JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDENTS
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIROMEMTAL ENGINEERING
HIGHWAY ENGINEERING STREAM

# Partial Replacement of Blended Corncob Ash and Saw Dust Ash as a Filler Material in Hot Mix Asphalt

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering).

By:
Ahadu Mengist

December, 2019
Jimma, Ethiopia

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Advisor: Engr. Elmer C.Agon (Ass Prof.)
Co-Advisor: Engr. Abel Tesfaye (Msc.)

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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 Blended Corncob ash and Saw dust ash as a filler Material in 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 other University, and all sources of materials used for this thesis have been duly acknowledged.

Candidate:

Ahadu Mengist

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As Master's research Advisors, We here by certify that we have read and evaluated this MSc Thesis prepared under our guidance by Ahadu Mengist entitled."Partial Replacement of Blended Corncob ash and Saw dust ash as a filler Material in Hot Mix Asphalt"

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

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## ABSTRACT

*The government of Ethiopia has allocated a huge amount of resources to upgrade the existing road network nationwide. In connection to this, in Ethiopia, most of the trunk, link roads and some economically sensitive area roads are constructed and rehabilitated using asphalt concrete.*

*In the construction of highway pavements, one of the main problems is insufficient amount of crushed stone dust from crushing of aggregates. Crushed stone dust is the most commonly used filler for hot mix asphalt construction in Ethiopia. Hence, it is important to see alternative mineral filler materials that could be replaced crushed stone dust partially or if it is possible fully. Thus, this study was conducted with this intention.*

*The objective of this research is partial replacement of blended corncob ash and saw dust ash as mineral filler in hot mix asphalt. Materials needed are aggregates, bitumen, crushed stone dust, corncob ash and saw dust ash. For all the materials quality test was done. to determine OBC and OFC three different gradations were prepared by varying amount of crushed stone dust (4.5%, 5.5% and 6.5% by weight of aggregates) with five different bitumen contents (4%, 4.5%, 5%, 5.5% and 6% by weight of total mix). The OBC and OFC at different values of crushed stone dust filler was selected based on NAPA (National Asphalt Pavement Association) curve plotting method. The replacement ratio of blended corncob ash and saw dust ash was 10 % (by weight of optimum filler content) by trial and error method.*

*According to the laboratory quality test results compared with the standard specification all the materials satisfied the criteria. Based on the results of Marshall Stability test 5.5% crushed stone dust and 5% bitumen content were OFC and OBC respectively. The potential of blended corncob ash and saw dust ash to be replaced crushed stone dust was 50% (by weight of OFC) after 50 % it cannot satisfied the standard requirements. To determine the optimum replacement ratio of BCSA it was based on Marshall Property test result values of maximum stability, maximum bulk density and air voids (VA, %) within the allowed range of specification. The values at 40% BCSA (by weight of OFC) replacement were stability of 10.06 KN, Bulk-Density of 2.375gm/cm$^3$ and Air void (VA) of 4% which were the best when compared to other percentage replacement ratio values. Hence 40% (by weight of OFC) is adopted as the optimum replacement ratio of blended corncob ash and saw dust ash.*

***Key-words; blended Corncob ash &Saw dust ash, crushed stone dust, Marshall Stability, Hot mix Asphalt***

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# ACRONYMS

| | |
|---|---|
| AACRA | Addis Ababa City Road Authority |
| AASHTO | American Association of State Highway and Transportation Officials |
| AC | Asphalt Content |
| ACV | Aggregate Crushing Value |
| AIV | Aggregate Impact Value |
| $Al_2O_3$ | Aluminum Oxide |
| ASTM | American Society for Testing Of Materials |
| BCSA | Blended corncob ash and saw dust ash |
| BS | British Standard |
| CaO | Calcium Oxide |
| CCA | Corncob Ash |
| CBR | California Bearing Ratio |
| CKO | Cement Kiln Dust |
| CSD | Crushed Stone Dust |
| EAPA | European Asphalt Pavement Association |
| ERA | Ethiopian Road Authority |
| FAA | Fine Aggregate Angularity |
| FAO | Food and Agriculture Organization |
| Fe2O3 | Iron Oxide |
| Gb | Specific gravity of Asphalt |
| Gmb | Bulk Specific gravity |
| Gmm | Maximum Specific gravity |
| Gsb | Bulk Specific gravity of Aggregate |
| GGKS | Ground Granulated Blast Furnace Slag |
| HMA | Hot mixed asphalt |
| LAA | Los Angles Abrasion |
| LKD | Lime Kiln Dust |
| MC | Medium Curing |
| NAPA | National Asphalt Pavement Association |
| NP | Non-Plasticity |
| OBC | Optimum Bitumen Content |

| | |
|---|---|
| OFC | Optimum Filler Content |
| RC | Rapid Curing |
| SC | Slow Curing |
| SDA | Saw Dust ash |
| SiO2 | Silicon Dioxide |
| USC | Unconfined compressive strength |
| VFA | Voids filled by Bitumen |
| VIM | Voids in total mix |
| VMA | Voids in Mineral Aggregates |
| Wt. | Weight |
| % | Percent |
| ℃ | Degree centigrade |
| μm | Micrometer |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

The government of Ethiopia has allocated a huge amount of resources to upgrade the existing road network nationwide. Nowadays in Ethiopia, most of the trunk roads, link roads and some economically sensitive area roads are constructed and rehabilitated using asphalt concrete according to (Anteneh, 2014).

Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. The construction industry has been identified as one of the areas where the waste can be absorbed, with the majority of such materials used as filler in concrete (Antihos et al., 2005). If these fillers have pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved (Hossain, 2003). Approximate utilization of these materials brings ecological and economic benefits.

Many literatures published on reuse of waste materials as raw materials in Hot Mix Asphalt Concrete (HMAC). Generally, there are three ways to state waste materials into HMAC. The first one is to introduce the waste material use as a modifier to the asphalt binder. Studies have shown that, when asphalt binder is modified with addition of rubber, polymer and many other waste materials, HMAC exhibit better properties (Yildirim, 2007; Ghasemi & Marandi, 2013; Mohammed, 2013).

The second advancement is solid waste materials use as replacement of conventional filler and aggregates in HMAC. Conclusions from several studies confess the importance of the filler used in asphalt concrete (Rocksana & Md. Kamal, 2017; Zulkati, et al., 2011). Furthermore, it is globally accepted that the natural filler can be replaced with any suitable material either natural or artificial (Tapkin, 2008). The third method is to use additives such as polymers and fibers to HMAC in addition to the binders and aggregates.

Waste material recycling into useful products has been the current method of solving waste problems (Ahmed, 2006). Material recycling has been a common practice for most of human history (Grosse, 2010). Recycling is a process to change 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 such wastes (Grosse, 2010).Many highway agencies are conducting wide variety of studies and research work on the feasibility, environmental suitability, and performance of using recycled products in highway construction (Ahmed, 2006).

The purpose of this study is to evaluate blended corncob ash and saw dust ash using as partial replacement of conventionally used filler materials such as crushed stone dust in hot mix asphalt concrete by preparing laboratory test samples with different percentage replacement rates. Marshall Properties like Stability, flow and volumetric properties are evaluated by the method of Marshall Mix design.

## 1.2. Statement of the Problem

Researches in the literature review shows that modification made regarding the ingredients of bituminous mixtures such as type of ingredient materials and relative proportion has altered. Some studies in the literature review proved that mineral fillers have indispensable role in the performance of hot mix asphalt. Depending on the filler characteristics, it was found that their purpose was not only to fill the voids but also modifying the mixture. The importance of filler in asphalt cannot be ignored in that the general effect of adding it to asphalt mixture is to make it harder and stiffer and helps to produce a dense graded strong material. (Kar, 2012).

In the construction of highway pavements, one of the main problems is insufficient amount of crushed dust from crushing of aggregates. Crushed dust also known as stone dust is the most commonly used filler in bituminous construction in Ethiopia. Moreover, there is also environmental deterioration resulting from blasting of more quarry areas to produce the required amount of mineral filler and its mode of production is expensive. Therefore, it is important to see an alternative mineral filler material that can replaced it partially or fully if it is possible by doing laboratory tests. Thus, this study was conducted with this intention.

Recent researches have focused on the use of locally available waste materials as possible substitute for cement or limestone dust as mineral filler in asphalt mixture (Adesanya and Raheem 2010).This research was aimed or focused at evaluating the suitability of blending of saw dust ash and corncob ash by equal amount as mineral filler in HMA asphalt production.

## 1.3 Research Questions

1) What are the physical properties of Aggregates, Crushed stone dust, Bitumen, Corncob ash and Saw dust ash In Hot Mix Asphalt?
2) What is the potential blend ratio of corncob ash and saw dust ash to be replaced a crushed stone dust in Hot Mix Asphalt as a filler material?
3) What is the optimum content of blended corncob ash and saw dust ash replaced crushed stone dust in Hot Mix Asphalt?
4) How the blended corncob ash and saw dust ash is utilized in Hot Mix Asphalt production as a filler material?

## 1.4 Objectives

### 1.4.1 General objective

The main objective of this research work is to evaluate the suitability of blended saw dust ash and corncob ash, as partial replacement for mineral filler in asphalt production. The aim of this study was achieved by the following specific objectives.

### 1.4.2 Specific Objectives

Specifically, this research was conducted on the following objectives.

1) To determine the physical properties of aggregates, crushed stone dust, Bitumen, corncob ash and saw dust ash for using in Hot Mix Asphalt concrete production.
2) To determine the potential blend ratio of corncob ash and saw dust ash to be replaced crushed stone dust filler in Hot Mix Asphalt Concrete.
3) To determine the optimum content of blended corncob ash & saw dust ash replaced crushed stone dust in Hot Mix Asphalt.
4) To suggest the utilization of blended corncob ash and saw dust ash for Hot Mix Asphalt concrete production.

## 1.5 Significance of the study

Crushed Stone dust is the main material that is used as a filler material in hot mix asphalt concrete production. This research was focused on replacing of crushed stone dust filler partially by blended corncob ash and saw dust ash. Currently the amount crushed stone dust that gets from crushing of aggregates is insufficient. Due to the intention of this insufficient amount, this research was focused on replacing of crushed stone dust fillers partially or if it is possible fully by blended corncob ash and saw dust ash by determining all the necessary engineering properties. No attention is given to replace the mineral fillers of Hot Mix Asphalt concrete by local available waste materials like corncob ash and saw dust ash. Hence the findings of this research work were help to;

- Using the local available waste materials that we get from our surrounding for replacing crushed stone dust fillers in Hot Mix asphalt concrete.
- To make this waste materials well effective and ready for replacing crushed stone dust fillers in Hot Mix asphalt concrete.
- To minimize the problem of insufficient amount of crushed stone dust fillers by replacing local available waste materials.

Generally this research paper was given a clue to those who are interested in conducting research on evaluation of partially replacing asphalt filler by blending corncob ash and saw dust ash.

## 1.6 Scope of the Study

The Scope of this study was to determine the optimum potential use of blended corncob ash and saw dust ash as a partial replacement of crushed stone dust filler in hot mix asphalt production. The study was kept to evaluate hot mix asphalt concrete properties by using of 60/70 asphalt binder; 19mm nominal size mineral aggregate gradation and crushed stone dust partially substitute with blended corncob ash and saw dust ash. The engineering properties of HMA concrete mix used in this research work was carried out by using Marshall Stability test.

## 1.7 Limitation of the Study

The results of this study were depended on set of limitations and criteria that were taken into consideration during the experimental work. These limitations include:

- ✓ This study was examine partially replacing the crushed stone dust filler with blended corncob ash and saw dust ash by using Marshall mix design procedures.
- ✓ Only clean and dry corncob and non-lubricated wanza's saw dust waste materials were used to replace crushed stone dust fillers in this study.

# CHAPTER TWO

# RELATED LITERATURE REVIEW

## 2.1. Introduction

The population growth is continuing rapidly day to day and this leads to increase in the demand of traffic. The traffic demand is increasing day by day, this demand of traffic increases in allowable axle loads. Hence it is need to improve the highway pavement materials. The main purpose of a highway pavement is to provide a suitable surface upon which highway vehicles can operate (Rocksana & Md. Kamal, 2017).

Highway pavement contains of more than one layer of different material supported by a layer called sub grade. Generally, pavement is two type flexible pavement and rigid pavement. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. This pavement structure generally composed of several layers of materials which can accommodate this "flexing". In this type of pavements**,** material layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom (Kar, 2012).

A typical flexible pavement is a composing of various layers. From those layers this study is concerned on 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, an existing pavement, or another HMA binder course (Ontario Provincial Standard Specification, 2002).

Its advantage is distributing the traffic loads, thus stresses transmitted to the pavement foundation will not result in permanent deformation of that layer, (Kar, 2012).


Figure 2. 1: Typical flexible pavement structure layers *(Mohammed, 2013)*

During the past years, asphalt concrete technology has attained a lot of achievements. One of the achievements is the incorporation of industrial wastes as filler in asphalt concrete production with technical, economic and environmental advantages.

Among the various studies conducted, many were concerned with the investigation of effects of aggregates in asphalt performance. These aggregates make up 90 to 95 percent by total weight of the mixture. They are the main influencing the performance of the mixture. Some industrial wastes have been studied for use as supplementary cementing materials such as fly ash (Siddique, 2004; Wang and Baxter; 2007), silica fume (Lee, et. al. 2005; Turker et al. 1977, pulverized fuel ash (Balendran and Martin Buades; 2000), volcanic ash (Hossain, 2005), rice husk ash (Waswa-Sabuni, *et. al.* 2002) and corn cob ash (CCA) (Adesanya and Raheem, 2009a; 2009b; 2010; Raheem, et. al. 2010, Raheem and Adesanya, 2011). Elinwa and Ejeh (2004) considered the effect of waste fly ash in cementing pastes and mortar. Cheah and Ramli (2011) investigated the implementation of wood waste ash as a partial replacement for cement in the production of structural grade concrete and mortar. Elinwa, et al. (2008) assessed the properties of fresh self-compacting concrete containing saw dust ash. Elinwa and Mahmood (2002) considered ash from timber waste as cement replacement material.

One of the roles of a conventional filler material in a bituminous mix is to increase the viscosity of the binder, thereby lessening the risk of stripping. It is now well established that, if a small amount of hydrated lime or cement (say, 1 to 2 percent by mass of the aggregate in the mix) is included as a replacement for some of the conventional filler material, a chemical action will take place between either additive and the bitumen that results in the formation of compounds that are adsorbed on negatively charged aggregate surfaces, and this has the effect of improving adhesion and rendering the bitumen less vulnerable to stripping (Brennan and O‟Flaherty, Addition of filler to asphalt 2002) is to make.it harder and stiffer, which primarily depends on the amount of filler added.

Nowadays the knowledge of natural pozzolanic materials used as partial replacement for cement has increased. Adesanya and Raheem (2010) investigated the permeability and acid attack of corncob ash blended Cement. Jimoh and Apampa (2014) have investigated the effects of corncob ash on the index properties, California bearing ratio (CBR) and unconfined compressive strength (UCS) of Lateritic soil. The maximum dry density of the soil investigated by Jimoh and Apampa (2014), slightly reduced as the corncob ash content increases.

Concrete is a construction material made by mixing of cement, fine aggregates, coarse aggregate and water in the appropriate proportions. It is a mixture of paste and aggregates, or rocks. The paste composed of Portland cement and water coats with fine (small) and coarse (larger) aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Aggregate in a concrete mix consists of coarse aggregate such as granite or limestone and fine aggregate such as sand. Portland cement is the most common type of cement that consists of a mixture of oxides of calcium, silicon and aluminum (Owolabi et al., 2015).There are many materials (rice husk ash, cassava peel ash, corncob ash, Guinea Corn husk Ash, fly ash, saw dust ash etc.) that can be added to concrete mix to improve the quality and consequently the durability of concrete these materials are known as pozollanic material. Olutoge et al (2010); presented a comparative study on fly ash and ground granulated blast furnace slag high performance concrete.

## 2.2 Asphalt Concrete

Asphalt concrete (commonly called asphalt, blacktop, or pavement in North America, and Tarmac in Great Britain) is a composite material used to form road surface, parking lots and runways. It consists of mineral aggregate bound together with bitumen, laid in layers, and compacted. The terms “asphalt” (asph and bituminous mixture are typically used in engineering and construction documents, to refer to asphalt). The different types of asphalt mixtures commonly used in pavement construction are hot-mix, hot-laid and cold-mix. When used in the construction of highway pavements, it must resist deformation from imposed traffic loads, be skid resistant even when wet and not affected easily by weathering forces.

The degree to which an asphalt mixture achieves these characteristics mainly is dependent on the design of the mix used in producing the material (Garber and Hoel, 2010).

### 2.2.1. Asphalt Ingredients

There are actually two basic ingredients in asphalt concrete. The first is aggregate; this is a mix of crushed stone, gravel, and sand. Aggregates make up about 95% of hot mix asphalt pavement. The other 5% is bitumen. Bitumen is the black or dark viscous material that holds the aggregates together, and is composed of polycyclic hydrocarbons (petroleum by - product) (Burdon, 2004).

**Production of Asphalt**

Asphalt can be produced in a fixed plant or even in a mobile mixing plant. It is possible to produce up to 800 tons per hour. The average production temperature of hot mix asphalt is between 150 and 190°C, which depends, however on the mixture produced (EAPA, 2015).

### 2.2.2. Types of Asphalt

To be able to provide the best performance to different sectors, a large variety of asphalt mixes can be offered. Due to the different requirements e.g. a road needs to fulfill (high traffic, tough weather conditions etc.) the respective mix used needs to have a sufficient stiffness and resistance to deformation in order to cope with the applied pressure from vehicle wheels on the one hand, yet on the other hand, the need to have an adequate flexural strength to resist cracking caused by the varying pressures exerted on them. Moreover, good workability during application is essential in order to ensure that they can be fully compacted to achieve optimum durability (EAPA, 2015).

#### 2.2.2.1. Cold Mix Asphalt

Cold mix asphalt is 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. Cold mixes are particularly recommended for lightly trafficked roads (European Asphalt Pavement Association, 2015).

#### 2.2.2.2. 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 (European Asphalt Pavement Association, 2015).

#### 2.2.2.3. Hot Mix Asphalt

Hot mix asphalt is produced at a temperature between 150 and 190 °C, it is the highest quality among the different types. Hot mix asphalt paving material consists of a combination of aggregates that are uniformly mixed and coated with asphalt cement (bituminous binder). (Randy, 2014). Such kind of asphalt has been used in this research.

### 2.2.3 Desirable properties of Hot Mix Asphalt (HMA)

Mix design seeks to achieve a set of properties in the final HMA product. These properties are related to some or all variables which include asphalt binder content, asphalt binder characteristics, degree of compaction and aggregate characteristics such as gradation, texture, shape and chemical composition. Some of the desirable properties of asphalt mixes are listed below with brief description of each (Wayne, et al., 2006):

- ❖ Workability: The mix must be capable of being placed and compacted to specific density with reasonable effort.
- ❖ Skid resistance: The mix must have sufficient resistance to skidding, particularly under wet weather conditions. Aggregate properties such as texture, shape, size, are all factors related to skid resistance.
- ❖ Resistance to permanent deformation: The mix should not distort or be displaced when subjected to traffic loads especially at high temperatures and long times of loading.
- ❖ Durability: The mix must be capable to resist weathering effects (both air and water) and abrasive action of traffic. Asphalt mix should contain sufficient asphalt cement to ensure an adequate film thickness around the aggregate particles.
- ❖ Moisture damage resistance: HMA should not degrade substantially from moisture penetration into the mix.
- ❖ Fatigue resistance: The mix should not crack when subjected to repeated loads over a period of time.
- ❖ Resistance to low temperature cracking: This mix property is important in cold regions.

## 2.3 Composition of Asphalt

The main ingredients of asphalt mix are bitumen, and aggregates. Aggregates usually are categorized as coarse, fine, and fillers. Coarse aggregate ranging from 14 mm, 12 mm to 10 mm in sizes and fine aggregates are referred to as sand sizes, while the fines are the fillers (Atkins, 1997).

### 2.3.1 Bitumen

Bitumen is used for road construction. It is viscous liquid or semi-solid materials consisting essentially of hydrocarbons and their derivatives, which are soluble in trichloroethylene (Brennan and O'Flaherty, 2002).

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. These were used in some earliest pavements in North America. Rock asphalts are rock deposits containing bituminous materials, which have been used for road surfaces in localities, where they occur. Tar bituminous materials are obtained from the destructive distillation of coal (Garber and Hoel, 2010).

The petroleum asphalts are products of the distillation of crude oil. These asphalts are the most common bituminous paving materials in use today. Bitumen 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 (Atkins, 1997).Bitumen used in road works occurs in three forms; penetration-grade or straight run bitumen, cut-back bitumen and bitumen-emulsion. Penetration-grade bitumen is obtained directly from the traditional distillation of the crude petroleum as residue without mixing with any solvent. The fractional distillation processes involve the separation of the different materials in the crude petroleum without significant changes in the chemical composition of each material. Ten grades of bitumen, from 15 pen (Hardest) to 450 pen (softest) are used in pavement materials in the United Kingdom. The harder grades (15 –25pen) are used in mastic asphalts, the medium grades (35 –70 pen) in hot rolled asphalts and the softer grades (100 – 450pen) in macadam asphalt (Brennan and O'Flaherty, 2002).

### 2.3.2. Aggregates

The main aggregates used in road pavements on their own or in combination with a cementations material are either natural rock materials, gravels and sands, or slag aggregates (Brennan and O'Flaherty, 2002).

Aggregates for asphalt mixture are usually classified as coarse aggregate, fine aggregate and fines otherwise known as fillers. The coarse aggregates are generally referred to as gravel sizes. They are aggregate particles mainly larger than 4.75mm (No.4) sieve. The fine aggregates are generally referred to as sand sizes. They are aggregate particles mainly between 4.75 mm (No.4 sieve) and 75 µm (No.200 sieve) in size. Fines are generally referred to as fillers. They are silt, clay or dust particles smaller than 75 µm (No.200 sieve). They occupy the empty space between the aggregate and enhances the wearing potential of the mix. It is fed in a dry condition into the mixture, during or may be after the addition of binder (Atkins, 1997).

According to (ERA, Pavement Design Manual, 2002) has suggested the following characteristics for aggregates used in HMA. The aggregate should have the following characteristics;

- Be angular and not excessively flaky, to provide good mechanical interlock;
- Be clean and free of clay and organic material;
- Be resistant to abrasion and polishing when exposed to traffic;
- Be strong enough to resist crushing during mixing and laying as well as in service.
- Be a non-absorptive - highly absorptive aggregate are wasteful of bitumen and also give rise to problems in mix design.

### 2.3.3. Coarse Aggregates

Geologists have classified rocks into three main groups, based on their mode of formation as; igneous, sedimentary and metamorphic. Igneous rocks were formed above (extrusive Rocks) or below (intrusive rocks) the earth's sure magma, which erupted from, or was trapped Cooled rapidly and the rocks formed are very often glassy or vitreous (without crystals) or partly vitreous and partly crystalline with very small grain sizes (Brennan and O'Flaherty, 2002). An extrusive rock may also contain cavities that give it a vesicular texture. By contract, the intrusive rocks are entirely crystalline, due to magma cooling slowly, and the crystals may be sufficiently large to be visible to the naked eyes. The best igneous road stones normally contain medium grain sizes. Particles with coarse grains (>1.250 mm) are liable to brittle and to break down under the crushing action of a compacting roller. If the grains are too fine (< 0.125mm), especially if the rock is vesicular, the aggregates are also liable to brittle and splintery (Brennan and O'Flaherty, 2002).

Basalt aggregates are strong and have a high resistance to polishing; however, those containing olivine which has decomposed to clay have high shrinkage characteristics that lead to problems in asphaltic concrete. Granites are strong and their resistance to polishing is usually good; however, being acidic, more attention may be paid to anti-stripping treatment if they are to be used with bitumen. The porphyries are generally considered to be good all-round road stone (Brennan and O'Flaherty, 2002).

### 2.3.4 Fine Aggregates

The effect of aggregate properties on the fatigue behavior of the conventional and polymer modified bituminous mixtures using two types of sand as fine aggregate, as reported by Yasreem and Ibrahim (2011) shows that, fine aggregate is a primary constituent in asphalt mixtures. The properties of fine aggregate namely its physical, chemical and mechanical properties play a significant role in determining the characteristics of the resulting bituminous mixture.

