +6hr			Test load: 520 N		
Passes  Remark:					
Page 2 of 2					
Tested by:			Verified by:		
Laboratory Technician			Material & Pavement Engineer		
			 		

Employer	Consultant	Contractor
 Ethiopian Roads Administration (ERA)	 LEA JV with Unicon P.L.C, Ethiopia	 JMC-LRBCL JOINT VENTURE
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
DETERMINATION OF TENSILE STRENGTH RATIO AASHTO T283		
Mixture conditioning: Cooling for 2hrs + Curing at 60°C for 16 hrs + Conditioning at compaction temp. for 2hrs		
Specimen conditioning: Dry 2hrs @ 25°C Applied Vacuum Pre.: 67 kPa [13-67kPa] Saturated 16hrs @ -18°C + 24hrs @ 60°C + 2 hrs @ 25°C Duration: 6 min [5 - 10 min]		
Filler 100% Red Ash		
Condition of test specimens		
Sample identification		
Diameter	D	mm
Thickness	t	mm
Saturated/conditioned		
Dry		
VOLUMETRIC		
Dry mass in air	A	gm.
SSD mass	B	gm.
Mass in water	C	gm.
Volume	E = B - C	cm³
Bulk specific gravity	G _{mb} = A/E	
Maximum specific gravity	G _{mm}	
Air voids	P _a = [100(G _{mm} - G _{mb})/G _{mm}]	%
Volume of air voids	V _a = (P _a x E/100)	cm³
TSR		
Thickness	t'	mm
SSD mass	B'	gm.
Volume of absorbed water	J' = B' - A	cm³
Saturation	S' = 100 x J'/V _a	%
Load	P'	N
Dry strength	S ₁ = 2000 x P/(π x t x D)	kPa
Wet strength	S ₂ = 2000 x P/(π x t' x D)	kPa
Average dry strength	Average S ₁	kPa
Average wet strength	Average S ₂	kPa
Tensile Strength Ratio	TSR = Average S ₂ /Average S ₁	%
As per ERA Flexible Pavement Design Manual-2013 (Min) % ≥ 80		
Remark:		
Tested by:		Verified by:
Tested by:		Material and Pavement Engineer
		



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

Wearing Course

29.03.2025

Specimen Information

Identification: AC -50 100% RA

Conditioning time: 2

Properties/Comments: Sample -1
29.03.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm²): 17203.4								

Test Parameters

Waveshape: Haversine

Target temperature (°C): 30

nts
Consta I1: 0.233936

Loading pulse width (ms): 100

Contact load (N): 50

I2: -0.780056

Rest period (ms): 900

Peak load (N): 1505

I3: 0.307445

Pulse repetition period (ms): 1000

I4: -1.069463

Number of conditioning pulses: 100

Test Results

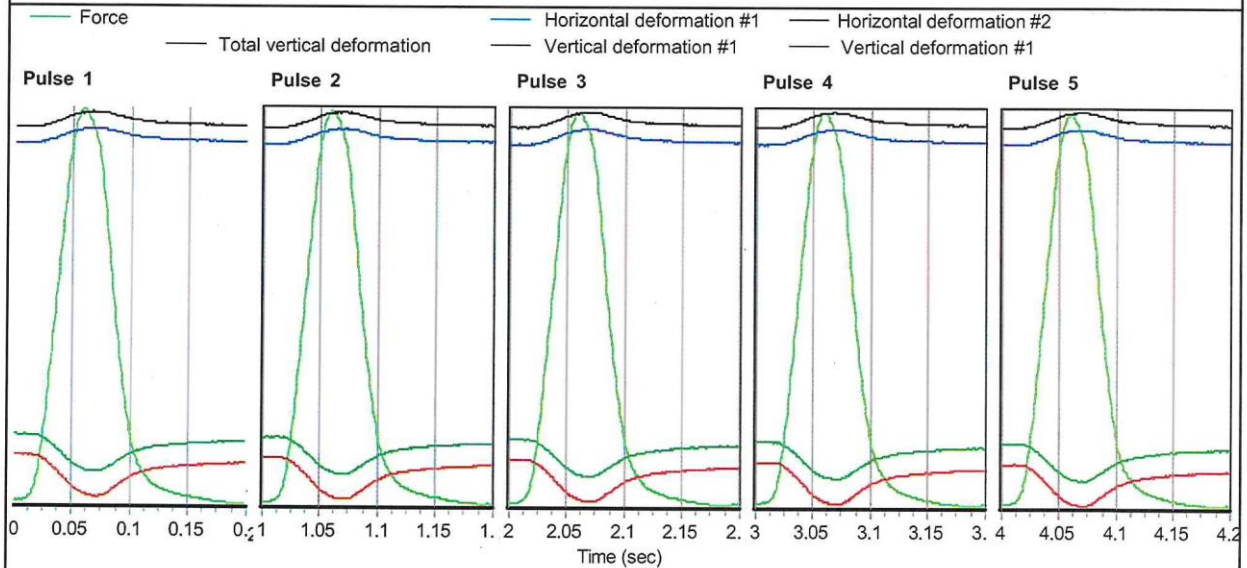
Test date & time: Saturday, March 29, 2025, at 15:29

