JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

Partial Replacement of Filler with Blending of Khat Ash and Eggshell Powder on Hot Mix Asphalt

A final thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By: Bereket Ayele Arasso

August, 2021

Jimma, Ethiopia

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APPROVED BY BOARD OF EXAMINERS

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DECLARATION

I, the undersigned, declare that this thesis entitled: **"Partial Replacement of Filler with Blending of Khat Ash and Eggshell Powder on Hot Mix Asphalt"** is my original work and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for this thesis have been duly acknowledged.

Candidate:

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As Master's Research Advisors, I hereby certify that we have read and evaluated this MSc research prepared under our guidance, by **Ms. Bereket Ayele Arasso** entitled **"Partial Replacement of Filler with Blending of Khat Ash and Eggshell Powder on Hot Mix Asphalt."**
We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Dr.-Ing. Fekadu Fufa (PhD)	__________________	_______________
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ABSTRACT

Asphalt concrete road construction is now an important aspect of Ethiopia's growth and transformation plan for developing a high-performance transportation network to support the country's economic development. Aggregate, asphalt binder, and filler make up flexible asphalt mixtures. One of the major issues in the construction of highway pavement is a lack of filler from crushed stone dust (CSD), as well as a scarcity of cement. The problem can be solved by substituting non-conventional filler material blending of khat ash and eggshell powder (BKE) for conventional filler material (CSD) replaced by 8, 16, 24, 32 and 40% weight of CSD filler. The aim of this research can be done for a variety of reasons, including the use of waste products to create a pollution-free and sustainable environment, waste materials have the potential to improve the strength and durability of the original materials, and these materials have the ability to lower construction costs. Waste Khat and Eggshell both easily obtainable waste products, for the purpose of to investigate the suitability of BKE as an equal proportion of mineral filler in hot mix asphalt (HMA).To achieve this objective prepared laboratory tests such as material quality, marshal properties and moisture susceptibility were done. All the laboratory test results satisfied standard specification criteria. The specific gravity of the fillers CSD, KA, ESP, and BKE, were 2.63, 2.38, 2.41, and 2.40 respectively and Marshall Mix design was carried out with bitumen content of 4.0, 4.5, 5.0, 5.5 and 6.0% by weight of total mix and filler content of 4.5, 5.5 and 6.5% by weight of aggregate. Based on this the optimum bitumen content (OBC) 5.5% and optimum filler content (OFC) 5.18% selected by using NAPA method and optimum replacement of BKE replaced with CSD filler is 24% on the mixture consisting of acceptable values of marshal stability, flow and volumetric properties. The tensile strength ratio at 0% BKE (100% CSD) filler and 24% BKE filler results were 82.08% and 82.56% respectively. Therefore, BKE are better resistance to moisture effects. In general, it can be concluded that the blending of Khat ash and eggshell powder can be used as filler materials instead of the most commonly used conventional fillers, such as crushed stone dust filler. Further studies recommended that partially replacing filler with 24% BKE filler content was the best when compared to other percentage replacement ratio values.

Key words: *Eggshell powder, Hot Mix Asphalt, Khat ash, Moisture susceptibility, Marshall Property, Optimum bitumen content, Optimum filler content.*

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ACRONYMS

AASHTO	American Association Of Highway And Transportation Officials
AC	Asphalt Concrete
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ASTM	American Society for Testing And Materials
BC	Bitumen Content
BKE	Blending of Khat ash and Eggshell powder
BS	British Standard
CSA	Central Statistics Authority
CSD	Crushed Stone Dust
ERA	Ethiopian Roads Authority
ESP	Eggshell Powder
FAO	The Food and Agriculture Organization
FI	Flakiness Index
Gmb	Bulk Specific Gravity
Gmm	Theoretical Maximum Specific Gravity
HMA	Hot Mix Asphalt
KA	Khat Ash
LAA	Loss Angeles Abrasion
LL	Liquid Limit
MT	Metric Tones
MW	Mega Watt
NP	Non Plastic
OBC	Optimum Bitumen Content
OFC	Optimum Filler Content
PL	Plastic Limit
PI	Plasticity Index
RR	Replacement Ratio
TSR	Tensile Strength Ratio
VA	Air Void

VFA	Void Filled With Asphalt
VMA	Void Mineral Aggregate

CHAPTER ONE

INTRODUCTION

1.1 Background

Highway pavement is designed and constructed to provide durable all-weather traveling surfaces for safe and speedy movement of people and goods with an acceptable level of comfort to users. A good road plays significant role for the development of country. Pavement structure generally classified into two: flexible pavements and rigid pavements. Mostly, roads in Ethiopia are flexible pavement type. It is a layer structure, which supports the traffic load on its surface, transfers, and spreads the load to the subgrade. It consists of subgrade, sub-base, base course and surface coarse. It is made of asphalt concrete by using high quality materials compared to other materials in other layers (Tesfaye and Geremew, 2021).

The main objective in the design of HMA mixture is to determine cost effective proportion of ingredients in the mixture having strong, durable, fatigue resistance, skid resistance properties (Vaidya and Bastwadkar, 2019). HMA known by many different names: asphaltic concrete, plant mix, bituminous mix, bituminous concrete, and many others (Tayeh, 2020). Asphalt concrete (AC) is a mixture of aggregate, binder (bitumen) and filler (crushed stone dust (CSD) or cement) used for construction and maintenance of all kinds of roads, parking areas, airport, playground and sport areas/stadium (Mix Design, 2021).

Asphalt pavement design is incomplete or becomes unstable without filler. A filler material is components that often used in asphaltic pavement serve as fulfill the cavities in the mixture. It consists of very fine, inert mineral that is added to the Hot Mix Asphalt (HMA) to improve the density and strength of the mixture (Zaniewski, 2013). Mineral filler plays a significant role in the engineering properties of bituminous materials. It is important to strengthen the structure of the road to be built, increasing the viscosity of the bitumen and reduce its concentration on temperature (Hassan, 2010). In addition, the filler material also works in the hardened bitumen layer and fills the cavities found in the mixture. Conventionally, crushed stone dust, cement, and lime are used as filler materials (Amid, 2018).

Suppose many wastes or by-product materials are generated instead of natural materials in construction projects used for several purposes amongst which are stabilization of soil and replacement of filler /binder materials. These wastes utilization would not only be economical but may also result to environmental pollution control (Hassan, 2010)**.** In road construction industry, as filler using waste materials three benefits can be derived: conservation of natural resources, decreasing the cost of road construction, disposing of waste materials (which are often unsightly) and freeing up valuable land for other uses (Fayissa, 2021) (Journal and Scientific, 2015). Recycling of waste materials is one of best methods to replace conventional filler materials by non-conventional materials. Such non-conventional materials include Khat ash, Eggshell powder, Sawdust ash, Corncob ash etc...

Khat, a tiny flowering bush native to the Horn of Africa, in most of Europe, Asia, and North America, it is prohibited to use. It has also become Ethiopia's largest export after coffee, valued at nearly 300 million USD in recent years (Regan, 2016). Ethiopian khat output has been steadily increasing. In the previous 15 years, the amount of land dedicated to khat growing has grown by 160 percent. The total amount produced has grown even faster, rising by 246 percent, amounting to hundreds of millions of kilograms of khat annually. From just a few thousand hectares in the 1950s, khat is now grown on half million hectares of land in Ethiopia by millions of farmers (Cochrane, 2019). Ethiopia is the leading producer of khat globally.

Global egg production has grown over the last ten years. Overall egg output has increased from 61.7 million tonnes in 2008 to 76.7 million tonnes in 2018 a notable increase of 24% in ten years (Tona, 2019). Egg production in Africa estimated at 2,367,000 tonnes per annum (representing only 3.7% of the global egg output). In Africa Nigeria is about 533,000 tonnes egg production per annum (Tona, 2019). The total egg production in Ethiopia was estimated at 53,662 tonnes in 2019 (Alemu *et al.*, 2021).

Moisture susceptibility is one of the most important distress mechanisms leading to premature failure of asphalt pavements, and it is known that the presence of moisture in a bituminous mix is a critical factor for failure. The main objective of this study was to evaluate BKE using partial replacement of as CSD in HMA concrete by preparing laboratory test samples with different percentage replacement rates and Marshall Properties like Stability, flow and volumetric properties are evaluated by the method of Marshall Mix design to improve the engineering properties of paving mixtures.

1.2 Statement of the Problem

Globally, Highway construction sector is regarded as the most important and expanded pillar for the sustainable development of the country in terms of economic and social development. Hence, the availability of Highway construction materials such as aggregate, bitumen and filler are very important to address the government strategy and policy on the sector (Materials and Course, 2011). However, Highway construction filler materials likes cement, lime, granite powder, crushed stone dust (CSD) and fly ash normally used as filler in asphalt concrete mixture in Hot Mix Asphalt. Cement, lime, granite powder, CSD, and fly ash are expensive (Shaffie, 2017).

Also in our country Ethiopia, insufficient amount filler, disposal of wastes and cost of filler materials like CSD, cement, lime, granite powder and fly ash are problems. So, Recycling process is mandatory to find an alternative filler material by changing waste materials into new products to prevent hazards associated with waste, reduces the consumption of fresh raw materials, and it also reduces greenhouse gas emissions arising from the conventional method of disposing of wastes (Azizi, 2018) (Nairn, 2009).

In addition, the presence of pavement failure is depends on the quality of construction materials like fillers, the amounts of fillers, aggregate gradation. When the best aggregate gradation can be used in the mix, decrease the failure due to aggregate gradation, i.e. the proper arrangements of the coarse, intermediate and fine aggregates. Generally, a good filler materials used for binding agents, decrease void space between the particles, improve the stiffness and improve durability (Hamid, 2015). Therefore, filler materials plays significant role in the mixture of HMA. Using such waste materials blending of khat ash and eggshell powder as ingredients in hot mix asphalt (HMA) based on the availability of the materials in a huge amounts, is an attractive and economically beneficial option in road construction.

As a result, the use of BKE for the partial replacements of filler has an alternative option for replacing the amount of CSD used in HMA. So, the aim of this study were the partial replacements of filler, conventional materials (CSD) by non-conventional materials (BKE) has one of a good method for effective HMA mix design and minimize possible delays and associated cost caused by filler shortage in asphalt concrete road projects.

1.3 Research Questions

The major questions that the research tried to answer include the following

1. What are the physical properties and chemical composition of BKE on HMA?
2. At what percentage RR of BKE filler best suitable potential effect as partial replacement of CSD on Marshall Properties of HMA?
3. What are the characteristics of BKE on the moisture susceptibility?

1.4 Objective

1.4.1 General Objective

The main objective of this research is to investigate the suitability of BKE as partially replacing CSD on HMA.

1.4.2 Specific Objectives

The specific objective of the study are:

1. to determine the physical properties and chemical composition of material filler on HMA
2. to evaluate the effect of BKE as partial replacement of CSD on Marshall Properties of HMA.
3. to determine the characteristics of BKE on the moisture susceptibility.

1.5 Significance of the Research

The significance of the research study is to determine the performance of HMA concrete that is to be done with the replacement of conventional fillers crushed stone dust (CSD) with non-conventional (BKE) for the benefit of, it were create an introduction for BKE to be a new filler material in a Marshall mix design and this can imply BKE as an alternative filler material from its sources which directly relate to the concept of income generation and job opportunity creation for the peoples who were involve in the business. Also the others significance of this study are Conservation of natural resources, preservation of the environment (reduce environmental pollution), renewably low costs, reduce consumption of conventional filler material (CSD) and cost effectiveness are some of the benefits obtained by reusing this kinds of waste materials.

The importance of the work is recycling waste khat and eggshell give as additional source of filler for road construction. In addition, the study is expected to provide to investigate BKE as partial replacement of conventional filler material in the HMA promote the use of non-conventional materials that are typical of local condition and the findings can be referenced as a source of information and as an input for further research. Therefore, using BKE for improving engineering properties of the asphalt concrete is an economical solution for Ethiopia as it is available in large quantity and Cost savings, because BKE is typically cheaper than other filler material such as CSD since it is waste product.

1.6 Scope of the study

The Scope of this study were to evaluate the potential use of BKE as alternative filler material in HMA. These studies has been done by using BKE filler materials sample from the wastage materials on Jimma town. In addition, selected materials for this research were from ERA Road maintenance Jimma district (Deneba) quarry site. The property of those materials such as properties of aggregate test, properties of bitumen test and filler test focused on this research. Test on Marshall Parameter (stability, flow, VFA, VMA and VA), TSR, and moisture susceptibility test were focused on this study and the range of the study was evaluate the effect of BKE as partially replace of filler materials in the HMA.

1.7 Limitation of the study

- Lack of excess laboratory equipment.
- The study was limited only one type of blending of waste khat ash and eggshell powder at equal amount that was the most available types of waste.
- The study examines the use of BKE as a filler material in HMA using Marshall Mix design procedures and determines moisture susceptibility.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The pavement is the most common part of the transportation infrastructure and the basic idea in building a pavement for all-weather use by vehicles is to prepare a suitable subgrade, provide necessary drainage and construct a pavement that will have sufficient total thickness and internal strength to carry the expected traffic loads. Pavement structure generally classified into two: flexible pavements and rigid pavements. Mostly, roads in Ethiopia are flexible pavement type. It is a layer structure, which supports the traffic load on its surface, transfers, and spreads the load to the subgrade. It consists of subgrade, sub-base, base course and surface coarse. It is made of asphalt concrete by using high quality materials compared to other materials in other layers (Tesfaye and Geremew, 2021).

2.2 Structural Components of Flexible Pavement Layers

Flexible pavement built up in several layers, consisting of sub-grade, sub-base layer and base course layer, asphalt binder course and asphalt wearing course. These layers together constitute the pavement. Each layer receives the loads from the above layer and spreads them out to the next layer (Prakash, 2013) (Asphalt, 2018). Typical flexible pavement structure consisting of the following

2.2.1 Asphalt wearing course (surface course)

This is the top layer and the layer that is exposed to traffic that is why it contains superior quality materials. This surface prevents the penetration of surface water to the base course. Wearing course provides characteristics such as friction, smoothness, noise control, rut and shoving resistance, and drainage (Prakash, 2013).

2.2.2 Asphalt binder course

Binder course is a hot mix asphalt (HMA) course between the wearing course and either a granular base course or stabilized base course of an existing pavement or another HMA binder course. Its purpose is to distribute traffic loads so that stresses transmitted to the pavement foundation will not result in permanent deformation of that layer (Asphalt, 2018).

2.2.3 Base course

This is the layer directly below the HMA layer. The base coarse serves as the principal structural component of the flexible pavement and it distributes the imposedwheel load to the pavement foundation, the sub-base and the subgrade. The base course is situated directly above the sub-base. If a sub-base course is not used, it is set directly above the subgrade. Crushed stone, crushed or uncrushed slag, crushed or uncrushed gravel and sand are common granular materials used in this course. This layer is used in areas where frost action is severe or the subgrade soil is extremely weak. Generally, consists of aggregate (either stabilized or un-stabilized) (Prakash, 2013).

2.2.4 Sub-base course

This is the layer (or layers) under the base layer. It functions like the base coarse i.e. it provides additional help to the base and the upper layers in distributing the load. The sub-base is the layer of material beneath the subgrade and the base course. It provides structural support, improve drainage and reduce the intrusion of fines from thesubgrade in the pavement structure. Sometimes the sub-base course is omitted from a pavement and a relatively thick base course is placed directly on the subgrade soil (Prakash, 2013) (Asphalt, 2018).

2.2.5 Subgrade

The in-place soils, called the subgrade,serve as the foundation that supports the road. The properties and characteristics of the subgrade soil determine the pavement thickness needed to carry the expected traffic loads. The subgrade is the natural layer that runs parallel to the pavement's horizontal orientation and acts as the pavement's base. It also may consist of a layer of selected borrow materials, well compacted to prescribed specifications (Prakash, 2013).

Figure 2.1: Typical flexible pavement structure layers (Prakash, 2013)

2.3 Types of Asphalt

2.3.1 Cold Mix Asphalt

CMA produced without heating the aggregate. This is only possible, due to the use of a specific bitumen emulsion, which breaks either during compaction or during mixing. After breaking, the emulsion coats the aggregate and over time, increases its strengths. Recommended for lightly trafficked roads *(MS-2 7 th Edition Asphalt Mix Design Methods*, 2008).

2.3.2 Warm Mix Asphalt

A typical warm mix asphalt is produced at a temperature around 20 - 40 °C lower than an equivalent hot mix asphalt. Less energy is involved and, during the paving operations, the temperature of the mix is lower, resulting in improved working conditions for the crew and an earlier opening of the road *(MS-2 7 th Edition Asphalt Mix Design Methods*, 2008).

2.3.3 Hot Mix Asphalt (HMA)

HMA is a combination of course and fine particles as well as an asphalt binder. HMA is mixed, positioned, and compacted at a higher temperature, as the name suggests. In most cases, HMA is placed in layers, with the lower layers supporting the top layer. Dense Graded Mixes, Stone Matrix Asphalt, and a variety of open graded HMA are among them(Mix, Material and Design, 2021). At temperatures ranging from 150 to 190°C, HMA is made and it is the highest quality among the different types. It is the highest quality paving material among the various sorts, and it is made up of a mixture of aggregates that are uniformly blended and coated with bituminous binder *(MS-2 7 th Edition Asphalt Mix Design Methods*, 2008). In this research only focused on asphalt binder course, i.e., the hot mix asphalt layer or the asphalt concrete layer.

2.4 Desirable properties of HMA

According to Clark *(*2014), the main objective in the design of HMA mixture is to determine cost effective proportion of ingredients in the mixture having the following properties (Clark *et al.*, 2014).

Durability: The asphalt binder film thickness surrounding aggregate particles and air void in the mix determines the HMA's durability. If the film thickness provided is insufficient, the asphalt cement will be exposed to the air, resulting in quick hardening or aging.

Stability: Throughout its service life, the quantity of resistance to deformation determines the stability of a mixture under traffic pressure.

Air voids content: There must be enough voids in the total compacted mix to allow for a little amount of extra compaction under traffic loads and a small amount of asphalt expansion owing to temperature changes that does not result in flushing, bleeding, or loss of stability.

Impermeability: Prevents air and water from entering or exiting the asphalt pavement. This property linked to the compacted mixture's void content, and much of the discussion on voids in mix design is around impermeability.

Moisture damage resistance: Moisture-induced damage must be controlled by HMA. The properties of aggregate with asphalt binder and air voids have a big impact on this attribute. Some aggregates are referred to as "water-loving" aggregates (hydrophilic).

Workability: Describes how easy it is to lay down and compact a pavement mixture. Mixtures with good workability are easy to place and compact, whereas those with poor workability are difficult to place and compact.

2.5 Components of HMA

2.5.1. Aggregates

Natural rock materials, gravels and sands, or slag aggregates are the most common aggregates used in road pavements, either alone or in combination with a cementation material (Tayeh, 2020). Aggregate is the most important component of HMA, and its physical properties have a big impact on mix performance. The main load-bearing elements of HMA pavement are aggregates. Since aggregates make up about 96% of the weight of dense-graded HMA (Nega *et al.*, 2013). According to their size, HMA aggregates categorized into three categories: coarse aggregates, fine aggregates, and mineral filler. Coarse aggregates are generally defined as those retained on the 2.36 mm sieve. Fine aggregates are those that pass through the 2.36 mm sieve and are retained on the 0.075 mm sieve (Abdul, 2007).

2.5.1.1 Aggregate Gradation

The distribution of particle sizes as a percentage of total weight is known as aggregate gradation. Gradation is perhaps the most important property of an aggregate in addition to the aggregate's properties. Gradation affects nearly all the major properties of HMA mixes, including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance, and moisture resistance (Asphalt, 2018). Density, or the ability of the aggregate particles to pack together, and aggregate surface area are the two factors linked to aggregate gradation that have the largest impact on VMA (Abdul, 2007). The gradation of aggregate is the most influential characteristic in determining the performance and design of the HMA mixture. The aggregate gradation expressed as the percentage by weight of the total sample that passes through each sieve.

In HMA mixtures, instability may result from excessively too small maximum particle sizes; and poor workability and/or segregation may result from excessively large maximum particle sizes (Asphalt, 2018). For HMA mix design and analysis, an aggregate sieve analysis uses the following standard sieve sizes: 37.5 mm, 25.0 mm, 19.0 mm, 12.5 mm, 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.60 mm, 0.30 mm, 0.15 mm, and 0.075 mm. Other sieve sizes are sometimes used for special purposes or in other aggregate test procedures (Abdul, 2007).

Table 2.1: Gradation of Asphalt Binder Course (ASTM D3515).