The use of crushed rock as fine aggregate in Hot Mix Asphalt (HMA) wearing course results in mixture with higher resistance to deformation, compared to most naturally occurring sand used as fine aggregate. Ahirich, (1991) shows that the replacement of the rounded aggregate by crushed fine aggregates improved mixture properties such as stability, rutting and water resistance. The aggregate gradation (distribution of particle sizes) is another important factor that enhances asphalt resistance to pavement distress. The chemical composition of aggregate has a significant effect on the stripping behavior; indirectly its effect on the cracking because one of the distresses that might be caused by stripping is cracking.

The physical property of sand can be determined using fine aggregate angularity (FAA). The fine aggregate angularity is measured by determining the percentage of voids in the sand, since it is known that the more angular the particles of sand, the higher the percentage of voids. Quarry sand has more angularity compared to the mining sand. It was found that fine aggregate with higher values of FAA produce more angular particles and greater rough surface texture, resulting in a larger interlock between particles consequently resulting in higher shear strength, and this enhances fatigue resistance (Yasreem and Ibrahim, 2011).The chemical composition of sand can be determined by the x-ray fluorescence .test by Yasreem and Ibrahim (2011), showed that mining sand has higher percentage of $SiO_2$ (80%), compared to the quarry sand (66.1%). It was found that large amount of $SiO_2$ can cause stripping of HMA pavements because silica reduces the bond strength between the aggregate and binder. Quarry sand has the higher total percentage of alumina ($Al_2O_3$) that is, 12.6% compared to mining sand which contains 8.98%. The $Al_2O_3$ content is related to the hardness of the material.

Quarry sand also has the higher total percentage of hematite ($Fe_2O_3$) that is, 5.30% compared to mining sand which contains 2.2% of the hematite. The hematite which has the smallest particle size compared to other elements increases the density of the bituminous mixture. The oil absorption property is needed to absorb the extensive oil in the bituminous mixtures; this property could decrease the pavement distress behavior. $Al_2O_3$ also has the highest oil absorption value of 25-225g/100g followed by $Fe_2O_3$ and $SiO_2$ respectively. This indicates that quarry sand showed the highest ability to absorb the extensive oil in bituminous mixture, because it has got higher $Al_2O_3$ and $Fe_2O_3$, whilst mining sand exhibited the lower ability to absorb oil in bituminous mixture, (Yasreem and Ibrahim, 2011).

The mechanical property of sand can be determined using shear box test. The angle of internal friction (∅) is an indication of particle interlocking and hence particle shape and surface texture. The direct shear test results showed that quarry sand has the higher ∅ value of $45^0$ compared to the mining sand which is $34.9^0$. It was found that rounded smooth textured aggregate particles tend to slide past one another producing a HMA mixture with relatively low shear strength. These results explain why crushed aggregate like quarry sand has higher shear resistance compared to natural sand (mining sand). Natural sands have more rounded particles with smooth surface texture resulting in less interlock between particles. The higher shear resistance is an indication of resistance to mixture deformation or distress. Study confirmed that the higher internal friction angle of fine aggregate indicates better interlocking mechanism results in a more resistant granular structure, (Yasreem and Ibrahim, 2011).

Ahirich (1991) considered the effects of natural sands on asphalt concrete engineering properties. According to the research, soils having more than 50% of their particles smaller than 75mm – that is, passed through (4.75mm) sieve –are sands. Natural sand material is generally considered to be an aggregate that has occurred naturally without any blasting or crushing. Natural sand is generally a siliceous material that has a smooth, rounded surface and is in the size range of the No.4 (4.75mm) and No. 200(0.075mm) sieves. Natural sands can be classified as a fine sand No. 40 (0.425mm) to No.200 (0.075mm), medium sand No.10 (2.0mm) to No.40 (0.425mm) and coarse sand No.4 (4.75mm) to No.10 (2.0mm).Natural sand materials, which are primarily uncrushed rounded particles, are often used in asphalt concrete mixtures because these materials are generally less expensive, readily available, and can be blended easily with other materials. Natural sand materials have a smooth, rounded surface texture that greatly reduces the interlocking properties of the asphalt concrete and reduces the strength properties. Low strength properties and stability values in asphalt concrete mixtures allow deformation to occur, which leads to rutting (Ahirich, 1991)

### 2.3.5 Filler

The term mineral filler is typically referred to the fine mineral particle with physical size passing the 200-mesh sieve (smaller than 75 microns). Mineral fillers are by-products of various stone crushing procedures, manifesting the feasibility of including them in the design of hot mix asphalt (Eltaher & Ratnasamy , 2016). Mineral fillers increase the stiffness of the asphalt mortar matrix. Mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures. filler plays an important role in properties of bituminous mixture particularly in terms of air voids, voids in mineral aggregate (Kar, 2012).

Generally, the aggregate material that is finer than 75µm in size is referred to as filler. Filler is defined as consisting of finely divided mineral matter, such as rock dust, slag dust, hydrated lime, hydraulic lime, fly ash, loess, or other suitable mineral matter, (Rahman, 2013). Filler as one of the components in an asphalt mixture plays a major role in determining the properties and the behavior of the mixture especially the binding and aggregate interlocking effects. The filler has the ability to increase the resistance of particle to move within the matrix and works as an active material when it interacts with the asphalt cement to change the properties of the mastic (Eltaher, et al., 2013).

**Effects of Mineral Fillers on Hot-Mix Asphalt Concrete**

Mineral filler in hot mix asphalt is an essential component of the mixture as the design and performance of hot mix asphalt (HMA) concrete is greatly influenced by the nature and amount of the mineral filler in the mix, excess quantity of filler tends to increase stability, brittleness, and proclivity to cracking. Deficiency of filler tends to increase void content, lower stability, and soften the mix. The filler content is particularly important as it has a significant impact on technical properties and, hence on potential end use. The gradation, shape, and texture of the mineral filler significantly influence the performance of hot mix asphalt regarding permanent deformation, fatigue cracking, and moisture susceptibility. A better understanding of the effects of fillers on the properties of mastics and HMA mixtures is crucial to good mix design and high performance of HMA mixtures (Eltaher & Ratnasamy, 2016).

According to the other researcher (Asmael, 2010).studied the effect of mineral filler type and content on properties of asphalt concrete mixes. The general overview of this study was to evaluate the influence of new different fillers extracted from different local sources on the performance of asphalt mixtures. It was also stated that filler content has a considerable effect on the mixture making it act as a much stiffer, and thereby affect the HMA pavement performance including its fracture behavior. Hence from the above views it clearly understands that fillers are important components of Asphalt concrete mixtures.

### 2.3.6 Types of Filler

Limestone dust and cement are the most common mineral materials used as mineral filler (Atkins, 1977) but over the years, research has shown the performance characteristics of some materials as mineral filler in asphalt mixture. These materials are as follows:

**Coal Fly Ash:**

The use of fly ash as filler in asphalt production was reported by Zimmer and Frank (1970); coal fly ash was used as mineral filler in hot mix asphalt paving applications. Asphalt mixtures containing low addition levels (approximately 5 percent by dry weight of aggregate) of fly ash as a mineral fillers exhibit mix design properties that are usually comparable to asphalt mixtures containing natural filler such as hydrated lime or stone dust.

**Kiln Dust**

Kiln dusts are fine by-products of Portland cement and lime high temperature rotary kiln production operations that are captured in the air pollution control dust collection system (for example, cyclones, electrostatic precipitators and bag houses). Kraszewski, *et al.,* (1981) observed that Cement Kiln Dust and Lime Kiln Dust have been used as mineral filler in asphalt concrete mixes. The blending of cement kiln dust into the asphalt cement binder prior to incorporation with the hot mix aggregate results in a binder (mastic) that can significantly reduce asphalt cement requirements (between 15 and 25 percent by volume). Furthermore, the lime components of the cement kiln dust can assist in promoting stripping resistance preventing moisture related damage resulting from the separation of the bitumen film from aggregate at its interface in the presence of moisture that is common in siliceous aggregate (Ciesielski *et al*., 1994)

### 2.3.7 Gradation Specifications for Asphalt binder coarse

An aggregate's particle size distribution, or gradation, is one of its most influential characteristics. In hot-mix asphalt, gradation helps to determine almost every important property including stiffness, stability, durability, permeability, workability, fatigue resistance, and resistance to moisture damage. Gradation is usually measured by a sieve analysis. Authorities will often base the choice of particle size distribution on local experience or the recommendations of the Asphalt Institute. Particle size distributions recommended by the

Asphalt Institute for binder course layers are shown in table 2.1 and Figure 2.2 indicates international gradation limits for the asphalt binder course (ASTM D3515).

Table 2. 1: Gradation of Asphalt Binder Course (ASTM D3515).

| Sieve No. | Sieve Size (mm) | Percentage by Weight Passing | |
|---|---|---|---|
| | | Min | Max |
| 1" | 25 | 100 | 100 |
| ¾ | 19 | 90 | 100 |
| ½ | 12.5 | 71 | 88 |
| ¾ | 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 |

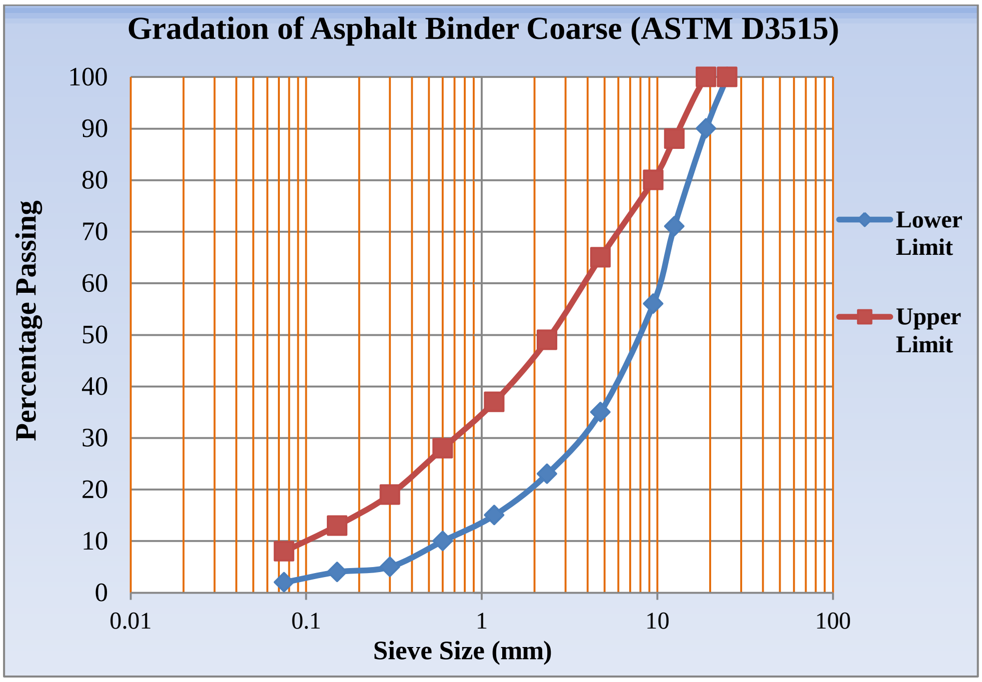



Figure 2. 2: Gradation of Asphalt Binder Course (ASTM D3515).

### 2.3.8 Specifications for the Mechanical Properties of Asphalt binder course.

Specifications for the mechanical properties of asphalt binder course are reviewed. Specification of asphalt binder course is established on different manuals such as ASTM, AASHTO, etc. and also in our country on manuals of Ethiopian Road Authority (ERA) and Addis Ababa City Road Authority (AACRA).Table summarizes these specifications of Ethiopian Road Authority (ERA).

Two specifications for the mechanical properties of asphalt binder course are reviewed. The first is the Ethiopian Road Authority (ERA) local projects specification. The second is the Asphalt Institute specification AS (MS-2). Table 2.2 and 2.3 summarizes these specifications.

Table 2.2: Mechanical properties of local specifications for asphalt binder course (ERA, Pavement Design Manual, 2002)

| Total Traffic (106 ESA) | < 1.5 | | 1.5 - 10.0 | | > 10.0 | |
|---|---|---|---|---|---|---|
| Traffic Class | T1, T2, T3 | | T4, T5, T6 | | T7, T8 | |
| | Min | Max | Min | Max | Min | Max |
| No. of blows of Marshall Compaction | 2*35 | | 2*50 | | 2*75 | |
| Stability (kN) | 3.5 | - | 6.0 | - | 7.0 | - |
| Flow, (mm) | 2 | | 2 | | 2 | 4 |
| Percent Air Voids | 3 | 5 | 3 | 5 | 3 | 5 |
| Percent Voids filled with Asphalt | 70 | 80 | 65 | 78 | 65 | 75 |
| Percent VMA (for 4% air voids and Nom. Max, Particle size of 19mm) | 13 | - | 13 | - | 13 | - |

Table 2.3: Mechanical properties international specifications for asphalt binder course (Asphalt Institute, 2003)

| **Marshal Method Mix Criteria** | **Light Traffic** | | **Medium Traffic** | | **Heavy Traffic** | |
|---|---|---|---|---|---|---|
| | Surface -Base | | Surface- Base | | Surface-Base | |
| | Min | Max | Min | Max | Min | Max |
| Compaction, number of blows each end of specimen | 35 | | 50 | | 75 | |
| Stability, (KN) | 3.336 | - | 5.338 | - | 8.006 | |
| Flow ,(mm) | 2 | 4.5 | 2 | 4 | 2 | 3.5 |
| Percent Air Voids, (%) | 3 | 5 | 3 | 5 | 3 | 5 |
| Percent Voids filled with Asphalt (VFA)),% | 70 | 80 | 65 | 78 | 65 | 75 |
| Percent VMA (for 4% air voids and Nom. Max Particle size of 19mm), (%) | 13 | - | 13 | - | 13 | - |

### 2.3.9 Determination of optimum bitumen content

There are a number of methods to select the optimum bitumen content once the data is arranged. Each agency that is involved with pavement construction has its own methods to selecting the optimum bitumen content. According to (asphalt institute, 2003) the following two methods are commonly used to select the optimum content.

**Method 1-NAPA (National Asphalt Pavement Association) Procedure**

The one commonly used procedure is recommended by NAPA, in which they suggest to be prepared the plot curves for the Marshall Stability test values, then after the optimum asphalt content, is determined by:

1. The asphalt content which corresponds to the specification's median air void content (4 percent typically) of the specification. This is the optimum asphalt content.
2. The asphalt content is then used to determine the value for Marshall Stability, VMA, flow, bulk density and percent voids filled from each of the plots.
3. Compare each of these values against the specification values for that property and if all are within the specification range, the asphalt content at 4 percent air voids is optimum asphalt content. If any of these properties is outside the specification range, the mixture should be redesigned.

**Method 2-Asphalt Institute Method**

1. Determine
   a) Asphalt content at maximum stability
   b) Asphalt content at maximum density
   c) Asphalt content at midpoint of specified air void range (4% typically).
2. Average the three asphalt content mentioned at step1 above.
3. For the average asphalt content, go to the plotted curves and determine the following properties: Stability, Flow, Air voids and VMA.
4. Compare values from Step 3 with criteria for acceptability.

## 2.4 The Use of Corn Cob Ash and Saw Dust Ash

Concrete is a construction material that consists, in its most common form, of Portland cement, fine aggregates, coarse aggregates and water. Each of these components contributes to the strength their concrete possesses, (Gambhir, 2004).Hence, the overall cost of concrete production depends largely on the availability and cost of its constituents. Concrete is used more than any other man made material on this planet. It is a low cost material and can be used for the construction of any type of structure. Because cement remains the most expensive ingredient in making a concrete and in Ethiopia, the price of cement is increasing day to day, it is therefore important to find means of economizing the use of cement.

The production of cement is increasing annually by 3% according to Olutoge et al, (2010). The current cement production rate of the world is approximately 1.2 billion tons per year. This is expected to grow to about 3.5 billion tons per year by 2015. It was gathered that the production of every ton of cement emits carbon dioxide ($CO_2$) to the tune of about one ton. When expressing it in another way, it can be concluded that 7% of the world's carbon dioxide emission is attributable to Portland cement industry, (Olutoge et al, 2010).

There is need to economize the use of cement in concrete production. One of the practical solutions to economize cement in concrete production is to replace cement with supplementary cementitious materials like rice husk ash, groundnut shell ash, palm kernel shell ash, pawpaw leaf ash, and corncob ash and saw dust ash, (Gambhir, 2004).. The use of combination of corncob ash and saw dust ash as partial replacement of cement for concrete production helps to reduce the cost of concrete production arising from the rising cost of cement, and reduce the volume of solid waste generated from corn cob and saw dust.

Appropriate utilization of the combination of these two materials as a partial replacement for cement will bring ecological and economic benefits to the country, (Olutoge et al, 2010).

Corncob is the hard thick cylindrical central core of maize (on which are borne the grains or kernels of an ear of corn). Adesanya and Raheem (2009a) described corn cob as the agricultural waste product obtained from maize or corn; which is the most important cereal crop in sub – Saharan Africa. According to Food and Agriculture Organization (FAO) data, 589 million tons of maize was produced worldwide in the year 2000 (FAO Records, 2002). The United States was the largest maize producer having 43% of world production. Africa produced 7% of the world's maize. South Africa has the highest production of maize in Africa with 8.04 million tons based on FAO Records (2002).

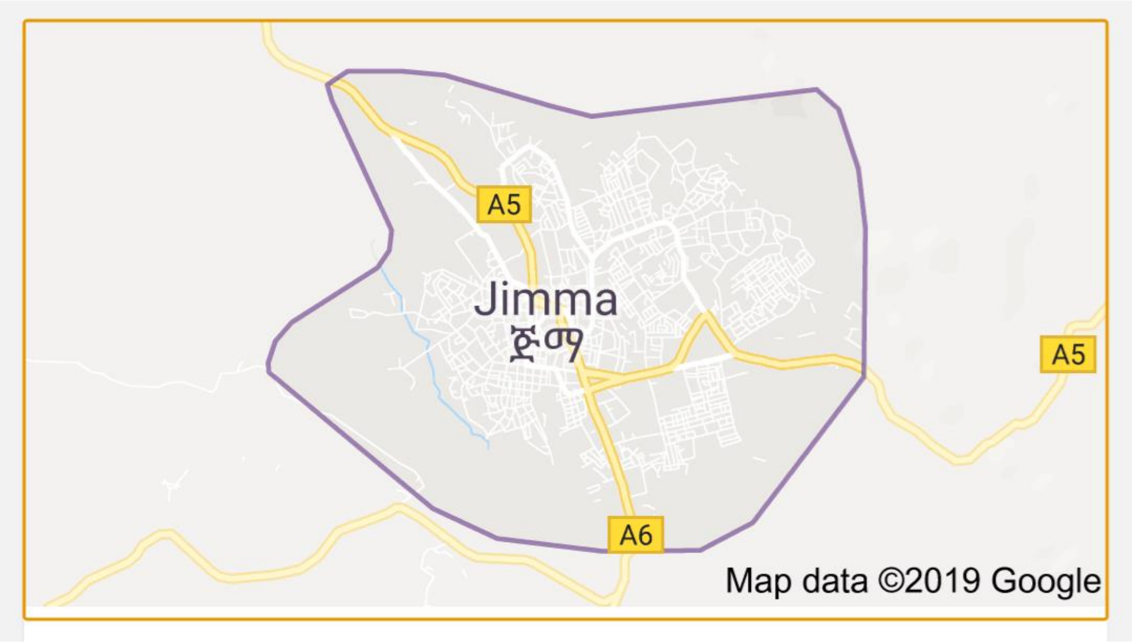
Saw dust is a waste material from the timber industry. It is produced as timber and sawn into planks at saw mills located in virtually all major towns in the country. This process is a daily activity causing heaps of saw dust to be generated after each day. The SDA produced from burning of sawdust is suitable for use in concrete making according to (Mageswari and Vidivelli 2009). CCA and SDA up to 10% replacement of Ordinary Portland cement in concrete would be acceptable to enjoy maximum benefit of strength gain was proposed. (Adesanya and Raheem 2009). The need to convert this waste products (corn cob and saw dust) into a useful by – product is the focus of the study.

# CHAPTER THREE

# RESEARCH MATERIALS AND METHODS

## 3.1 Study Area

The study area of this research is jimma. Jimma is found in jimma zone, Oromia regional state south-west of Ethiopia. It is located at a latitude and longitude of 7°40N 36°50E. The city is located approximately at a distance of 350 Km away from the capital of Ethiopia-Addis Ababa.




Source: Google Map.

Figure 3. 1: study area.

## 3.2 Study Period

This study was conducted from June to December, 2019.

## 3.3 Population

The population of the study included Aggregates (Coarse, Intermediate and Fine), Bitumen, Crushed Stone Dust, Corncob ash and Saw Dust ash.

## 3.4 Study Variables

The study variables are Dependent and Independent Variables.

**Dependent Variable**

The dependant variable of this research work is Partial Replacement of filler Materials in Hot Mix Asphalt.

**Independent Variables**

- ✓ Physical properties of materials (aggregates crushed stone dust, bitumen, corncob ash and saw dust ash.)
- ✓ Marshall Properties of materials (Marshall Stability, Flow, VIM, VMA, VFA and bulk density)

## 3.5 Materials

The materials that were used for performing this research work are;

- ✓ Aggregate (Coarse and Fine).
- ✓ Bitumen
- ✓ Crushed Stone Dust (filler)
- ✓ Corncob ash.
- ✓ Saw dust ash.

## 3.6 Methods

The methods that were used for making saw dust and corncob as mineral filler materials in Hot Mix Asphalt was as follows:

The collected Corncob and Saw dust were burned on corrugated iron at room temperature as shown in fig 3.2 for making them to ash. After that they were sieved by 0.075mm sieve size and blended with equal amount (i.e.50% CCA and 50% SDA).

The percentage rate that used to replaced crushed stone dust with blended corncob ash and saw dust ash was 10% (by weight of optimum filler content) until the maximum potential of blended corncob and saw dust ash can replaced crushed stone dust by trial and error method. The reason of using 10% interval was, because of this study sampling method is purposive. The percentage replacement rates were as follows.

- ❖ 10 % blended corncob ash and saw dust ash (by weight of OFC) mix with 90% of Crushed Stone dust (by weight of OFC).
- ❖ 20% blended corncob ash and saw dust ash (by weight of OFC) mix with 80% of Crushed Stone dust (by weight of OFC).
- ❖ 30% blended corncob ash and saw dust ash (by weight of OFC) mix with 70% of Crushed Stone dust (by weight of OFC).
- ❖ 40% blended corncob ash and saw dust ash (by weight of OFC) mix with 60% of Crushed Stone dust (by weight of OFC).

- ❖ 50% blended corncob ash and saw dust ash (by weight of OFC) mix with 50% of Crushed Stone dust (OFC).
- ❖ 60% blended corncob ash and saw dust ash (by weight of OFC) mix with 40% of Crushed Stone dust (OFC). It was extends through this method trial and error up to the maximum potential rate of blended corncob ash and saw dust ash that replaced Crushed stone dust fillers on the basis of standard specifications of Marshall Stability Criteria.