Conditioning pulses: 100

Core temperature (°C): 31.5

Surface temperature (°C): 27.5

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4380	4406	4391	4381	4365	4385	4385	13.46	0.31
Poisson Ratio #1	0.24	0.24	0.25	0.25	0.24	0.24	0.24	0.00	1.30
Recoverable horizontal deformation #1 (µm)	2.065	2.067	2.076	2.096	2.074	2.076	2.076	0.011	0.530
Recoverable vertical deformation #1 (µm)	-5.607	-5.574	-5.587	-5.607	-5.606	-5.596	-5.596	0.013	-0.238
Resilient Modulus #2 (MPa)	5034	5013	5009	5015	5040	5022	5022	12.46	0.25
Poisson Ratio #2	0.33	0.34	0.33	0.33	0.34	0.33	0.33	0.01	1.65
Recoverable horizontal deformation #2 (µm)	2.103	2.123	2.100	2.101	2.133	2.112	2.112	0.013	0.635
Recoverable vertical deformation #2 (µm)	-5.000	-5.020	-5.008	-5.005	-4.987	-5.004	-5.004	0.011	-0.210
Maximum applied load (N)	1354	1352	1350	1350	1347	1351	1351	2.05	0.15
Contact load (N)	51	50	50	51	51	50	50	0.37	0.73



UTS003 2.11 Indirect Tensile Modulus Test

Test method: US: ASTM D7369 - 11 Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test

Data file name C:\IPCglobal UTS\003 IT Modulus Test\Default.D003

Template file C:\Users\IPC GLOBAL\Desktop\UTS003- EHAE ASTM Template Binder Course.P003

Project: Adama-Awash km 60

Operator: Ravi

Comments: AC -50

28.03.2025

Specimen Information

Identification: AC -50 100% RA

Conditioning time: 2

Properties/Comments: Sample -2
28.03.2025

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev.
Diameter (mm)	148.0						148.00	
Height (mm)	63.0						63.00	
Cross-sectional area (mm²): 17203.4								