Sieve No.	Sieve Size (mm)	% by Weight Passing	
		Min	Max
1"	25	100	100
3/4	19	90	100
1/2	12.5	71	88
3/8	9.5	56	80
No. 4	4.75	35	65
No. 8	2.36	23	49
No. 16	1.18	15	37
No. 30	0.6	10	28
No. 50	0.3	5	19
No. 100	0.15	4	13
No. 200	0.075	2	8
Bitumen content (%)		4	10

2.5.1.2. Desirable Properties of Aggregates

According to (Izevbekhai, 2014) Selection of an aggregate material for use in an Asphalt Concrete pavement depends on the availability, cost, and quality of the material, as well as the type of construction for which it is intended. To determine if an aggregate material is suitable for use in asphalt construction, evaluate it in terms of the following properties (Izevbekhai, 2014):

Size and grading: The smallest sieve through which 100% of the material will pass is the maximum size of an aggregate. How the Asphalt Concrete is to be used determines not only the maximum aggregate size, but also the desired gradation (distribution of sizes smaller than the maximum).

Cleanliness: Foreign substances make some materials unsuitable for paving mixtures.

Particle shape: The shapes of aggregate particles influence the asphalt mixture's overall strength and workability as well as the density achieved during compaction. When irregular particles like crushed stone are compacted, they tend to "lock" together and resist displacement.

Absorption: An aggregate's porosity allows it to absorb asphalt and create a bond between the particle and the asphalt. A degree of porosity is desired, but aggregates that are highly absorbent are generally not used.

2.5.2 Asphalt binder (bitumen)

Bitumen is a black or dark colored solid or viscous cementitious substance having an adhesive property. It consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, and it acts as binding agent for aggregates in bituminous mixes, which are soluble in trichloroethylene (Dejen, 2019). There are different types of bitumen such as native asphalt, rock asphalt, tars, and petroleum asphalt. The native asphalt is obtained from asphalt in Trinidad and other Caribbean areas. Rock asphalts are rock deposits containing bituminous materials. Tar bituminous materials are obtained from the destructive distillation of coal. The petroleum asphalts are products of the distillation of crude oil. (Materials and May, 2007).

The physical properties of the asphalt binder vary considerably with temperature it is known by its penetration grades. Their grades and temperature relationships are extremely important in the design of asphalt concrete Viscosity decreases as temperature increases (Parthasarathi, Prakash and Satyanarayanan, 2017). Bitumen 60/70 grade penetration is moderate type of bitumen in terms of hardness, meaning it is not whether too hard nor too soft, a temperature (from -22 to +76). But this is not the only reason that bitumen 60/70 is popular in the world. Accordingly, it is a perfect choice for road engineer in various regions, particularity Asia and African countries, mainly because it is cost effective solution that reduce the expense, without affecting quality (Dejen, 2019).

2.5.2.1. Desirable Properties of Asphalt Binder

In general, Bitumen should possess following desirable properties (Materials and May, 2007).

The bitumen should not be highly temperature susceptible: during the hottest weather, the mix should not become too soft or unstable, and during cold weather, the mix should not become too brittle causing cracks.

The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing. There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

2.5.3. Filler Materials

Mineral filler is defined as that portion of the aggregate passing the 0.075-mm sieve (Federal, Republic and Authority, 2013). It is components that often used in asphaltic pavement serve as fulfill the cavities in the mixture. It consists of fine powder used in bituminous mixes for road pavement. It is important to strengthen the structure of the road to be built (Amid, 2018). Practically filler material role in increasing the viscosity of the bitumen and reduce its concentration on temperature (Ramezanianpour, 2017).

In addition, the filler material also works in the hardened bitumen layer. It usually consists of rock powder, limestone powder, hydrated lime and Portland cement and referred to as mineral dust or rock dust - consists of very fine, inert mineral with the consistency of flour, which is added to the hot mix asphalt to improve the density and strength of the mixture (Banerjee, 2016). Mineral fillers are by-products of stone crushing procedures, manifesting the feasibility of including them in the design of hot mix asphalt (Ramezanianpour, 2017). Filler material shall pass the sieve size 0.075mm and must have properties such as cleanliness and purity, fineness, and affinity for bitumen (Tayeh, 2020).

Researcher called (Getahun, 2021). Studies that the mineral filler increases the stiffness of the asphalt mortar matrix, improving the rutting resistance of pavements. Mineral filler also help reduce the amount of asphalt drain down in the mix during construction, which improves durability of the mix by maintaining the amount of asphalt initially used in the mix. The addition of fillers is known to stiffen asphalt (Getahun, 2021).

2.6 Agricultural Waste materials

According to Shaffie (2017)**,** Mineral filler is defined as that portion of the aggregate passing the 0.075-mm sieve. It consists of very fine, inert mineral with the consistency of flour, which is added to the hot mix asphalt to improve the density and strength of the mixture (Shaffie and Arshad, 2017). Partial replacements of filler, conventional materials (CSD) by non-conventional materials (BKE) has one of a good method for effective HMA mix design and minimize possible delays and associated cost caused by filler shortage in asphalt concrete road projects. Using such waste materials blending of khat ash and eggshell powder (BKE) as ingredients in hot mix asphalt (HMA) is an attractive and economically beneficial option in road construction.

In the direction of study, the strength parameters of the eggshell powder diverse specimens and to contrast it with conservative specimens. Calcium wealthy in eggshell powder (EP) is a fowl waste by means of chemical composition almost like that of limestone (Shaffie and Arshad, 2017). To obtain a perspective on the use of khat ash (KA) as filler in asphalt pavement, a survey was conducted involving state agencies and companies (Hamid, 2015). Major uses for khat include highway and airport runway construction, as well as its use as ballast in railways (Nairn, 2009)

2.6.1 Availability of Egg

Agriculture is the one sector of the world economy; Chickens are one of agricultural products. It is egg-laying creatures are kept widely throughout the world and mass production of chicken eggs is a global industry. Its production has an important economic, social, and cultural benefit and plays a significant role in egg consumption in the developing countries (Tona, 2019).

2.6.1.1 Global Egg Production

The Global Egg Production Continues to Grow over the past ten years, global egg production has witnessed impressive growth. According to data from the FAO, total egg production has grown from 61.7 million tonnes in 2008 to 76.7 million tonnes in 2018 a notable increase of 24% in ten years. Figure 2.2 shows the development of egg production since 2000, illustrating the continuous growth of global egg production. In 2017, world production of chicken eggs was 80.1 million tonnes. The largest producers were China with 31.3 million of this total, the United States with 6.3 million, India at 4.8 million, Mexico at 2.8 million, Japan at 2.6 million, and Brazil and Russia with 2.5 million each. A typical large egg factory ships a million dozen eggs per week (Kumar, 2020).

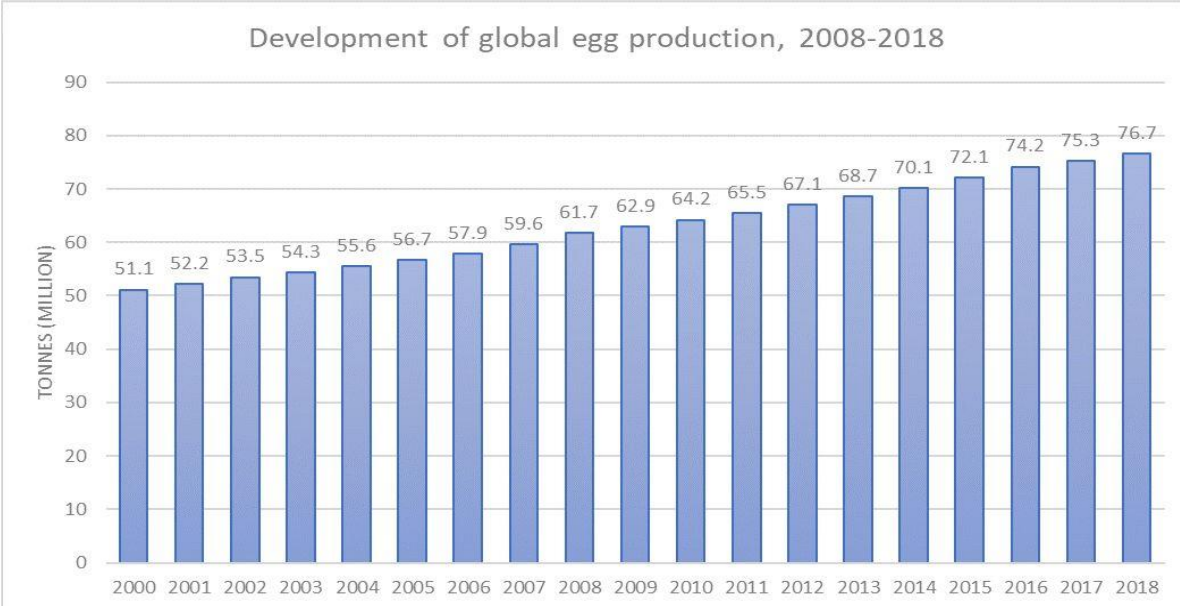

Figure 2.2 Development of global egg production, 2000 – 2018 (Source FAO database 2020)

Some of the key players in egg production in number of eggs per year: China ranks highest in egg production as it produces about 466 billion eggs annually, the top egg-producing provinces in China are Henan, Shandong, Hebei, Liaoning, and Jiangsu. USA about 109 billion eggs are produced annually in the United States ranking it in the second position and the five biggest egg-producing states in the US are Indiana, Pennsylvania, Ohio, Iowa, and California. India is third in egg production as about 95 billion eggs are produced there annually and the leading egg-producing states in India are Andhra Pradesh, Tamil Nadu, Maharashtra, Haryana, and Punjab. Mexico is fourth in world egg production, at about 57 billion eggs are produced annually. It is recovering fast to remain a world-class egg-producer in Latin America and the top areas in Mexico for egg production are Veracruz, Torreon, Campeche, Guanajuato, and Yucatan. Brazil makes it to the fifth spot in global egg production, with about 54 billion eggs produced annually. The top states in Brazil in egg production are Sao Paulo, Espirito Santo, Rio Grande do Sul, Goias, and Santa Catarina. Decreased egg exports to Africa have affected its egg production and market, although domestic egg consumption in the country has increased (Kumar, 2020)

2.6.1.2 Egg Production in Africa

Egg production in Africa is estimated at 2 367 000 tonnes per annum (representing only 3.7% of the global egg output). There is considerable variation among countries - from as high as 533 000 tonnes for Nigeria to as low as 1000 tonnes for countries such as Central African Republic, Comoros, Congo, Gambia, Guinea and Swaziland. This low level of productivity translates into low per capita egg consumption of 36 eggs/person/year, much lower than the world average of 145 eggs. The low performance of the poultry industry in Africa could be attributed to the inefficient scavenging management system that is predominant in most rural communities. Improvement of the performance of the industry could be achieved by adapting more efficient production systems (Khan, 2017).

2.6.1.3 Egg Production in Ethiopia

Distribution of the total poultry population among the different regions of Ethiopia in 2016. The figures indicate that Oromia region has the largest number of chickens, followed by Amhara. The SNNPR, Oromia, Tigray and Amhara regions together represent 96 percent of the total national chicken population. The remaining 4 percent are mainly distributed among Afar, Somali, Benshangul gumuz and Gambella regions. Almost all of the exotic and hybrid chickens are found in the SNNPR, Oromia, Tigray and Amhara regions (Maguire, 2020).

Table 2.2: The distribution of chicken in 2016 and 2019 (Source: CSA, 2017 and 2020)

Geographic area (region)	Chickens (thousands)							
	Total		Indigenous		Exotic		Hybrid	
	2016	2019	2016	2019	2016	2019	2016	2019
SNNP	11 197	26345	9 997	24534	485	3094	715	6765
Oromia	20 408	52764	19 604	50653	291	2786	513	5876
Tigray	5 746	15432	4 288	15643	892	2456	566	8985
Amhara	19 962	47655	18 020	47653	930	9387	1 012	9843
Benshangul gumuz	1249	9453	1225	10989	4	212	20	1043
Gambella	386	3458	378	56798	4	197	4	967
Afar	198	2543	198	3023				
Somali	161	2540	161	3976				
Harar	91	345	91	1985				
Dire Dawa	101	1574	98	2889				
Country's total	59 499	162109	54 060	218143	2 606	20132	2 833	33479

Ethiopia has a large chicken population (58.3 million) with respect to the number of eggs, local hens in Ethiopia produced about 280 eggs per bird under high input management conditions (Tona, 2018).

2.6.1.4 Advantages of Eggshell powder

Eggshell is one of the best highway construction materials. Some of the advantages of using eggshell powder as filler are: it's more economical, it's most eco-friendly and reduced the global warming, It is high in calcium, magnesium carbonate, and lime content, considerable reduction in alkali-silica and sulfate expansions, meets the most stringent environmental regulations nationwide, ideal for painting in occupied spaces, excellent durability and washable finish and a better combination of cement mortar and concrete admixture (Parthasarathi, 2017) (Dhanalakshmi, 2015).

2.6.2 Availability of khat

Khat [chat] or Catha edulis Forsk is a large green shrub that grows naturally at elevations of 1500 - 2000 m but was found at altitudes of 1200 - 2500 m. In the region extending from eastern to southern Africa, as well as Arabian Peninsula. This plant is known by several names, the common ones being: Chat [in Amharic], Gat, Khat, Qat, [in Arabic], Mira, Mlonge [in Swahili]. Originating in Ethiopia, It now also grows in Somalia, Kenya, Malawi, Uganda, Tanzania, Congo, Zambia, Zimbabwe, Afghanistan, Yemen, and Madagascar (Cochrane, 2019) (Hamid, 2020). The production of khat in Ethiopia has boomed over the last two decades, making the country the world is leading source. It is now one of Ethiopia's largest crops by area of cultivation, the country's second largest export earner, and an essential source of income for millions of Ethiopian farmers. It has no definite harvest time. Consumption has also spread from the traditional khat heartlands in the eastern and southern regions of Ethiopia to most major cities (Hamid, 2020).

Table 2.3: Regions of Rapid Khat Production, in Hectares (Source: CSA (2004–2019)).

Regions	Years		
	2003 and 2004	2014 and 2015	2018 and 2019
Amhara	2718	9563	18947
Benishangul-Gumuz	46	1183	5768
Dire Dawa	713	1325	8762
Gambella	39	393	3034
Harari	2038	4844	10075
Oromia	75,196	156,522	245,598
SNNP	22,570	69,505	149,891

2.6.2.1 Uses of Khat Ash

The different uses of chat can be broadly divided into the following categories: based on the type of use: Asphalt pavement (Engineering issues such as the effect on engineering properties, for example strength and durability of HMA, Environmental questions regarding fugitive dust, emissions, leachability and Exposure during handling and processing procedures; and Economic concerns, such as initial and life cycle costs), Stabilized bases and subbases with non-asphalt additives , Cement concrete and other purpose (Catha, 2003).

2.7 The Role of Mineral Filler in Asphalt Mixtures

Mineral filler materials in hot mix asphalt are an important component of the mixture as the design and performance of hot mix asphalt concrete. Evaluate the effect of mineral filler, maximum aggregate size, aggregate gradation, crushed particles and stripping tendencies on the performance of asphalt concrete by gathered information from various laboratory and field studies (Asphalt, 2018). Filler type and particle size directly affect the engineering properties of the asphalt mixtures, In addition to filling the voids, the fillers' components interact with the binder present in the mix, potentially making it stiff and brittle. This attributes to the fact that as filler content in the mix increases, lower air voids can be achieved and change in mix properties is strongly related to the properties of the filler (Society and Engineers, 2013). Fillers tend to increase the resilient modulus of asphalt mixes (Getahun and Bewket, 2021). Excessive amount of fillers will result in an increase in the bitumen content and can result in a weak asphalt mix (Asphalt, 2018).

According to (Society and Engineers, 2013), having a high content of filler, however, will result in undesirable stiffness which can affect the workability of the mix. The stiffening effect of fillers tends to decrease at lower temperatures instead the mineral fillers tend to improve the fracture properties of the asphalt binder. Clearly, neither too little nor too much mineral filler is desirable. Unfortunately, the maximum or minimum allowable filler content depends on a number of factors such as the source and gradation of the filler and the gradation of the mixture. Stiffening and extension of the asphalt by mineral filler can also affect the design asphalt selected during mix design (Society and Engineers, 2013).

2.8 Marshall Stability and Flow

Stability is defined as the maximum compressive load carried by a compacted specimen tested at 60^{o}C at a loading rate of 50.8 mm/min. The Marshall Stability values can be increased by using “stiffer” or ore viscous asphalt binder grade, aggregates that are more angular or a blend of all crushed aggregates and any material that can stiffen an asphalt binder will also increase the Marshall stability (Alshamsi, 2006).

The flow is the vertical deformation of the compacted specimen from the start of the Marshall stability loading until the stability values begin to decrease. High flow values indicate an asphalt mixture that has plastic behavior and has the potential for permanent deformation, such as rutting or shoving, under traffic loading. Low flow values indicate a mixture that may have insufficient asphalt binder, which may lead to durability problems with the pavement. Low flow values may also indicate a mixture with a binder so stiff, that the pavement experiences low temperature or fatigue cracking (Alshamsi, 2006).

2.9 Mixture Volumetric Composition

The volumetric properties indications of the potential performance of the mixture as a pavement. Therefore, understanding the volumetric composition of asphalt concrete and the ability to perform a volumetric analysis are two of the most important skills that any designers must master in order to develop effective asphalt concrete mix designs. This part of the research presents the volumetric analysis from the values of bulk specific gravity (Gsb) and theoretical specific gravity (Gmm) (Ameli *et al.*, 2020).

2.9.1 Bulk Specific Gravity

The bulk specific gravity of a mixture refers to the specific gravity of a specimen of compacted mixture, including the volume of air voids within the mixture. It is equivalent to the mass of a given specimen in grams, divided by its total volume in cubic centimeters. To determine the bulk specific gravity of dense graded mixture, the compacted specimens are extruded from the mold, cooled to room temperature, and the dry weight recorded. Each specimen is then immersed in water at 25°C for three to five minutes, and the immersed weight is recorded. The specimen is removed from the water, surface dried by blotting with a damp cloth, and the surface dry weight recorded in air (Zaniewski, 2013).

2.9.2 Theoretical Maximum Specific Gravity

The theoretical maximum specific gravity often referred to as maximum theoretical density and thus abbreviated (MTD) is the HMA density excluding air voids. Thus, theoretically, if all the air voids were eliminated from HMA sample, the combined density of the remaining aggregate and asphalt binder would be the MTD. MTD is a critical HMA characteristic because it is used to calculate percent air voids in compacted HMA and provide target values for HMA compaction. MTD is determined by taking a sample of oven-dry HMA in loose condition (versus compacted condition), weighing it and then completely submerging it in a 25°C water bath. A vacuum is then applied for 15 minutes to remove any entrapped air. The sample volume is then calculated by subtracting its mass in water from its dry mass (Zaniewski, 2013).

2.9.3 Voids in the Mineral Aggregate

VMA defined as the inter granular void space between the aggregate particles in a compacted asphalt mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume. VMA is calculated by subtracting the volume of the aggregate determined by its bulk specific gravity from the volume of the compacted asphalt mixture (Shaffie, 2017). Given that mix designs typically aim for 4 percent air voids, 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 (Nairn, 2009).

2.9.4 Air Voids in Compacted Mixture

AV (Air voids) are small pockets of air that exist within the asphalt binder and between aggregate particles expressed as percent of the bulk volume of the compacted paving mixture (Khan, 2017) (Vasudevan and Ash, 2017). The air voids, in the total compacted paving mixture consists of the small air spaces between the coated aggregates particles (Abdul, 2007).

2.9.5 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 (Prakash, 2013).

2.10 Moisture Susceptibility

Presence of water reduces the performance and durability of HMA and may cause sudden failure of flexible pavement. A major durability problem is associated with moisture damage, commonly referred to as “Stripping.” This typically is the result of water in combination with repeated traffic loadings, causing a scouring effect as the water is pushed into and pulled out of the voids in the pavement. Stripping involves water or water vapor getting between the asphalt film and the aggregates, thereby breaking the adhesive bond between the aggregate and the asphalt binder film. This will “strip” the asphalt from the aggregate (Izevbekhai, 2014). If asphalt pavement does suffer from water sensitivity, serious distresses may occur. As a result, the asphalt pavement reduces in performance and increases in maintenance costs. To alleviate or control this problem, various liquid or solid anti-stripping additives have been developed, which can be used to promote adhesion between asphalt and aggregate (Hot Mix Asphalt 101, 2009).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Study Area

This experimental study area is located in Jimma town. It is found in Jimma zone, Oromia regional state, south-west of Ethiopia, and is located about 354 km southwest of Addis Ababa. It is geographically located between 7°39’52” and 7°43’14” N latitude, and between 36° 49’ 00” and 36° 53’ 24” E longitude. Jimma town is found in an area of average altitude of about 1780 m above mean sea level. Jimma has a total population of 3.5 million, approximately. It lies in the climatic zone locally known as Woyna-Dega. All selected materials were obtained from jimma town and ERA Jimma district Deneba quarry site.