Source: Ahadu Mengistu

Figure 3. 2: Burning of Corncob

Source: Terefe Marito

Figure 3.3 : Sieving Saw dust and Corn cob

Source: Terefe Marito

Figure 3. 4: Measuring Corncob ash

Source: Terefe Marito

Figure 3. 5: Measuring saw dust ash

### 3.6.1 Research design

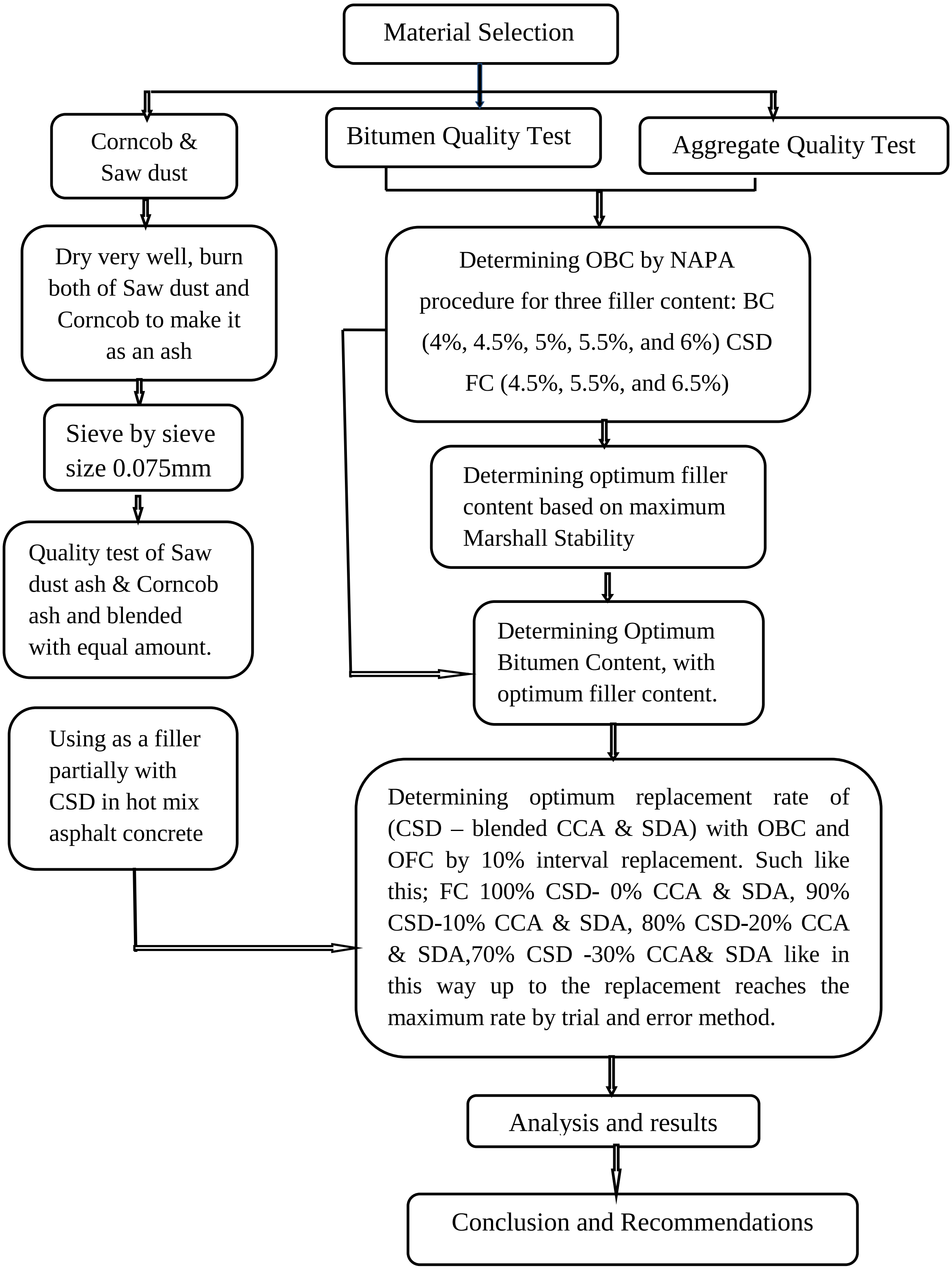



Figure 3. 6: Research Design flow chart.

### 3.6.2 Source of Data

Different types of data were collected for the purpose of accomplishing this research which was primary and secondary data.

**Primary Data**

The primary data were collected through laboratory tests on aggregate, asphalt binder and filler material properties.

**Secondary Data**

The secondary data were obtained from the existing relevant documents; pavements design manuals, Literatures and scientific researches.

### 3.6.3 Sampling techniques and size

**Sampling techniques**

The sampling technique used for this research was a purposive sampling which is non-probability method. This sampling was performed by laboratory tests on HMA concrete to investigate the potential of blended corncob ash and saw dust ash on mineral fillers replacement.

**Sampling size**

The materials selected for this study were collected from different sources. Crushed stone dust filler and aggregates were obtained from jimma road up grading quarry site around assendabo area with different sizes of 14-25mm, 6-14mm, 3-6mm, and 0-3mm. The asphalt cement of 60/70 penetration grade was also obtained from jimma road upgrading batching plant. The main reason of using 60/70 asphalt grade is because of its common type of asphalt that widely use in most road projects in our country to construct roads. Corncob was collected around from jimma town farmers, who grows maize crop. Saw dust was also collected from jimma town timber production result sites.

### 3.6.4 Data collection methods

The primary research data were collected through performing experiments, experimental result etc. whereas the secondary data were collected from relevant documents or literatures tried to review and analyse the issues related to the concerned objectives of the study.

### 3.6.5 Data processing and analysis

The research was conducted first by identification of the effects of blended corncob ash and saw dust ash on replacing of asphalt concrete filler mainly crushed stone dust through laboratory and Data was collected using standard formats for recording test results. The results of laboratory tests were analyzed using excel through draw different kinds of graphs. Comparison of test results with standard specification for asphalt concrete filler materials were important aspects of analysis.

#### 3.6.6 Data quality assurance

Pre–test of the available instruments were done before the main data collection period begin and the data were collected after gaining an awareness on how to collect relevant data by principal investigators. Samples were collected from appropriate sources. Standard formats were used for recording test results to prevent loss of data.

#### 3.6.7 Ethical Consideration

Prior to data collection an official letter was written by Jimma University and send to concerned local authorities and other respective agencies for taking samples and perform the relevant tests.

## 3.7 Tests and Material Preparations.

### 3.7.1 Physical properties of mineral fillers

Mineral fillers contain finely divided mineral matter such as rock dust, slag dust, hydrated lime hydraulic cement, fly ash, and Aggregate that passing through 0.075 mm sieve is called as filler. It fills the voids, stiffens the binder and offers permeability (Mohanty, 2013).

In this study crushed stone dust, corncob ash and saw dust ash were the used fillers. Laboratory tests were performed on mineral filler to show the physical characteristics that were believed to be considerable value in evaluating mineral filler, such as specific gravity, plastic index and gradation parameters were determined as specification limits. With respect to the methodological choice for this study, laboratory test was used before using them in any road construction in order to determine their physical properties whether they can meet or not the specification limits. According to AASHTO standard, the mineral filler needs to be non-plastic and the plastic index is less than four. The laboratory test results are discussed in chapter four.

### 3.7.2 Mineral aggregate tests and preparation

Aggregates (mineral aggregates) are hard, inert materials such as sand, gravel, crushed rock, slag, or rock dust. Aggregate gradation, shape, surface texture, water absorption, soundness, resistance to crushing and impact loads have a great impact on a shear strength of hot mix asphalt properties. AASHTO, ASTM and BS standards are taken for the methods of tests for road construction for dense graded asphalt. The mineral aggregates used in the research were subjected to various tests in order to determine their physical characteristics and suitability for use the road construction various tests were conducted and the results are presented in chapter four .

### 3.7.3. Asphalt binder selection and test

Bituminous binder of grade 60/70 penetration was used in the preparation of mixtures since it is widely used and suitable for hot temperature area like Ethiopia. According to Manual Series –2 (1997), the annual air temperature greater or equal to $24^0$C the asphalt grade is 60/70 pen. This bituminous binder was used in the preparation of mixtures in this research that is Partial Replacement of Blended Corncob ash and Saw dust ash as a filler Material in Hot Mix Asphalt. The summary of test results obtained is shown in chapter four.

## 3.8 Marshal Mix Design

The Marshall method of design was originally developed by Bruce Marshall, formerly of the Mississippi Highway Department, and improved by the U.S Army Corps of Engineers. The Marshall method is applicable only to hot mix asphalt using penetration, viscosity or PG graded asphalt binder or cement and containing aggregate with maximum size of 25.0 mm (1 in.) or less.

The purpose of marshal method is to determine the optimum asphalt content for a particular blend of aggregate. And also provide information about the properties of the resulting pavement mix, including density and void content, which are used during pavement constriction.

The Marshall method uses standard test specimen 64 mm (2.5 in) height and 102 mm (4 in.) internal diameter. A series of specimens, each containing the three varying in aggregate blend and varying in asphalt content from 4 % to 6 % (by weight of total mix) with increment of 0.5% depending on Asphalt Institute Manual series recommendations. The marshal test procedures have been standardized by the ASTM and published as ASTM D1559. The test procedure starts with the preparation of test specimens, and steps preliminary to specimen preparation are:

- All materials proposed to use would meet the physical requirement of the specification.
- Aggregate blend combination meets the graduation requirements of the specification.

- Determine the bulk specific gravity of all aggregate used in the blend and the specific gravity of asphalt cement for performing density and void analyses.

### 3.8.1. Gradation of coarse and fine aggregates

Aggregate grain size distribution or gradation is one of the properties of aggregates which influence the quality of hot mix asphalt. The coarse and fine aggregate particles were separated into different sieve size and proportioned to obtain the desired gradation for bituminous mixtures of ASTM 3515. Therefore, coarse aggregate [retained on 2.36mm (NO.8) sieve], fine aggregate [passing 2.36 mm (NO.8) sieve] and mineral filler [Passing 0.075mm (NO.200) sieve]

The aggregate gradation is normally expressed as the percentage (by weight) of total sample that passes through each sieve. It is determined by weight the contents of each sieve following the sieve analysis and then calculating the percentage passing each sieve by one of several mathematical procedures. 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. Available aggregate materials, coarse aggregate (14-20mm), intermediate aggregate (6-14mm and 3- 6mm), fine aggregate (0- 3mm) and filler, were integrated in order to get the proper gradation within the allowable limits according to ASTM specifications using mathematical trial method. Three gradations were prepared in this research with varying amount of conventional mineral filler content. The first gradation was prepared with 4.5% CSD (by weight of aggregate), the second gradation was prepared with 5.5% CSD (by weight of aggregate) and the third gradation was prepared with 6.5% CSD (by weight of aggregate) using of purposive sampling method

### 3.8.2 Preparation of specimens for HMA mixtures

Materials are needed to prepare HMA mixture. Blended aggregates, bitumen, marshal Mold with collar, balance, oven, compactor, filter paper and pan are the main materials used for preparing the HMA mixture specimens. To prepare the HMA mixture specimen the following listed processes were done.

- ✓ 1200g blended aggregates were dried in oven with a temperature of 160-170℃ for minimum of 16 hours and bitumen also heated by 150-170℃ as shown in fig 3.7 below.
- ✓ Standard Marshall Molds were heated in an oven for a minimum of 8 hours before mixing.

- ✓ For each gradation trial bitumen was added in required quantity i.e. 4 %, 4.5 %, 5%, 5.5% & 6% (by weight of total mix), and next to that the heated aggregates and bitumen are mixed by hand properly until a homogeneous mix is obtained as shown in figure 3.9
- ✓ The mixed mixtures were placed in the preheated Mold as shown below in Fig 3.10 and compacted by a Marshall compactor hammer that have 4.5Kg weight and a free fall of 45.7cm covering each side of the specimen by filter paper and applying 75 blows on each side of the specimen with the standard Marshall hammer as specified in ASTM D1559.
- ✓ After applying 75 blows on each side of the specimen the filter papers were removed from each specimen side.

Source: Dejene Dereje

Figure 3. 7: Aggregate and fillers put in the oven.

Source: Dejene Dereje

Figure 3. 8: Bitumen put in the oven.

Source: Dejene Dereje

Figure 3. 9: Mixing by hand

Source: Dejene Dereje

Figure 3. 10: Spacemen placing in mold

After 24 hours the specimens were removed from the Mold by using specimen extractor as shown below in Fig 3.11. The specimens were then weighed dry in air, weighed in water and saturated surface dry weight for determining the bulk specific gravity of the specimen as shown below in Fig 3.13. After the specimens were weighed in air, water and saturated surface dry weight they were put in the water bath with 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 as shown below in Fig 3.14. The flow meter or deformation measuring dial gauge is placed in position and adjusted to read zero. The load is applied through the Marshall Test setup. Maintaining a constant deformation rate of 50.8 mm per minute, the minimum load is failure (stability) and the corresponding deformation (flow) readings are carefully noted.

To determine the optimum bitumen content and optimum filler content a total of 45 specimens were prepared as shown below in Fig 3.12 as a sample. Marshall Test was done for each gradation prepared with 4.5%, 5.5% and 6.5 % CSD (by weight of aggregates) with five different percentages of bitumen contents (4%, 4.5%, 5%, 5.5% and 6% by weight of total mix) and each test have three trials totally it becomes 45 samples.

Source: Terefe Marito

Figure 3. 11: Remove the specimen from the mold


Source: Terefe Marito

Figure 3. 12: Hot Mix Asphalt specimens

Source: Terefe Marito

Figure 3. 13: Measuring the Weight of the specimen

Source: Terefe Marito

Figure 3. 14: Put the specimens in water bath.

### 3.8.3. Determination of optimum bitumen content

According to (asphalt institute, 2003) There are a number of methods to select the optimum bitumen content once the data is arranged. Each agency that is involved with pavement construction has its own methods to selecting the optimum bitumen content. In this research work NAPA (National Asphalt Pavement Association) procedure was used. The reason of selecting this method was because of its commonly used.

### 3.8.4 Determination of Optimum Replacement Rate of Blended Corncob Ash and Saw Dust Ash

To determine the optimum replacement rate of BCSA as filler materials in HMA laboratory tests were carried out using Marshall Stability Test by the same aggregate source and the same bitumen content source for the preparation of all mixtures. Blended corncob ash and saw dust ash was used to replace conventionally crushed stone dust starting from 10 % (by weight of optimum filler content) interval through trial and error method with the basis of optimum bitumen content. After that the mixtures were prepared and the Marshall Stability properties of these replaced asphalt mix such as stability, flow, bulk density and volumetric properties (i.e.VA. VMA and VFA) were determined and checked according to the specification range. to determine the optimum replaced percentage rate (by weight of optimum filler content) of blended corncob ash & saw dust ash it was depending on the Marshall Test results of having maximum stability, maximum bulk density, and air voids with in the standard range of specification rates (Jendia, 2000).

### 3.8.5 Volumetric properties of HMA Mixes

Fundamentally, mix design is meant to determine the volume of bitumen binder and aggregates necessary to produce a mixture with the desired properties (Roberts et al., 1996). Since weight measurements are typically much easier, are taken and then converted to volume by using specific gravities. The following is a discussion of the important volumetric properties of bituminous mixtures

The important volumetric properties of bituminous mixtures that are to be considered include the theoretical maximum specific gravity ($G_{mm}$), the bulk specific gravity ($G_{mb}$), percentage of voids in total mix (VTM)), percentage void in mineral aggregate (VMA) and percentage voids filled with asphalt (VFA).

**Theoretical maximum specific gravity (Gmm)**

Theoretical maximum specific gravity is the ratio of the weight in air of a unit volume of un-compacted bituminous paving mixture at a stated temperature to the weight of an equal volume of gas free distilled water a stated temperature. The maximum specific gravity ($G_{mm}$) at different asphalt contents was measured to calculate air voids. The theoretical maximum specific gravity of a mix is defined as: -

$$Gmm = \frac{A}{(A+B)-C} \quad \text{......} (3.1)$$

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

A= Mass of the dry sample in air, g

B = Mass of jar filled with water, g, and

C = Mass of jar filled with water + sample, gs

**Bulk specific gravity of compacted specimen ($G_{mb}$)**

According to (Asphalt Institute, 2003) 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. This value, as stated at ASTM D1189 and D2726, is used to determine weight per unit volume of compacted mixture. The standard procedure for determining the bulk specific gravity of compacted asphalt concrete involves weighing the specimen in air and in water. The bulk specific gravity ($G_{mb}$) of a compacted mix is equal to:

$$Gmb = \frac{A}{B - C} \quad \text{......} (3.2)$$

Where: Gmb = Bulk specific gravity of compacted specimen.

A = mass of the dry specimen in air, g

B = mass of the saturated surface-dry specimen in air, g

C= mass of the specimen in water, g

**Air Voids (Va)**

According to (Asphalt Institute, 2003), the total volume of the small pockets of air between the coated aggregates particles throughout a compacted paving mixture, expressed as percent of the bulk volume of the compacted paving mixture. The air voids, Va, in the total compacted paving mixture consists of the small air spaces between the coated aggregates particles. 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.

$$Va = 100 * \frac{(G_{mm} - G_{mb})}{G_{mm}} \quad \text{......} (3.3)$$

Where: $V_a$ = air voids in compacted mixtures.

$G_{mm}$ = maximum specific gravity of paving mixture.

$G_{mb}$ =bulk specific gravity of compacted mixture.

### Voids in Mineral Aggregates (VMA)

According to (Asphalt Institute, 2003), the voids in the mineral aggregates, are defined as the inter-granular void space between the aggregate's particles in compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume of the sample. The VMA are calculated based on the bulk specified gravity of the aggregates and is expressed as a percentage of the bulk volume of the compacted paving mixture. It is calculated as:

$VMA = 100- (G_{mb} * P_s)/G_{sb}$ ............................................ (3.4)

Where: VMA=voids in the mineral aggregate.

$G_{mb}$ = bulk specific gravity of total aggregates.

$G_{sb}$ = bulk specific gravity of total aggregates.

$P_s$ =aggregate content, percent by mass of total mixture.

### Voids Filled with asphalt (VFA)

According to Asphalt Institute 2003, the percentage portion of the volume of inter-granular Void space between the aggregate particles that is occupied by the effective asphalt. It is expressed as the ratio of (VMA-VA) to VMA. The voids filled asphalt, VFA is the percentage of the integral void space between the aggregate particles (VMA) that are filled with asphalt. The mathematical relationship has shown as:

$VFA= 100* (VMA- V_A)/VMA$ ……………………………………. (3.5)

Where: VFA=voids filled with asphalt, percent of VMA.

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

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

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## 4.1 General

This chapter includes the analysis of all results and discussions that obtained from the laboratory test. All results are discussed and analyzed in different categories. Firstly three different asphalt concrete samples were produced using crushed stone dust in different proportions (4.5%, 5.5% and 6.5% by weight of aggregates) as mineral filler. The Marshall test was carried out with different percentages of bitumen content which are (4, 4.5, 5.0, 5.5 & 6 % by weight of total mix**)** and the results are analyzed to determine the optimum bitumen content (OBC) and optimum filler content (OFC) in asphalt mixes. In the second way of the study crushed stone dust filler was replaced by blended corncob ash and saw dust ash by 10% (by weight OFC)) interval replacement rate and Marshall Samples prepared by using the obtained OBC. After the Marshall test was conducted on the produced samples and the results are analyzed in order to find the optimum replacement ratio.

## 4.2 Material Property Test Results

### 4.2.1 Physical Properties of Mineral Filler Test Results

The fillers that used for this study are namely crushed stone dust, corncob ash and saw dust ash. Laboratory tests have been conducted in order to evaluate the physical properties of each type of fillers, which consist of the gradation parameters, plasticity index and apparent specific gravity. Apparent specific gravity test was conducted according to ASTM D-854 by using Water Pycnometer method.

Table 4. 1: physical properties of Mineral fillers.

| Sieve No | %passing | | | ASTM D242 |
|---|---|---|---|---|
| | Corncob ash | Saw dust ash | Crushed stone dust | |
| NO 30 | 100 | 100 | 100 | 100 |
| No 50 | 100 | 100 | 100 | 95-100 |
| No 200 | 100 | 100 | 100 | 70-100 |
| Plasticity index | NP | NP | NP | <4 |
| Apparent specific gravity | 2.26 | 2.24 | 2.725 | - |

Table 4.1 shows all types of filler are passing through sieve #30, #50 and #200, which satisfies the standards specified in ASTM D242. the plastic index of corncob ash, saw dust ash and crushed stone dust are <4, which are non-plastic and they satisfies the standard of ASTM D242.apparaent specific gravity of corncob ash, saw dust ash and stone dust are 2.26,2.24 and 2.725 respectively. Apparent specific gravity of corncob ash and saw dust ash are slightly lower than crushed stone dust.

### 4.2.2. Physical properties of Aggregates

To investigate the physical properties of aggregates and their suitability in road construction, various laboratory tests were conducted on aggregate including sieve analysis, specific gravity, aggregate crushing value (ACV) and Los Angeles abrasion tests. Table 4.2 summarizes the physical property of aggregates laboratory results and the specification.

Table 4. 2: Physical properties of aggregate test results.

| Test | Test Method | Test Results | | | | Specification requirements |
|---|---|---|---|---|---|---|
| | | 14mm-25mm | 6mm-14mm | 3mm-6mm | 0mm-3mm | |
| Bulk dry S.G | AASHTO T 85-91 | 2.625 | 2.612 | 2.60 | 2.60 | - |
| Bulk SSD S.G | | 2.673 | 2.664 | 2.610 | 2.641 | - |
| Apparent SG | | 2.764 | 2.753 | 2.745 | 2.767 | - |
| Water absorption,% | BS 812, Part 2 | 1.88 | 1.88 | 1.88 | - | <2 |
| Sand equivalent,% | AASHTO T176-86 | 75.4 | - | - | - | >40 |
| Flakiness index | BS 812 Part 105 | 23 | - | - | - | <45 |
| Aggregate Crushing Value (ACV),% | BS:812 Part 110 | 13 | - | - | - | <25 |
| Los Angeles Abrasion (LAA), % | AASHTO T 96` | 15 | - | - | - | <30 |

- Table 4.2 describes physical properties of aggregates for different sizes with the specification requirements, the laboratory test results indicate that all are within the specification requirements.

### 4.2.3 Bitumen property test

Bituminous binder of grade 60/70 penetration was used in the preparation of mixtures since it is widely used and suitable for hot temperature area like Ethiopia. According to Manual Series –2 (1997), the annual air temperature greater or equal to 24℃ the asphalt grade is 60/70 pen

Table 4. 3: Laboratory test results of bituminous binder

| Test Type | Test Method (ASTM) | Test Result | Specification as per ERA,2002 | Status |
|---|---|---|---|---|
| Ductility (cm) at 25℃ | ASTM D 113 | 147 | >50 | ok |
| Penetration at 25℃ | ASTM D 5 | 65 | 60-70 | ok |
| Softening point ℃ | ASTM D 36 | 53 | 46-56 | ok |
| Flash point ℃ | ASTM D 92 | 288 | >232 | ok |
| Specific gravity 25℃ | ASTM D 70 | 1.05 | - | |

Table 4.3 shows the laboratory test results of bitumen.as shown in the table the tests were done by ASTM method and for each test type the results were compared with specifications of ERA Manual.2002.The test results indicate that all the test types were satisfied the standard requirements.

### 4.2.4 Gradation of Coarse and Fine Aggregates

The combined gradation of aggregates and the specification criteria for asphalt binder coarse is summarized in table 4.4 and figure 4.1 to 4.3 shows the three types of gradation on the basis of three different percentages of fillers (4.5%, 5.5% and 6.5 % by weight of total mix).

Table 4. 4: Aggregates graduation and specification criteria

| Sieve size (mm) | **Gradation for the three different filler** percentage passing | | | **ASTM D3515 Specification** | |
|---|---|---|---|---|---|
| | **4.5%** | **5.5%** | **6.5%** | **Lower Limit** | **Upper Limit** |
| 25 | 100 | 100 | 100 | 100 | 100 |
| 19 | 94.2 | 94.2 | 94.2 | 90 | 100 |
| 12.5 | 77.7 | 77.7 | 77.5 | 71 | 88 |
| 9.5 | 67.8 | 67.8 | 67.5 | 56 | 80 |
| 4.75 | 47.5 | 47.3 | 47.4 | 35 | 65 |
| 2.36 | 33 | 33 | 33 | 23 | 49 |
| 1.18 | 22.4 | 22.5 | 22.4 | 15 | 37 |
| 0.6 | 14.8 | 14.9 | 14.9 | 10 | 28 |
| 0.3 | 9.8 | 9.7 | 9.7 | 5 | 19 |
| 0.15 | 7.2 | 7.3 | 7.2 | 4 | 13 |
| 0.075 | 4.5 | 5.5 | 6.5 | 2 | 8 |

Table 4.4 shows the final proportion of each aggregate material in asphalt binder course and the proposed aggregate gradation curves are shown in fig 4.1 to 4.3 based on ASTM specification for asphalt binder coarse specification.