Test Parameters

Waveshape: Haversine

Target temperature (°C): 30

Consta, I1: 0.233936

Loading pulse width (ms): 100

Contact load (N): 50

I2: -0.780056

Rest period (ms): 900

Peak load (N): 1456

I3: 0.307445

Pulse repetition period (ms): 1000

I4: -1.069463

Number of conditioning pulses: 100

Test Results

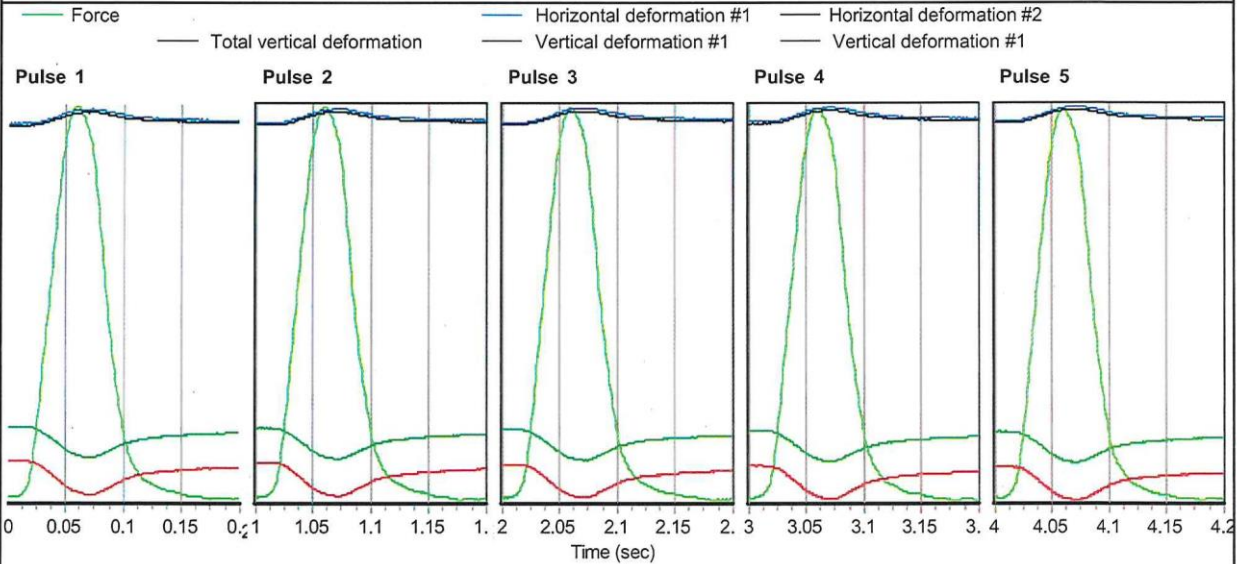
Test date & time: Friday, March 28, 2025, at 15:48

Conditioning pulses: 100

Core temperature (°C): 30.0

Surface temperature (°C): 28.6

	Total	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient Modulus #1 (MPa)	4584	4609	4601	4649	4582	4605	24.12	0.52	
Poisson Ratio #1	0.34	0.35	0.34	0.36	0.34	0.35	0.01	2.34	
Recoverable horizontal deformation #1 (µm)	2.262	2.268	2.236	2.287	2.246	2.260	0.017	0.773	
Recoverable vertical deformation #1 (µm)	-5.303	-5.277	-5.273	-5.240	-5.285	-5.276	0.021	-0.390	
Resilient Modulus #2 (MPa)	4935	4958	4941	4999	4944	4956	23.00	0.46	
Poisson Ratio #2	0.34	0.34	0.33	0.35	0.34	0.34	0.01	2.32	
Recoverable horizontal deformation #2 (µm)	2.105	2.087	2.055	2.107	2.078	2.087	0.019	0.915	
Recoverable vertical deformation #2 (µm)	-4.928	-4.898	-4.899	-4.865	-4.896	-4.897	0.020	-0.406	
Maximum applied load (N)	1304	1302	1303	1300	1300	1302	1.57	0.12	
Contact load (N)	51	50	49	49	49	49	0.70	1.42	



Stress Strain Test

Data file name: C:\Users\IPC GLOBAL\Desktop\CT Index AC 50,22.03.2025.D002
Template file name: C:\IPCglobal UTS\002 Stress Strain Test\Templates\UTS002 - Stress Strain Test.P002
Test date & time: 22/03/2025 09:56:51
Project: EHAE
Operator:
Comments: AC 50 100% Red Ash Cracking Tolerance Index
22.03.2025

Specimen Information

Identification: CT Index
Remarks...
AC 50

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	95.0						95.0	
Diameter (mm)	150.0						150.0	
Cross-sectional area (mm²): 17671.5								