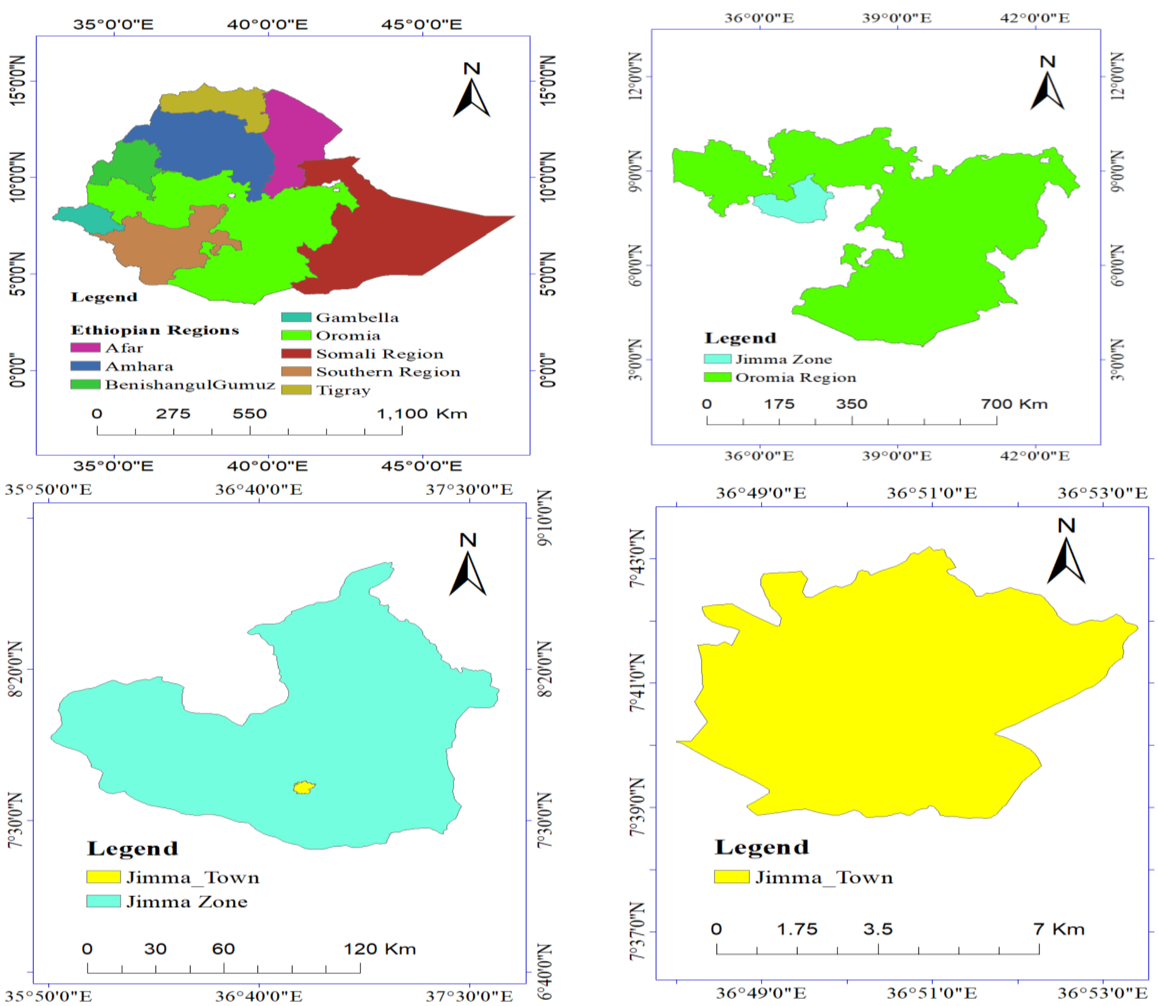

Figure 3.1: Map of study area (source: - GIS)

3.2 Study Design

To conduct the studies effectively, a well-organized design can be carried out by passing through the following steps for successful results. Based on that, to limit the scope of the study. Sampling of all input materials: eggshell powder, khat ash, bitumen and aggregate sample collection for the laboratory tests. The property of those materials such as properties of Aggregate test (Bulk dry S.G, Bulk saturated surface dry S.G, Apparent S.G, Flakiness index, Aggregate crushing value, Aggregate impact value, and Los Angles Abrasion test). Properties of bitumen test (penetration, ductility, softening point, flash point and specific gravity). And Filler test (plasticity index and specific gravity) done on laboratory.

The marshal mix performing tests on material according to ASTM D 1559 and five different bitumen content (4 - 6%) with 0.5% increment and three different filler contents (4.5, 5.5, and 6.5% by weight of aggregate) were used to obtained the optimum filler content and the optimum bitumen content based on Marshall Properties of the asphalt mix such as stability, flow, and volumetric properties. The optimum filler content and the optimum bitumen content were used for the purpose of replacement ratio with non-conventional filler BKE with different percentage. BKE was used to partially replaced by CSD filler starting from 0% up to 40% by 8% interval of weight of optimum filler content. The optimum replacement ratio was obtained the BKE having maximum stability, maximum bulk density, and the median value of air void (4%).

Laboratory test result on TSR also done on laboratory. Finally, check and analyze laboratory test result and compare with the requirements specification criteria for findings suitability of the BKE filler as partial replacement of CSD filler on HMA and recommendations were expressed based on the laboratory test results. The overall design of the study shown in Figure 3.2.

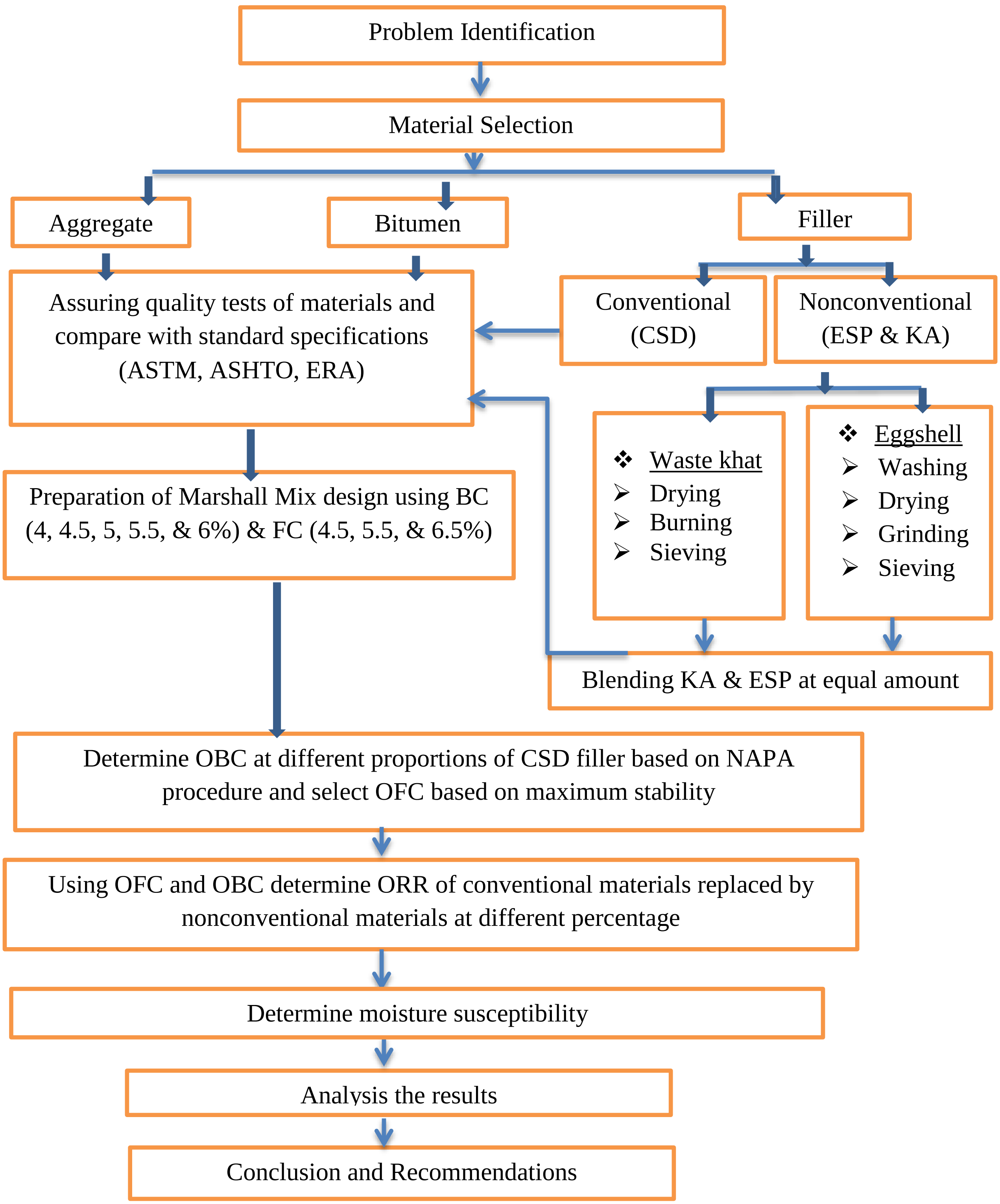

Figure 3.2: Flow chart of the study design

3.3 Study Variable

The study variables, which consist of this research, contained both independent and dependent variables.

3.3.1 Dependent Variables

For the purpose of this study dependent variable were the effects of BKE filler partially replaced with CSD filler on HMA.

3.3.2 Independent Variables

The independent variables were aggregate quality test, bitumen quality test, filler quality test, Marshall Parameter properties and Tensile strength ratio.

3.4 Population

The population of the study included aggregates (coarse, intermediate and fine), bitumen, CSD, Khat ash and eggshell powder.

3.5 Sample collection techniques

Sampling has expressed to know the research results are economical and accurate. This sampling technique was proposed based on the information needed to determine the experimental investigation into the suitability of BKE as a filler material in HMA concrete.

3.6 Materials collection

The materials used in the mix design of asphalt include filler materials (BKE and CSD), aggregates (fine, intermediate and coarse), and binder (60/70 Penetration grade of bitumen). All materials were primarily tested in order to examine the both physical and chemical characteristics and evaluate the suitability of materials for road construction.

Table 3.1: Material source

Materials	Source
Aggregates	ERA Jimma district Deneba quarry site
Bitumen	ERA batching plant e Jimma district around the Deneba quarry site.
Filler/CSD	ERA Jimma district Deneba quarry site
Waste Khat	Jimma town and found in huge amount
Eggshell	Jimma town from the poultry farms, hotels, bakeries, food processing and egg breaking

3.7 Sources of Data

The source of data were conducted mainly based on to achieve the objective of the research. Both primary and secondary data sources were used.

3.7.1 Primary Sources of Data

The primary research data was collected through performing experiments and experimental results such as laboratory tests on aggregate properties, filler properties, bitumen quality tests, Marshall Properties of materials (Marshall Stability, flow, mixture volumetric composition) and tensile strength ratio.

3.7.2 Secondary Sources of Data

Secondary data was collected from scientific research, journals, pavement design manuals, literature review of previous studies, books, laboratory manuals, and specifications of international and national standards such as (ASTM, AASHTO, and ERA).

3.8 Software and Instruments

The following instruments and software were used for this study: laboratory equipment, a digital camera for documentation, mendeley, MS Microsoft Word, and Excel to analyze laboratory data were used in this study.

3.9 Laboratory Works

The samples were collected from different sources and subjected to various characterizations. The individual ingredients of the mixture are tested in the laboratory before all. Then to compare the results as per set by AASHTO, ASTM, and BS standards. The basic tests such as physical properties of materials, chemical composition of filler, Marshal Stability, flow value, volumetric properties of bituminous concrete mix, OFC and OBC.

3.9.1 Aggregate property

The aggregate selected for this study was a crushed stone aggregate obtained from the ERA Jimma district Deneba quarry site in three different sizes. The three different sizes of available aggregate materials are coarse aggregate (19 mm - 9.5 mm), intermediate aggregate (9.5 mm - 4.75 mm), and fine aggregate (4.75 mm - 0.075 mm). The laboratory tests were prepared as shown in Table 3.2.

Table 3.2: Laboratory test as per standard

Material	Laboratory test	Standard (ERA manual, 2013)
Aggregate	Bulk dry S.G	AASHTO T 85-91
	Bulk SSD S.G	AASHTO T 85-91
	Apparent SG	AASHTO T 85-91
	Water absorption	BS 812, Part 2
	Aggregate crushing value	BS:812 part 110 (1990)
	Aggregate impact value	BS:812 part 112
	Los Angeles abrasion	AASHTO T-96
	Flakiness index	BS:812 part 105

3.9.2 Bitumen property

The physical properties of bitumen depends on the temperature. The asphalt binder specification was design based on temperature. The asphalt binder used in this study had a penetration grade of 60/70. The main reason for the common type of asphalt that is widely used in most road projects in our country because of the annual air temperature of greater or equal to 24^0C.

Table 3.3: Laboratory test as per standard

Material	Laboratory test	Standard (ERA manual, 2013)
Bitumen	Penetration	ASTM D5-IP49
	Ductility	ASTM D113
	Softening point	ASTM D36
	Flash point	ASTM D92
	Specific gravity	AASHTO T-228

3.9.3 Filler property

The filler is one of the most ingredient of HMA for the purpose of binding and improve performance of mixes and fill the voids. The fillers, which passed the sieve size (No.200) of 0.075 mm used for this study, were crushed stone dust, khat ash and eggshell powder.

Table 3.4: Filler laboratory test as per standard

Material	Laboratory test	Standard
CSD, KA, ESP and BKE	Plasticity Index	<4
	Apparent specific gravity	

3.9.3.1 Crushed stone dust

The crushed stone dust used for this research was obtain from ERA Road maintenance Jimma district area around Deneba quarry site, which passed the sieve size of 0.075mm used in bituminous mixes for road pavement. Sieving fine aggregates to get crushed stone dust filler as shown in figure 3.3**.** The crushed stone dust filler tests were conducts on laboratory works as per standard specifications.

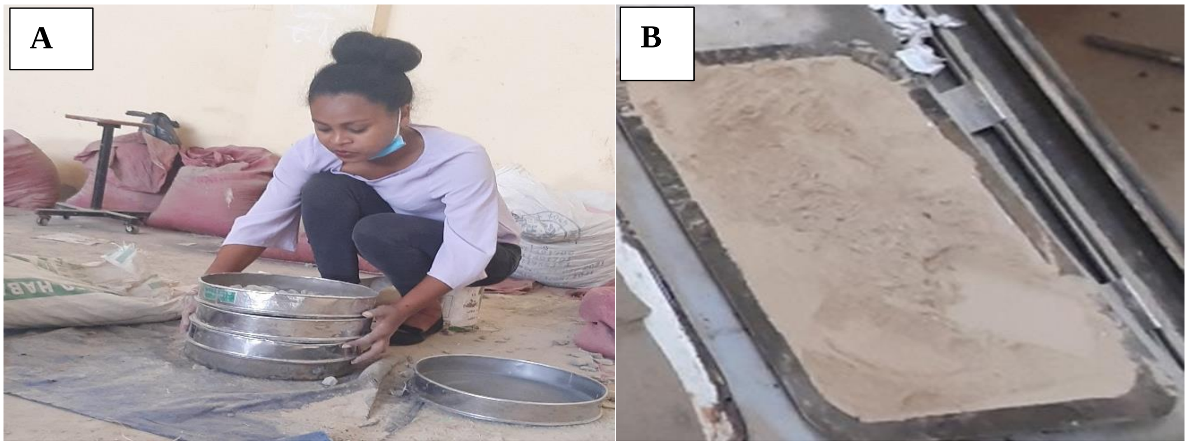

Figure 3.3: preparation of CSD filler (picture taken on 4/05/2021)

3.9.3.2 Khat waste

The Khat sample was obtained from Jimma town from khat consumer, sellers and farms in huge amount. The collected Khat was dried and burned at surface area to obtain ash. After getting the required ash, it is then sieved through No.200 (0.075 mm) to remove other unnecessary material. The fraction passing through the sieve was used during testing. The process shown in figure 3.4.

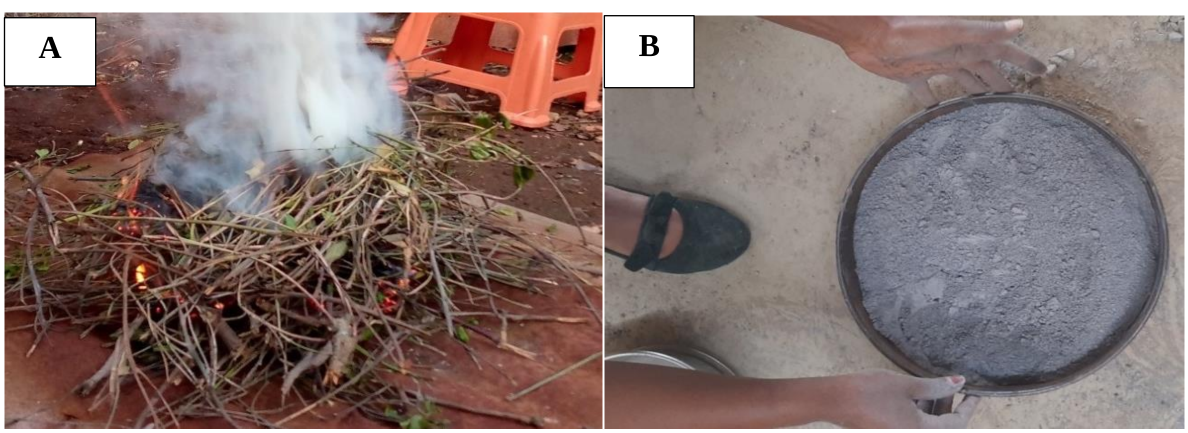

Figure 3.4: Khat ash sample preparation (picture taken on 04/05/2021)

3.9.3.3 Eggshell

ES waste is available in excess amounts from poultry farms, hotels, bakeries, food processing and egg breaking. Then the collected eggshell were washed in normal water and then dried in hot sun light for a day to make them dry enough to make eggshell powder (ESP) easily by using grinding electronic equipment. After that, they sieved the powder by sieve size No.200 (0.075 mm) used during testing. The ESP sample preparation shown in Figure 3.5.

Figure 3.5 Eggshell powder sample preparation (picture taken on 4/05/2021)

3.10 Marshall Mix design

Marshall stability test was used in this study for both determining the optimum binder content (OBC) and evaluating the specimens were prepared by partial replacing BKE as filler. The Marshall method is applicable only to hot mix asphalt. The design of asphalt paving mix materials to obtain the desired properties in the finished pavement structure. These are aggregates, 60/70 penetration grade asphalt binder and filler materials crushed stone dust, khat ash, and eggshell powder. A series of specimens, each containing the same aggregate blend but different bitumen content (4 - 6%) with 0.5% increment were used. Before mixing, all gradation aggregate satisfied the requirements of the project specification. Marshall mix design methods used to determine the optimum bitumen content and optimum filler contents

3.10.1 Gradation of Aggregates

The aggregate gradation is normally expressed as the percentage (by weight) of total sample that passes through each sieve. It is calculated by weighing the contents of each sieve after the sieve analysis, then using one of several mathematical processes to calculate the percentage of sieves that pass. One method is to subtract the weight of the contents of each sieve from the weight of the material passing the previous sieve, resulting in the total weight passing each sieve. Therefore, coarse aggregate [retained on 2.36 mm (No 8) sieve], fine aggregate [passing 2.36 mm (No 8) sieve] and mineral filler [Passing 0.075 mm (No.200) sieve]. All aggregate types were separated based on size coarse (19 mm -9.5 mm), intermediate (9.5 mm -4.75 mm) and fine aggregate (4.75 mm – 0.075 mm) and filler (pass sieve size 0.075 mm) particles to obtain the desired gradation for bituminous mixtures of ASTM 3515. Three gradations were prepared in this research with varying amount of mineral filler content prepared with 4.5, 5.5, and 6.5% CSD (by weight of aggregate).

3.10.2 Preparation Marshall Mix design

In determining the design asphalt content for a particular blend or gradation of aggregate by the Marshall method, a series of test specimens were prepared for a range of different asphalt contents. According to ASTM specifications using mathematical trial method aggregates were blended together in order to get a proper gradation. Mathematical trial method depends on suggesting different trial proportions for each type of aggregate. The percentage of each type of aggregate was computed and compared with the specification limits. The materials used for preparing the Marshall Mix design were blended aggregates, bitumen, marshal mold with collar, balance, oven, compactor, filter paper, thermometer, bitumen heater and pan are the main materials used for preparing the HMA mixture specimens. Procedures for the HMA mixture specimen processes were listed.

Primarily, a total amount of 1200 gm blended aggregates were dried in an oven at a temperature of 150 - 170 ^{o}c for less than or equal to 16 hours and bitumen was heated at a temperature of 155 - 165^{o}c and also, standard Marshall molds were heated in an oven for greater than or equal to 8 hours before mixing 160 -170 ^{o}c as shown in Figure 3.6.