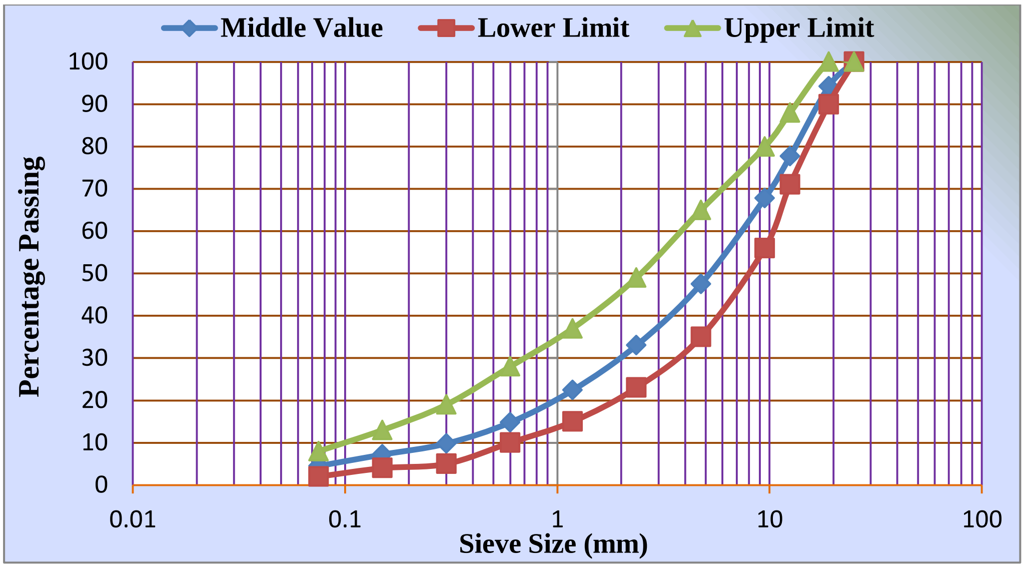



Figure 4. 1: Gradation curve for 4.5% CSD

Fig 4.1 indicates the curve of gradation that was prepared based on the standard specification of ASTM D3515 limits. In this gradation the aggregates were selected from each size by their limit ranges and the crushed stone dust filler was 4.5% (by weight of Aggregates). The graph shows three different color lines. The green line indicates the upper limit of ASTM Specification, the red line indicates lower limit of ASTM Specification and the blue line indicates the prepared gradation by 4.5 % crushed stone dust fillers. The prepared gradation is between the upper and lower limits of ASTM Specification as shown in fig 4.1. Hence the prepared gradation satisfies the specification requirements.

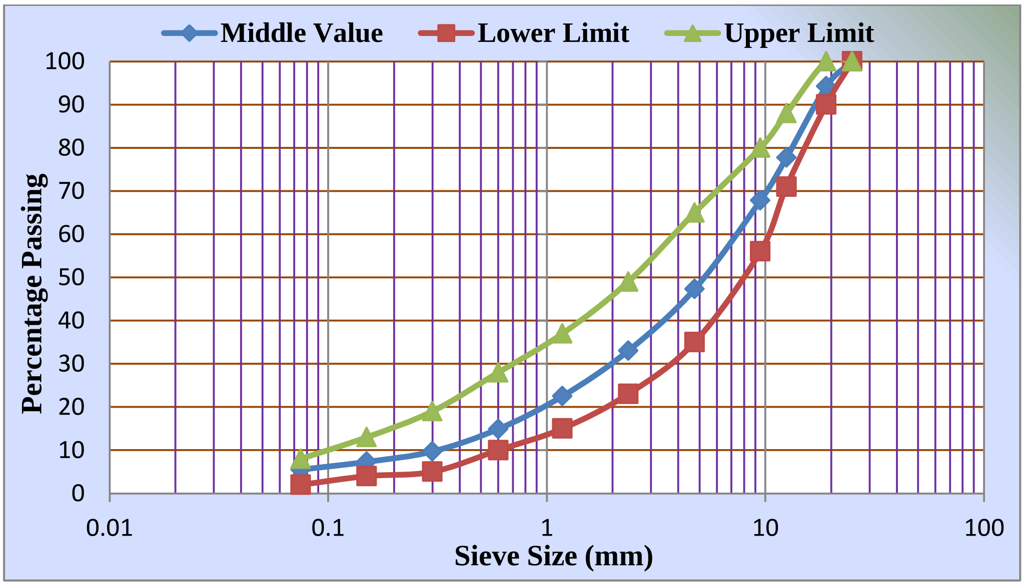



Figure 4. 2 : Gradation curve for 5.5% CSD

Fig 4.2 indicates the curve of gradation that was prepared based on the standard specification of ASTM D3515 limits. In this gradation the aggregates were selected from each size by their limit ranges and the crushed stone dust filler was 5.5% (by weight of Aggregates). The graph shows three different color lines. The green line indicates the upper limit of ASTM Specification, the red line indicates lower limit of ASTM Specification and the blue line indicates the prepared gradation by 5.5 % crushed stone dust fillers. The prepared gradation is between the upper and lower limits of ASTM Specification as shown in fig 4.2. Hence the prepared gradation satisfies the specification requirements.

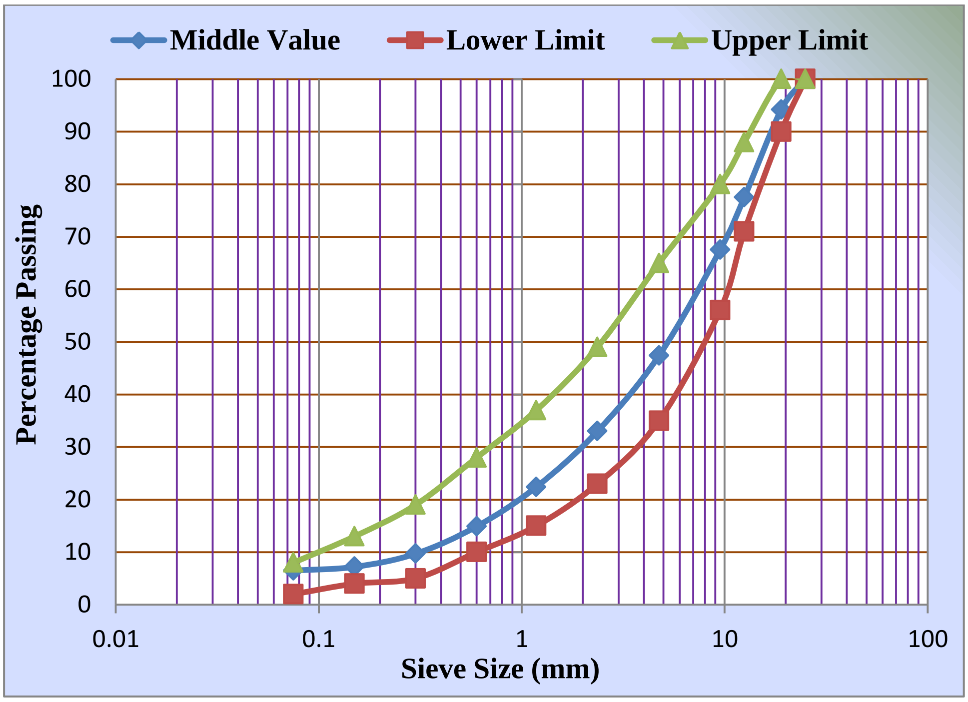



Figure 4. 3 : Gradation curve for 6.5% CSD

Fig 4.3 indicates the curve of gradation that was prepared based on the standard specification of ASTM D3515 limits. In this gradation the aggregates were selected from each size by their limit ranges and the crushed stone dust filler was 6.5% (by weight of Aggregates). The graph shows three different color lines. The green line indicates the upper limit of ASTM Specification, the red line indicates lower limit of ASTM Specification and the blue line indicates the prepared gradation by 6.5 % crushed stone dust fillers. The prepared gradation is between the upper and lower limits of ASTM Specification as shown in fig 4.3. Hence the prepared gradation satisfies the specification requirements.

## 4.3 Analysis of asphalt mixture properties

### 4.3.1 Marshall Test Results and Discussion

Results of asphalt mix laboratory work had been obtained and analyzed in order to achieve the study objectives which include studying the effect of crushed stone dust on Marshall Properties of asphalt mix. The results of Marshall Properties of specimens prepared with varying content 4.5%, 5.5%, and 6.5% of crushed stone dust as filler by weight of aggregate with varying bitumen contents. A total of 45 samples each one of them weighs 1200 grams, were prepared using five different bitumen contents (4.0, 4.5, 5.0, 5.5 and 6.0% by weight of total mix) in order to determine the optimum filler and optimum bitumen content. Table 4.5, 4.6, and 4.7 indicates the properties of mixtures at their various asphalt content for mixes with different crushed stone dust filler content. Further details are presented in Appendix E.

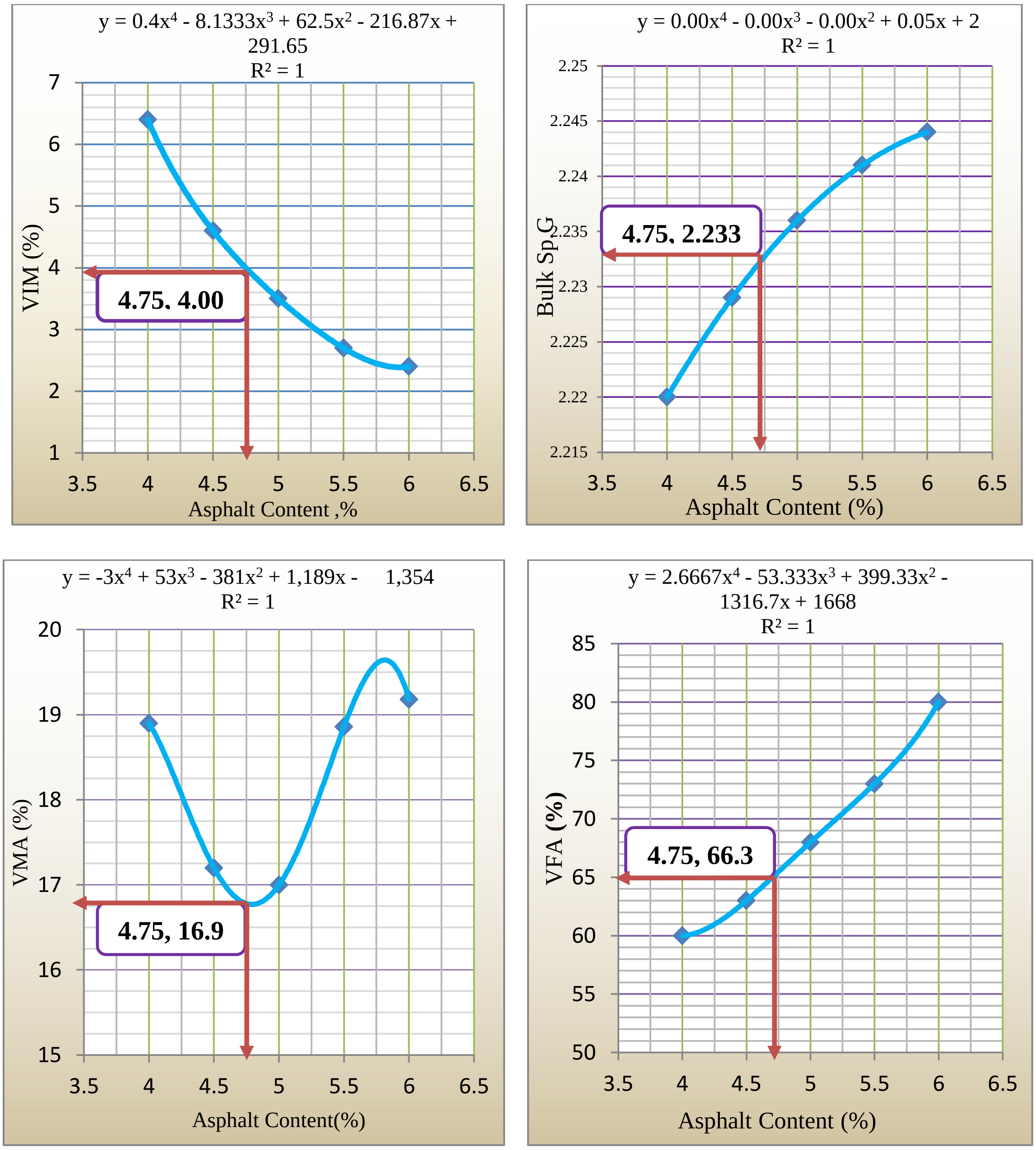
The Marshall Mix design method as recommended by the Asphalt Institute uses five mix design criteria. These are Minimum Marshall Stability, Range of acceptable Marshall Flow, Range of acceptable air voids, Percent voids filled with asphalt (VFA), and Minimum amount of VMA.

According to (ERA, Pavement Design Manual, 2002) Marshall Design criteria for Heavy Traffic, minimum stability must be 7 kN at $60^0$C, flow value must be ranged between 2 to 4mm, percentage of air voids must be ranged between 3 to 5%, minimum VMA related to 4% air voids and nominal maximum particle size of 19mm must be 13% and VFB must be ranged between 65 to 75%.

Table 4. 5: Marshall Properties of asphalt mixes with 4.5% CSD.

| % of AC By Weight of total mix | ρA (g/cm$^3$) | VIM (%) | VMA (%) | VFA (%) | Stability (KN) | Flow (mm) |
|---|---|---|---|---|---|---|
| 4 | 2.22 | 6.4 | 18.9 | 60 | 7.7 | 2.74 |
| 4.5 | 2.229 | 4.6 | 17.2 | 63 | 8.2 | 3.1 |
| 5 | 2.236 | 3.5 | 17 | 68 | 8.6 | 3.4 |
| 5.5 | 2.241 | 2.7 | 18.86 | 73 | 8.7 | 3.73 |
| 6 | 2.244 | 2.4 | 19.18 | 80 | 7.7 | 4.1 |

Table 4.5 indicates the Marshall Property laboratory test results for a gradation that prepared by using 4.5% crushed stone dust filler ( by weight of Aggregates) with five different bitumen contents ( by weight of total mix). For each Marshall properties Curves are plotted in fig 4.4 by 4th order degree because the data points are five as shown in table 4.5.



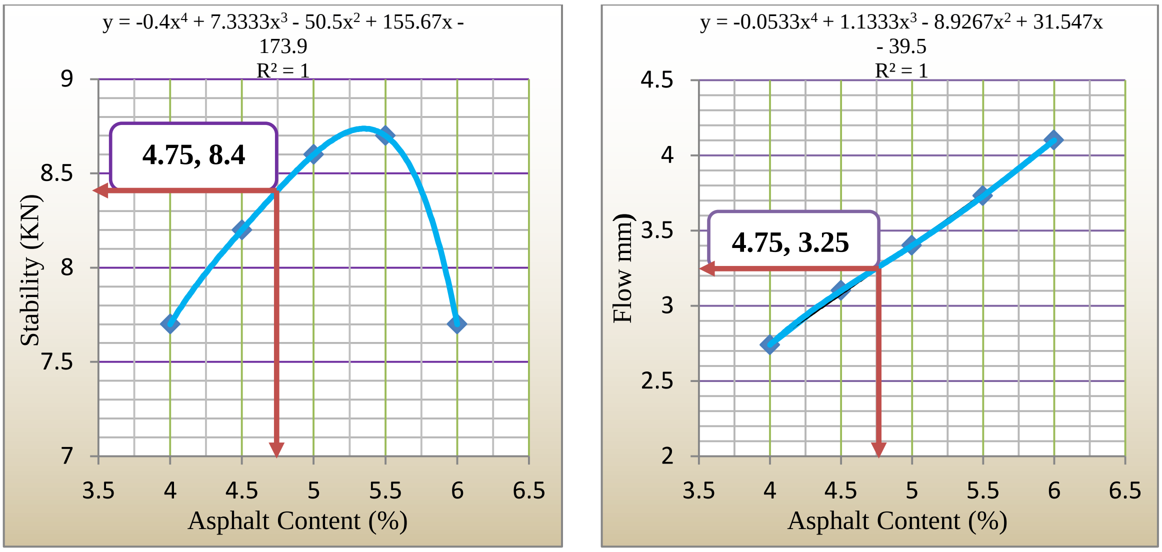



Figure 4. 4: OBC and the properties of mixtures with 4.5 % CSD filler.

fig 4.4 shows the relationships between binder content and the properties of mixtures with 4.5% CSD. the unit weight for total mix and the value of stability increases with the value of asphalt content increases up to a maximum and through gradually decreases as shown in the figure above, also the value of voids filled with asphalt (VFA) and flow increases with increase of asphalt content,where as the percent voids in mineral aggregates (VMA) decreases to the minimum value and then increase with increasing of asphalt content.The NAPA mix design method requires the mix to have 4% air voids at the optimum binder content (OBC), by using this method as shown in the fig above the optimum binder content (OBC) is equal to 4.75% by weight of the total mix.

Table 4. 6: Marshall Properties of asphalt mixes with 5.5% CSD

| % of AC By Weight of total mix | ρA ($g/cm^3$) | VIM (%) | VMA (%) | VFA (%) | Stability (KN) | Flow (mm) |
|---|---|---|---|---|---|---|
| 4 | 2.3 | 7.3 | 15.08 | 60.43 | 8.55 | 2.7 |
| 4.5 | 2.33 | 5.7 | 14.75 | 67.2 | 10.04 | 2.9 |
| 5 | 2.355 | 4 | 14.7 | 73 | 11.2 | 3.1 |
| 5.5 | 2.37 | 2.6 | 15 | 76 | 11.52 | 3.26 |
| 6 | 2.38 | 1.9 | 15.1 | 83 | 8.65 | 3.4 |

Table 4.6 in the above indicates the Marshall Property laboratory test results for a gradation that prepared by using 5.5% crushed stone dust filler ( by weight of Aggregates) with five different bitumen contents ( by weight of total mix). The curves are plotted below in fig 4.5.

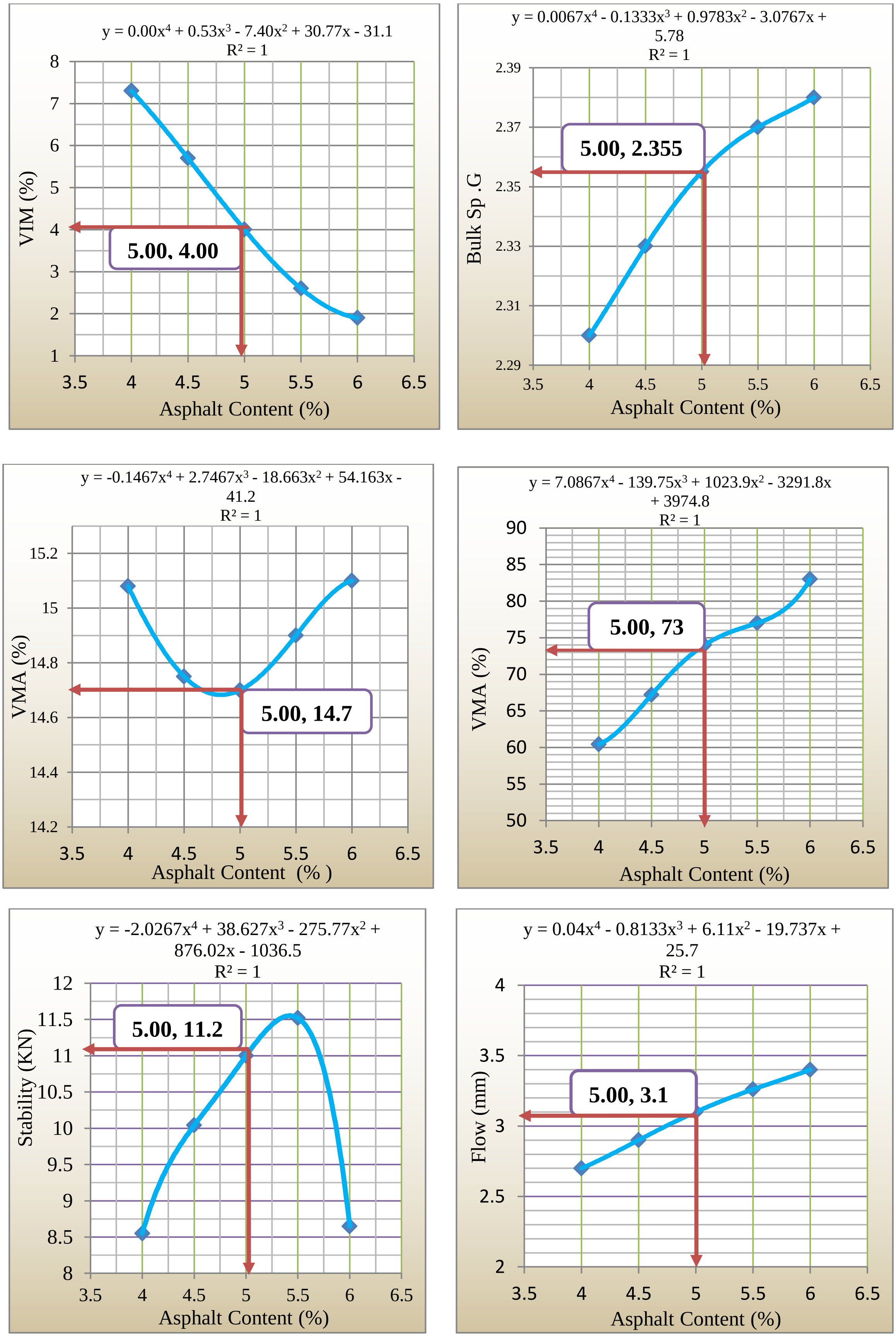


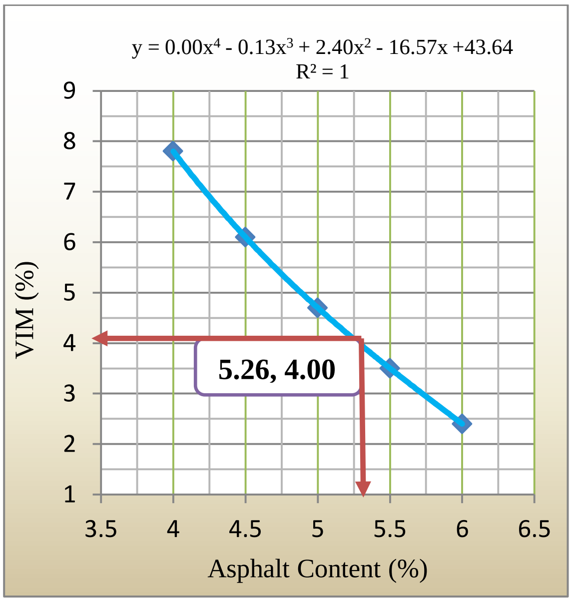

Figure 4. 5: OBC and the properties of mixtures with 5.5 % CSD filler.

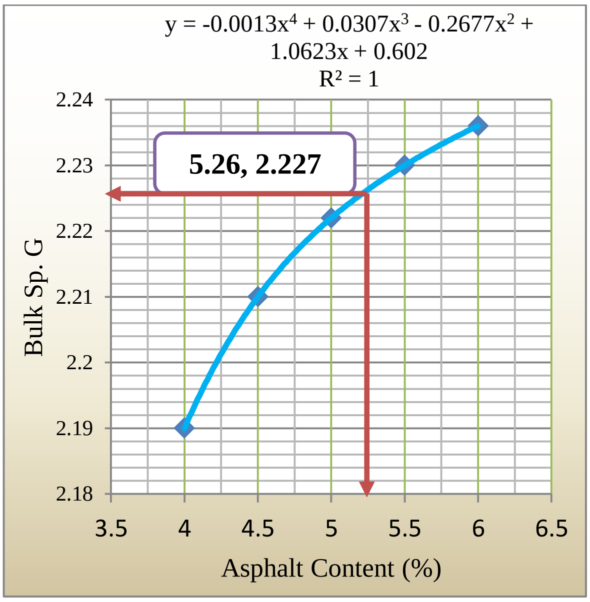
Fig 4.5 shows the relationships between binder content and the properties of mixtures with 5.5% CSD. The optimum bitumen content of the mix result is 5% as shown in the graph above based on the median air void content (4 percent) of the specification. The general ways of the curves for 5.5% crushed stone dust filler content is similar with the curve of 4.5 % crushed stone dust filler.