Setup Parameters

Axial loading control: Actuator displ.
Rate (mm/min): 50
Pre-load: off

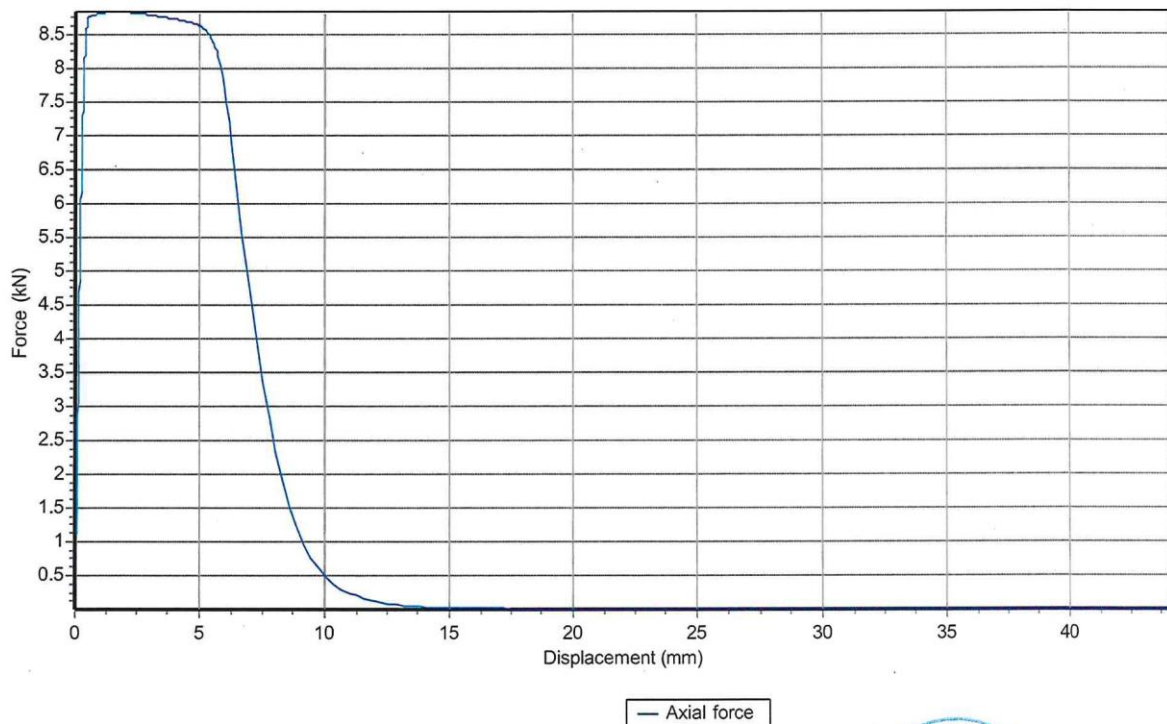
Strain conversion parameters
Actuator gauge length (mm): 150

Stress conversion parameters
Actuator area (mm²): 7854.0

Test Results

Total time (hh:mm:ss): 00:01:14
Displayed time (hh:mm:ss): 00:01:14
Displayed seconds: 74
Actuator displ. (mm): 43.987
Actuator microstrain: 2.9324E5
Actuator position (mm): 24.482

Axial force (kN): 0.003
Axial stress (kPa): 0.2
Maximum axial force (kN): 8.844
Minimum axial force (kN): 740.8



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EN12697-25 Cyclic Compression Test

Data file name: C:\Users\IPC GLOBAL\Desktop\Creep,AC-50.D030

Template file name: C:\Users\IPC GLOBAL\Desktop\UTS030 - EHAE Creep template AC 50.P030

Test date & time: 22.03.2025 100% Red Ash, at 11:17 AM

Project: Adama Awash km 60

Operator: Ravi

Comments: Creep Modulus

Specimen Information

Identification: 100% Red Ash

Remarks...