Figure 3.6: Preparation of sample for Marshall Mix design (picture taken on 9/05/2021)

Secondly, each gradation trial bitumen was added in the required quantity, i.e. 4, 4.5, 5, 5.5 & 6% (by weight of total mix), then after the heated aggregates and bitumen are mixed manually until a similar mix is obtained, then mixed mixtures were placed in the mold which has 101.6 mm inside diameter and 63.5 mm height and both face of specimen was compacted with 75 blows on each side of the specimen covered by filter paper. After applying 75 blows on each side of the specimen, the specimens were then left to cool at room temperature for 24 hours. The heated aggregates and bitumen are mixed manually until a similar mix is obtained and the specimen was compacted with 75 blows on each side of the specimen covered by filter paper. Which is shown in the figure 3.7:

Figure 3.7: Spacemen mixing and compacting manually (picture taken on 10/05/2021)

Finally, they were weighed dry in air, weighed in water, and saturated surface dry weight to determine the bulk specific gravity of the specimen. After that, the specimens were put in the water bath at a temperature of 60 for 30 minutes, and then they were removed from the water bath and placed quickly in the Marshall Stability and flow tester machine. Then the maximum load resistance and the corresponding flow values were recorded. Three specimens for each combination were prepared and the average results were reported. The bulk specific gravity, air voids in total mix and voids filled with asphalt percentages were determined for each specimen. Measuring the weight of the specimen as shown in Figure 3.8.

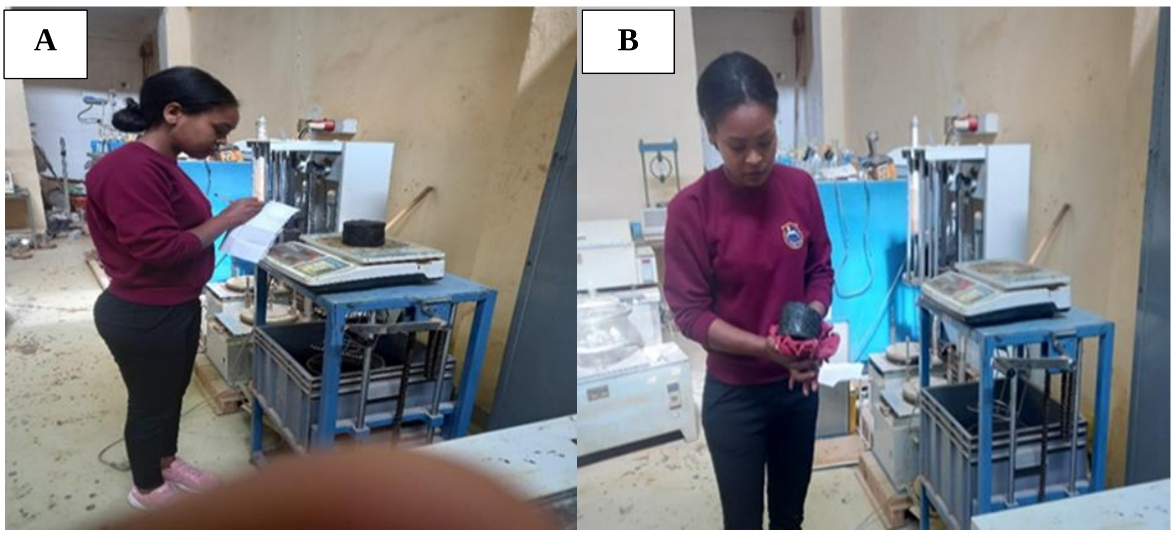

Figure 3.8: Measuring the weight of the specimen (picture taken on 11/05/2021)

3.10.3 Optimum Bitumen Content

Laboratory work were conducted to get (determine) the optimum asphalt content and optimum filler content using the Marshall method. The Marshall mix performing tests on material according to ASTMD1559 and five different bitumen content (4 - 6%) with 0.5% increment were used. Marshall Properties of the asphalt mix such as stability, flow, density and volumetric properties were obtained for various bitumen contents. Then the following graphs were utilized in order to determine the optimum bitumen content for the mix: air voids vs Bitumen content, Stability vs Bitumen content, Flow vs Bitumen content, Bulk Specific Gravity vs bitumen content, and Voids Filled with asphalt vs Bitumen content. According to NAPA (National Asphalt Pavement Association) method. NAPA Procedure, firstly determine the asphalt content which corresponds to the specification's median air void content (4% typically). This is the optimum asphalt content. Secondly, determine the following properties at this optimum asphalt content by referring to the plots: Marshall Stability, VMA, Flow, Bulk density, and Percent voids filled with Asphalt. Lastly, compare each of these values against the specification values and if all are within the specification, then the preceding optimum bitumen content is satisfactory. If any of these properties is outside the specification range, the mixture should be redesigned.

3.10.3.1 Volumetric properties of the mix

The important volumetric properties of bituminous mixtures that are to be considered include the theoretical maximum specific gravity, the bulk specific gravity, percentage of voids in total mix (VTM), percentage void in mineral aggregate, percentage voids filled with asphalt, and Effective asphalt content.

❖ **Theoretical maximum specific gravity (Gmm)**

The theoretical maximum specific gravity of a mix is defined as:

$$G\mathrm{mm} = A/(A+B) - C$$

Where: Gmm =Maximum theoretical specific gravity is calculated as per ASTM D2041,

A= Mass of the dry sample in air (gm)

B = Mass of jar filled with water (gm)

C = Mass of jar filled with water + sample (gm)

❖ **Bulk specific gravity (G_{mb})**

This value, as stated at ASTM D1189, is used to determine weight per unit volume of compacted mixture.

$$\mathrm{Gmb} = \frac{A}{B-C}$$

Where: Gmb = Bulk specific gravity of compacted specimen

A = Mass of the dry specimen in air (gm)

B = Mass of the saturated surface-dry specimen in air (gm)

C = mass of the specimen in water (gm).

❖ **Air Voids (VA)**

The voids in a compacted mixture are obtained in accordance with ASTM D3203- 94 standard test method. The voids in a compacted mixture are obtained as follows:

$VA = 100 * \frac{\text{Gmm}-\text{Gmb}}{\text{Gmm}}$

Where: VA = air voids in compacted mixtures

Gmm = maximum specific gravity of paving mixture

Gmb =bulk specific gravity of compacted mixture.

- **Voids in Mineral Aggregates (VMA)**

Expressed as a percent of the total volume. It is calculated as:

$VMA = 100 - (G\text{mb} * \text{Ps})/\text{Gsb}$

Where: VMA = voids in the mineral aggregate

Gmb = bulk specific gravity of total aggregates

Gsb = bulk specific gravity of total aggregates

Ps = aggregate content, percent by mass of total mixture.

- **Voids Filled with asphalt (VFA)**

It is determined as:

$VMF = 100 * (VMA - VA)/VMA$

Where: VFA=voids filled with asphalt percent of VMA

VMA = voids in mineral aggregate, percent of the bulk volume

VA = air voids in compacted mineral, percent of total volume.

3.10.4 Determination of optimum Replacement Ratio of blending of KA and ESP

The optimumfiller content and the optimum bitumen content were used for the purpose of replacement ratio with non-conventional filler BKE with different percentage. BKE was used to partially replaced by CSD starting from 8% interval (by weight of optimum filler content) i.e. 0% (control mix), 8, 16, 24, 32, and 40% by weight of optimum CSD filler. The optimum replacement ratio was obtained the blending of khat ash and eggshell powder having maximum stability, maximum bulk density, and median (4%) air void (VA).

3.11 Moisture Susceptibility

Water susceptibility of HMA determining the difference in stiffness value before and after conditioning in water by indirect tensile strength test. The indirect tensile strength procedure was described by (ASTM D-6931) to determine using the following equation: $St = \frac{2000P}{\pi DH}$

Where: St= Tensile strength (kPa), P= maximum load (N), D= Diameter of the specimen (mm), H= thickness of specimen (mm). The Marshall Procedure (ASTM D-1559) was followed to prepare a set of six specimens for each mixture. Three conditioned specimens were immersed in a water bath at 60°C, for a period of 24 hours then removed from the water bath and kept at a temperature of 25°C for a period of 2 hours. The other three unconditioned specimens were kept at normal temperature for a period of 4 hours without soaking. The maximum load resistance has been recorded at each case. Then the tensile strength ratios were calculated using the following equation: $TSR = St(cond)/St(uncond)$ Where: TSR= Tensile Strength Ratio (%), $\mathrm{St\ (cond)}$ = Average tensile Strength of Conditioned Sample (kpa), $\mathrm{St\ (uncond)}$ = Average tensile Strength of Unconditioned Sample (kpa).

3.12 Data Processing and Analysis

Processing and analysis of data going to be undertaken in this study was presented and explained using tables, percentage, charts and graphs. The results of laboratory tests were analyze and compared with the standards, outstanding and present specification suggested by ASTM, AASHTO and ERA. The result obtained were organized and interpreted using MS-excels according to set objective and were presented as chart, table and graph.

3.13 Data Quality Management

The quality of the data were assured through replicate the samples by using standard operating procedures. To check the accuracy and validity of data instrument calibration and verification were checked. Laboratory test and field work manual were prepared in order to avoid error of data. And also, given attention during data collection and recording carefully.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introductions

The results and discussion obtained from the laboratory tests and the results section from the point of the objectives of the research. The results obtained from the conducted tests on aggregates, bitumen and fillers all results within the permissible values of ERA Manual specifications and the final output have discussed in different steps and procedures. Primarily, the physical properties of material results, three different asphalt concrete samples were produced using CSD in different proportions 4.5, 5.5, and 6.5% by weight of aggregates as a mineral filler and five different percentages of bitumen content, which were 4, 4.5, 5, 5.5 & 6% by weight of total mix to determine the OBC and OFC in asphalt mixes. Then, CSD filler was replaced by BKE in different percentages. Lastly, to obtain the effects of BKE materials on Mixture volumetric composition are discussed.

4.2 Interpretation of Material Property Test Results

4.2.1 Physical Properties of Aggregates

There are different laboratory tests were conducted on Aggregate, including Bulk dry S.G, Bulk SSD S.G, Apparent S.G, Flakiness index, Aggregate crushing value, Aggregate impact value, Water absorption and Los Angles Abrasion test were summarized in the Table 4.1.

Table 4.1: physical property of aggregates laboratory results and the specification.

Test	Test Method	Test result			Standard (ERA,2013)
		Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	
Bulk dry S.G	AASHTO T 85-91	2.661	2.652	2.615	-
Bulk SSD S.G	AASHTO T 85-91	2.670	2.663	2.624	-
Apparent SG	AASHTO T 85-91	2.686	2.681	2.639	-
Water absorption (%)	BS 812, Part 2	0.345	0.328	0.314	< 2
FI (%)	BS:812 Part 105	27			< 35
ACV (%)	BS:812 Part 110	17.54			< 25
LAA (%)	AASHTO T 96	19.05			< 30
AIV (%)	BS:812 Part 112	12.07			< 25

Table 4.1 shows the apparent specific gravity of coarse, intermediate and fine aggregate are greater result value than bulk specific gravity and saturated surface dry specific gravity. The range of specific gravity of aggregate normally used in road construction are 2.6 to 2.9. The flakiness index result is 27%, which is satisfy the recommended ERA standard. Rounded and angular shape of aggregate improves workability and ensure better interlocking. The aggregate crushing value is 17.54%, this indicates the minimum value of aggregates to achieve a high quality of pavement aggregate and aggregate impact value is 12.07%, the result from 10% up to 20% indicates that the aggregate have more strength and which is less than 25% the minimum recommended ERA standards. The Los Angeles Abrasion result is 19.05%, which is best for road construction. Based on the result conclude that all the aggregate test results are satisfy the requirement standard specification and the aggregate has good quality and can be used in hot mix asphalt. The detail work for aggregate show in Appendix A

4.2.2 Properties of Bitumen

The asphalt binder grade of 60/70 penetration was used to assess its quality for usage. The test results shown in Table 4.3. Such as the penetration, ductility, Softening point, flash point, and specific gravity of the bitumen satisfy the requirements of ERA specifications. Therefore, the material used in the preparation of HMA design.

Table 4.2: Characteristics of Bitumen

No	Test Description	Test Method	Result	ERA, 2013 Specification for 60/70	Status
1	Penetration, 25 ^{o}c (1/10 mm)	ASTM D5-IP 49	65.3	60 – 70	ok
2	Ductility, 25 ^{o}c (cm)	ASTM D113	87	Min 50	ok
3	Softening Point (^{o}c)	ASTM D36	52	46 –56	ok
4	Flash Point (^{o}c)	ASTM D92	299	Min 232	ok
5	Specific gravity (kg/m^3)	AASHTO T-228	1.041	1.01-1.06	ok

Summary of the various properties of the 60/70 penetration grade binder laboratory test result of bitumen as shown in the Table 4.2 the test were done by ASTM and AASHTO method and compared with ERA Pavement Design, 2013 standard specifications. All the test results satisfy the requirements of standards specifications. The test results of penetration, softening point, and specific gravity are 65.3, 52 and 1.041 respectively within the range of standard specification. The test result of ductility 87 and flash point 299 are above the minimum value of the requirement standard specification. From the test results it can be deduced that the bitumen has good quality and can be used in hot mix asphalt. The detail work for bitumen show in Appendix B.

4.2.3 Filler Test Results

4.2.3.1 Physical Properties of Filler Test Results

Currently, crushed stone dust, khat ash and eggshell powder are being used for this research. Laboratory tests such as plasticity index and apparent specific gravity have been conducted in order to evaluate the physical properties of each type of filler. The test was done by using water pycnometer method and conducted according to ASTM D 854 test method. Table 4.3 shows a summary of laboratory test results for crushed stone dust, khat ash, eggshell powder and blending of khat ash and eggshell powder.

Table 4.3: Physical properties of fillers

Sieve No	% passing				ASTMD242
	CSD	KA	ESP	BKE	
No 30	100	100	100	100	100
No 50	100	100	100	100	95 - 100
No 200	100	100	100	100	70 - 100
Liquid Limit	30.01	33.32	32.52	33.04	
Plastic Limit	26.95	29.91	29.26	30.67	
Plasticity Index	NP	NP	NP	NP	< 4
Apparent specific gravity	2.63	2.38	2.41	2.40	-

Table 4.3 shows CSD, KA, ESP and BKE fillers passing through the sieve number 30, 50 and 200. Plasticity index results not higher than four, which means plasticity index is equal to liquid limit minus plastic limit. Therefore, CSD, KA, ESP and BKE are non- plastic (NP). The apparent specific gravity of CSD equal to 2.63, KA equal to 2.38, ESP equal to 2.41 and BKE equal to 2.40 it indicates that the apparent specific gravity of CSD is higher than that of KA, ESP and BKE. Based on the result conclude that the lower specific gravity material has the higher absorption capacity. Therefore khat ash has higher absorption capacity compare with the other.

4.2.3.2 Chemical Composition of BKE Test Results

According to the specified ASTM C 618 standard, the summation of the weight of chemical composition of silica, aluminum, and iron oxides greater than 50% by weight fraction can be deduced to be class C (Statistically, $Si0_2 + Al_20_3 + Fe_20_3 > 50\%$) it indicate that the materials is a good pozzolanic materials. Hundred percent of the adopted filler materials are passes through 0.075 mm sieve which is almost the same size with CSD filler and signifies that the BKE are suitable for use in HMA.

Table 4.4: Chemical Composition of BKE, Khat ash (KA) and Eggshell powder (ESP)

Constituent	SiO_2	Al2O3	Fe2O3	Cao	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
BKE (%)	56.80	8.02	5.47	20.01	5.01	0.31	1.00	0.22	0.52	0.20	0.80	0.50
KA (%)	51.41	9.74	5.01	23.04	6.11	0.62	1.84	0.19	0.43	0.31	0.10	0.64
ESP (%)	56.22	8.00	4.11	22.32	5.93	0.11	0.23	0.10	0.31	0.15	0.90	1.35

Table 4.4 shows that the material which contains a combination ingredient weight of silica, aluminum, and iron oxides greater than 50% by weight fraction (Statistically, $Si0_2 + Al_20_3 + Fe_20_3 = 70.29\%$) it indicate that the materials is a good pozzolanic materials. Hence, it can partially replace CSD and used as a mineral filler in HMA design. In addition, SiO_2 has the highest composition oxide in all the three materials (BKE, KA and ESP) this indicate that it can possible for partial replacement as CSD filler in HMA design. The detail work for filler show in Appendix C.

4.2.4 Aggregate Gradation

Starting from nominal size of sieve 19 mm to 0.075 mm as specification requirement criteria of gradation wearing course or Asphalt institute standards. Based on this percentage passing Table 4.5 shows three different percentages of fillers (4.5, 5.5, and 6.5% by weight of aggregate) at each sieve size.

Table 4.5: Aggregates gradation and specification criteria

Sieve size (mm)	Gradation for the three different filler % passing			ASTM D3515 Specification	
	4.5%	5.5%	6.5%	Lower Limit	Upper Limit
25	100	100	100	100	100
19	90.3	94.5	92.2	90	100
12.5	78.2	84.4	81.8	71	88
9.5	66.7	69.7	69	56	80
4.75	48.6	48.2	43.9	35	65
2.36	34	32.5	31.5	23	49
1.18	20.4	25.9	20	15	37
0.6	16	16.9	15.8	10	28
0.3	12.5	9.4	8.2	5	19
0.15	8	8.6	6	4	13
0.075	4.5	5.5	6.5	2	8

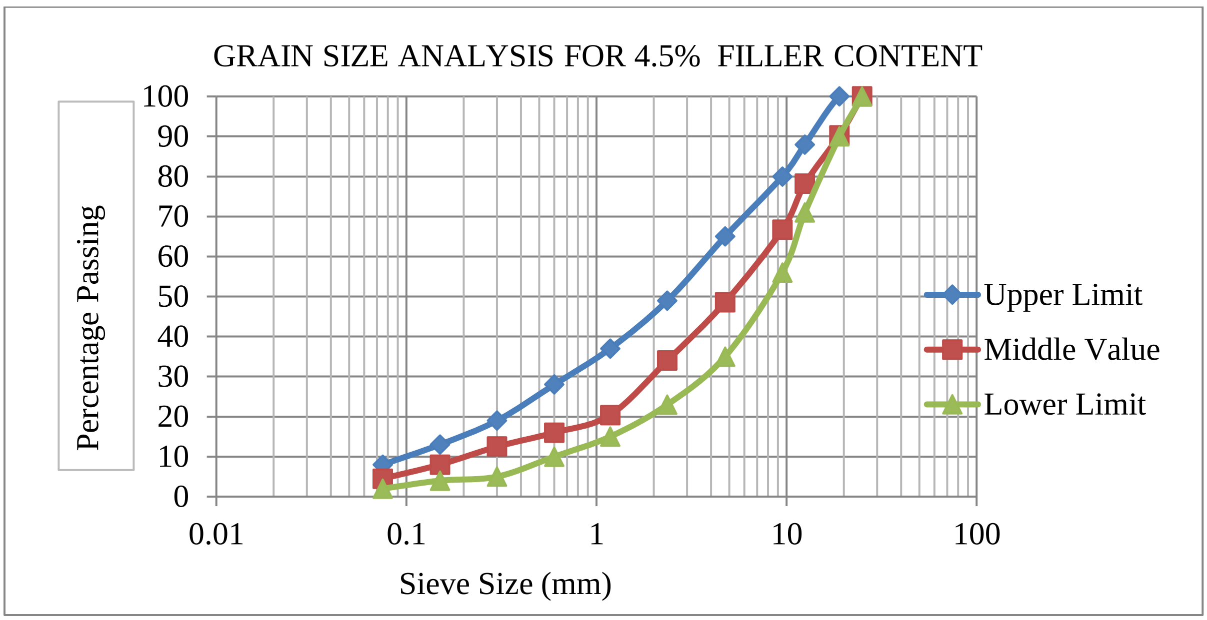

Figure 4.1: Gradation Curve for 4.5% Filler Content

Figure 4.1 indicates gradation curve for 4.5% filler content that was prepared based on the ASTM D3515 standard specification limits. The three fillers are on the range. In this gradation, the aggregates selected from each size by their limit ranges and the filler was 4.5% (by weight of aggregates). The graph shows three different color lines. The blue line indicates the upper limit of ASTM Specification, the green line indicates lower limit of ASTM Specification and the brown line indicates the prepared gradation by 4.5% filler content. The prepared gradation is between the upper and lower limits of ASTM Specification as shown in Figure 4.1. Hence, the prepared gradation satisfies the specification requirements. The detail work for aggregate gradation show in Appendix D.