Table 4. 7: Marshall Properties of asphalt mixes with 6.5% CSD.

| % of AC By Weight of total mix | ρA ($g/cm^3$) | VIM (%) | VMA (%) | VFA (%) | Stability (KN) | Flow (mm) |
|---|---|---|---|---|---|---|
| 4 | 2.19 | 7.8 | 19.45 | 55 | 8.26 | 3.01 |
| 4.5 | 2.21 | 6.1 | 19.14 | 63.13 | 10.39 | 3.11 |
| 5 | 2.222 | 4.7 | 19.12 | 70.42 | 10.3 | 3.22 |
| 5.5 | 2.23 | 3.5 | 19.26 | 76.83 | 9.78 | 3.31 |
| 6 | 2.236 | 2.4 | 19.47 | 82.67 | 9.3 | 3.4 |

Table 4.7 indicates the Marshall Property laboratory test results for a gradation that prepared by using 6.5% crushed stone dust filler ( by weight of Aggregates) with five different bitumen contents ( by weight of total mix). For each Marshall properties Curves are plotted in fig 4.6 by 4th order degree because the data points are five as shown in table 4.7



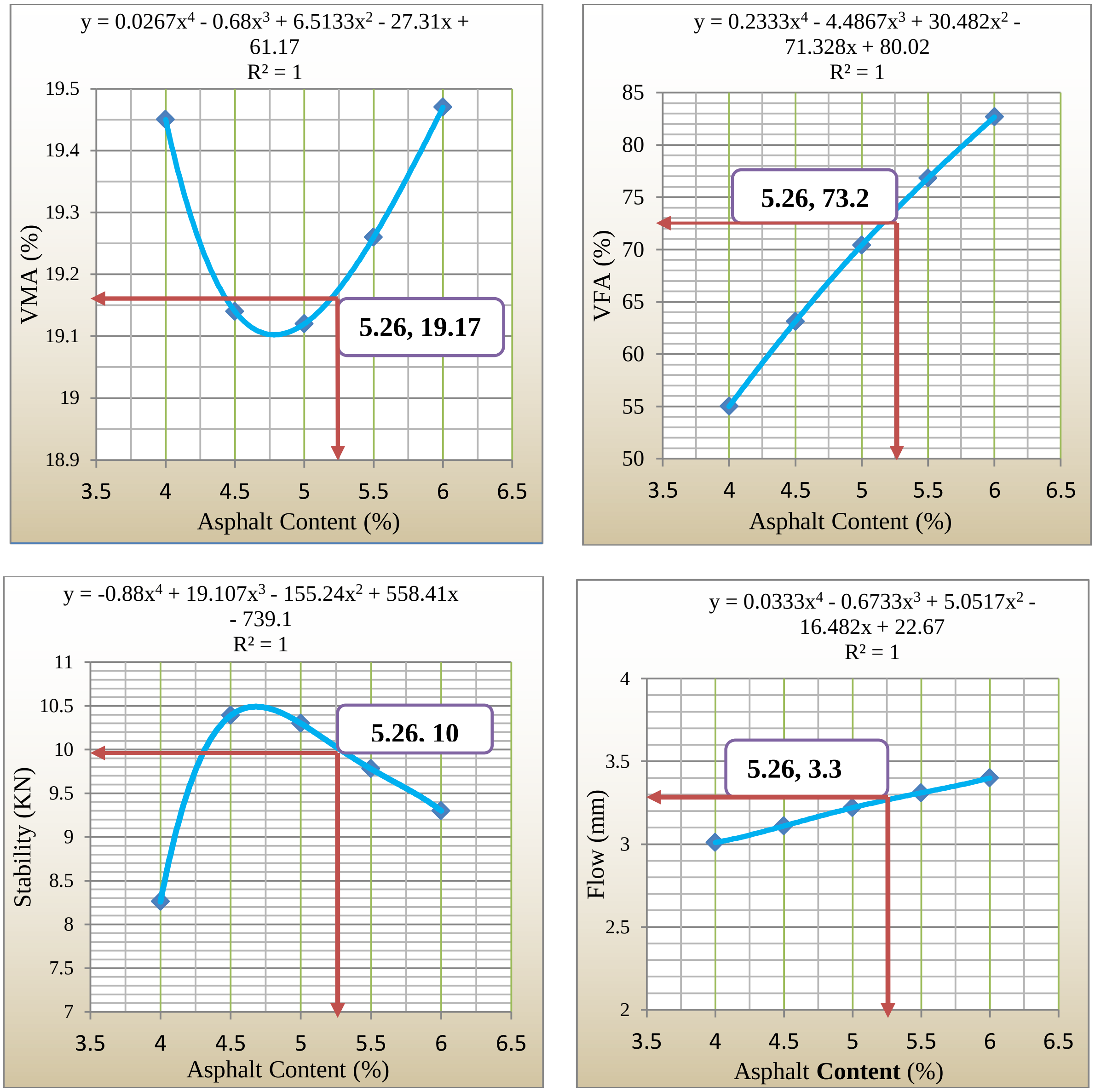



Figure 4. 6: OBC and the properties of mixtures with 6.5 % CSD filler.

Fig 4.6 shows the relationships between binder content and the properties of mixtures with 6.5% CSD. The optimum bitumen content of the mix result is 5.26 % as shown in graph 4.6 based on the median air void content (4 percent) of the specification. The general ways of the curves for 6.5% crushed stone dust filler content is similar with the curve of 4.5 % & 5.5% crushed stone dust filler content plotting curves.

### 4.3.2 Determining the optimum Bitumen Content

In this study .to determine the optimum asphalt content National Asphalt Pavement Association (NAPA) was used, as this method suggests that preparing of plotting curves is necessary, depending on these making plots were done and it shows in the above figures 4.4-4.6. After plotting the curves the following procedures were done.

- Finding of the asphalt content which corresponds to median air void (4%) of the specification from the plotting curve as shown in fig 4.4 to 4.6.
- By using this asphalt content the values of Marshall Stability, Flow, VMA, VFA and Bulk specific gravity was determined as shown in the plot curves as located in Fig 4.4 to 4.6.
- Each value is compared against the specified value for that property and if all values are within the specified range ,the asphalt content at 4% air voids is the optimum bitumen content (Asphalt Institute,2003).

Based on the above procedures the optimum asphalt contents are 4.75 %, 5 % and 5.26 % (by weight of total mix) at 4% air void for 4.5 5.5 and 6.5 percent Crushed Stone Dust filler respectively. The summarized properties of mixtures at their optimum bitumen content for mixes with 4.5%, 5.5 % and 6.5 % of crushed stone dust filler are illustrated by table 4.8, 4.9 and 4.10 respectively below.

Table 4. 8: Marshall Properties of the asphalt mix with 4.75% OBC and 4.5% CSD filler.

| Mix property | Values Obtained | ERA Specification Limit | | Asphalt Institute Limit | | Status |
|---|---|---|---|---|---|---|
| | | Lower | Upper | Lower | Upper | |
| Asphalt ,% | 4.75 | 4 | 10 | 4 | 10 | ok |
| Air Void,% | 4.00 | 3 | 5 | 3 | 5 | ok |
| VMA,% | 16.9 | Min 13 | - | Min 13 | - | ok |
| VFA,% | 66.3 | 65 | 75 | 65 | 75 | ok |
| Stability KN | 8.4 | Min 7.0 | - | Min 8.006 | - | ok |
| Flow ,mm | 3.25 | 2 | 4 | 2 | 3.5 | ok |
| Bulk Sp.gm/cm$^3$ | 2.233 | - | - | - | - | |

Table 4.8 describes the asphalt content corresponding to the standard specification criteria. As shown in the table 4.8 Mix properties are located with their values obtained from the plot curve. The stability of the asphalt mix for 4.5% crushed stone dust filler is 8.4 KN at 4.75% OBC. And this result is greater than the minimum requirement value of 7.0 KN specified by the standard limits. Also VMA, VFA, flow and Specific gravity of the asphalt mix at 4.75% OBC are 16.9%, 66.3%, 3.25mm and 2.233 gm/cm$^3$ respectively as shown in fig 4.4. Therefore it indicates that the mix at 4.5% crushed stone dust filler satisfied the criteria with 4.75 % of OBC.

Table 4. 9: Marshall Properties of the asphalt mix with 5.% OBC and 5.5% CSD filler.

| Mix property | Values Obtained | ERA Specification Limit | | Asphalt Institute Limit | | Status |
|---|---|---|---|---|---|---|
| | | Lower | Upper | Lower | Upper | |
| Asphalt ,% | 5.00 | 4 | 10 | 4 | 10 | Ok |
| Air Void,% | 4.00 | 3 | 5 | 3 | 5 | Ok |
| VMA,% | 14.72 | Min 13 | - | Min 13 | - | Ok |
| VFA,% | 73 | 65 | 75 | 65 | 75 | Ok |
| Stability KN | 11.2 | Min 7.0 | - | Min 8.006 | - | Ok |
| Flow ,mm | 3.1 | 2 | 4 | 2 | 3.5 | Ok |
| Bulk Sp.gm/cm$^3$ | 2.355 | - | - | - | - | |

Table 4.9 describes the asphalt content corresponding to the standard specification criteria. As shown in table 4.9 Mix properties are located with their values obtained from the plot curve. The stability of the asphalt mix for 5.5% crushed stone dust filler is 11.2KN at 5 % OBC. This result is greater than the minimum requirement value of 7.0 KN specified by the standard limits. Also VMA, VFA, flow and Bulk Specific gravity of the asphalt mix at 5 % OBC is 14.72 %, 73 %, 3.1mm and 2.355gm/cm$^3$ respectively .Hence it indicates that the mix at 5.5% crushed stone dust filler satisfied the criteria of ERA and Asphalt Institute standards.

Table 4. 10: Marshall Properties of the asphalt mix with 5.26% OBC and 6.5% CSD filler**.**

| Mix property | Values Obtained | ERA Specification Limit | | Asphalt Institute Limit | | Status |
|---|---|---|---|---|---|---|
| | | Lower | Upper | Lower | Upper | |
| Asphalt ,% | 5.26 | 4 | 10 | 4 | 10 | Ok |
| Air Void,% | 4.00 | 3 | 5 | 3 | 5 | Ok |
| VMA,% | 19.17 | Min 13 | - | Min 13 | - | Ok |
| VFA,% | 73.2 | 65 | 75 | 65 | 75 | Ok |
| Stability KN | 10 | Min 7.0 | - | Min 8.006 | - | Ok |
| Flow ,mm | 3.3 | 2 | 4 | 2 | 3.5 | Ok |
| Bulk Sp.gm/cm$^3$ | 2.227 | - | - | - | - | |

Table 4.10 describes the asphalt content corresponding to the standard specification criteria. As shown in the table above Mix properties are located with their values obtained from the plot curve. The stability of the asphalt mix at 6.5% crushed stone dust filler is 10 KN with

5.26% OBC. This result is greater than the minimum requirement value of 7.0 KN specified by the standard limits. Also VMA, VFA, flow and Specific gravity of the asphalt mix at 5.26% OBC is 19.17%, 73.2%, 3.3 mm and 2.227gm/cm$^3$ respectively. Hence it indicates that the mix at 6.5% crushed stone dust filler satisfied the criteria of ERA and Asphalt Institute standard Specifications.

### 4.3.3. Comparison of OBC at Percentage mix proportion of Crushed Stone Dust filler

Table 4. 11: OBC and Marshall Properties of the three percentages of mix proportions.

| Properties | Crushed Stone Dust Filler | | | Specification (ERA Pavement Design Manual) |
|---|---|---|---|---|
| | **4.5%** | **5.5%** | **6.5%** | |
| Asphalt,% | 4.75 | **5** | 5.26 | 4-10% |
| Air Void,% | 4 | **4** | 4 | 3-5% |
| VMA,% | 16.9 | **14.72** | 19.17 | Min 13 |
| VFA,% | 66.3 | **73** | 73.2 | 65-75% |
| Stability, KN | 8.4 | **11.2** | 10 | Min 7KN |
| Flow, mm | 3.25 | **3.1** | 3.3 | 2-4mm |
| Bulk Specific Gravity (gm/cm$^3$) | 2.233 | **2.355** | 2.227 | - |

Table 4.11 describes the Marshall Properties of the mixes corresponding to the three varying Crushed Stone Dust filler content (4.5%, 5.5% and 6.5%).The OBC were 4.75%, 5 % & 5.26 % respectively. Marshall Stability of the mix for the three filler contents is 8.4 KN, 11.2 KN & 10 KN respectively. Flow of the mix for the three filler contents is 3.25mm, 3.1mm & 3.3 mm respectively. Also the volumetric properties of the three filler contents satisfied the specification ranges of ERA pavement design Manual. From the results described in table 4.11, the bitumen content of all the three percentage crushed stone dust fillers were within the range of the specification. Comparing all the mixtures, it indicates that at 5.5% crushed stone dust filler with 5% bitumen content (by weight of total mix) shows higher Stability than all other mixtures. So the result of 5.5% crushed stone dust filler is considered as Optimum filler content and 5% bitumen content is optimum bitumen content based on Maximum Marshall Stability. These optimum contents are used for replacement of mix in this study.

## 4.4 Marshall Properties of Partial Replacement of filler materials with Blended Corncob ash and Saw dust ash.

in this research the crushed stone dust filler materials were replaced by different percentages of blended corncob ash & saw dust ash and the Marshall properties (Stability, flow and volumetric properties) of a typical binder coarse asphalt concrete were evaluated the percentage interval of replacement rate was 10% (by weight of OFC) up to the Marshall properties becomes decline to fulfill the standards of ERA pavement design Manual. Different filler contents and the proportion of the mixtures were described by table 4.12 below.

Table 4. 12: Mix Proportion of Asphalt Concrete Mixtures Prepared by using different filler content and their proportion of used aggregate.

| Sample Name | Coarse aggregate | Intermediate aggregate | | Fine aggregates | % of Crushed Stone dust (By Wt. Of aggregates) | % of blended Corncob ash &Saw dust ash (by Wt. of OFC) | Filler (CSD+ blended CCA and SDA) |
|---|---|---|---|---|---|---|---|
| | (14-20mm) | (6-14mm) | (3-6mm) | (0-3mm) | | | |
| Control sample | 5.8 | 26.4 | 20.5 | 41.8 | 5.5 (100%) | 0 (0%) | 5.5 (100%) |
| BCSA1 | 5.8 | 26.4 | 20.5 | 41.8 | 4.95 (90%) | 0.55 (10%) | 5.5 (100%) |
| BCSA2 | 5.8 | 26.4 | 20.5 | 41.8 | 4.4 (80%) | 1.1 (20%) | 5.5 (100%) |
| BCSA3 | 5.8 | 26.4 | 20.5 | 41.8 | 3.85 (70%) | 1.65 (30%) | 5.5 (100%) |
| BCSA4 | 5.8 | 26.4 | 20.5 | 41.8 | 3.3 (60%) | 2.2 (40%) | 5.5 (100%) |
| BCSA5 | 5.8 | 26.4 | 20.5 | 41.8 | 2.75 (50%) | 2.75 (50%) | 5.5 (100%) |
| BCSA6 | 5.8 | 26.4 | 20.5 | 41.8 | 2.2 (40%) | 3.3 (60%) | 5.5 (100%) |
| BCSA7 | 5.8 | 26.4 | 20.5 | 41.8 | 1.65 (30%) | 3.85 (70%) | 5.5 (100%) |

Table 4.12 describes the mix design proportion consists of coarse aggregates (14-20mm) of 5.8%, intermediate aggregates (6-14mm) of 26.4% and (3-6mm) of 20.5%, fine aggregates (0-3mm) of 41.8% and mineral fillers (0.075mm size) of 5..5%. A total of 24 Marshall Specimens of mixtures were prepared. Each specimen weights 1200gm. eight different percentage rate of replacements were prepared which are; 0%, 10%, 20%, 30%, 40% 50%, 60% and 70% (by weight of OFC) and 5% bitumen content (by weight of total mix, i.e. one

specimen). The Marshall test was used to evaluate the specimens. More details are presented in Appendix E**.**

Table 4. 13: Marshall Properties of asphalt mixes with blended Corncob ash & Saw dust ash at constant bitumen content of 5%.

| % of replacement rate | CSD and BCSA Content by % of total Mix | ρA (g/cm3) | VIM (%) | VMA (%) | VFA (%) | Stability (KN) | Flow (mm) |
|---|---|---|---|---|---|---|---|
| 0 (Control Sample) | 5.5CSD + 0 BCSA | 2.35 | 4.28 | 14.46 | 70.4 | 10.4 | 3.02 |
| 10 | 4.95 CSD + 0.55 BCSA | 2.35 | 4.3 | 14.46 | 70.26 | 10 | 3.12 |
| 20 | 4.4 CSD +1.1 BCSA | 2.36 | 4.1 | 14.1 | 70.9 | 9.62 | 3.12 |
| 30 | 3.85 CSD +1.65 BCSA | 2.37 | 4.05 | 13.74 | 70.52 | 9.94 | 3.29 |
| 40 | 3.3 CSD + 2.2 BCSA | 2.375 | 4 | 13.55 | 70.48 | 10.06 | 3.22 |
| 50 | 2.75 CSD + 2.75 BCSA | 2.344 | 4.25 | 14.68 | 71.05 | 7.5 | 3.41 |
| 60 | 2.2 CSD + 3.3 BCSA | 2.345 | 4.29 | 14.65 | 70.72 | 6.98 | 3.36 |
| 70 | 1.65 CSD + 3.85 BCSA | 2.33 | 4.31 | 15.19 | 71.63 | 6.93 | 3.44 |

Table 4.13 shows the laboratory test results of asphalt mixtures with different percentage replacement rate of crushed stone dust filler by blended corncob ash & saw dust ash with a constant bitumen content of 5%. The properties of asphalt mixtures with different percentage replacement of blended corncob ash and saw dust ash are discussed below in each different section.

### 4.4.1 Marshall Stability-blended corncob ash & Saw dust ash Content relationship.

The relationship between Marshall Stability and blended corncob ash and saw dust ash is described below in table 4.14 and in fig 4.7.

Table 4.14: Relationship between stability and replacement rate of BCSA

| Replacement ratio of blended CCA and SDA, (%) | 10 | 20 | 30 | **40** | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| Marshall Stability Value (KN) | 10 | 9.62 | 9.94 | **10.06** | 7.5 | 6.98 | 6.93 |

Table 4.14 describes the laboratory test result of Marshall Stability with different replacement ratio of corncob ash and saw dust ash from 10% up to 70% (by weight of optimum filler

content ) used as a mineral filler in Hot Mix asphalt concrete production in this study. The laboratory test results are shown below in graph.

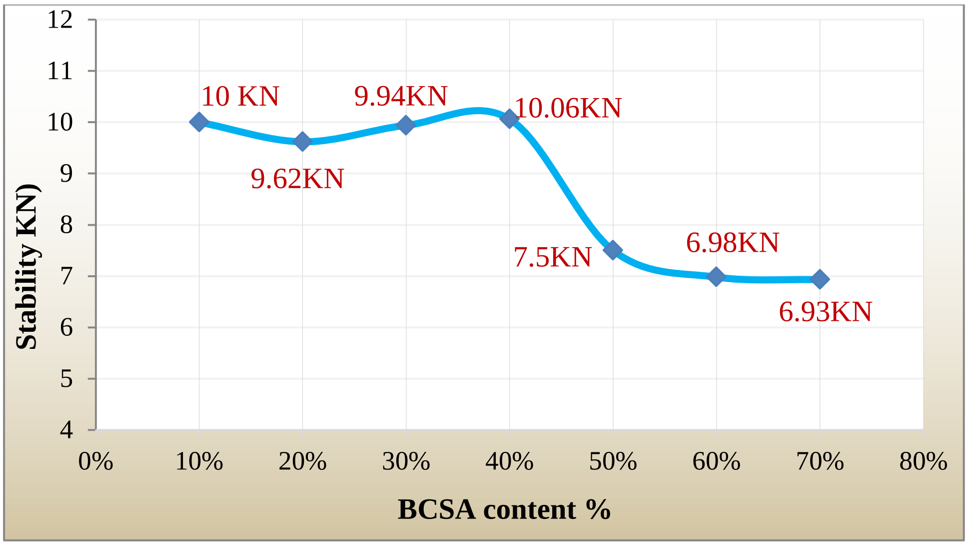



Figure 4. 7: Relationship of Stability (KN) to BCSA %

Fig 4.7 describes the relationship between Marshall Stability value and the replacement rate of crushed stone dust filler with blended corncob ash & Saw dust ash (BCSA).The first purpose of this study was determining the maximum percentage replacement rate of blended corncob ash & saw dust ash for replacing crushed stone dust. Hence when we see the replacement rate starting from 10% interval it was achieved the requirement of the ERA Pavement Design Manual, 2002 specification up to 50% but as shown in the table & fig above at 60 % and 70% the stability value was below the standard specification, i.e. 6.98 KN & 6.93 KN respectively.

### 4.4.2 Flow-blended corncob ash & Saw dust ash Content relationship.

The relationship between Flow and blended corncob & saw dust ash is described below in table 4.15 and in fig 4.8 below.

Table 4. 15: Relationship between Flow and replacement rate of BCSA

| Replacement ratio of blended CCA and SDA, (%) | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| Flow Value (mm) | 3.12 | 3.12 | 3.29 | 3.22 | 3.41 | 3.36 | 3.44 |

Table 4.15 describes the laboratory test result of flow with different replacement ratio of corncob ash and saw dust ash from 10 % up to 70% (by weight of optimum filler content )

used as a mineral filler in Hot Mix asphalt concrete production in this study. The laboratory test results are shown below in graph.

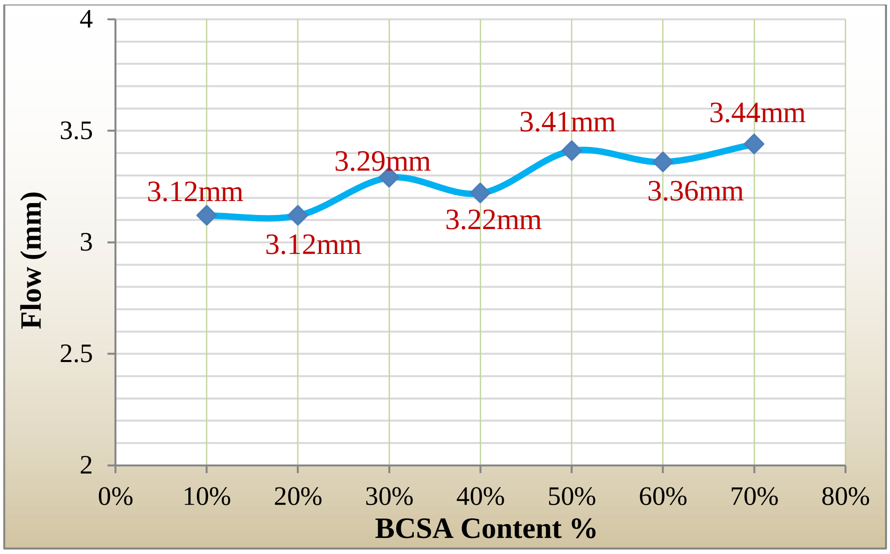



Figure 4. 8: Relationship of Flow (mm) to BCSA %

Fig 4.8 indicates the relationship between flow value and the replacement rate of crushed stone dust filler with blended corncob ash & saw dust ash. The value indicates all the replacement percentage rates satisfy the specification requirement. As discussed above for the relationship between stability value and the replacement rate of crushed stone dust filler with blended corncob ash & saw dust ash it was achieved the specification requirement up to 50% (2.75% CSD &2.75% BCSA) percentage replacement rate. But here for flow condition it satisfied the requirement in all percentage replacement rates. The maximum flow value was recorded at 70% replacement rate (1.65% CSD and 3.85% BCSA by weight of aggregates) which was 3.44mm.

### 4.4.3 Bulk Density-blended corncob ash & Saw dust ash Content relationship.

The relationship between Bulk -Density and blended corncob & saw dust ash is described below in table 4.16 and in fig 4.9 below.