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	150.0						150.0	

Cross-sectional area (mm²): 17671.5

Set up parameters

Loading function: Square

Target temperature (°C): 50

Upper platen diameter (mm): 96

Preload time (s): 120

Loading pulse width (ms): 1000

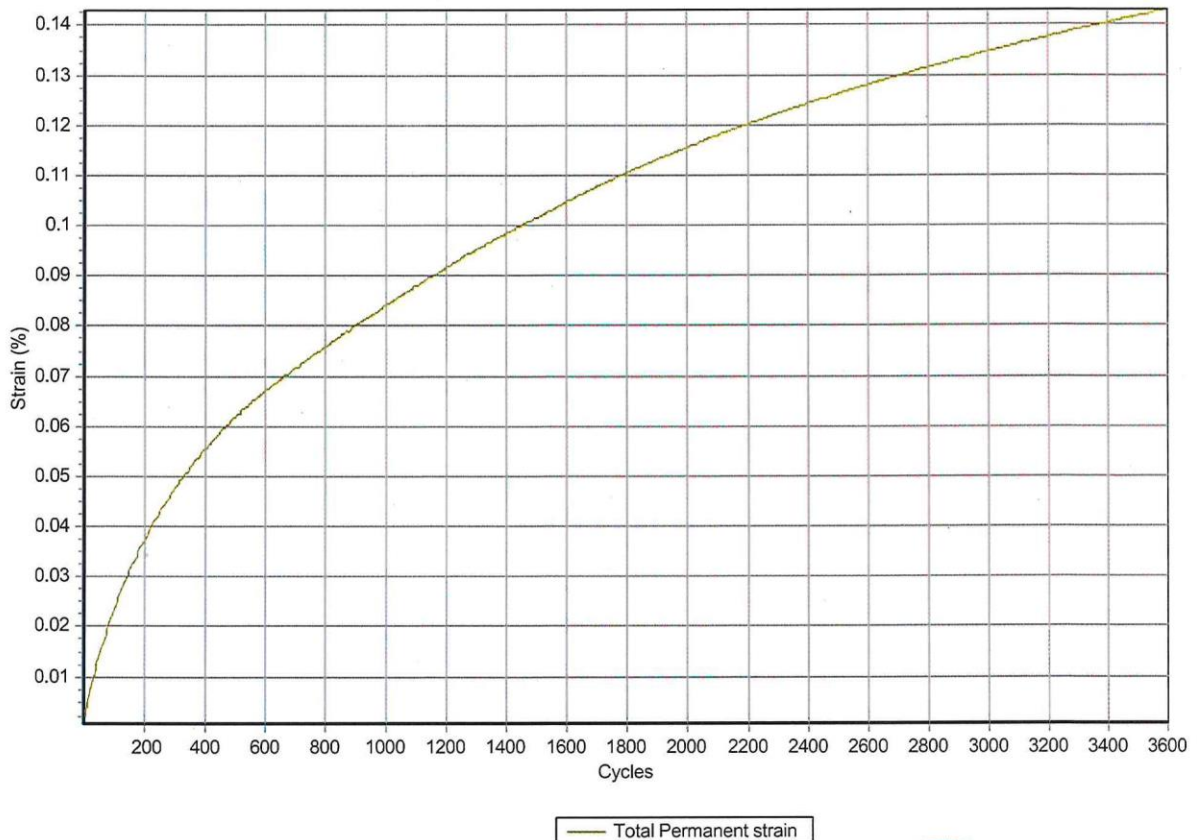
Rest period (ms): 1000

Loading cycle width (ms): 2000

Termination cycle count: 3600

Permanent deformation limit (mm): 10

	Preload	Axial	Rest period
Stress (kPa): 10	100	2	
Load (N): 72	724	15	



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Appendix 13 Laboratory Trial Bach for Wearing Course of Asphalt Mixture