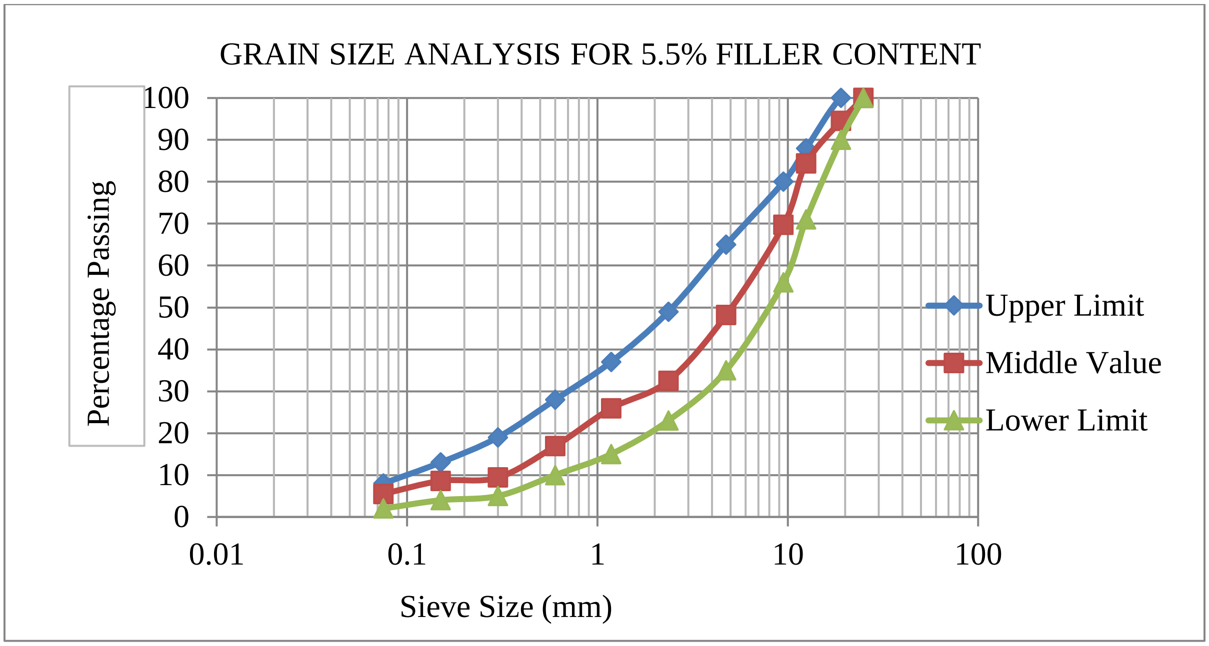

Figure 4.2: Gradation Curve for 5.5% Filler content

Figure 4.2 indicates gradation curve for 5.5% filler content that was prepared based on the ASTM D3515 standard specification limits. The three fillers are on the range. In this gradation, the aggregates selected from each size by their limit ranges and the filler was 5.5% (by weight of Aggregates). The graph shows three different color lines. The blue line indicates the upper limit of ASTM Specification, the green line indicates lower limit of ASTM Specification and the brown line indicates the prepared gradation by 5.5 % filler content. The prepared gradation is between the upper and lower limits of ASTM Specification as shown in Figure 4.2. Hence, the prepared gradation satisfies the specification requirements. The detail work for aggregate gradation show in Appendix D.

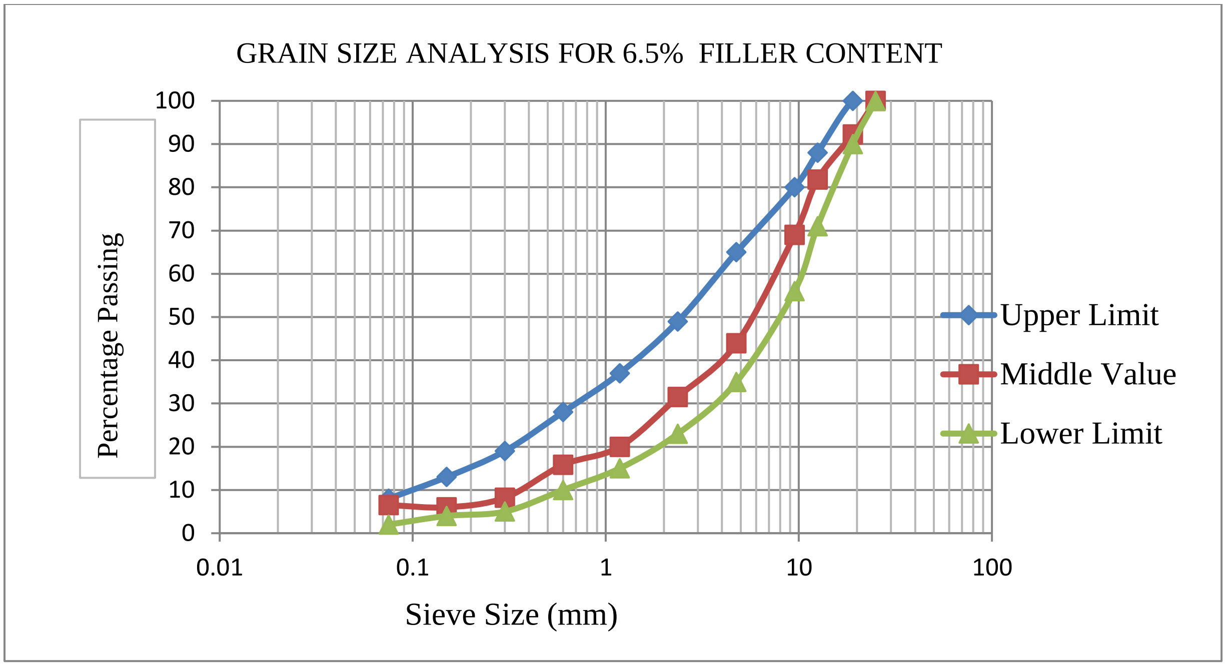

Figure 4.3: Gradation Curve for 6.5% Filler content

Figure 4.3 indicates gradation curve for 6.5% filler content that was prepared based on the ASTM D3515 standard specification limits. The three fillers are on the range. In this gradation, the aggregates selected from each size by their limit ranges and the filler was 6.5% (by weight of Aggregates). The graph shows three different color lines. The blue line indicates the upper limit of ASTM Specification, the green line indicates lower limit of ASTM Specification and the brown line indicates the prepared gradation by 6.5% filler content. The prepared gradation is between the upper and lower limits of ASTM Specification as shown in Figure 4.3. Hence, the prepared gradation satisfies the specification requirements. The detail work for aggregate gradation show in Appendix D.

4.3 Marshal Properties

For the result of Marshall Properties total 45 specimens with each weight of 1200 grams were prepared using by different percentages of 4.5, 5.5, and 6.5% by weight of aggregate. Conventional materials (CSD) replaced by different percentages of 4.5, 5.5, and 6.5% by weight of aggregate with different bitumen contents (4, 4.5, 5, 5.5, and 6.5%) of the total weight to determine the optimum bitumen content and optimum filler content. The laboratory work of marshal mix design was prepared based on the range. Which recommended in both the ERA Pavement Design Manual (ERA, 2013) and the Asphalt Institute. Uses evaluation of test results from the marshal design method, such as minimum marshal stability, range of acceptable marshal flow, range of acceptable air void, percent of voids filled with asphalt and the minimum amount of void in mineral aggregates.

According to ERA Pavement Design Manual (2013) Marshall Design Criteria for heavy traffic, minimum stability, flow value, percentage of VA, minimum VMA, and VFB must be 8 kN at 60^0C, 2 to 3.5 mm, 3 to 5%, 13%, and 65 to 75% respectively. The detail work for Marshal Properties show in Appendix E.

Table 4.6: Marshall test result for mixes with 4.5% CSD filler & different bitumen content.

BC (%)	(Gmb)(gm/cm3)	VA (%)	VMA (%)	VFA (%)	Stability (kN)	Flow (mm)
4	2.321	5.830	13.700	57.443	8.817	3.080
4.5	2.339	4.875	13.500	63.892	10.483	3.230
5	2.346	3.540	13.700	74.158	11.920	3.320
5.5	2.361	2.700	13.600	80.145	10.830	3.510
6	2.366	1.603	14.900	88.466	9.557	3.670

Table 4.6 shows the Marshall Property laboratory test results of a mix with 4.5% CSD filler (by weight of aggregates) with five different bitumen contents (4, 4.5, 5, 5.5, and 6.5% by weight of total mix). For each Marshall property, plotted curves the relationships between the different marshal properties (stability, flow, air void, void filled with asphalt, void in mineral aggregate and bulk specific gravity) with different bitumen content shown in Figure 4.4.

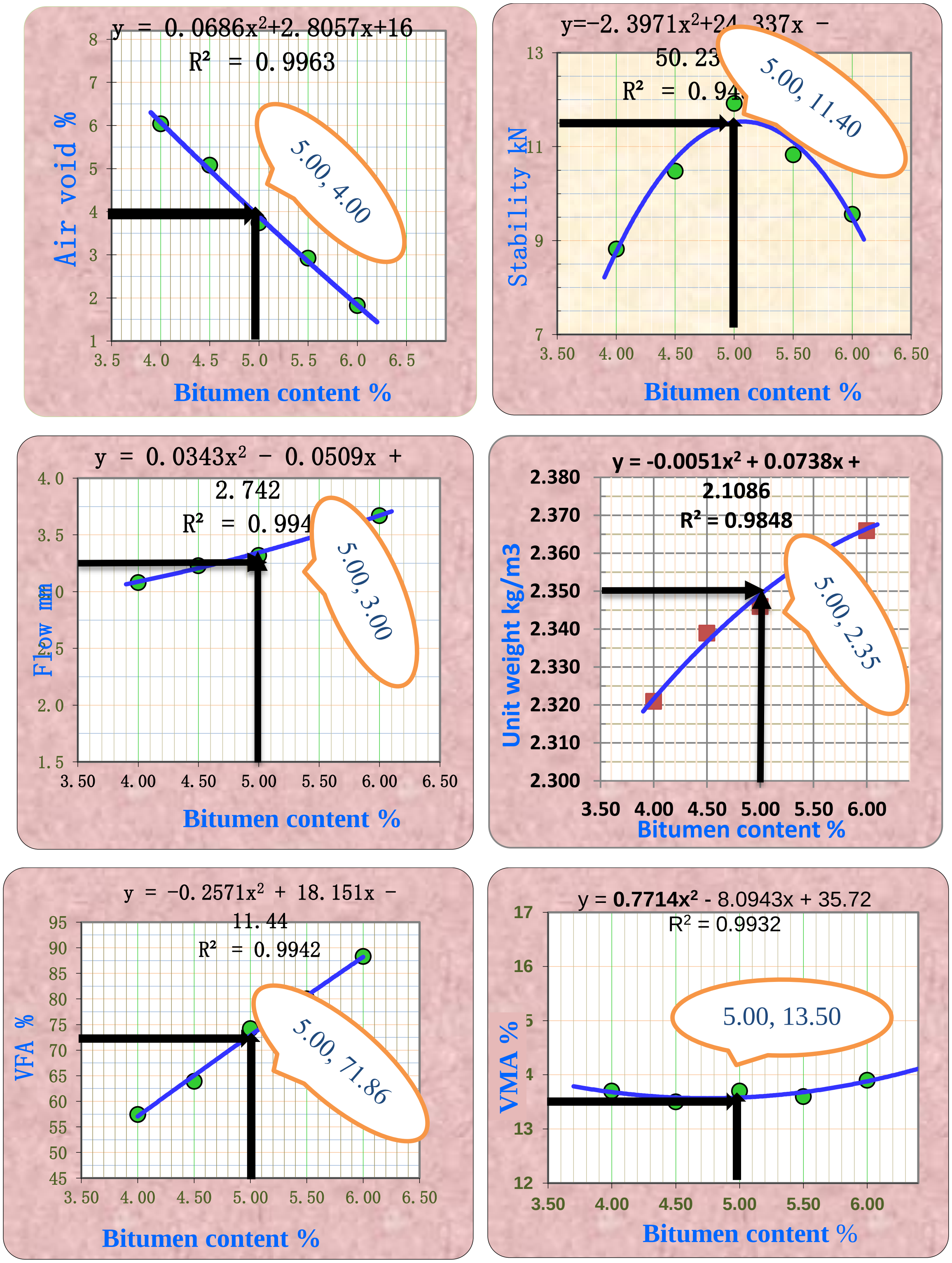

Figure 4.4: OBC and the marshal properties of mixtures with 4.5% CSD filler.

Figure 4.4 shows the relationships between binder content and the marshal properties of mixtures with 4.5% CSD. According to the chosen method, which was the NAPA (National Asphalt Pavement Association) mix design method, the optimum bitumen content of the mix result is 5% based on the median air void content (4%) of the specification. From the Figure 4.4, conclude that the stability increase with the increase in asphalt content up to maximum value and then decrease with the increase in asphalt content. The increased in stability indicates an improved in adhesion between aggregate and binder that strongly resist road damage due to the traffic movements and an excess in the binder results in low stability of the mix design. On the other hand, the VFA, unit weight and flow increase with an increase in asphalt content. Whereas, the percent of VMA decreases to the minimum value then increases with increase BC and also decrease with increase BC and increase to the higher BC. VA decrease with increase in asphalt content.

Table 4.7: Marshall test result for mixes with 5.5% CSD filler & different bitumen content.

BC (%)	Gmb (gm/cm3)	VA (%)	VMA (%)	VFA (%)	Stability (KN)	Flow (mm)
4	2.319	5.943	13.800	56.936	9.070	3.140
4.5	2.332	5.149	13.800	62.690	11.600	3.290
5	2.341	3.742	13.900	73.079	12.807	3.320
5.5	2.356	2.921	13.800	78.834	11.787	3.510
6	2.362	1.790	14.000	87.216	9.890	3.630

Table 4.7 shows the Marshall Property laboratory test results of a mix with 5.5% CSD filler (by weight of aggregates) with five different bitumen contents (4, 4.5, 5, 5.5, and 6.5% by weight of total mix). For each Marshall property, plotted curves the relationships between the different marshal properties (stability, flow, air void, void filled with asphalt, void in mineral aggregate and bulk specific gravity) with different bitumen content shown in Figure 4.5.

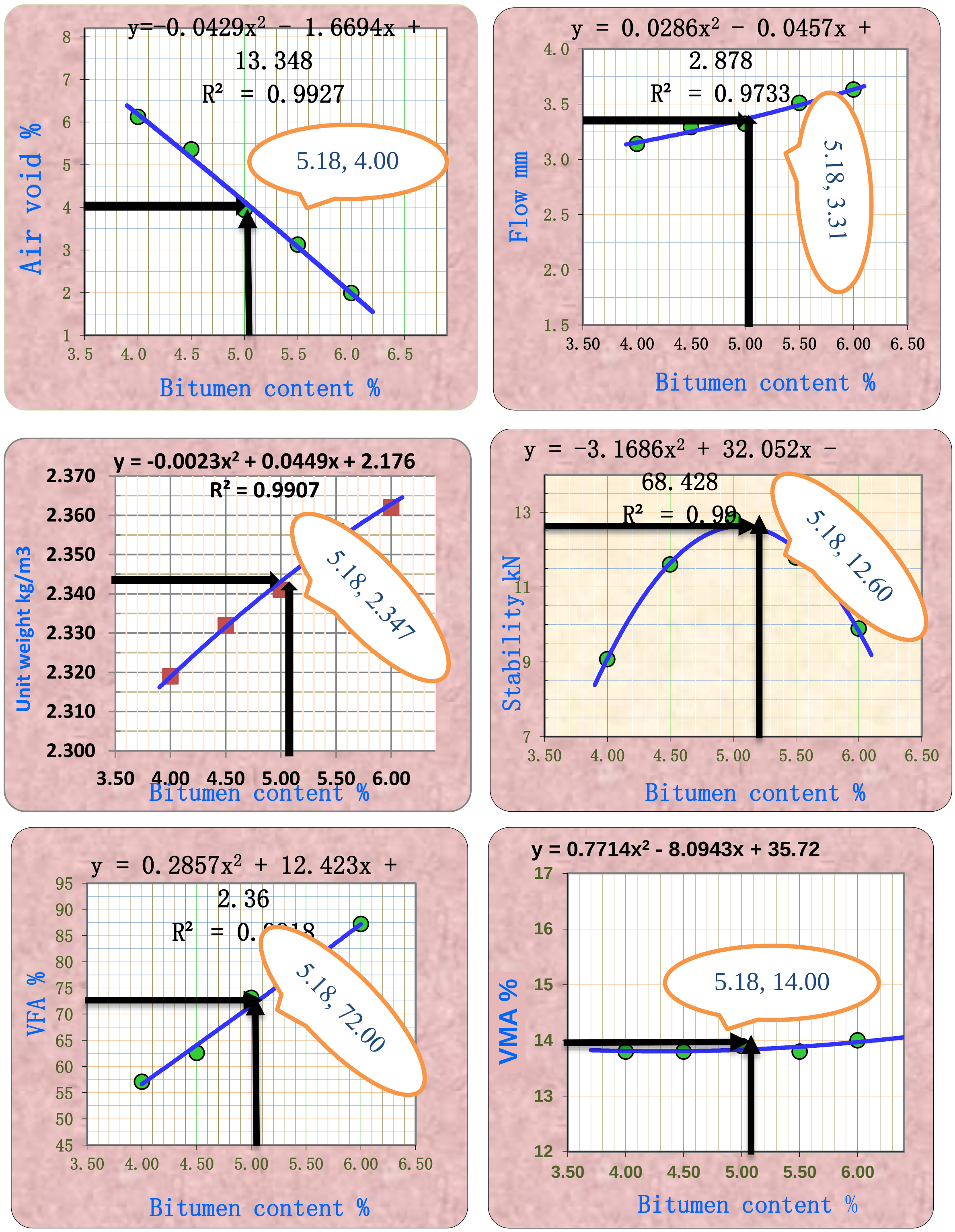

Figure 4.5: OBC and the marshal properties of mixtures with 5.5% CSD filler

Figure 4.5 shows the relationships between binder content and the marshal properties of mixtures with 5.5% CSD. According to the chosen method, which was the NAPA mix design method, the optimum bitumen content of the mix result is 5.18% based on the median air void content (4%) of the specification. From the Figure 4.5, conclude that the stability increase with the increase in asphalt content up to maximum value and then decrease with the increase in asphalt content. The increased in stability indicates an improved in adhesion between aggregate and binder that strongly resist road damage due to the traffic movements and an excess in the binder results in low stability of the mix design. On the other hand, the VFA, flow and unit weight increase with an increase in asphalt content. Whereas, the percent of VMA decreases to the minimum value then increases with increase BC and also decrease with increase BC and increase to the higher BC. In addition, the VA decrease with increase in asphalt content.

Table 4.8: Marshall Test result for Mixes with 6.5% CSD filler & different bitumen content

BC (%)	Bulk SG (Gsb) (gm/cm3)	VA (%)	VMA (%)	VFA (%)	Stability (KN)	Flow (mm)
4	2.324	7.824	13.600	42.471	9.523	2.990
4.5	2.340	6.482	13.400	51.624	10.993	3.020
5	2.345	5.514	13.700	59.755	11.903	3.210
5.5	2.354	4.365	13.800	68.372	12.323	3.410
6	2.348	3.998	14.500	72.430	11.087	3.560

Table 4.8 indicates the Marshall Property laboratory test results of a mix with 6.5% CSD filler (by weight of aggregates) with five different bitumen contents (4, 4.5, 5, 5.5, and 6.5% by weight of total mix). For each Marshall property, plotted curves the relationships between the different marshal properties (stability, flow, air void, void filled with asphalt, void in mineral aggregate and bulk specific gravity) with different bitumen content shown in figure 4.6.

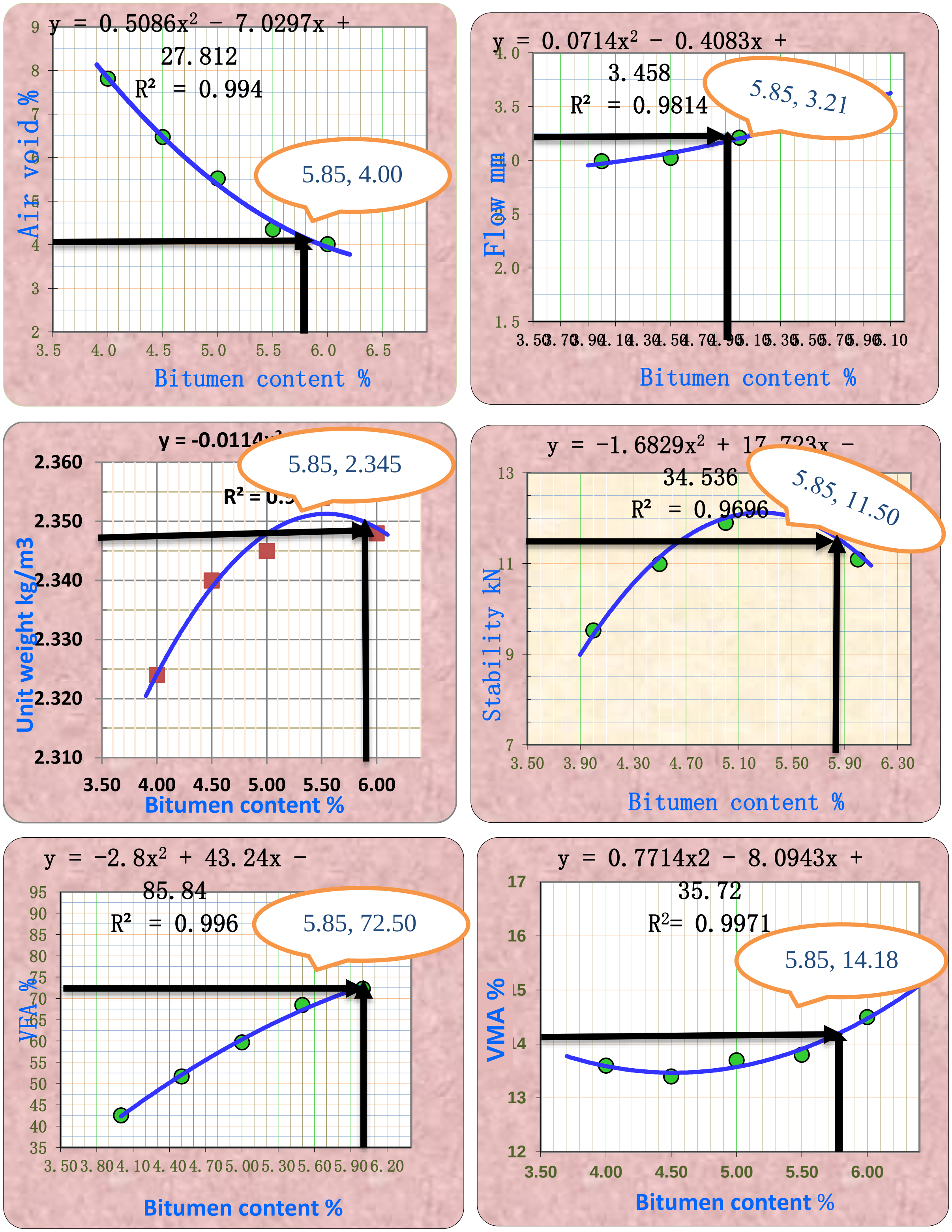

Figure 4.6: OBC and the properties of mixtures with 6.5% CSD filler.