Table 4. 16: Relationship between Bulk –density and replacement rate of BCSA

| Replacement ratio of blended CCA and SDA, (%) | 10 | 20 | 30 | **40** | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| Bulk Density value (gm/cm3) | 2.36 | 2.36 | 2.37 | **2.375** | 2.344 | 2.345 | 2.33 |

Table 4.16 describes the laboratory test result of bulk-density with different replacement ratio of blended corncob ash and saw dust ash from 10 % up to 70% (by weight of optimum filler

content ) used as a mineral filler in Hot Mix asphalt concrete production in this study . The laboratory test results are shown below in graph.

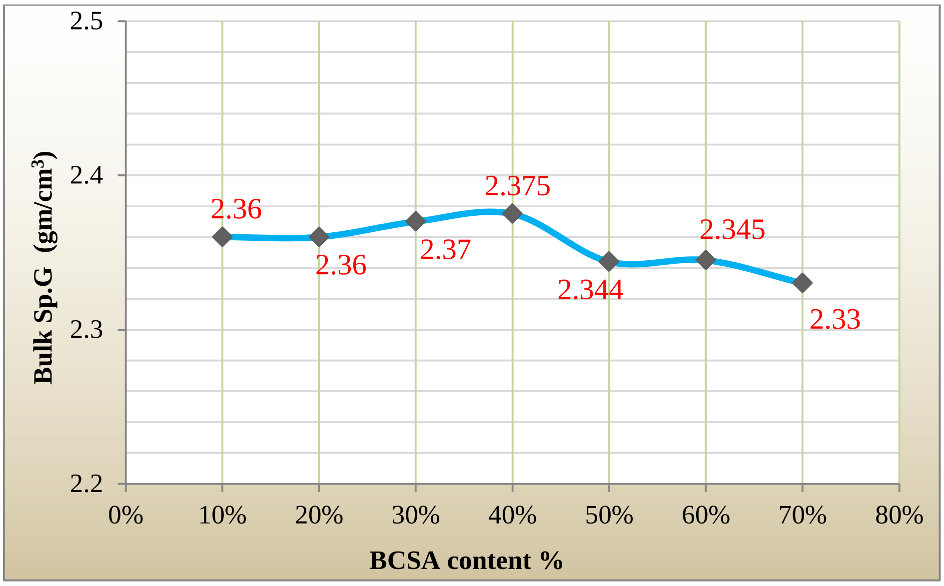



Figure 4. 9: Relationship of Bulk Sp.G (gm/cm$^3$) to BCSA

Fig 4.9 indicates the relationship between Bulk -density value and the replacement rate of crushed stone dust filler with blended corncob ash & Saw dust ash. Bulk density was increases with percentage rate increases until 40% replacement rate and then starts to decrease with increasing of percentage replacement rate. In this study the maximum bulk density is 2.375gm/cm$^3$ at 40% blended corncob ash & saw dust ash content (the samples prepared with 3.3% CSD and 2.2% BCSA by weight of aggregates).

#### 4.4.4 Air Voids (VA)-blended corncob ash & Saw dust ash Content relationship

The relationship between Air voids (VA) and blended corncob & saw dust ash is described in table 4.17 and fig 4.10.

Table 4. 17: Relationship between Air Voids (VA) and replacement rate of BCSA

| Replacement ratio of blended CCA and SDA ,(%) | 10 | 20 | 30 | **40** | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| Air Void (Va() value ,(%) | 4.3 | 4.1 | 4.05 | **4** | 4.25 | 4.29 | 4.31 |

Table 4.17 describes the laboratory test result of Air Voids with different replacement ratio of blended corncob ash and saw dust ash from 10 % up to 70% (by weight of optimum filler content ) used as a mineral filler in Hot Mix asphalt concrete production in this study . The laboratory test results are shown below in graph.

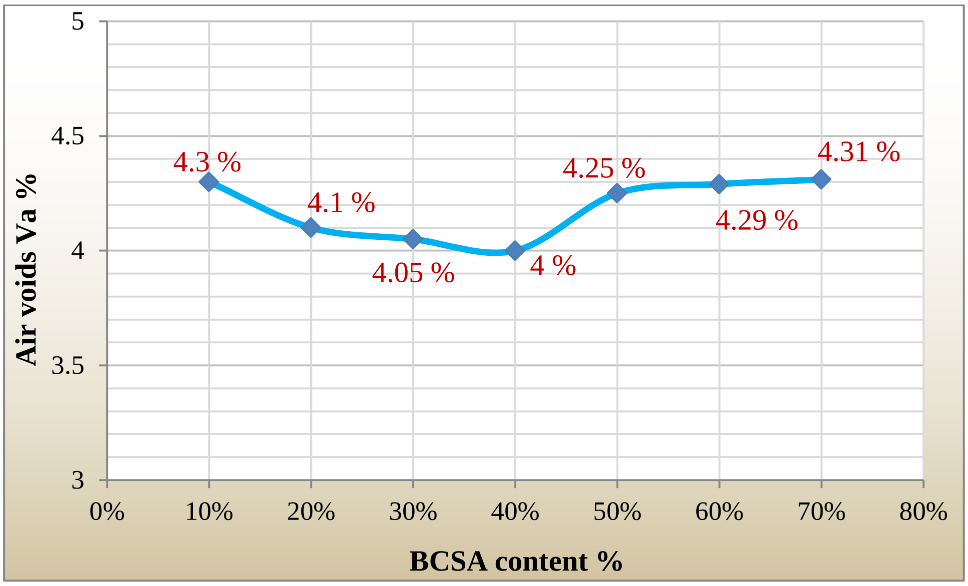



Figure 4. 10: Relationship of Air Voids (Va) % to BCSA %

Fig 4.10 indicates the air void content for replaced mixtures 0-70% blended corncob ash & saw dust ash (by weight of OFC). all the replacement rates satisfied the specification criteria ranges (3-5%) specified by ERA pavement design Manual, 2002. at 40% blended corncob ash & saw dust ash content (by weight of OFC) the air void value is 4% which is the median value of international and local specification.

**4.4.5 Voids in mineral aggregates (VMA)-blended corncob ash & Saw dust ash Content relationship**

The relationship between Voids in mineral aggregates (VMA) and blended corncob & saw dust ash is described in table 4.18 and fig 4.11.

Table 4. 18: Relationship between (VMA) and replacement rate of BCSA

| Replacement ratio of blended CCA and SDA ,(%) | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| VMA value ,(%) | 14.6 | 14.1 | 13.736 | 13.55 | 14.68 | 14.65 | 15.19 |

Table 4.18 describes the laboratory test result of Voids in mineral aggregates with different replacement ratio of blended corncob ash and saw dust ash from 10 % up to 70% (by weight of optimum filler content ) used as a mineral filler in Hot Mix asphalt concrete production in this study . The laboratory test results are shown below in graph.

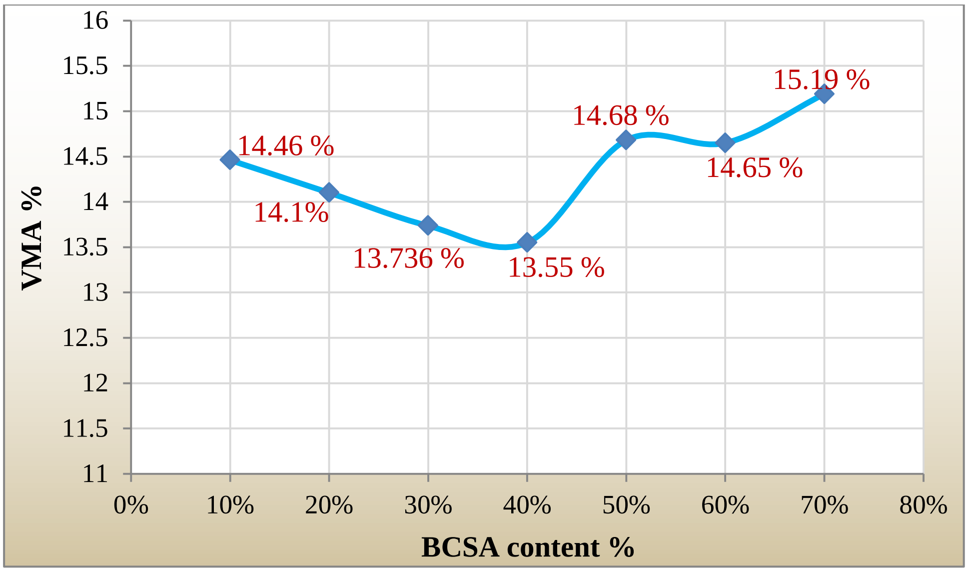



Figure 4. 11: Relationship of VMA % to BCSA %

Fig 4.11 describes the relationship between Voids in mineral aggregates (VMA) value and the replacement rate of crushed stone dust filler with blended corncob ash & Saw dust ash. The results indicate that all the percentage rates satisfied the specification criteria. The minimum value in this study was recorded at 40% blended corncob ash & saw dust ash content (by weight of OFC) which is 13.55%. All other percentage rate values were within the specification range of ERA pavement design manual, 2002.

### 4.4.6 Percent Voids filled with asphalt (VFA)-blended corncob ash & Saw dust ash Content relationship.

The relationship between Voids in mineral aggregates (VMA) and blended corncob & saw dust ash is described below in table 4.19 fig 4.12

Table 4. 19: Relationships between (VFA) and replacement rate of BCSA.

| Replacement ratio of blended CCA and SDA ,(%) | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| VFA value, (%) | 70.26 | 70.9 | 70.52 | 70.48 | 71.05 | 70.72 | 71.63 |

Table 4.19 describes the laboratory test result of Voids filled with Asphalt with different replacement ratio of blended corncob ash and saw dust ash from 10 % up to 70% (by weight of optimum filler content ) used as a mineral filler in Hot Mix asphalt concrete production in this study . The laboratory test results are shown below in graph.

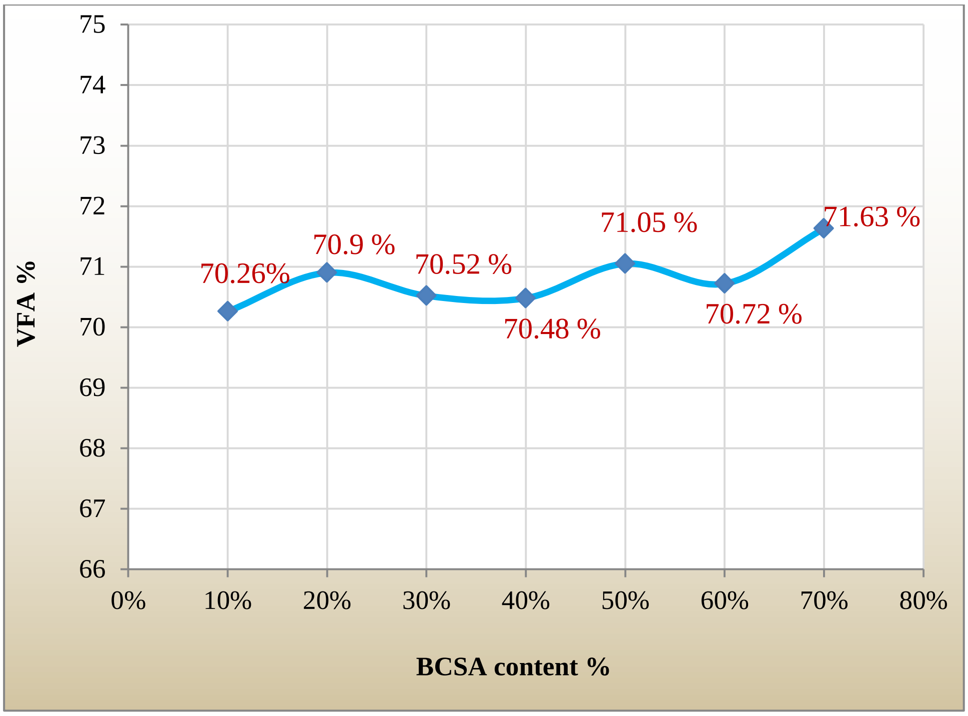



Figure 4. 12 : Relationship of VFA % to BCSA %

Fig 4.12 shows the relationship between percent voids filled with asphalt (VFA) value and the replacement rate of crushed stone dust filler with blended corncob ash & Saw dust ash. All the samples prepared with replacement of crushed stone dust with blended corncob ash & saw dust ash satisfied the specification criteria (ERA pavement design manual, 2002) which were 65%-75%.

### 4.4.7. Summary of properties of replaced mix with different percentages of blended corncob ash & saw dust ash.

Marshall Stability test is done for replaced mix with different percentage rate of blended corncob ash and saw dust ash as discussed above. The relationship between each Marshall Property with the replaced mix by blended corncob ash and saw dust ash also discussed. The summarized Marshall Property test results of replaced mix are shown below by table 4.20.

Table 4.20: summarized properties of replaced asphalt mix with different percentages of blended corncob ash and saw dust ash

| Property | Percentage Replacement of blended CCA & SDA, (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | **40** | 50 | 60 | 70 |
| % of Optimum Bitumen Content (OBC) | 5 | 5 | 5 | 5 | **5** | 5 | 5 | 5 |
| Stability (KN) | 10.4 | 10 | 9.62 | 9.94 | **10.06** | 7.5 | 6.98 | 6.93 |
| Flow (mm) | 3.02 | 3.12 | 3.12 | 3.29 | **3.22** | 3.41 | 3.36 | 3.44 |
| Bulk- Density (gm/cm$^3$) | 2.35 | 2.35 | 2.36 | 2.37 | **2.375** | 2.344 | 2.345 | 2.33 |
| % of Voids in total Mix ($V_a$ %) | 4.28 | 4.3 | 4.1 | 4.05 | **4** | 4.25 | 4.29 | 4.31 |
| % of voids in Mineral Aggregates (VMA) | 14.46 | 14.46 | 14.1 | 13.736 | **13.55** | 14.68 | 14.65 | 15.19 |
| % of Voids Filled With Asphalt (VFA) | 70.4 | 70.26 | 70.9 | 70.52 | **70.48** | 71.05 | 70.72 | 71.63 |

Table 4.20 indicates the Marshall Stability test results for different mixes prepared with 10% percentage rate replacement of blended corncob ash and saw dust ash. As the table indicates the replacement was done up to 70 % and all the results for each percentage replacements are shown. from the percentage replacement rates starting from 10% the maximum stability (10.06 KN) was recorded at 40 % (by weight of OFC) and the minimum was recorded at 70 % which is 6.93 KN. the median air void (4% ) also recorded at 40 % replacement rate and maximum bulk density (2.375 gm/cm3) also recorded at 40 % replacement rate.

**4.4.8 Determination of the potential replacement ratio of blended corncob ash and saw dust ash in Hot mix Asphalt Concrete.**

This study was focused on determining the potential percentage ratio of blended corncob ash and saw dust ash fillers that used to be replaced the crushed stone dust filler. This was depending on the laboratory test results which satisfied all the necessary specification standards. as discussed above the study was done by 10% interval (trial and error method) of replacement rate until it fulfill the specification standards in all properties, hence as shown above in each property related with replacement rate of blended corncob ash & saw dust ash it was satisfied up to 50% replacement rate in all properties. however starting from 60%

replacement rate mainly stability could not achieved the specification standard of ERA pavement Design Manual, 2002 .at 60% the stability is 6.98 KN and at 70 % the stability is 6.93 KN which is below the minimum standard requirement of ERA Pavement Design Manual, 2002. Hence blended corncob ash and saw dust ash fillers could be replaced crushed stone dust filler in Hot mix Asphalt up to 50% replacement rate in all parameters requirement value. Generally based on ERA, pavement Design Manual, 2002 criteria the potential replacement ratio of blended corncob ash and saw dust ash can be replaced crushed stone dust fillers in Hot Mix Asphalt production is 50% (by weight of OFC, i.e.5.5 %).

### 4.4.9 Determination of the optimum replacement ratio of blended corncob ash and saw dust ash in Hot Mix Asphalt Concrete.

From this study determining the optimum replacement ratio of blended corncob ash & saw dust ash is necessary. a set of controls is recommended in order to obtain the optimum replacement rate that produce an asphalt mix with the best Marshall properties (Jendia,2000).the asphalt mix with optimum replacement rate must satisfies the following criteria.

- ✓ Maximum Stability
- ✓ Maximum bulk-density
- ✓ Va (%) with in the allowed range of specifications.

Table (4.14, 4.16 & 4.17) are used to obtain the optimum replacement rate of blended corncob ash and saw dust ash fillers which satisfies the above three criteria. Hence the maximum stability was recorded at 40% replacement rate. (Considering from 10%-50% replacement rate). Table 4.16 also represents the air voids percentage at different filler content that all replacement rates were within the requirement specification range (3%-5%), at 40% BCSA (by weight of OFC) the corresponding air voids value was 4% which is the median air voids in the specification. Table 4.17 also describes the bulk-density and from that the maximum bulk density was also recorded at 40% BCSA replacement rate which value was 2.375gm/cm$^3$.summarized results are described below in table 4.21.

Table 4. 21: Summary of controls properties of Mix to obtain optimum replacement rate.

| Property | Replacement rate of BCSA by weight of OFC (%) |
|---|---|
| Maximum Stability | 40 |
| Maximum Bulk-Density | 40 |
| 4% Median Air Voids | 40 |

Table 4.21 shows the mix that obtained by using 40% BCSA (by weight of OFC) and 60 % CSD (by weight of OFC) meets the criteria of selecting optimum replacement rate. Generally 40% blended corncob ash and saw dust ash (by weight of optimum filler content) with 5% of asphalt content (by weight of total mix) was adopted as the optimum replacement rate.

Comparison of Marshall Properties of asphalt mix with the optimum replacement rate of 40% (by weight of optimum filler content) with local and international specifications is necessary. Table 4.22 below describes a comparison of the Marshall properties of asphalt mix containing 40% of blended corncob ash and saw dust ash filler content with local and international specification.

Table 4.22: Comparison of Optimum replacement rate of asphalt mix with specification

| Marshall Method Mix Criteria | 40% of Replaced Asphalt mix | Local Specification (ERA pavement Design, Manual,2002) | | International specification (Asphalt Institute ,2003) | | Remark |
|---|---|---|---|---|---|---|
| | | Heavy Traffic | | Heavy Traffic | | |
| | | Min | Max | Min | Max | |
| No of Blows | 2*75 | 2* 75 | | 2 *75 | | Satisfied. |
| Stability, KN | 10.06 | 7 | - | 8.006 | - | Satisfied. |
| Flow, mm | 3.22 | 2 | 4 | 2 | 3.5 | Satisfied. |
| Percent Air Voids Va,% | 4 | 3 | 5 | 3 | 5 | Satisfied. |
| Percent Voids Filled With Asphalt (VFA),% | 70.48 | 65 | 75 | 65 | 75 | Satisfied. |
| % of Voids in Mineral Aggregates (VMA),% | 13.55 | 13 | - | 13 | - | Satisfied. |

Table 4.22 describes the asphalt mixtures prepared with optimum blended corncob ash & saw dust ash content. As shown in table above it satisfied the requirements of ERA pavement design manual, 2002 and Asphalt Institute, 2003 for all tested Properties. Hence it is more effective to use blended corncob ash and Saw dust ash fillers (blend by equal amount) with maximum replacement rate of 40% BCSA by weight of optimum filler content or 2.2% by weight of one specimen mixture of aggregates.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

Corncob and saw dust are locally available materials. Making these materials by the size mineral filler and using partially for replacing crushed stone dust fillers in hot mix asphalt concrete was the main objective of this research. These two materials (corncob ash and saw dust ash) were used by blending of equal amount. This study was focused on the objectives of;

- ❖ Determining the physical properties of aggregates, bitumen, crushed stone dust, corncob ash and saw dust ash which used for preparing the mixtures.
- ❖ Determining the potential of blended corncob ash and saw dust ash as filler materials in Hot Mix Asphalt concrete.
- ❖ Determining the optimum content of blended corncob ash and saw dust ash that can replace crushed stone dust fillers in Hot Mix Asphalt Concrete.
- ❖ Suggest the utilization of blended corncob ash and saw dust ash for hot mix asphalt concrete.

Depending on the results of the research the following conclusions are drawn.

- ✓ Laboratory test was done to determine the materials property. Depending on the laboratory test results all the materials used in this research satisfied all the standard specification criteria.
- ✓ To determine the optimum bitumen content and filler content three gradations were prepared based on varying percentages of crushed stone dust filler contents (4.5%, 5.5%, and 6.5% by weight of aggregate).
- ✓ All the three gradations prepared with different crushed stone dust filler contents Marshall Stability and Flow values were satisfied According to ERA Pavement Design Manual, 2002.
- ✓ To determine the optimum filler content the basic determination way was accordance with the Maximum Stability recorded from the three filler contents. Depending on that 5.5 % (by weight of aggregate) and 5% (by weight of total mix) were the optimum filler content and optimum bitumen contents respectively.

- ✓ The corncob and saw dust was prepared by the size of conventional fillers and then they were blended by equal amount that is 50% corncob ash and 50% saw dust ash. This blended corncob ash and saw dust ash were used to be replaced crushed stone dust fillers by varying amount trial and error method until its maximum potential replacing rate.
- ✓ The mix was replaced by 10% (by weight of OFC) interval until it starts decline to fulfilled the specification requirements. Depending on that it was fulfilled the criteria until 50% replacement rates and after that mainly stability was below the standard. Hence the potential of BCSA to replaced crushed stone dust was 50% (by weight of optimum filler content) or 2.75% (by weight of aggregate, i.e. one specimen).
- ✓ The mix obtained by using 10%, 20%, 30% 40% & 50% replacement ratio of BCSA were meets the standards specified in terms of Stability, flow, Va, VMA and VFA at an optimum Bitumen Content of 5.0%.
- ✓ Marshall Test result values indicated that the asphalt mixtures prepared using by 40% BCSA fillers and 60% CSD fillers with 5% of bitumen content has Maximum Stability, Maximum Bulk-Density and VA (%) within the allowable specification requirement ranges to select the optimum replacement percentage rate Hence, BCSA can partially replace the Crushed Stone Dust filler in hot mix asphalt at optimum replacement rate of 40% (by weight of optimum filler content) or 2.2 % (by weight of one specimen mixture aggregate) with a constant bitumen content of 5%.

## 5.2 Recommendation

Each region of the world should play role in environmental protection and sustainability use of natural resources. Ethiopian Construction companies also play a great role by using locally available materials partially and benefits from it as the other countries did. Therefore based on the study the following recommendations are forwarded from the researcher.

- ✓ locally available materials like saw dust ash and corn cob ash are waste materials of timber and corncob respectively, using these materials for a filler in hot mix asphalt has two advantages that are; minimizing the shortage of HMA filler and the other one is preparing these locally available materials as income of source for the owners.
- ✓ Using this corncob ash and saw dust ash partially as a filer material initiates the other researchers to do their researches on new ideas that were not done previously.

- ✓ The other researchers must have to do chemical properties, when they use lubricated materials i.e. Saw dust ash.
- ✓ In this research mechanical mixture was not used in HMA preparation because it was not functional.
- ✓ Using these waste materials is used for decreasing environmental pollution.
- ✓ This type of studies helps to co-operate the construction agencies with the society.
- ✓ 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.
- ✓ Finally the researcher recommends the Ethiopian Road Authority there are so many researches like this partial replacement of blended corncob ash and saw dust ash as a mineral filler in hot mix Asphalt, therefore they must be use from the researchers study work.
- ✓ To simplify the use of Corncob ash and Saw dust ash it is better to collect them at the right time of their availability at the constructed store to facilitate a good transportation system for addressing them.