Laboratory Trial Batch for Wearing Course

Trial Blend-2

Bitumen Content 5.40%

% Passing

Sieve	Sieve size raise to 0.45	Maximum density line $(d/D)^{0.45} \times 10^0$	Aggregate Type				Blend	Grading Specification NMAS 19 mm		
			14/7	7/4	4/0	Dust		Lower	Upper	Control point
19	3.8	100	100	100	100	100	100	100		
12.5	3.1	82.8	88.7	100	100	100	94.2	90	100	
9.5	2.8	73.2	36.4	99.7	100	100	67.5		90	
4.75	2.0	53.6	9.2	78.8	99.3	100	50.3			
2.36	1.5	39.1	1.9	26.5	93.6	100	37.0	23	58	39.0
1.18	1.1	28.6	0.5	9.0	67.6	100	25.9			
0.6	0.8	21.1	0.3	4.3	47.6	100	19.1			
0.3	0.6	15.5	0.2	2.1	25.3	99.5	12.0			
0.15	0.4	11.3	0.1	1.2	7.7	97.5	6.4			
0.075	0.3	8.3	0.1	0.6	3.1	93.5	4.8	2	10	
% blending			51	15	30	4	100			

Total aggregate needed for the mix **4400**

Stockpile passing/retained

plus 37.5					
37.5 to 20					
19 to 12.5	11.3	0.0	0.0	0.0	
12.5 to 9.5	52.3	0.3	0.0	0.0	
9.5 to 4.75	27.2	20.9	0.7	0.0	
4.75 to 2.36	7.3	52.3	5.7	0.0	
2.36 to 1.18	1.4	17.5	26.0	0.0	
minus 1.18	0.5	9.0	67.6	100.0	
total	100.0	100.0	100.0	100.0	
Stockpile batch weights. → Mould Weight					
plus 37.5	0	0	0	0	
37.5 to 20	0	0	0	0	
19 to 12.5	254	0	0	0	
12.5 to 9.5	1174	2	0	0	
9.5 to 4.75	610	138	9	0	
4.75 to 2.36	164	345	75	0	
2.36 to 1.18	31	116	343	0	
minus 1.18	11	59	892	176	
total	2244	660	1320	176	
Gand Total	4400.0				
Corection For N.M.C	2244	660	1320	176	



Appendix 14 Selected Pictures during the Study



Sampling of Pumice Volcanic Ash



Sampling of Red Volcanic Ash Cinder



Physical Property Testing Process



The Preparation Process of Asphalt Mix



The Preparation Process of Asphalt Mix



Gyratory Compaction of Asphalt Mix



Compacted Specimen of Asphalt Mix



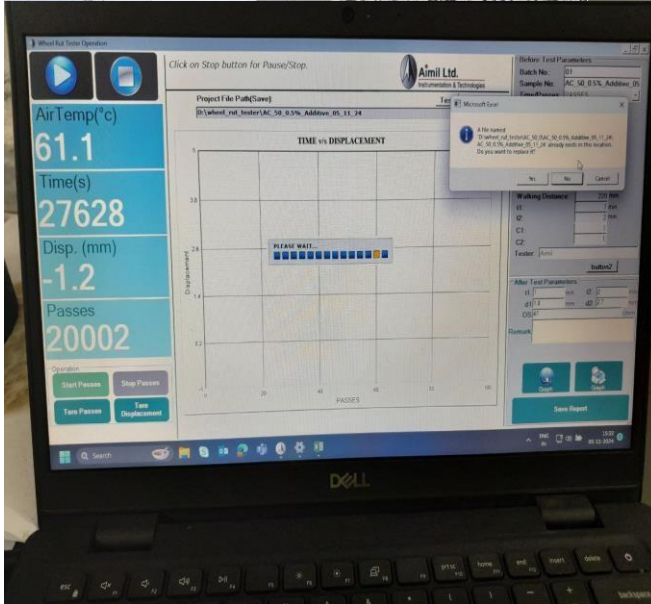
Theoretical Maximum Specific Gravity (Gmm) Test



Bulk Specific Gravity Test (Gmb)



Moisture Susceptibility (Tensile Strength Ratio - TSR) Test



Rutting Resistance (Wheel Rutting) Test



Extraction and Sieve Analysis Test



Specimen Preparation for Resilient Modulus, Creep Index and Cracking Tolerance Index Test



Resilient Modulus Test



Creep Index and Cracking Tolerance Index Test