Figure 4.6 shows the relationships between binder content and the marshal properties of mixtures with 6.5% CSD. According to the chosen method, which was the NAPA mix design method, the optimum bitumen content of the mix result is 5.85% based on the median air void content (4%) of the specification. From the Figure 4.6, conclude that the stability and unit weight increase with the increase in asphalt content up to maximum value and then decrease with the increase in asphalt content. The increased in stability indicates an improved in adhesion between aggregate and binder that strongly resist road damage due to the traffic movements and an excess in the binder results in low stability of the mix design. On the other hand, the VFA and flow increase with an increase in asphalt content. Whereas, the percent of VMA decreases to the minimum value then increases with increase BC and also decrease with increase BC and increase to the higher BC. In addition, the VA decrease with increase in asphalt content.

4.3.1 Determination of Optimum Bitumen Content

The OBC determined by the method previously stated by NAPA. These methods recommend making the plotting curves as presented in Figure 4.4 to 4.6. The OBC is determined by finding the bitumen content which corresponds to the median air void 4.0% of the specification. In this method, preparing plotting curves is mandatory. Having this bitumen content versus Marshall Stability, Flow, VFA, VMA, and Bulk specific gravity was determined as shown in Figures 4.4, 4.5, and 4.6. The obtained values were compared with the specification values and all are within the specification of (ERA, 2013 and Asphalt Institute, 2003). Finally, the OBC at 4% air void for 4.5% CSD filler is 5% (by weight of total mix), for 5.5% CSD filler is 5.18% (by weight of total mix) and for 6.5% CSD filler is 5.85% (by weight of total mix), Tables 4.9, 4.10, and 4.11 shows for 4.5% CSD filler, 5.5% CSD filler, and 6.5% CSD filler respectively illustrate the summarized properties.

Table 4.9: Marshall Properties of the asphalt mix with 5% OBC and 4.5% CSD filler.

Mix property	Values Obtained	ERA Specification Limit (2013)		Asphalt Institute Limit (2003)		Status
		Lower	Upper	Lower	Upper	
Asphalt (%)	5	4	10	4	10	ok
VA (%)	4.00	3	5	3	5	ok
VMA (%)	13.50	Min 13	-	Min 13	-	ok
VFA (%)	71.86	65	75	65	75	ok
Stability (kN)	11.50	Min 7.0	-	Min 8.00	-	ok
Flow (mm)	3.00	2	4	2	3.5	ok
Gmb (gm/cm^3)	2.35	-	-	-	-	

Table 4.9 describes the asphalt content and the Marshal values of the mix (Stability, Flow, VMA, and VFA) at 4.5% CSD filler, and 5% OBC. The results of Asphalt content, VFA and Flow are 5%, 71.86% and 3.00 mm respectively within the range of standard specification. The result of VMA 13.5% and stability 11.5 kN are above the minimum value of the requirement standard specification. In addition, bulk specific gravity 2.35 gm/cm^3 satisfy standard specification. All value fulfill ERA and Asphalt Institute standard specification criteria.

Table 4.10: Marshall Properties of the asphalt mix with 5.18% OBC and 5.5% CSD filler.

Mix property	Values Obtained	ERA Specification Limit (2013)		Asphalt Institute Limit (2003)		Status
		Lower	Upper	Lower	Upper	
Asphalt (%)	5.18	4	10	4	10	Ok
VA (%)	4.00	3	5	3	5	Ok
VMA (%)	14.00	Min 13	-	Min 13	-	Ok
VFA (%)	72.00	65	75	65	75	Ok
Stability (kN)	12.60	Min 7.0	-	Min 8.00	-	Ok
Flow (mm)	3.31	2	4	2	3.5	Ok
Gmb (gm/cm^3)	2.34	-	-	-	-	

Table 4.10 describes the asphalt content and the Marshal values of the mix (Stability, Flow, VMA, and VFA) at 5.5% CSD filler, and 5.18 % OBC. The results of Asphalt content, VFA and Flow are 5.18%, 72% and 3.31 mm respectively within the range of standard specification. The result of VMA 14.00% and stability 12.60 kN are above the minimum value of the requirement standard specification. In addition, bulk specific gravity 2.34 gm/cm^3 satisfy standard specification. All value fulfill ERA and Asphalt Institute standard specification criteria.

Table 4.11: Marshall Properties of the asphalt mix with 5.85% OBC and 6.5% CSD filler**.**

Mix property	Values Obtained	ERA Specification Limit (2013)		Asphalt Institute Limit (2003)		Status
		Lower	Upper	Lower	Upper	
Asphalt (%)	5.85	4	10	4	10	Ok
VA (%)	4.00	3	5	3	5	Ok
VMA (%)	14.18	Min 13	-	Min 13	-	Ok
VFA (%)	72.50	65	75	65	75	Ok
Stability (kN)	11.50	Min 7.0	-	Min 8.00	-	Ok
Flow (mm)	3.21	2	4	2	3.5	Ok
Gmb (gm/cm^3)	2.34	-	-	-	-	

Table 4.11 describes the asphalt content and the Marshal values of the mix (Stability, Flow, VMA, and VFA) at 6.5% CSD filler, and 5.85 % OBC. The results of Asphalt content, VFA and Flow are 5.85%, 72.50% and 3.21 mm respectively within the range of standard specification. The result of VMA 14.18% and stability 11.50 kN are above the minimum value of the requirement standard specification. In addition, Gmb satisfy 2.34 gm/cm^3 standard specification. All value fulfill ERA and Asphalt Institute standard specification criteria.

4.3.2 Comparison of OBC at Percentage mix proportion of CSD

Table 4.12: OBC and Marshall Properties of the three percentages of mix proportions.

Properties of mix	% of CSD Filler content			Specifications	
	4.5%	5.5%	6.5%	ERA spec.	Asphalt Inst.
Asphalt content (%)	5	5.18	5.85	4 - 10	4 - 10
VFA (%)	71.86	72.00	72.50	65 - 75	65 - 75
VMA (%)	13.5	14.00	14.18	min 13	Min 13
Stability (kN)	11.40	12.60	11.50	min 8	Min 7
Gmb (gm/cm3)	2.35	2.347	2.345	-	-
Flow (mm)	3.00	3.31	3.21	2 - 4	2 - 3.5
Air void (%)	4	4	4	3 - 5	3 - 5

Table 4.12 describes the summary of marshal properties of the mixes corresponding to the three varying CSD filler content (4.5, 5.5 and 6.5%). Marshall Stability the volumetric properties of the mixed bitumen content for the three fillers contents satisfied the specification ranges of the ERA pavement design manual and Asphalt institute. Comparing all the above three properties of the mix, at 5.5% CSD filler with 5.18 % bitumen content (by weight of total mix) indicates higher stability than all other mixtures. Therefore, this 5.5% CSD filler referred to as OFC and the 5.18% bitumen content referred optimum bitumen content based on Maximum Marshall Stability. These optimum contents used for replacement of mix with BKE.

4.4 Partial Replacement of filler materials with BKE in Marshal Properties

The aim of this study was to determine the maximum percentage RR of BKE for replacing CSD. The effect of CSD filler materials replacing different percentages of the BKE on Marshall Properties (Stability, flow and volumetric properties) of the mixture evaluated. 5.5% and 5.18% were the optimum filler content and bitumen content respectively at six different percentages of BKE filler with 8% interval replacement rate. Different percentages of filler content and the proportion of the mixtures described in Table 4.13.

Table 4.13 Marshal Properties at the different proportion of CSD and BKE

CSD filler (%)	RR of KA filler (%)	RR of ESP filler (%)	RR of BKE filler (%)	Gmb (gm/cm3)	VA (%)	VMA (%)	VFA (%)	Stability (kN)	Flow (mm)
100	0	0	0	2.364	4.110	13.100	68.628	12.807	3.000
92	4	4	8	2.322	4.848	14.600	66.798	10.467	3.220
84	8	8	16	2.327	4.253	14.400	70.467	11.627	3.120
76	12	12	24	2.333	4.000	14.200	74.720	12.907	3.110
68	16	16	32	2.313	4.036	14.900	72.912	11.773	3.360
60	20	20	40	2.309	4.190	15.100	72.300	10.490	3.590

Table 4.13 shows all laboratory results of stability, flow, VA, VMA, VFA & Gmb with different replacement ratio of both CSD and BKE and with constant bitumen content of 5.18% from 0% replacement ratio of BKE filler (control mix) up to 40% (by weight of OFC) has satisfied the specification requirement. At 0% (100% CSD filler) used for full amount of CSD filler i.e. (5.5% CSD filler + 0% BKE filler), at 8% replacement ratio of BKE filler used (5.06 CSD filler + 0.44 BKE filler), at 16% replacement ratio of BKE filler (4.62 CSD filler + 0.88 BKE filler), at 24% replacement ratio of BKE filler (4.18 CSD filler + 1.32 BKE filler), at 32% replacement ratio of BKE filler (3.74 CSD filler + 1.76 BKE filler), and at 40% replacement ratio of BKE filler (3.3 CSD filler + 2.2 BKE filler).

4.4.1 Relationship of BKE – Marshal Stability

Relationship between stability and replacement ratio of blended KA and ESP filler at 0, 8, 16, 24, 32, and 40% the stability values are 12.807, 10.4467, 11.627, 12.907, 11.773, and 10.490 kN respectively. All laboratory results of stability with different replacement ratio of both CSD filler and BKE filler from 0% (100% CSD filler) up to 40% (by weight of OFC) has satisfied the specification requirement.

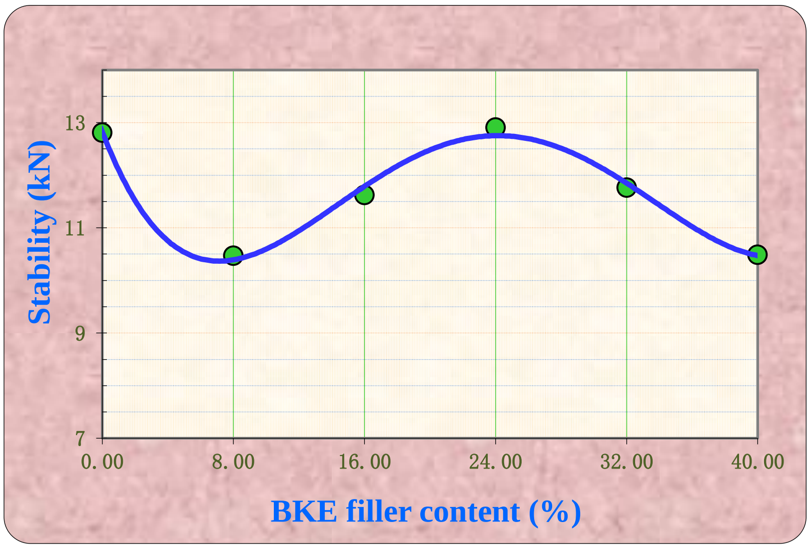

Figure 4.7: Relationship between Stability (kN) and blending of KA and ESP (percentage)

Figure 4.7 describes the effect of BKE on stability, which implies that adding the proportion of BKE to a mixture similarly increases the stability of the mix from 8% up to 24% of BKE, and then it started to decrease up to 40%. All laboratory results of stability with different RR of BKE from 0% BKE (100% CSD) filler up to 40% by weight of OFC has satisfied the specification requirement. The control mix 100% CSD filler, the stability was 12.807 KN. The maximum stability was 12.9O7 KN at 24% BKE filler and 76% of CSD filler by weight of aggregate. This indicates that increasing the BKE contents in the asphalt mix had significant effects by reducing deformation, then it started to decrease, but it satisfied the specification requirement. Based on the results, conclude that an increase in stability indicates the strong adhesion between aggregates and binder for this mix design while it signifies poor adhesion for the decreased case than the other. The stability described as the maximum load resistance.

4.4.2 Relationship of BKE – Flow

Relationship between flow and replacement ratio of blended KA and ESP filler at 0, 8, 16, 24, 32, and 40% the flow values are 3.000, 3.220, 3.120, 3.110, 3.360, and 3.590 mm respectively. All laboratory results of flow with different replacement ratio of both CSD filler and BKE filler from 0% (100% CSD filler) up to 40% (by weight of OFC) has satisfied the specification requirement.

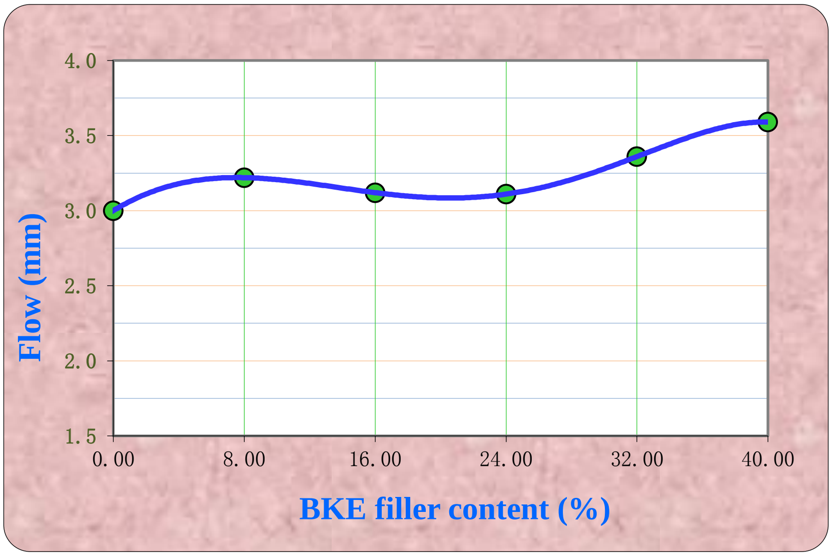

Figure 4.8: Relationship between flow (mm) and blending of KA and ESP (percentage)

Figure 4.8 describes the effect of BKE on flow, which implies that adding the proportion of BKE to a mixture but decrease the flow of the mix from 8% up to 24% of BKE, then it started to increase from 24% up to 40%. All laboratory results of flow with different RR of BKE from 0% (control mix) up to 40% by weight of OFC has satisfied the specification requirement. The maximum flow value was 3.59 mm at 40% BKE and 60% of CSD by weight of aggregate. The control mix 100% CSD, the flow value was 3.00 mm. RR at 24 % BKE and 76% of CSD by weight of optimum filler content is 3.11 mm. Based on the results, conclude that high flow values was indicate an asphalt mixture that has plastic behavior and has the potential for permanent deformation under traffic, whereas low flow values may indicate a mix with higher air void in the mix than acceptable voids and insufficient asphalt and may experience premature cracking due to mixture brittleness during the life of the pavement. Flow is the total amount of deformation during at the maximum load.

4.4.3 Relationship of BKE – Voids in Mineral Aggregate

Relationship between VMA and RR of blended KA and ESP filler at 0, 8, 16, 24, 32, and 40% the VMA values are 13.100, 14.600, 14.400, 14.200, 14.900, and 15.100% respectively. All laboratory results of VMA with different replacement ratio of both CSD filler and BKE filler from 0% (100% CSD filler) up to 40% (by weight of OFC) has satisfied the specification requirement.

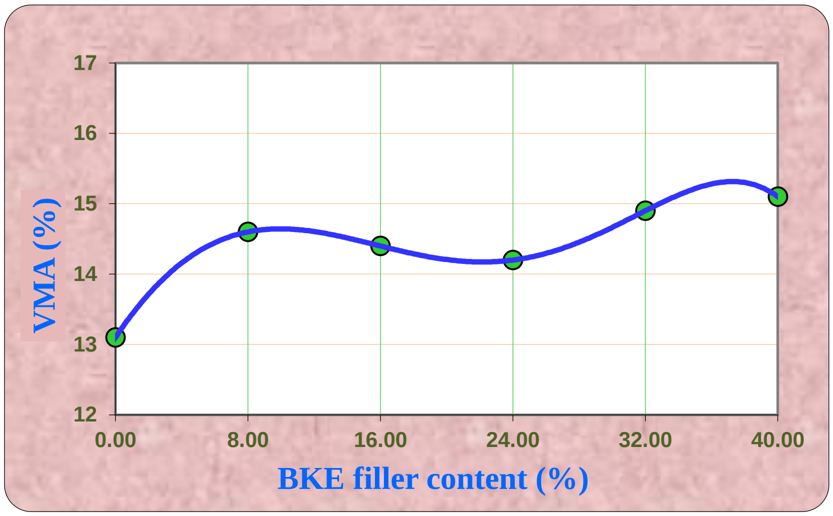

Figure 4.9: Relationship between VMA (percentage) and BKE (percentage)

Figure 4.9 describes the effect of BKE on VMA, which implies that adding the proportion of BKE to a mixture but decrease the VMA of the mix from 8% up to 24% of BKE. Then it started to increase from 24% up to 40%. All the percentage rates results satisfied the specification criteria. Lower values of VMA result in fewer spaces to accommodate the required asphalt to produce a good coating and durable mix. The result shows that the minimum value of VMA was determined at 24% RR of BKE filler that is 14.2% but it is greater than 13.1% of the control mixes. Therefore, conclude that the minimum value recorded at 0% BKE (control mix) result more durable mixes as compared to the mixes with BKE filler. VMA are described as the inter-granular void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective bitumen content.

4.4.4 Relationship of BKE –Void Filled with Asphalt

Relationships between VFA and RR of blended KA and ESP filler at 0, 8, 16, 24, 32, and 40% the VFA values are 68.628, 66.798, 70.467, 74.720, 72.912, and 72.300% respectively. All laboratory results of VFA with different replacement ratio of both CSD filler and BKE filler from 0% (100% CSD filler) up to 40% (by weight of OFC) has satisfied the specification requirement.

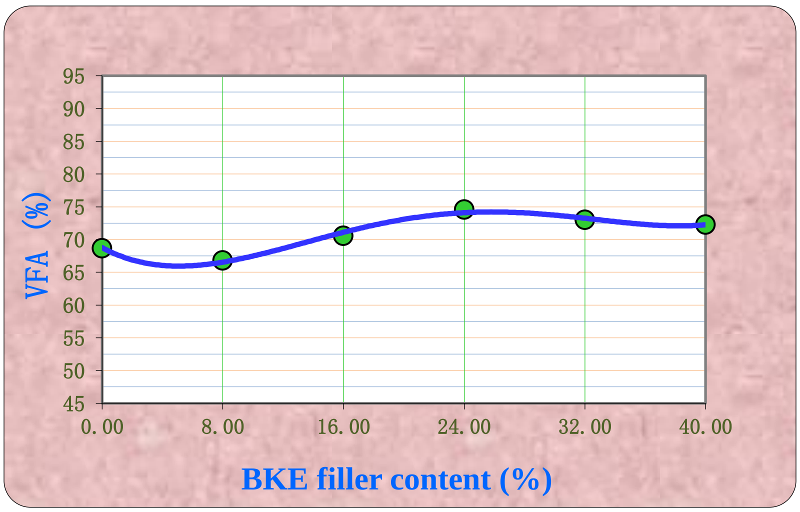

Figure 4.10: Relationship between VFA (percentage) and BKE (percentage)

Figure 4.10 describes the effect of BKE on VFA, which implies that adding the proportion of BKE to a mixture similarly increases the VFA of the mix from 8% up to 24% of BKE, then it started to decrease up to 40%, but it satisfied the specification requirement. The highest value of VFA in a mix indicates the lowest VA for the mix. It concluded from the results that RR at 24% improves the mix by providing more effective bitumen content in the mix to fill voids between the inter-granular spaces. VFA represents the volume of effective bitumen content in the mixture. It is inversely related to air voids hence, as air voids decrease, the VFA increases and directly related to the asphalt content.