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# APPENDIXIES

## APPENDIX – A Physical Property of Mineral Fillers Test Results

TEST METHOD: AASHTO T84-95

Table A1: Physical Properties of Crushed Stone Dust Filler

| Material Type : | Crushed Stone Dust | |
|---|---|---|
| Trial No | 1 | 2 |
| Mass of Pycnometer ,(g) | 31.5 | 28 |
| Mass of Pycnometer with Water at Initial Temp,Ti (g) | 130.4 | 128.87 |
| Initial Temperature in degree Celicuous,Ti | 22 | 22 |
| Mass of Pycnometer and soil,g | 56.5 | 53 |
| Mass of Pycnometer soil and Water,g **(Wb)** | 145.85 | 145.09 |
| Final Temperature in degree Celicuous,Tx | 22 | 22 |
| Mass of Soil ,(g)) ( **Wo)** | 25 | 25 |
| Mass of Pycnometer with Water at Final Temp,Tx (g) (**Wa)** | 130.3 | 129 |
| Apparent Specific Gravity ,Gs=(Wo/Wo+(Wa-Wb))*K | 2.645 | 2.805 |
| Average Apparent Specific Gravity | **2.725** | |

Table A2: Physical Properties of Corncob Ash Filler

| Material Type : | Corncob Ash | |
|---|---|---|
| Trial No | 1 | 2 |
| Mass of Pycnometer ,(g) | 32 | 31 |
| Mass of Pycnometer with Water at Initial Temp,Ti (g) | 125.8 | 129.2 |
| Initial Temperature in degree Celicuous,Ti | 22 | 22 |
| Mass of Pycnometer and soil,g | 57 | 56 |
| Mass of Pycnometer soil and Water,g **(Wb)** | 139.5 | 145.09 |
| Final Temperature in degree Celicuous,Tx | 22 | 22 |
| Mass of Soil ,(g)) ( **Wo)** | 25 | 25 |
| Mass of Pycnometer with Water at Final Temp,Tx (g) (**Wa)** | 125.71 | 129 |
| Apparent Specific Gravity ,Gs=(Wo/**Wo+(Wa-Wb))*K** | 2.23 | 2.29 |
| Average Apparent Specific Gravity | **2.26** | |

Table A3: Physical Properties of Saw dust Ash Filler

| Material Type | Saw Dust Ash | |
|---|---|---|
| Trial No | 1 | 2 |
| Mass of Pycnometer ,(g) | 30.14 | 31.25 |
| Mass of Pycnometer with Water at Initial Temp,Ti (g) | 125.8 | 130.5 |
| Initial Temperature in degree Celicuous,Ti | 22 | 22 |
| Mass of Pycnometer and soil,g | 55.14 | 56.25 |
| Mass of Pycnometer soil and Water,g **(Wb)** | 139.2 | 144.46 |
| Final Temperature in degree Celicuous,Tx | 22 | 22 |
| Mass of Soil ,(g)) ( **Wo)** | 25 | 25 |
| Mass of Pycnometer with Water at Final Temp,Tx (g) (**Wa)** | 125.93 | 130.6 |
| Apparent Specific Gravity ,Gs=(Wo/**Wo+(Wa-Wb))*K** | 2.236 | 2.244 |
| Average Apparent Specific Gravity | **2.24** | |

Where:
K = 0.9996 at Tx =22℃

## APPENDIX - B Particle Size Distribution of Aggregates

TEST METHOD: AASHTO T 27

Table B1: Particle Size Distribution of Coarse aggregates (14-20) mm

| Dry Sample Weight (g) | | | 7300 | | 7268 | | |
|---|---|---|---|---|---|---|---|
| after Wash dry sample (g) | | | 7290 | | 7259 | | |
| Sieve size (mm) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Average Comulative Passing (%) |
| 25 | 0 | 7300 | 100 | 0 | 7268 | 100 | 100 |
| 19 | 1677 | 5623 | 77.03 | 1670 | 5598 | 77.02 | 77.025 |
| 12.5 | 4857 | 766 | 10.49 | 4836 | 762 | 10.48 | 10.485 |
| 9.5 | 671 | 95 | 1.3 | 668 | 94 | 1.29 | 1.295 |
| 4.75 | 77 | 18 | 0.25 | 77 | 17 | 0.23 | 0.24 |
| 2.36 | 6 | 12 | 0.16 | 6 | 11 | 0.15 | 0.155 |
| 1.18 | 2 | 10 | 0.14 | 2 | 9 | 0.12 | 0.13 |
| 0.6 | | 10 | 0.14 | | 9 | 0.12 | 0.13 |
| 0.3 | | 10 | 0.14 | | 9 | 0.12 | 0.13 |
| 0.15 | | 10 | 0.14 | | 9 | 0.12 | 0.13 |
| 0.075 | | 10 | 0.14 | | 9 | 0.12 | 0.13 |
| pan | 0 | | | 0 | | | |
| Wash lose | 10 | | | 9 | | | |
| Total | 7300 | | | 7268 | | | |

Table B2: Particle Size Distribution of Intermediate aggregates (6-14) mm

| Dry Sample Weight (g) | | | 6125 | | 6121 | | |
|---|---|---|---|---|---|---|---|
| after Wash dry sample (g) | | | 6116 | | 6111 | | |
| Sieve size (mm) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Average Comulative Passing (%) |
| 25 | 0 | 6125 | 100 | 0 | 6121 | 100 | 100 |
| 19 | 0 | 6125 | 100 | 0 | 6121 | 100 | 100 |
| 12.5 | 147 | 5978 | 97.6 | 146 | 5975 | 97.61 | 97.6 |
| 9.5 | 1645 | 4333 | 70.74 | 1644 | 4331 | 70.76 | 70.75 |
| 4.75 | 3846 | 485 | 7.92 | 3843 | 488 | 7.97 | 7.95 |
| 2.36 | 450 | 35 | 0.57 | 452 | 36 | 0.59 | 0.58 |
| 1.18 | 20 | 15 | 0.24 | 20 | 16 | 0.26 | 0.25 |
| 0.6 | 4 | 11 | 0.18 | 4 | 12 | 0.196 | 0.19 |
| 0.3 | 2 | 9 | 0.15 | 2 | 10 | 0.16 | 0.155 |
| 0.15 | | 9 | 0.15 | | | 0.16 | 0.155 |
| 0.075 | | 9 | 0.15 | | | 0.16 | 0.155 |
| pan | 0 | | | 0 | | | |
| Wash lose | 9 | | | 10 | | | |
| Total | 6125 | | | 6121 | | | |

Table B3: Particle Size Distribution of Intermediate aggregates (3-6) mm

| Dry Sample Weight (g) | | | 3555 | | 4000 | | |
|---|---|---|---|---|---|---|---|
| after Wash dry sample (g) | | | 3540 | | 3980 | | |
| Sieve size (mm) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Average Comulative Passing (%) |
| 25 | 0 | 3555 | 100 | 0 | 4000 | 100 | 100 |
| 19 | 0 | 3555 | 100 | 0 | 4000 | 100 | 100 |
| 12.5 | 0 | 3555 | 100 | 0 | 4000 | 100 | 100 |
| 9.5 | 7.5 | 3547.5 | 99.9 | 8.44 | 3991.56 | 99.8 | 99.85 |
| 4.75 | 223 | 3324.5 | 93.52 | 250.9 | 3740.66 | 93.52 | 93.52 |
| 2.36 | 2627 | 697.5 | 19.62 | 2955.84 | 784.82 | 19.62 | 19.62 |
| 1.18 | 418 | 279.5 | 7.86 | 468.31 | 316.51 | 7.9 | 7.88 |
| 0.6 | 134 | 145.5 | 4.1 | 150.7 | 165.81 | 4.15 | 4.125 |
| 0.3 | 91.7 | 53.8 | 1.51 | 102.17 | 63.64 | 1.6 | 1.555 |
| 0.15 | 35 | 18.8 | 0.53 | 39.38 | 24.26 | 0.61 | 0.57 |
| 0.075 | 3.8 | 15 | 0.42 | 4.26 | 20 | 0.5 | 0.46 |
| pan | 0 | | | 0 | | | |
| Wash lose | 15 | | | 20 | | | |
| Total | 3555 | | | 4000 | | | |

Table B4: Particle Size Distribution of Fine aggregates (0-3) mm

| Dry Sample Weight (g) | | | 1926 | | 1915 | | |
|---|---|---|---|---|---|---|---|
| after Wash dry sample (g) | | | 1665 | | 1655 | | |
| Sieve size (mm) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Average Comulative Passing (%) |
| 25 | 0 | 1926 | 100 | 0 | 1915 | 100 | 100 |
| 19 | 0 | 1926 | 100 | 0 | 1915 | 100 | 100 |
| 12.5 | 0 | 1926 | 100 | 0 | 1915 | 100 | 100 |
| 9.5 | 0 | 1926 | 100 | 0 | 1915 | 100 | 100 |
| 4.75 | 7.9 | 1918.1 | 99.59 | 7.85 | 1907.15 | 99.59 | 99.59 |
| 2.36 | 127 | 1791.1 | 93 | 126.2 | 1780.95 | 93 | 93 |
| 1.18 | 539 | 1252.1 | 65 | 535.92 | 1245.03 | 65 | 65 |
| 0.6 | 426.8 | 825.3 | 42.85 | 424.36 | 820.67 | 42.85 | 42.85 |
| 0.3 | 282.9 | 542.4 | 28.2 | 281.23 | 539.44 | 28.2 | 28.2 |
| 0.15 | 148.4 | 394 | 20.46 | 147.3 | 392.14 | 20.48 | 20.47 |
| 0.075 | 133 | 261 | 13.55 | 132.14 | 260 | 13.58 | 13.57 |
| pan | 0 | | | 0 | | | |
| Wash lose | 261 | | | 260 | | | |
| Total | 1926 | | | 1915 | | | |

Table B5: Particle Size Distribution of Mineral fillers

| | | Crushed stone dust | | Corncob ash | | | Saw dust ash | | |
|---|---|---|---|---|---|---|---|---|---|
| Dry Sample Weight (g) | | | 275 | | | 150 | | | 150 |
| after Wash dry sample (g) | | | 0 | | | 0 | | | 0 |
| Sieve size (mm) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) | Mass of Retained Sample (g) | Comulative Passing (g) | Comulative Passing (%) |
| 0.3 | 0 | 275 | 100 | 0 | 150 | 100 | 0 | 150 | 100 |
| 0.15 | 0 | 275 | 100 | 0 | 150 | 100 | 0 | 150 | 100 |
| 0.075 | 0 | 275 | 100 | 0 | 150 | 100 | 0 | 150 | 100 |
| pan | 0 | | | 0 | | | 0 | | |
| Wash lose | 275 | | | 150 | | | 150 | | |
| Total | 275 | | | 150 | | | 150 | | |

Table B6:.Aggregate gradation for filler 4.5% CSD

| Test Sieve size (mm) | Weight Retained **(gm)** | Percent Retained | Percent pass | Combined asphalt aggregate specification limit | |
|---|---|---|---|---|---|
| | | | | Lower limit | Upper limit |
| 25.0 | 0.0 | 0.0 | 100 | 100 | 100 |
| 19.0 | 69.6 | 5.8 | 94.2 | 90 | 100 |
| 12.5 | 198 | 16.5 | 77.7 | 71 | 88 |
| 9.5 | 118.8 | 9.9 | 67.8 | 56 | 80 |
| 4.75 | 243.6 | 20.3 | 47.5 | 35 | 65 |
| 2.36 | 174 | 14.5 | 33 | 23 | 49 |
| 1.18 | 127.2 | 10.6 | 22.4 | 15 | 37 |
| 0.600 | 91.2 | 7.6 | 14.8 | 10 | 28 |
| 0.300 | 60 | 5 | 9.8 | 5 | 19 |
| 0.150 | 31.2 | 2.6 | 7.2 | 4 | 13 |
| 0.075 | 32.4 | 2.7 | 4.5 | 2 | 8 |
| Pan | 54 | **4.5** | 0.00 | | |
| Total | 1200 | 100 | | | |

Table B7:.Aggregate gradation for filler 5.5% CSD

| Test Sieve size (mm) | Weight Retained (**gm**) | Percent Retained | Percent pass | Combined asphalt aggregate specification limit | |
|---|---|---|---|---|---|
| | | | | Lower limit | Upper limit |
| 25.0 | 0.00 | 0.00 | 100 | 100 | 100 |
| 19.0 | 69.6 | 5.8 | 94.2 | 90 | 100 |
| 12.5 | 198 | 16.5 | 77.7 | 71 | 88 |
| 9.5 | 118.8 | 9.9 | 67.8 | 56 | 80 |
| 4.75 | 246 | 20.5 | 47.3 | 35 | 65 |
| 2.36 | 171.6 | 14.3 | 33 | 23 | 49 |
| 1.18 | 126 | 10.5 | 22.5 | 15 | 37 |
| 0.600 | 91.2 | 7.6 | 14.9 | 10 | 28 |
| 0.300 | 62.4 | 5.2 | 9.7 | 5 | 19 |
| 0.150 | 28.8 | 2.4 | 7.3 | 4 | 13 |
| 0.075 | 21.6 | 1.8 | 5.5 | 2 | 8 |
| Pan | 66 | **5.5** | 0.00 | | |
| Total | 1200 | 100 | | | |

Table B8:.Aggregate gradation for filler 6.5% CSD

| Test Sieve size (mm) | Weight Retained (**gm**) | Percent Retained | Percent pass | Combined asphalt aggregate specification limit | |
|---|---|---|---|---|---|
| | | | | Lower limit | Upper limit |
| 25.0 | 0.00 | 0.00 | 100 | 100 | 100 |
| 19.0 | 69.6 | 5.8 | 94.2 | 90 | 100 |
| 12.5 | 200.4 | 16.7 | 77.5 | 71 | 88 |
| 9.5 | 120 | 10 | 67.5 | 56 | 80 |
| 4.75 | 241.2 | 20.1 | 47.4 | 35 | 65 |
| 2.36 | 172.8 | 14.4 | 33 | 23 | 49 |
| 1.18 | 127.2 | 10.6 | 22.4 | 15 | 37 |
| 0.600 | 90 | 7.5 | 14.9 | 10 | 28 |
| 0.300 | 62.4 | 5.2 | 9.7 | 5 | 19 |
| 0.150 | 30 | 2.5 | 7.2 | 4 | 13 |
| 0.075 | 8.4 | 0.7 | 6.5 | 2 | 8 |
| Pan | 78 | **6.5** | 0.00 | | |
| Total | 1200 | 100 | | | |

## APENDIX- C Aggregate and Bitumen Quality Test Results

Table C1: Aggregate quality test results

| Test | Test Method | Test Result | | | | Specification |
|---|---|---|---|---|---|---|
| | | (14-25mm) | (6-14mm) | (3-6mm) | (0-3mm) | |
| Bulk dry S.G | | 2.625 | 2.612 | 2.6 | 2.6 | - |
| Bulk SSD S.G | AASHTO T 85-91 | 2.673 | 2.664 | 2.61 | 2.641 | - |
| Apparent SG | | 2.764 | 2.753 | 2.745 | 2.767 | - |
| Water absorption,% | BS 812, Part 2 | 1.88 | 1.88 | 1.88 | - | <2 |
| Sand equivalent,% | AASHTO T176-86 | 75.4 | - | - | - | >40 |
| Flakiness index | BS 812 Part 105 | 23 | - | - | - | <45 |
| Aggregate Crushing Value (ACV),% | BS:812 Part 110 | 13 | - | - | - | <25 |
| Los Angeles Abrasion (LAA), % | AASHTO T 96` | 15 | - | - | - | <30 |

Table C2: Test Records of Penetration, Ductility, Softening point, flash point and Specific Gravity of Bituminous Materials.

| | 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 | 67 | 65 | 63 | 65 |
| | | 2 | 25 | 5 | 100 | 68 | 65 | 65 | 66 |
| | | 3 | 25 | 5 | 100 | 64 | 65 | 63 | 64 |
| | | | | | | **Average:** | | | **65** |

| | Test Method | Test No | Test Temp. (degree celcious) | Speed (cm/min) | Ductility (cm) | Average (cm) |
|---|---|---|---|---|---|---|
| **Ductility** | AASHTO T 51 | 1 | 25 | 5 | 148 | |
| | | 2 | 25 | 5 | 146 | **147** |
| | | 3 | 25 | 5 | 147 | |

| | Test Method | Test No | Temp.when starting heating (degree celcious) | Record of liquid Temp in beaker | | | Softening point |
|---|---|---|---|---|---|---|---|
| | | | | 4min | 5min | 6min | |
| **Softning point** | AASHTO T 53 | 1 | 7 | 4min | | | 52.5 |
| | | 2 | 7 | 4min | | | 53.5 |
| | | | | | **Average :** | | **53** |

| | Test Method | Flash Point |
|---|---|---|
| Flash Point | AASHTO T 48 | 288 |
| Specific Gravity | AASHTO T 228 | S.gravity |
| | | 1.05 |

**APPENDIX- D: Maximum Theoretical Density of the Uncompact Asphalt Mixtures.**

Test Method: ASTM Designation: D 2041 -90

Table D1: Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures With 4.5 % Crushed Stone Dust Filler.

| **AC** | **AC 4%** | | **AC 4.50%** | | **AC 5%** | | **AC 5.50%** | | **AC 6%** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Trial No. | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| A | 1232 | 1241 | 1240 | 1242 | 1249 | 1248.5 | 1229.5 | 1232.3 | 1231 | 1238.5 |
| B | 6015 | 5997 | 6000 | 5999 | 5994 | 6013 | 6009.5 | 5998.4 | 5998 | 6004 |
| C | 6737.91 | 6733.53 | 6736.96 | 6739.19 | 6732.16 | 6757.06 | 6728.2 | 6724.21 | 6720.32 | 6734.92 |
| Gmm | 2.42 | 2.46 | 2.465 | 2.475 | 2.445 | 2.475 | 2.407 | 2.433 | 2.42 | 2.44 |
| **Average Gmm** | **2.44** | | **2.47** | | **2.46** | | **2.42** | | **2.43** | |

Table D2: Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures With 5.5 % Crushed Stone Dust Filler

| **AC** | **AC 4%** | | **AC 4.50%** | | **AC 5%** | | **AC 5.50%** | | **AC 6%** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Trial No. | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| A | 1234.5 | 1239.5 | 1246.5 | 1239.5 | 1240 | 1237.4 | 1245.6 | 1241 | 1237.5 | 1240.8 |
| B | 6009.7 | 5999.7 | 6004.8 | 5996.5 | 6002.5 | 5995.5 | 6009.5 | 5988.5 | 6001.2 | 5996.5 |
| C | 6736.18 | 6733.28 | 6743.56 | 6733.16 | 6729.04 | 6726.81 | 6753.85 | 6724 | 6730.49 | 6733.93 |
| Gmm | 2.43 | 2.45 | 2.455 | 2.465 | 2.415 | 2.445 | 2.485 | 2.455 | 2.435 | 2.465 |
| **Average Gmm** | **2.44** | | **2.46** | | **2.43** | | **2.47** | | **2.45** | |

Table D3: Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures With 6.5 % Crushed Stone Dust Filler.

| **AC** | **AC 4%** | | **AC 4.50%** | | **AC 5%** | | **AC 5.50%** | | **AC 6%** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Trial No. | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| A | 1243.3 | 1239.8 | 1241 | 1246.8 | 1237.5 | 1240.5 | 1238.8 | 1240.2 | 1238.3 | 1241.7 |
| B | 5998 | 6003.5 | 5996.5 | 6005.8 | 5994.6 | 5994.6 | 5992.5 | 6008.3 | 5991.5 | 6001.3 |
| C | 6738.96 | 6740.34 | 6735.07 | 6751.88 | 6721.79 | 6725.65 | 6723.6 | 6744.35 | 6721.26 | 6735.15 |
| Gmm | 2.475 | 2.465 | 2.47 | 2.49 | 2.425 | 2.435 | 2.44 | 2.46 | 2.435 | 2.445 |
| **Average Gmm** | **2.47** | | **2.48** | | **2.43** | | **2.45** | | **2.44** | |

Table D4: Theoretical Maximum Specific Gravity of Different Percentage Replacement of BCSA with 5% Asphalt Content.

| Filler Proportion | Trial No | A | B | C | Gmm | **Average Gmm** |
|---|---|---|---|---|---|---|
| 100 % CSD and 0% BCSA | 1 | 1239.5 | 599.7 | 6733.53 | 2.45 | **2.455** |
| | 2 | 1241 | 599.7 | 6733.53 | 2.46 | |
| 90 % CSD and 10% BCSA | 1 | 1237.6 | 5995.5 | 6726.81 | 2.446 | **2.456** |
| | 2 | 1240 | 6000 | 6736.96 | 2.465 | |
| 80 % CSD and 20% BCSA | 1 | 1249 | 5994 | 6732.16 | 2.445 | **2.46** |
| | 2 | 1242 | 5999 | 6739.19 | 2.475 | |
| 70 % CSD and 30% BCSA | 1 | 1245.6 | 6009.5 | 6753.85 | 2.485 | **2.47** |
| | 2 | 1241 | 5988.5 | 6724 | 2.453 | |
| 60 % CSD and 40% BCSA | 1 | 1246.8 | 6005.8 | 6751.88 | 2.49 | **2.474** |
| | 2 | 1247.5 | 6006.7 | 6746.67 | 2.458 | |
| 50 % CSD and 50% BCSA | 1 | 1241.7 | 6001.3 | 6735.15 | 2.445 | **2.448** |
| | 2 | 1240 | 5999 | 6733 | 2.451 | |
| 40 % CSD and 60% BCSA | 1 | 1240.8 | 6008.3 | 6744.35 | 2.46 | **2.45** |
| | 2 | 1238.8 | 5992.5 | 6723.6 | 2.44 | |
| 30 % CSD and 70% BCSA | 1 | 1237.5 | 5994.6 | 6721.79 | 2.425 | **2.435** |
| | 2 | 1250 | 5992 | 6731 | 2.445 | |

Where: BCSA =Blended Corncob Ash and Saw dust Ash.

CSD =Crushed Stone Dust.

A= Mass of dry sample in air.

B= Mass of Jar filled with water.

C= Mass of Jar filled with water + Sample.

K= 1.0 at 25℃

Gmm (Theoretical Maximum Specific Gravity) =K*A/ (A+B-C)

## APPENDIX -E: Test Results From Marshall Mix Design

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**

| | | |
|---|---|---|
| TESTED BY :AHADU MENGIST | **S.G Of AGGREGATES** | |
| PURPOSE : FINAL THESIS | Fraction size mm | Gsb |
| GRADE OF ASPHALT: 60/70 | a (14-25mm) | 2.625 |
| MARSHALL COMPACTION : 2*75 BL0WS | b (6-14mm) | 2.612 |
| % OF CRUSHED STONE DUST | c (3-6mm) | 2.6 |
| FILLED BY WEIGHT 0F TOTAL MIX : 4.5 % | d ( 0-3mm) | 2.6 |
| | e . Filler | - |
| | Combined (Gsb): | 2.61 |

| Asphalt Content % | Speciemen height (mm) | Max S.G of the Mix (Gmm) | mass of specimen(g) Air dry | Water | Air SSD | Volume of speceimen (CC) | Bulk S.G of compacted mix | Air voids % | VMA % | VFA % | Stability Load (kN) | Flow by (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | G | H | I | J | K | | |
| A | B | C | D | E | F | F-E | D/G | (C-H)*100/C | 100-[(H/Gsb)*(100-A)] | 100*(J-I)/J | | |
| 4% | 69.5 | | 1204 | 690.2 | 1236.2 | 546 | 2.23 | 6.2 | 18.4 | 59 | 8 | 2.78 |
| | 69 | | 1204.1 | 686.6 | 1234.1 | 547.5 | 2.22 | 6.5 | 19.12 | 60.5 | 7.5 | 2.72 |
| | 68.5 | | 1204.06 | 692.7 | 1241.1 | 548.4 | 2.21 | 6.5 | 19.12 | 60.5 | 7.6 | 2.72 |
| **AVERAGE** | **69** | **2.44** | **1215.006** | **689.83** | **1237.13** | **547.3** | **2.22** | **6.4** | **18.9** | **60** | **7.7** | **2.74** |
| 4.50% | 70.5 | | 1260.2 | 690 | 1235 | 545 | 2.23 | 4.3 | 17.5 | 65 | 7.8 | 3.4 |
| | 70 | | 1262.2 | 684 | 1238.3 | 554.3 | 2.23 | 4.8 | 16.88 | 64 | 8.1 | 3.2 |
| | 69.5 | | 1261.2 | 688 | 1241 | 553 | 2.227 | 4.7 | 16.54 | 60 | 8.7 | 2.7 |
| **AVERRAGE** | **70** | **2.47** | **1261.2** | **687.33** | **1238.1** | **550.77** | **2.229** | **4.6** | **17.2** | **63** | **8.2** | **3.1** |
| 5% | 71 | | 1219.3 | 691.7 | 1236 | 544.3 | 2.24 | 3.51 | 18.47 | 72 | 9 | 3.6 |
| | 68.5 | | 1218.3 | 690.3 | 1237.5 | 547.2 | 2.226 | 3.52 | 18.98 | 63 | 8.5 | 3.4 |
| | 70.5 | | 1226.3 | 687.5 | 1234.5 | 547 | 2.245 | 3.47 | 18.28 | 69 | 8.3 | 3.2 |
| **AVERAGE** | **70** | **2.46** | **1221.23** | **689.83** | **1236** | **546.17** | **2.236** | **3.5** | **17** | **68** | **8.6** | **3.4** |
| 5.50% | 68 | | 1226.9 | 686 | 1234 | 548 | 2.239 | 2.78 | 18.93 | 76 | 9.2 | 3.88 |
| | 71 | | 1228.9 | 688 | 1235.5 | 547.5 | 2.245 | 2.52 | 18.71 | 72 | 8.6 | 3.8 |
| | 69.5 | | 1224 | 690.7 | 1237 | 546.3 | 2.24 | 2.8 | 18.9 | 71 | 8.3 | 3.51 |
| **AVERAGE** | **69.5** | **2.42** | **1226.5** | **688.23** | **1235.5** | **547.27** | **2.241** | **2.7** | **18.86** | **73** | **8.7** | **3.73** |
| 6% | 68.5 | | 1223.6 | 690.6 | 1233 | 542.4 | 2.256 | 1.9 | 18.75 | 79.5 | 7.9 | 3.9 |
| | 68 | | 1223.64 | 688 | 1234.5 | 546.5 | 2.239 | 2.61 | 19.36 | 82.5 | 8 | 3.8 |
| | 69 | | 1224.71 | 689 | 1236 | 547 | 2.239 | 2.6 | 19.3 | 79 | 7.2 | 4.6 |
| **AVERAGE** | **68.5** | **2.43** | **1223.65** | **689.2** | **1234.5** | **545.3** | **2.244** | **2.4** | **19.18** | **80** | **7.7** | **4.1** |

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**

| | | | |
|---|---|---|---|
| TESTED BY :AHADU MENGIST | S.G Of AGGREGATES | | |
| PURPOSE : FINAL THESIS | Fraction size mm | propertion % | Gsb |
| GRADE OF ASPHALT: 60/70 | a (14-25mm) | 24 | 2.625 |
| MARSHALL COMPACTION : 2*75 BL0WS | b (6-14mm) | 30 | 2.612 |
| % OF CRUSHED STONE DUST | c (3-6mm) | 14 | 2.6 |
| FILLED BY WEIGHT 0F TOTAL MIX : 5.5 % | d ( 0-3mm) | 29.7 | 2.6 |
| | e . Filler | 2.3 | - |
| | Combined (Gsb): | 100 | *2.61* |

| Asphalt Content % | Speciemen height (mm) | Max S.G of the Mix (Gmm) | Mass of specimen(g) | | | Volume of Speceimen (CC) | Bulk S.G of Compacted mix | Air voids % | VMA % | VFA % | Stability Load (kN) | Flow by (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Air dry | Water | Air SSD | G | H | I | J | K | | |
| A | B | C | D | E | F | F-E | D/G | (C-H)*100/C | 100-[(H/Gsb)*(100-A)] | 100*(J-I)/J | | |
| 4% | 69 | | 1212.7 | 699.2 | 1224.8 | 525.6 | 2.31 | 7.3 | 15.08 | 60 | 8.16 | 2.7 |
| | 70 | | 1216.1 | 700.7 | 1226.9 | 526.2 | 2.31 | 7.3 | 15.08 | 60.5 | 8.6 | 2.69 |
| | 71 | | 1210.4 | 694.8 | 1218 | 523.2 | 2.31 | 7.3 | 15.08 | 60.8 | 8.89 | 2.71 |
| **AVERAGE** | **70** | **2.44** | **1213.1** | **698.2** | **1223.2** | **525** | **2.3** | **7.3** | **15.08** | **60.43** | **8.55** | **2.7** |
| 4.50% | 69.5 | | 1230.5 | 705.2 | 1233.7 | 528.5 | 2.33 | 5.7 | 14.75 | 67.2 | 9.89 | 2.6 |
| | 68 | | 1236 | 707.1 | 1237.9 | 530.8 | 2.33 | 5.7 | 14.75 | 67.2 | 9.8 | 3 |
| | 71 | | 1244.6 | 712.4 | 1247.3 | 534.9 | 2.33 | 5.7 | 14.75 | 67.2 | 10.44 | 3.1 |
| **AVERRAGE** | **69.5** | **2.46** | **1237** | **708.2** | **1239.6** | **531.4** | **2.33** | **5.7** | **14.75** | **67.2** | **10.04** | **2.9** |
| 5% | 69.5 | | 1237.9 | 714.6 | 1239.7 | 525.1 | 2.357 | 4 | 14.7 | 73 | 11.4 | 3.14 |
| | 71 | | 1236.9 | 712.1 | 1237.7 | 525.6 | 2.355 | 4 | 14.7 | 73.5 | 11.02 | 3.1 |
| | 68 | | 1236.8 | 713.7 | 1238.3 | 524.6 | 2.353 | 4 | 14.7 | 72.5 | 11 | 3.1 |
| **AVERAGE** | **69.5** | **2.43** | **1237.2** | **713.5** | **1238.6** | **525.1** | **2.355** | **4** | **14.7** | **73** | **11.2** | **3.1** |
| 5.50% | 70 | | 1237.9 | 716.9 | 1238.9 | 522 | 2.373 | 2.61 | 15 | 76 | 10.7 | 2.98 |
| | 71 | | 1236 | 714.8 | 1236.6 | 521.8 | 2.37 | 2.6 | 14.8 | 76 | 12.3 | 3.4 |
| | 70.5 | | 1239.7 | 719.2 | 1240.3 | 521.1 | 2.37 | 2.6 | 14.9 | 76 | 11.55 | 3.4 |
| **AVERAGE** | **70.5** | **2.47** | **1237.9** | **717** | **1238.6** | **521.6** | **2.37** | **2.6** | **14.9** | **76** | **11.52** | **3.26** |
| 6% | 68 | | 1246 | 722.2 | 1246.4 | 524.2 | 2.4 | 1.88 | 15.1 | 79.97 | 8.26 | 3.8 |
| | 71 | | 1240.3 | 719.1 | 1240.7 | 521.6 | 2.38 | 1.9 | 15 | 79.97 | 8.7 | 3.3 |
| | 69.5 | | 1238.2 | 717.9 | 1238.8 | 520.9 | 2.36 | 1.92 | 15.2 | 79.97 | 8.99 | 3.11 |
| **AVERAGE** | **69.5** | **2.44** | **1241.5** | **719.7** | **1242** | **522.3** | **2.38** | **1.9** | **15.1** | **79.97** | **8.65** | **3.4** |

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**

| | | | |
|---|---|---|---|
| TESTED BY :AHADU MENGIST | S.G Of AGGREGATES | | |
| PURPOSE : FINAL THESIS | Fraction size mı | propertion % | Gsb |
| GRADE OF ASPHALT: 60/70 | a (14-25mm) | 24 | 2.625 |
| MARSHALL COMPACTION : 2*75 BL0WS | b (6-14mm) | 30 | 2.612 |
| % OF CRUSHED STONE DUST | c (3-6mm) | 14 | 2.6 |
| FILLED BY WEIGHT 0F TOTAL MIX : 6.5 % | d ( 0-3mm) | 29.7 | 2.6 |
| | e .Filler | 2.3 | - |
| | Combined (Gsł | 100 | 2.61 |

| Asphalt Content % | Speciemen height (mm) | Max S.G of the Mix (Gmm) | mass of specimen(g) Air dry | Water | Air SSD | Volume of speceimen (CC) | Bulk S.G of compacted mix | Air voids % | VMA % | VFA % | Stability Load (kN) | Flow by (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | G | H | I | J | K | | |
| A | B | C | D | E | F | F-E | D/G | (C-H)*100/C | 100-[(H/Gsb)*(100-A)] | 100*(J-I)/J | | |
| | 69 | | 1217.5 | 687.8 | 1236.7 | 548.9 | 2.22 | 6.72 | 18.34 | 58.36 | 8.4 | 2.98 |
| 4% | 69.5 | | 1223 | 678.5 | 1241 | 562.5 | 2.17 | 8.82 | 20.18 | 51.36 | 8.47 | 3.45 |
| | 70.5 | | 1222.8 | 677 | 1238.8 | 561.8 | 2.18 | 8.4 | 19.82 | 52.72 | 7.9 | 2.77 |
| AVERAGE | 69.67 | 2.47 | 1221.1 | 681.1 | 1238.83 | 557.73 | 2.19 | 7.8 | 19.45 | 55 | 8.26 | 3.01 |
| | 69.5 | | 1221 | 682 | 1240.5 | 558.5 | 2.19 | 6.97 | 19.87 | 59.92 | 10.96 | 3.15 |
| 4.50% | 70.5 | | 1231 | 678.5 | 1239 | 560.5 | 2.2 | 6.54 | 19.5 | 61.46 | 10.34 | 3.04 |
| | 68 | | 1229.5 | 690.6 | 1238.7 | 548.1 | 2.24 | 4.84 | 18.04 | 68.17 | 9.88 | 3.14 |
| AVERRAGE | 69.33 | 2.48 | 1227.2 | 683.7 | 1239.4 | 555.7 | 2.21 | 6.1 | 19.14 | 63.13 | 10.39 | 3.11 |
| | 72 | | 1227 | 679.8 | 1237.5 | 557.7 | 2.2 | 5.66 | 19.92 | 67 | 10.12 | 3.26 |
| 5% | 69.5 | | 1228.9 | 688 | 1235.5 | 547.5 | 2.245 | 3.73 | 18.29 | 74.12 | 12 | 3.15 |
| | 70 | | 1225.5 | 687.9 | 1239.6 | 551.7 | 2.22 | 4.8 | 19.2 | 70 | 8.77 | 3.25 |
| AVERAGE | 70.5 | 2.43 | 1227.1 | 685.23 | 1237.53 | 552.3 | 2.222 | 4.7 | 19.12 | 70.42 | 10.3 | 3.22 |
| | 68.5 | | 1221.5 | 685.8 | 1234.8 | 549 | 2.22 | 3.94 | 19.62 | 74.92 | 10.12 | 3.2 |
| 5.50% | 71.5 | | 1228.5 | 691 | 1238 | 547 | 2.25 | 2.64 | 18.53 | 80.75 | 9.78 | 2.98 |
| | 69 | | 1219 | 688.3 | 1238.6 | 550.3 | 2.22 | 3.94 | 19.62 | 74.92 | 9.44 | 3.76 |
| AVERAGE | 69.67 | 2.45 | 1223 | 688.37 | 1237.13 | 548.76 | 2.23 | 3.5 | 19.26 | 76.83 | 9.78 | 3.31 |
| | 70 | | 1219.3 | 691.7 | 1236 | 544.3 | 2.24 | 2.18 | 19.33 | 83.72 | 8.48 | 3.6 |
| 6% | 69.5 | | 1218.3 | 690.3 | 1237.5 | 547.2 | 2.226 | 2.79 | 19.83 | 80.93 | 9.1 | 3.2 |
| | 71 | | 1226.3 | 687.5 | 1234.5 | 547 | 2.245 | 1.97 | 19.15 | 84.71 | 10.33 | 3.4 |
| AVERAGE | 70.17 | 2.44 | 1221.2 | 689.83 | 1236 | 546.17 | 2.236 | 2.4 | 19.47 | 82.67 | 9.3 | 3.4 |

## MARSHALL TEST RESULTS

## OFC = 5.5% and OBC =5%

Table E4: Combination of Blended Corncob Ash and Saw Dust Ash with Crushed Stone Dust Filler Contents.

**MARSHALL PROPERTIES OF BITUMINOUS MIXTURE ASTM D1559/AASHTO T 245**

| | | | |
|---|---|---|---|
| **TESTED BY :AHADU MENGIST** | **S.G Of AGGREGATES** | | |
| **PURPOSE : FINAL THESIS** | **Fraction size mm** | **propertion %** | **Gsb** |
| **GRADE OF ASPHALT: 60/70** | **a (14-25mm)** | **24** | **2.625** |
| **MARSHALL COMPACTION : 2*75 BL0WS** | **b (6-14mm)** | **30** | **2.612** |
| **Combination of blended Corncob Ash and saw dust** | **c (3-6mm)** | **14** | **2.6** |
| **ash with crushed stone dust by weight of** | **d ( 0-3mm)** | **29.7** | **2.6** |
| **total Mix : 5.5%** | **e . Filler** | **2.3** | **-** |
| | **Combined (Gsb):** | **100** | ***2.61*** |

| asphalt content % | Speciemen height (mm) | Mineral Filler Type | | Max S.G of the mix [Gmm] | Mass of Spacimen in [g] | | | volume of speciemen (cc) | Bulk S.G of Compacted mix | Air voids % | VMA % | VFA % | Stability Load (KN) | Flow (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % of Crushed stone dust | % of blended CCA & SWA | | Air dry | Water | SSD | | | | | | | |
| | | | | | | | | G | H | I (C-H)* 100/C | J 100- [(H/Gsb) *(100-A)] | K 100* (J-I)/J | | |
| **A** | **B** | | | **C** | **D** | **E** | **F** | F-E | D/G | | | | | |
| | 65.4 | 100% | 0% | | 1238.9 | 714.3 | 1240 | 525.7 | 2.357 | 3.99 | 14.21 | 71.92 | 10.1 | 2.88 |
| **5** | 66 | 100% | 0% | | 1238 | 712.5 | 1238.7 | 526.2 | 2.353 | 4.15 | 14.35 | 71.08 | 9.8 | 3.11 |
| | 65.6 | 100% | 0% | | 1239.3 | 710.8 | 1240.5 | 529.7 | 2.34 | 4.68 | 14.83 | 66.84 | 11.3 | 3.08 |
| **Average** | **65.7** | | | **2.455** | **1238.7** | **712.5** | **1239.7** | **527.2** | **2.35** | **4.28** | **14.46** | **70.4** | **10.4** | **3.02** |
| | 66.5 | 90% | 10% | | 1239 | 714 | 1239 | 525 | 2.36 | 3.91 | 14.1 | 72.23 | 9.3 | 3.21 |
| **5** | 65 | 90% | 10% | | 1238.3 | 712.8 | 1238.5 | 525.7 | 2.36 | 3.91 | 14.1 | 72.27 | 10.9 | 3.18 |
| | 65.4 | 90% | 10% | | 1239.4 | 710.5 | 1240.3 | 529.8 | 2.34 | 4.72 | 14.83 | 68.17 | 9.8 | 2.96 |
| **Average** | **65.6** | | | **2.456** | **1238.9** | **712.43** | **1239.27** | **526.8** | **2.35** | **4.3** | **14.46** | **70.26** | **10** | **3.12** |
| | 65.7 | 80% | 20% | | 1241.3 | 716.1 | 1241 | 524.9 | 2.36 | 4.07 | 14.1 | 71.13 | 8.8 | 3.24 |
| **5** | 66.5 | 80% | 20% | | 1240 | 714.5 | 1237 | 522.5 | 2.37 | 3.66 | 13.74 | 73.36 | 9.75 | 3.12 |
| | 65.7 | 80% | 20% | | 1241 | 713 | 1241 | 528 | 2.35 | 4.47 | 14.46 | 69.09 | 10.3 | 3 |
| **Average** | **66** | | | **2.46** | **1240.8** | **714.53** | **1239.7** | **525.13** | **2.36** | **4.1** | **14.1** | **70.9** | **9.62** | **3.12** |
| | 65.5 | 70% | 30% | | 1242.3 | 718.5 | 1242.2 | 523.7 | 2.37 | 4.05 | 13.736 | 70.52 | 10.4 | 2.98 |
| **5** | 66.1 | 70% | 30% | | 1241 | 717.6 | 1241.3 | 523.7 | 2.37 | 4.05 | 13.736 | 70.52 | 9.65 | 3.57 |
| | 65.3 | 70% | 30% | | 1239.8 | 719 | 1243 | 524 | 2.37 | 4.05 | 13.736 | 70.52 | 9.77 | 3.33 |
| **Average** | **65.6** | | | **2.47** | **1241** | **718.4** | **1242** | **523.77** | **2.37** | **4.05** | **13.736** | **70.52** | **9.94** | **3.29** |
| | 69 | 60% | 40% | | 1234 | 716.5 | 1236.2 | 519.7 | 2.375 | 4 | 13.55 | 70.48 | 10.7 | 3.22 |
| **5** | 69 | 60% | 40% | | 1231 | 722 | 1240 | 518 | 2.38 | 3.8 | 13.37 | 71.6 | 9.8 | 2.98 |
| | 68 | 60% | 40% | | 1233.5 | 717 | 1237 | 520 | 2.37 | 4.2 | 13.74 | 69.4 | 9.68 | 3.47 |
| **Average** | **68.7** | | | **2.474** | **1233** | **718.5** | **1238** | **519.23** | **2.375** | **4** | **13.55** | **70.48** | **10.06** | **3.22** |
| | 66.5 | 50% | 50% | | 1225.4 | 719 | 1241.6 | 522.6 | 2.344 | 4.25 | 14.68 | 71.05 | 7.69 | 3.58 |
| **5** | 65 | 50% | 50% | | 1222.2 | 716 | 1238.75 | 522.75 | 2.338 | 4.49 | 14.9 | 69.87 | 7.38 | 3.27 |
| | 65.4 | 50% | 50% | | 1226 | 696 | 1218 | 522 | 2.349 | 4 | 14.5 | 72.41 | 7.45 | 3.39 |
| **Average** | **65.6** | | | **2.448** | **1225** | **710/3** | **1232.8** | **522.45** | **2.344** | **4.25** | **14.68** | **71.05** | **7.5** | **3.41** |
| | 65.5 | 40% | 60% | | 1229 | 712 | 1235 | 523 | 2.35 | 4.08 | 14.46 | 71.78 | 7.08 | 3.66 |
| **5** | 66.3 | 40% | 60% | | 1230 | 719 | 1240 | 521 | 2.33 | 4.89 | 15.19 | 67.8 | 6.75 | 3.26 |
| | 65.5 | 40% | 60% | | 1231.5 | 718 | 1238.5 | 520.5 | 2.36 | 3.67 | 14.1 | 73.97 | 7.1 | 3.15 |
| **Average** | **65.8** | | | **2.45** | **1230** | **716.3** | **1237.8** | **521.5** | **2.345** | **4.29** | **14.65** | **70.72** | **6.98** | **3.36** |
| | 66.3 | 30% | 70% | | 1228.5 | 713 | 1240.25 | 527.25 | 2.33 | 4.31 | 15.19 | 71.63 | 6.89 | 3.55 |
| **5** | 64.8 | 30% | 70% | | 1228 | 711 | 1239.6 | 528.6 | 2.32 | 4.72 | 15.56 | 69.66 | 6.97 | 3.41 |
| | 65.2 | 30% | 70% | | 1226 | 712 | 1237 | 525 | 2.34 | 3.9 | 14.83 | 73.7 | 6.94 | 3.362 |
| **Average** | **65.4** | | | **2.435** | **1228** | **712** | **1239** | **527** | **2.33** | **4.31** | **15.19** | **71.63** | **6.93** | **3.44** |

## APPENDEX F: Plastic Index (PI) of Mineral Fillers

Table F1: PI of Crushed stone dust

| **Liquid Limit of Crushed Stone Dust (LL)** | | | | | | |
|---|---|---|---|---|---|---|
| | Mc (gm) | Mcws (gm) | Mcds (gm) | Mw (gm) | Mds (gm) | Liquid limit (%) |
| Code of Container | | | | D | E | F |
| | A | B | C | B-C | C-A | (D/E)*100% |
| B5 | 18 | 49.15 | 36 | 13.15 | 18 | **73** |
| **Plastic Limit of Crushed Stone Dust (PL)** | | | | | | |
| | Mc (gm) | Mcws (gm) | Mcds (gm) | Mw (gm) | Mds (gm) | Plastic limit (%) |
| Code of Container | | | | D | E | F |
| | A | B | C | B-C | C-A | (D/E)*100% |
| B9 | 14 | 38.12 | 28 | 10.12 | 14 | **72.28** |

**PI =LL-PL= (73% -72.28%) = 0.72%**

Table F2: PI of Corncob Ash.

| **Liquid Limit of Corcob Ash (LL)** | | | | | | |
|---|---|---|---|---|---|---|
| | Mc (gm) | Mcws (gm) | Mcds (gm) | Mw (gm) | Mds (gm) | Liquid limit (%) |
| Code of Container | | | | D | E | F |
| | A | B | C | B-C | C-A | (D/E)*100% |
| A3 | 16.98 | 46.02 | 32.03 | 13.99 | 15.05 | **90.25** |
| **Plastic Limit of Corncob Ash (PL)** | | | | | | |
| | Mc (gm) | Mcws (gm) | Mcds (gm) | Mw (gm) | Mds (gm) | Plastic limit (%) |
| Code of Container | | | | D | E | F |
| | A | B | C | B-C | C-A | (D/E)*100% |
| A9 | 2.494 | 7.247 | 5.044 | 2.203 | 2.55 | **86.4** |

**PI =LL-PL= (90.25% -86.4%) = 3.85 %**

Table F2: PI of Saw dust Ash.

| **Liquid Limit of Saw dust Ash (LL)** | | | | | | |
|---|---|---|---|---|---|---|
| | Mc (gm) | Mcws (gm) | Mcds (gm) | Mw (gm) | Mds (gm) | Liquid limit (%) |
| Code of Container | | | | D | E | F |
| | A | B | C | B-C | C-A | (D/E)*100% |
| G3 | 16 | 45.8 | 31.5 | 14.3 | 15.5 | **92.26** |
| **Plastic Limit of Saw dust Ash (PL)** | | | | | | |
| | Mc (gm) | Mcws (gm) | Mcds (gm) | Mw (gm) | Mds (gm) | Plastic limit (%) |
| Code of Container | | | | D | E | F |
| | A | B | C | B-C | C-A | (D/E)*100% |
| G9 | 5.391 | 16.126 | 11.091 | 5.035 | 5.7 | **88.34** |

**PI =LL-PL= (92.26% -88.34%) = 3.92%**

Where: Mc=Mass of Container

Mcws=Mass of Container + wet soil (filler)

Mcds= Mass of Container + dry soil (filler)

Mw= Mass of water

Mds =Mass of dry filler

LL= Liquid Limit

PL= Plastic Limit

PI= Plastic Index

## APPENDEX-G: Sample Photos during Laboratory

Source: Assefa Feysa

Sieve the aggregates by different sieve number.

Source: Assefa Feysa

Arrange the aggregates by each size.

Source: Ahadu Mengistu

Burning of Corncob

Source: Ahadu Mengistu

Burnt Corncob

Source: Terefe Marito

Burnt Saw dust and sieve to prepare ash.

Source: Ahadu Mengistu

Balance CSD, CCA and SDA

Source: Dejene Dereje
Weighting the heated Aggregate.

Source: Dejene Dereje
Put the aggregate and fillers in oven.

Source: Dejene Dereje
Add bitumen on heated aggregates.

Source: Dejene Dereje
Mixing before compactio

Preparing of filter papers., Source: Dejene .D

Compaction Machine., Source: Dejene D.

Source: Assefa Feysa

Removing the mold


Source: Assefa Feysa

Hot Mix Asphalt Concrete Specimen

Source: Assefa Feysa

Weighting the hot mix asphalt specimen in water.

Source: Assefa Feysa

Making dry by cloth after weight in water.

Source: Assefa Feysa
Water bath

Source: Assefa Feysa
recording the Marshall Test results

Source: Tesfaye Meshesha
Uncompact hot mix asphalt specimen

Source: Tesfaye Meshesha
shaking the sample

Source: Terefe Marito
Recording the weight for Gmm

Source: Terefe Marito
Fill water in pycnometer jar.

Source: Assefa Feysa

Soaking the CCA and SDA

Source: Assefa Feysa

Ready the sample for liquid limit test


Source: Assefa Feysa

Digital Liquid limit Apparatus

Source: Assefa Freya

arrange the apparatus with the test sample.

Source : Assefa Feysa

Sieve arrangement by size.

Source : Assefa Feysa

Measuring the water Temperature.