4.4.5 Relationship of BKE –Air void

Relationship between VA and RR of blended KA and ESP filler at 0, 8, 16, 24, 32, and 40% the VA values are 4.110, 4.848, 4.253, 4.000, 4.036, and 4.190% respectively. All laboratory results of VA with different replacement ratio of both CSD filler and BKE filler from 0% (100% CSD filler) up to 40% of BKE (by weight of OFC) has satisfied the specification requirement.

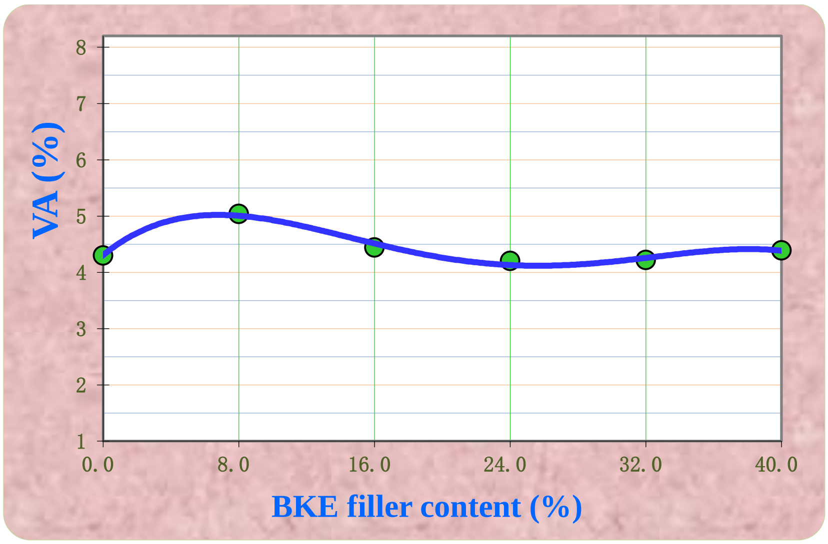

Figure 4.11: Relationship between VA (percentage) and BKE (percentage)

Figure 4.11 describes the effect of BKE on VA, which implies that adding the proportion of BKE to a mixture but decrease the VA of the mix from 8% up to 24% of BKE, then it started to increase from 24% up to 40%, at 24% BKE, the VA percentage was 4%, which is the median value of local and international specifications. And from the results, the air void content for replaced mixes with all proportions of BKE showed within the range of 3-5% specified by both ERA, Pavement Design Manual, 2013. VA in the mix refer to the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture. The value of air void affected by asphalt content, and content of mineral fillers.

4.4.6 Relationship of BKE –Bulk specific Gravity

Relationship between bulk specific gravity and RR of blended KA and ESP filler at 0, 8, 16, 24, 32, and 40% the bulk specific gravity values are 2.364, 2.322, 2.327, 2.333, 2.313, and 2.309 gm/cm^3 respectively. All laboratory results of bulk specific gravity with different replacement ratio of both CSD filler and BKE filler from 0% (100% CSD filler) up to 40% BKE filler (by weight of OFC) has satisfied the specification requirement.

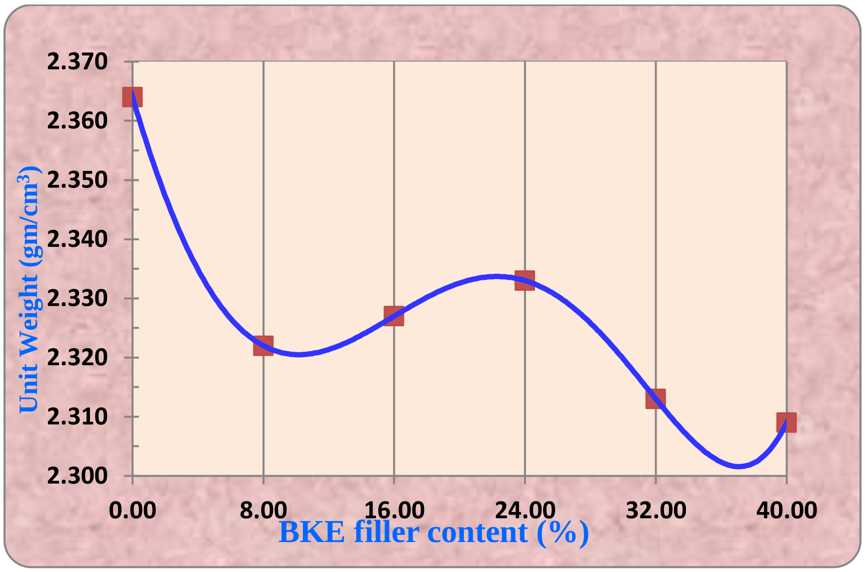

Figure 4.12: Relationship between Bulk–density (gm/cm3) & BKE (percentage)

Figure 4.12 describes the effect of BKE on bulk density, which implies that adding the proportion of BKE to a mixture similarly increases the bulk density of the mix from 8% up to 24% of BKE. Then it started to decrease up to 40%, but it satisfied the specification requirement. Based on the result conclude that the greater density of the compacted specimen is the less in void content. The density of the compacted mix is the unit weight of the mixture. Density is depend on closeness packing of materials.

Table 4.14: Summarized properties of different percentages of blended KA and ESP

Property	Replacement of BKE (%)					
	0	8	16	24	32	40
OBC (%)	5.18	5.18	5.18	5.18	5.18	5.18
Stability (KN)	12.807	10.467	11.627	12.907	11.773	10.490
Flow (mm)	3.000	3.220	3.120	3.110	3.360	3.590
Gmb (gm/cm^3)	2.364	2.322	2.327	2.333	2.313	2.309
VA (%)	4.110	4.848	4.253	4.000	4.036	4.190
VMA (%)	13.100	14.600	14.400	14.200	14.900	15.100
VFA (%)	68.628	66.798	70.467	74.720	72.912	72.300

Table 4.14 below describes all Marshall Properties of asphalt mix with different percentage of fillers content BKE satisfy local and international specification.

4.5 Determination of the optimum replacement ratio of BKE in HMA.

From this study, determining the optimum replacement ratio of BKE is necessary. A set of controls is recommended in order to obtain the optimum RR that produces an asphalt mix with the best Marshall properties. The asphalt mix with an optimum replacement rate must satisfy the following criteria: Maximum stability, Maximum bulk-density and VA (4%) with ln median air voids.

Table 4.15: Optimum replacement rate of asphalt mix with specification

Property	Replacement rate of BKE by weight of OFC (%)
Maximum Stability, Maximum Gmb and 4% Median air voids	24

Table 4.15 shows the mix that obtained by using 24% BKE (by weight of OFC) and 74 % CSD (by weight of OFC) with 5.18 % of asphalt content (by weight of total mix) meets the criteria of selecting optimum replacement rate.

4.6 Moisture Susceptibility of HMA with TSR parameter

The test result for the tensile strength ratio (TSR) indicates that the moisture susceptibility of the mix. TSR values are obtained from ratio of average tensile strength of conditioned sample and average tensile strength of unconditioned sample. The minimum specification requirement of TSR has 80%. The TSR result at 24% of BKE filler and 76% of CSD filler with 5.18% OBC was the maximum replacement ratio for moisture susceptibility of the mix. Conventional filler (control mix 0%) and non-conventional fillers BKE filler at the maximum percentage of TSR value at 24% and above and below 24% prepared for asphalt mixture describes Table 4.22.

Table 4.16: Tensile strength ratio for BKE and CSD

Filler type	Filler content	OBC	St_2	St_1	TSR%
BKE	16% BKE + 85% CSD	5.18	693.139	887.338	81.22
	24% BKE + 76% CSD	5.18	718.235	876.849	82.56
	32% BKE + 68% CSD	5.18	687.698	869.262	79.11
CSD	100% CSD	5.18	727.132	882.770	82.08

Table 4.16 shows the laboratory test results of optimum replacement of BKE on asphalt mixture with boundary and CSD (control mix 0%) are discussed. At 100% CSD filler, 16% BKE filler and 24% BKE filler of the specimens are not sensitive to the action of water and improves the resistance of water-induced damage but at 32% BKE filler of the specimens are sensitive to the action of water and does not improves the resistance of water-induced damage.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main goal of this study was evaluating the suitability of partial replacement of BKE by equal amount as mineral filler in HMA. This two locally available (non-conventional) waste materials KA and ESP and conventional materials such as CSD, bitumen, aggregates tests conducted in a laboratory and all the results were pass the necessary specifications.

The following conclusions can be drawn from the results based on the objective of the study

- All Laboratory test result was satisfied all the standard specification criteria.
- The chemical composition BKE was the combined percentage of Silica, Aluminum and Ironoxides meets the specification in ASTM standard ($Si0_2$ + Al_20_3 + Fe_20_3 = 70.29% > 50%).
- Five different amounts of bitumen content (4, 4.5, 5, 5.5, and 6%) by weight of total mix and three different percentage of conventionally used crushed stone dust filler content (4.5, 5.5, and 6.5%) by weight of aggregate was prepared.
- The optimum filler content for the control mix was 5.5% with a maximum stability value of the three filler content and the respective bitumen content is 5.18%.
- Replacement ratio of the mix obtained by using 8, 16, 24, 32 & 40% by weight of CSD filler, from this optimum replacement ratio at 24% BKE and 76% CSD as filler with a constant bitumen content of 5.18% by weight of total mix have the test result in terms of Stability, flow, bulk density, VA, VMA and VFA are 12.907 KN, 3.110mm, 2.333, 4.002%, 14.200%, and 74.720% respectively.
- The TSR value at 24% of BKE and 76% of CSD with 5.18 OBC was in a good performance than the TSR value at 100% CSD filler, i.e. the TSR value at 24% of BKE filler 82.56% better than the TSR value at 100% of CSD filler 82.08%.
- Therefore, the study shows that BKE can be used as filler in HMA at 5.5% by weight of CSD filler is possible as alternative filler material.

5.2 Recommendations

Based on the results of this research, the following recommendations are forwarded:

- For the developing countries like Ethiopia using locally available materials is one means develop the economy of the society and also for the country itself.
- Partial replacement of CSD with BKE as a filler passing sieve size 0.075mm to clearly identify the effect of BKE on HMA conduct for further studies are needed using various percentages of filler.
- Using Non-Conventional filler (BKE) as partial replacement of conventional filler (CSD) in HMA with a maximum percentage of 24% by weight of optimum BKE filler. In addition to reducing the consumption of CSD filler, reduce environmental pollution, renewably low cost, and environment ecofriendly.
- 24% of BKE and 76% of CSD with 5.18 optimum bitumen content was the best replacement ratio for the resistance of moisture.
- From the above result, it is evident that BKE as filler using 60/70 penetration grade bitumen in HMA is good. Therefore, the client should use this material as filler.

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APPENDIXIES

APPENDIX – A Physical property of Aggregates Test Results

Table A1: Aggregate Crushing, Value Aggregate impact value and Los angeles abrasion test results

Aggregate Crushing Value

TRIAL No.	1	2	3
Mass of mold and plate (gm)	11920.50	11920.50	11920.50
Mass of sample (14mm pass and 10mm Retain)(M1)	2663.20	2679.80	2667.30
Mass of sample passing B.S Sieve,2.36mm (gm) (M2)	455.40	488.00	462.10
Aggregate Crushing Value (ACV) (%)=(M2/M1)*100	17.10	18.21	17.32
Average ACV (%)	17.54		

Aggregate impact value

TRIAL No.	1.00	2.00	3.00
mold (g)	2749.50	2745.60	2745.60
mold + sample	3433.70	3486.60	3412.40
sample (M1)	720.50	737.10	750.40
weight of aggregate passing on seive 2.34mm(gm) (M2)	87.60	81.40	97.70
Aggregate impact value (%)=(M2/M1)*100	12.16	11.04	13.02
Average impact value (%)	12.07		

Los angeles abrasion

TRIAL No.	1.00	2.00	3.00
NUMBER OF REVOLUTION	500.00	500.00	500.00
TOTAL WT. OF SAMPLE TESTED, (g) (M1)	5000.00	5000.00	5000.00
WT. TESTED SAMPLE RETAINED No. 12 SIEVE, (g) (M2)	4052.40	4028.50	4061.50
PERCENT LOSS (%)=(M1-M2)/M1*100	18.95	19.43	18.77
Average los angeles abrasion (%)	19.05		

Table A2: Aggregatr Flakiness Index test results

Flakiness Index Record						
	Mass					
Separated fraction Size, mm	individual fraction(g)	Sum, M1 (g)	individual fraction % of M1(g)	Sum of masses after discarding 5% or less. M2(g)	mass of flaky passing(g)	Sum, M3(g)
28 to 20	822	4999.5	16.72	4999.5	277	2077
20 to 14	1143		23.25		394.5	
14 to 10	802		16.31		309	
10 to 6.3	2232.5		44.66		1096.5	
FLAKINESS INDEX (%)=(M3/M2)*100						22

Table A3: Specific Gravity and Absorption of Coarse Aggregate

Trial	1	2	3	AVER
S. Mass of SSD sample in air (g)	2000	2000	2000	
B. Mass of basket in water (g)	682.10	678.50	669.5	
C. Basket + Sample in water (g)	1927.10	1932.50	1926	
Mass of saturated sample in water (g)	2019.90	2026.00	2011	
A. Mass of oven dry sample in air	1993.40	1992.50	1993.5	

oC	18	19	20	21	22	23	24	25	26	27	28 29
K	1.0004	1.0002	1	0.9998	0.9996	0.9993	0.999	0.9991	0.9986	0.999	0.998 0.9977

	1	2	3	AVER
Bulk sp. gravity (oven dry) Sd = A*k/S-(C-B)	2.638	2.667	2.679	2.661
Bulk sp. gravity (SSD) Ss = S*k/S-(C-B)	2.647	2.677	2.688	2.670
Apparent specific gravity Sr = A*k/A-(C-B)	2.661	2.694	2.702	2.686
Water absorption Aw = (S-A)*100/A	0.331	0.376	0.326	0.345

Table A4: Specific Gravity and Absorption of Medium Aggregate

Trial					1		2		3		AVER
S. Mass of SSD sample in air (g)					2000		2000		2000		
B. Mass of basket in water (g)					678.00		673.60		677.7		
C. Basket + Sample in water (g)					1926.00		1930.50		1922		
Mass of saturated sample in water (g)					2018.40		2021.30		2012.7		
A. Mass of oven dry sample in air					1993.80		1991.80		1990.6		
oC	18	19	20	21	22	23	24	25	26	27	28 29
K	1.0004	1.0002	1	0.9998	0.9996	0.9993	0.999	0.9991	0.9986	0.999	0.998 0.9977
Bulk sp. gravity (oven dry) Sd = A*k/S-(C-B)					2.649		2.677		2.632		2.652
Bulk sp. gravity (SSD) Ss = S*k/S-(C-B)					2.657		2.688		2.644		2.663
Apparent specific gravity Sr = A*k/A-(C-B)					2.671		2.707		2.665		2.681
Water absorption Aw = (S-A)*100/A					0.311		0.321		0.351		0.328

Table A5: Specific Gravity and Absorption of Fine Aggregate

Trial					1		2		3		AVER
S. Mass of SSD sample in air (g)					2000		2000		2000		
B. Mass of basket in water (g)					676.70		672.60		675.5		
C. Basket + Sample in water (g)					1915.00		1913.54		1912.4		
Mass of saturated sample in water (g)					2017.70		2019.00		2020		
A. Mass of oven dry sample in air					1994.60		1991.60		1993		
oC	18	19	20	21	22	23	24	25	26	27	28 29
K	1.0004	1.0002	1	0.9998	0.9996	0.9993	0.999	0.9991	0.9986	0.999	0.998 0.9977
Bulk sp. gravity (oven dry) Sd = A*k/S-(C-B)					2.616		2.620		2.609		2.615
Bulk sp. gravity (SSD) Ss = S*k/S-(C-B)					2.623		2.631		2.619		2.624
Apparent specific gravity Sr = A*k/A-(C-B)					2.635		2.649		2.634		2.639
Water absorption Aw = (S-A)*100/A					0.271		0.321		0.351		0.314

APPENDIX – B Physical Property of Bitumen Test Results

Table B1: Test Records of Penetration, Ductility, Softening point, and flash point

	Test Method	Test no	Test Temp(degree celcious	Time of Test (S)	Test Load (g)	Reading Date (0.1mm)			Average(0.1mm
						1st Time	2nd time	3rd time	
Penetration	AASHTO T 49	1	25	5	100	59	59.8	60.77	59.86
		2	25	5	100	67.87	68.57	69.98	68.81
		3	25	5	100	61.66	62.43	63.86	62.65
AASHTO T 49									63.77

	Test Method	Test No	Test Temp(degree celcious	Speed (cm/min)	Ductility (cm)	Average (cm)
Ductility	AASHTO T 51	1	25^0c	5	92	94
		2	25^0c	5	94	
		3	25^0c	5	96	

	Test Method	Test no	Temp. when starting heating (degree celcious)		Record of liquid Temp in beaker			Softening point
					4min	5min	6min	
Softening point	AASHTO T 53	1	7		4			52.3
		2	7		4			52.5
	Average							52.4

	Test Method	Flash Point
Flash Point	AASHTO T 48	292

Table B2: Specific Gravity of Bituminous Materials

Source:		Asphalt Batching Plant	
Trial		1	2
1. Weight of Pycnometer , g		102.73	104.13
2. Weight of Pycnometer Filled With Sample, g		168.16	167.58
3. Weight of Pycnometer Filled with Water , g @ 25 ± 0.10C		245.58	248.42
4. Weight of Pycnometer + Sample + Water , g @ 25± 0.10C		248.80	250.19
5. Weight of Water replaced by Sample , g {(3-1)+2} – 4		61.21	61.7
6. Specific Gravity ,(2-1)/5		1.053	1.028
7. Average Specific Gravity (g/ Cm3)		1.041	

APPENDIX – C Properties of Mineral Fillers Test Results

TEST METHOD: ASTMD242

Table C1: Physical Properties of Crushed Stone Dust Filler

Material Type :						Crushed Stone Dust		
Trial No						1.00	2.00	3.00
Mass of Pycnometer ,(g)						30.62	30.50	30.40
Mass of Pycnometer soil and Water,g (Wb)						142.00	144.50	143.60
Final Temperature (^{o}c),Tx				k=0.9991		25.00	25.00	25.00
Mass of Soil ,(g)) (Wo)						26.00	26.00	26.70
Mass of Pycnometer with Water at Final Temp,Tx (g) (Wa)						126.40	127.50	127.90
Apparent Specific Gravity ,Gs=(Wo/Wo+(Wa-Wb))*K						2.56	2.89	2.43
Average Apparent Specific Gravity						2.63		

Table C2: Physical Properties of Eggshell powder

Material Type :						Eggshell powder		
Trial No						1.00	2.00	3.00
Mass of Pycnometer ,(g)						31.20	31.40	30.30
Mass of Pycnometer soil and Water,g (Wb)						141.80	141.30	142.00
Final Temperature (^{o}c),Tx				k=0.9991		25.00	25.00	25.00
Mass of Soil ,(g)) (Wo)						26.00	26.00	26.00
Mass of Pycnometer with Water at Final Temp,Tx (g) (Wa)						127.10	126.10	126.30
Apparent Specific Gravity ,Gs=(Wo/Wo+(Wa-Wb))*K						2.30	2.41	2.53
Average Apparent Specific Gravity						2.41		

Table C3: Physical Properties of Khat ash

Material Type :						Khat ash		
Trial No						1.00	2.00	3.00
Mass of Pycnometer ,(g)						30.30	31.10	30.60
Mass of Pycnometer soil and Water,g (Wb)						142.70	141.10	141.30
Final Temperature (^{o}c), Tx				k=0.9991		25.00	25.00	25.00
Mass of Soil ,(g)) (Wo)						26.00	26.00	26.00
Mass of Pycnometer with Water at Final Temp,Tx (g) (Wa)						127.30	126.70	126.00
Apparent Specific Gravity ,Gs=(Wo/Wo+(Wa-Wb))*K						2.46	2.24	2.43
Average Apparent Specific Gravity						2.38		

Table C4: Physical Properties of Blending of Khat ash and Eggshell powder

Material Type :						Blending of KA and ESP		
Trial No						1.00	2.00	3.00
Mass of Pycnometer ,(g)						30.20	31.00	30.30
Mass of Pycnometer soil and Water,g (Wb)						142.20	141.50	142.00
Final Temperature (^{o}c), Tx					k=0.9991	25.00	25.00	25.00
Mass of Soil ,(g)) (Wo)						26.00	26.00	26.00
Mass of Pycnometer with Water at Final Temp,Tx (g) (Wa)						126.60	127.00	126.70
Apparent Specific Gravity ,Gs=(Wo/Wo+(Wa-Wb))*K						2.50	2.26	2.43
Average Apparent Specific Gravity						2.40		

Table C5: Chemical composition of Blending of KA and ESP, KA and ESP

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	GEOCHEMICAL LABORATORY DIRECTORATE		Page 1 of 1
Document Title:	Complete Silicate Analysis Report	Effective date:	May, 2017

Issue Date: -28/07/2021

Customer Name:-Bereket Ayele

Request No:- GLD/RQ/1142/21

Report No:- GLD/RN/693/21

Sample type :Blending of KA & ESP(BA01),Khat Ash (BA02) & Egg Shell Powder (BA03)

Sample Preparation: - 200 Mesh

Date Submitted :-17/06/2021

Number of Sample:-Three(03)

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

Analytical Method: $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
BA-01	56.80	8.02	5.47	20.01	5.01	0.31	1.00	0.22	0.52	0.20	0.81	0.50
BA-02	51.41	9.74	5.01	23.04	6.11	0.62	1.84	0.19	0.43	0.31	0.12	0.64
BA-03	56.22	8.00	4.11	22.32	5.93	0.11	0.23	0.10	0.31	0.15	0.90	1.35

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

Analysts	Checked By	Approved By	Quality Control
Lidet Endeshaw Nigist Fikadu Elisa Fisha	Tizita Zemene	Yohannes Getachew	Gosa Haile

APPENDIX – D Particle Size Distribution of Aggregate

Test method ASTEM D3515

Table D1: Aggregates graduation for filler 4.5%

Sieve size (mm)	Retained (gm)	Retained %	pass %	Combined asphalt aggregate limit	
				Lower limit	Upper limit
25	0	0	100	100	100
19	116.4	9.7	90.3	90	100
12.5	145.2	12.1	78.2	71	88
9.5	138	11.5	66.7	56	80
4.75	217.32	18.11	48.6	35	65
2.36	175.2	14.6	34	23	49
1.18	163.2	13.6	20.4	15	37
0.6	52.68	4.39	16	10	28
0.3	42	3.5	12.5	5	19
0.15	54	4.5	8	4	13
0.075	42	3.5	4.5	2	8
pan	54	4.5	4.5		
Total	1200	100			

Table D2: Aggregate gradation for filler 5.5%

Sieve size (mm)	Retained (gm)	Retained %	pass %	Combined asphalt aggregate limit	
				Lower limit	Upper limit
25	0	0	100	100	100
19	66	5.5	94.5	90	100
12.5	121.2	10.1	84.4	71	88
9.5	176.4	14.7	69.7	56	80
4.75	258	21.5	48.2	35	65
2.36	188.4	15.7	32.5	23	49
1.18	79.2	6.6	25.9	15	37
0.6	108	9	16.9	10	28
0.3	86.4	7.2	9.4	5	19
0.015	13.2	1.1	8.6	4	13
0.075	37.2	3.1	5.5	2	8
pan	66	5.5	5.5		
Total	1200	100			

Table D3: Aggregate gradation for filler 6.5%

Sieve size (mm)	Retained (gm)	Retained %	pass %	Combined asphalt aggregate limit	
				Lower limit	Upper limit
25	0	0	100	100	100
19	93.6	7.8	92.2	90	100
12.5	124.8	10.4	81.8	71	88
9.5	153.6	12.8	69	56	80
4.75	301.2	25.1	43.9	35	65
2.36	148.8	12.4	31.5	23	49
1.18	138	11.5	20	15	37
0.6	50.4	4.2	15.8	10	28
0.3	19.2	1.6	8.2	5	19
0.015	62.4	5.2	6	4	13
0.075	30	2.5	6.5	2	8
pan	78	6.5	6.5		
Total	1200	100			

APPENDIX – E Marshall Test Results

Table E1: Marshall Test Results Prepared by 4.5 % Crushed Stone Dust Filler Content by Weight of Total Mix MARSHALL PROPERTIES OF BITUMINOUS MIXTURE ASTM D1559/AASHTO T 245

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Specimen t No	Bitumen content %	Height of specimen (cm)	Weight of specimen t in air (gm)	Wt of spacimen t in water (gm)	Wt of spacimen t in SDD (gm)	Bulk volume (cc)	Bulk SG comp mix(Gmb) (cc)	max spacific gravity (Gmm)	Air void	VMA %]	VFA %	Marshal stability KN			Flow (mm)
						E-D	C/F		(H-G) *100/H	(100-[(Gsb*Pa/ Gsb)	100*(J-I)/J	Load	Coff factor	Corrected load N*M*ring factor	
1	4%	6.9	1229.5	700.5	1230.5	530.0	2.31981					10.34	0.88975	9.20	3.40
2		6.8	1230.0	701.0	1231.5	530.5	2.31857					10.20	0.79118	8.07	2.75
3		7.0	1232.5	704.0	1234.0	530.0	2.32547					10.29	0.89213	9.18	3.10
Average		6.9	1230.7	701.8	1232.0	530.2	2.32128	2.465	5.8	13.7	57.4	10.28	0.85793	8.82	3.08
1	4.50%	6.8	1230.0	709.0	1232.0	523.0	2.35182					14.62	0.76334	11.16	3.09
2		7.0	1234.0	706.5	1236.5	530.0	2.3283					12.11	0.77209	9.35	3.20
3		7.0	1233.0	707.0	1234.5	527.5	2.33744					13.70	0.79854	10.94	3.40
Average		6.9	1232.3	707.5	1234.3	526.8	2.33913	2.459	4.9	13.5	63.9	13.48	0.77789	10.48	3.23
1	5%	6.9	1233.5	710.0	1234.0	524.0	2.35401					14.57	0.82498	12.02	3.04
2		6.8	1235.0	709.0	1236.0	527.0	2.34345					13.47	0.89384	12.04	3.29
3		6.9	1234.5	708.0	1235.5	527.5	2.34028					14.04	0.83333	11.70	3.62
Average		6.9	1234.3	709.0	1235.2	526.2	2.3459	2.432	3.5	13.7	74.2	14.03	0.84981	11.92	3.32
1	5.50%	6.8	1234.0	712.0	1235.0	523.0	2.35946					12.62	0.82488	10.41	3.70
2		6.8	1236.5	713.0	1237.5	524.5	2.35748					14.62	0.75787	11.08	3.50
3		6.8	1237.0	715.5	1238.0	522.5	2.36746					14.00	0.78571	11.00	3.34
Average		6.8	1235.8	713.5	1236.8	523.3	2.36146	2.427	2.7	13.6	80.1	13.75	0.78783	10.83	3.51
1	6%	6.9	1238.5	714.5	1239.5	525.0	2.35905					10.59	0.88480	9.37	3.70
2		6.8	1238.0	717.0	1240.0	523.0	2.36711					11.00	0.90000	9.90	3.61
3		6.7	1240.0	718.5	1241.0	522.5	2.37321					10.64	0.88346	9.40	3.71
Average		6.8	1238.8	716.7	1240.2	523.5	2.36644	2.405	1.6	13.9	88.5	10.74	0.88954	9.56	3.67

Table E2: Marshall Test Results Prepared by 5.5 % Crushed Stone Dust Filler Content by Weight of Total Mix MARSHALL PROPERTIES OF BITUMINOUS MIXTURE ASTM D1559/AASHTO T 245

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Specimen t No	Bitumen content %	Height of specimen (cm)	Weight of specimen t in air (gm)	Wt of spacimen t in water (gm)	Wt of spacimen t in SDD (gm)	Bulk volume (cc)	Bulk SG comp mix(Gmb) (cc)	max spacific gravity (Gmm)	Air void	VMA %]	VFA %	Marshal stability KN			Flow (mm)
									(H-G) *100/H	(100-[(Gsb*Pa/ Gsb)	100*(J-I)/J	Load	Coff factor	Correcte d load	
						E-D	C/F							N*M*rin g factor	
1	4%	6.9	1233.0	700.0	1234.5	534.5	2.30683					10.34	0.79304	8.20	3.12
2		6.8	1235.0	704.0	1236.5	532.5	2.31925					10.20	0.91569	9.34	2.96
3		7.0	1233.5	705.0	1234.5	529.5	2.32956					10.29	0.93975	9.67	3.34
Average		6.9	1233.8	703.0	1235.2	532.2	2.31851	2.465	5.9	13.8	56.9	10.28	0.88258	9.07	3.14
1	4.50%	6.8	1235.0	710.0	1237.5	527.5	2.34123					14.62	0.83174	12.16	3.44
2		7.0	1239.0	705.5	1240.5	535.0	2.31589					12.11	0.88026	10.66	3.34
3		7.0	1238.0	711.0	1240.0	529.0	2.34026					13.70	0.87445	11.98	3.08
Average		6.9	1237.3	708.8	1239.3	530.5	2.33239	2.459	5.1	13.8	62.7	13.48	0.86075	11.60	3.29
1	5%	6.9	1238.5	711.0	1240.0	529.0	2.34121					14.57	0.87989	12.82	3.34
2		6.8	1240.0	710.0	1241.5	531.5	2.33302					13.47	0.94581	12.74	3.45
3		6.9	1239.0	714.0	1241.5	527.5	2.34882					14.04	0.91595	12.86	3.16
Average		6.9	1239.2	711.7	1241.0	529.3	2.34099	2.432	3.7	13.9	73.1	14.03	0.91302	12.81	3.32
1	5.50%	6.8	1249.0	720.0	1251.5	531.5	2.34995					12.62	0.90967	11.48	3.65
2		6.8	1245.5	718.5	1246.5	528.0	2.3589					14.62	0.81259	11.88	3.47
3		6.8	1247.0	719.5	1248.0	528.5	2.35951					14.00	0.85714	12.00	3.40
Average		6.8	1247.2	719.3	1248.7	529.3	2.35611	2.427	2.9	13.8	78.8	13.75	0.85742	11.79	3.51
1	6%	6.9	1260.5	724.5	1261.5	537.0	2.3473					10.59	0.88480	9.37	3.50
2		6.8	1253.0	725.0	1254.0	529.0	2.36862					11.00	0.90000	9.90	3.78
3		6.7	1255.0	726.5	1256.0	529.5	2.37016					10.64	0.97744	10.40	3.61
Average		6.8	1256.2	725.3	1257.2	531.8	2.36196	2.405	1.8	14.0	87.2	10.74	0.92057	9.89	3.63

Table E3: Marshall Test Results Prepared by 6.5% Crushed Stone Dust Filler Content by Weight of Total Mix MARSHALL PROPERTIES OF BITUMINOUS MIXTURE ASTM D1559/AASHTO T 245

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Specimen t No	Bitumen content %	Height of specimen (cm)	Weight of specimen t in air (gm)	Wt of spacimen t in water (gm)	Wt of spacimen t in SDD (gm)	Bulk volume (cc)	Bulk SG comp mix(Gmb) (cc)	max spacific gravity (Gmm)	Air void	VMA %]	VFA %	Marshal stability KN			Flow (mm)
									(H-G) *100/H	(100-[(Gsb*Pa/ Gsb)	100*(J-I)/J	Load	Coff factor	Corrected load N*M*ring factor	
						E-D	C/F								
1	4%	6.9	1239.5	704.0	1238.0	534.0	2.32116					10.34	0.85106	8.80	3.10
2		6.8	1242.0	705.0	1240.5	535.5	2.31933					10.20	0.88922	9.07	2.78
3		7.0	1240.0	706.0	1238.0	532.0	2.33083					10.29	1.03984	10.70	3.10
Average		6.9	1240.5	705.0	1238.8	533.8	2.32376	2.521	7.8	13.6	42.5	10.28	0.92669	9.52	2.99
1	4.50%	6.8	1241.0	711.0	1240.0	529.0	2.34594					14.62	0.71819	10.50	3.01
2		7.0	1246.0	711.5	1244.5	533.0	2.33771					12.11	0.87036	10.54	3.04
3		7.0	1245.0	710.0	1243.0	533.0	2.33583					13.70	0.87153	11.94	3.00
Average		6.9	1244.0	710.8	1242.5	531.7	2.33981	2.502	6.5	13.4	51.6	13.48	0.81573	10.99	3.02
1	5%	6.9	1245.0	715.0	1244.0	529.0	2.3535					14.57	0.79341	11.56	3.08
2		6.8	1247.0	713.0	1246.0	533.0	2.33959					13.47	0.93912	12.65	3.44
3		6.9	1245.0	713.0	1244.5	531.5	2.34243					14.04	0.81909	11.50	3.12
Average		6.9	1245.7	713.7	1244.8	531.2	2.34515	2.482	5.5	13.7	59.8	14.03	0.84862	11.90	3.21
1	5.50%	6.8	1252.0	720.0	1251.5	531.5	2.3556					12.62	0.97623	12.32	3.44
2		6.8	1251.0	718.5	1250.0	531.5	2.35372					14.62	0.86662	12.67	3.40
3		6.8	1254.5	719.5	1253.0	533.5	2.35145					14.00	0.85571	11.98	3.40
Average		6.8	1252.5	719.3	1251.5	532.2	2.35359	2.461	4.4	13.8	68.4	13.75	0.89646	12.32	3.41
1	6%	6.9	1266.5	724.5	1264.0	539.5	2.34754					10.59	1.08593	11.50	3.56
2		6.8	1260.5	721.0	1258.0	537.0	2.3473					11.00	0.98000	10.78	3.40
3		6.7	1259.5	721.5	1257.5	536.0	2.34981					10.64	1.03195	10.98	3.71
Average		6.8	1262.2	722.3	1259.8	537.5	2.34822	2.446	4.0	14.5	72.4	10.74	1.03196	11.09	3.56

APPENDIX – F Partial RR with BKE in Marshal Properties Test Results

Table F1: Partial Replacement of filler materials with Blending of Khat ash and Eggshell powder with 5.18% OBC and 5.5% OFC

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Specimen t No	Bitumen content %	Height of specimen (cm)	Weight of specimen t in air (gm)	Wt of spacimen t in water (gm)	Wt of spacimen t in SDD (gm)	Bulk volume (cc)	Bulk SG comp mix(Gmb) (cc)	max spacific gravity (Gmm)	Air void	VMA %]	VFA %	Marshal stability KN			Flow (mm)
						E-D	C/F		(H-G) *100/H	(100-[(Gsb*Pa/ Gsb)	100*(J-I)/J	Load	Coff factor	Corrected load N*M*ring factor	
1	4%	6.9	1244.0	717.0	1245.5	528.5	2.35383					10.34	1.15861	11.98	3.20
2		6.8	1246.0	719.0	1247.5	528.5	2.35762					10.20	1.26275	12.88	3.12
3		7.0	1247.0	724.0	1248.0	524.0	2.37977					10.29	1.31778	13.56	2.67
Average		6.9	1245.7	720.0	1247.0	527.0	2.36369	2.465	4.1	13.1	68.6	10.28	1.24619	12.81	3.00
1	4.50%	6.8	1232.0	709.0	1233.0	524.0	2.35115					14.62	0.78317	11.45	2.87
2		7.0	1232.5	702.0	1234.0	532.0	2.31673					12.11	0.81503	9.87	3.34
3		7.0	1234.0	699.0	1236.0	537.0	2.29795					13.70	0.73577	10.08	3.44
Average		6.9	1232.8	703.3	1234.3	531.0	2.32172	2.44	4.8	14.6	66.8	13.48	0.77665	10.47	3.22
1	5%	6.9	1239.0	709.5	1240.0	530.5	2.33553					14.57	0.80096	11.67	3.09
2		6.8	1238.5	704.0	1241.0	537.0	2.30633					13.47	0.87454	11.78	2.98
3		6.9	1240.5	711.0	1241.5	530.5	2.33836					14.04	0.8141	11.43	3.30
Average		6.9	1239.3	708.2	1240.8	532.7	2.32666	2.43	4.3	14.4	70.5	14.03	0.8289	11.63	3.12
1	5.50%	6.8	1253.0	717.0	1254.5	537.5	2.33116					12.62	0.95721	12.08	3.56
2		6.8	1250.0	717.0	1251.0	534.0	2.34082					14.62	0.87415	12.78	3.21
3		6.8	1251.0	715.0	1252.5	537.5	2.32744					14.00	0.99	13.86	2.56
Average		6.8	1251.3	716.3	1252.7	536.3	2.33313	2.42	3.6	14.2	74.7	13.75	0.93889	12.91	3.11
1	6%	6.9	1258.5	710.5	1250.0	539.5	2.33272					10.59	1.11426	11.80	3.44
2		6.8	1249.0	709.0	1250.0	541.0	2.30869					11.00	1.07909	11.87	3.31
3		6.7	1253.0	709.0	1254.5	545.5	2.29698					10.64	1.09492	11.65	3.33
Average		6.8	1253.5	709.5	1251.5	542.0	2.31273	2.41	4.0	14.9	72.9	10.74	1.09587	11.77	3.36

APPENDIX – G Moisture susceptibility Test Results

Table G1: Moisture susceptibility with TSR parameter test result at 24% BKE and boundaries and 100% CSD fillers

			Resistance of compacted bituminious mixture to moisture damage										
			layer asphalt wearing course							Source of bitumen **ERA**			
			Compaction 75 blow per side							Grade of bitumen **60/70**			
			Specific gravity of Bitumen 1.012 Mix type 19mm NMAS										
Trial	BKE	WetP(KN)	WetP(N)	Dry P(KN)	Dry P(N)	PI (Π)	Thickness wet (mm)	Thickness dry (mm)	Diameter (mm)	St_2	St_1	TSR	Average TSR (%)
1	24%	7.55	7635	9.42	9448	3.14	68.76	69.46	100	705.2608	864.7654	0.815593	**82.56%**
2		8.03	8008	9.57	9778	3.14	68.91	70.33	100	738.8796	883.8754	0.837655	
3		7.7	7618	9.51	9508	3.14	69	68.92	100	710.5656	881.9086	0.823456	
										Mean		0.825568	
Trial	BKE	WetP(KN)	WetP(N)	Dry P(KN)	Dry P(N)	PI (Π)	Thickness wet (mm)	Thickness dry (mm)	Diameter (mm)	St_2	St_1	TSR	Average TSR (%)
1	16%	7.53	7530	9.42	9448	3.14	69.33	68.66	100	691.7898	864.0695	0.800618	**81.22%**
2		7.31	7310	9.57	9778	3.14	70	69	100	665.1501	885.7244	0.832456	
3		7.94	7940	9.51	9508	3.14	70	69.33	100	722.475	882.2203	0.803456	
										Mean		0.812177	
Trial	BKE	WetP(KN)	WetP(N)	Dry P(KN)	Dry P(N)	PI (Π)	Thickness wet (mm)	Thickness dry (mm)	Diameter (mm)	St_2	St_1	TSR	Average TSR (%)
1	32%	7.5	7657	9.68	9546	3.14	68.45	69.45	100	693.342	843.7652	0.791001	**79.11%**
2		7.37	7256	9.65	9744	3.14	69	69.56	100	653.765	883.5673	0.790011	
3		7.89	7768	9.57	9654	3.14	68.02	69	100	715.987	880.4529	0.790011	
										687.698	869.2618	0.812177	
Trial	CSD	WetP(KN)	WetP(N)	Dry P(KN)	Dry P(N)	PI (Π)	Thickness wet (mm)	Thickness dry (mm)	Diameter (mm)	St_2	St_1	TSR	Average TSR (%)
1	100%	7.742	7742	9.52	9520	3.14	69.33	69	100	711.2664	878.7963	0.802348	**82.08%**
2		7.84	7840	9.42	9420	3.14	69.66	70	100	716.8577	857.1429	0.829995	
3		8.12	8120	9.931	9931	3.14	68.66	69.33	100	753.2733	912.3724	0.830112	
										Mean		0.820818	

APPENDIX – H Sample Pictures during Laboratory Test


Burning of Khat


Sieve the burning khat to get the required ash


Dry Eggshell to get the required powder

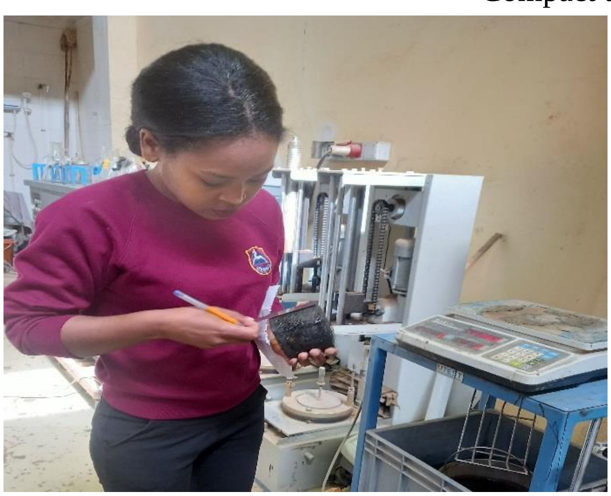
Sieve the aggregates to get crushed stone dust filler

Sieve the aggregates and arrange by each size

Prepare the aggregates for Marshall Mix

Put the aggregate and fillers in oven and then mix

Compact the mixes



Measuring and Weighting the specimen

Weighting the specimen in water and after drying by cloth

Put the specimen in water bath and ready for flow and stability test results

Recording the flow and stability test results