Jimma University

Jimma Institute of Technology

School Of Graduate Studies

School of Civil and Environmental Engineering

Department of Civil Engineering

Highway Engineering Stream

EVALUATION ON THE PERFORMANCE OF BRICK DUST AS A FILLER MATERIAL FOR HOT ASPHALT MIX DESIGN IN JIMMA ZONE

By
Fisseha Wagaw

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 Highway Engineering

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October, 2016
Jimma, Ethiopia

SCHOOL OF POST GRADUATE STUDIES JIMMA UNIVERSITY

As a member of the examining board of the final Msc open defense. We certify that we have read and evaluate the thesis prepared by Fisseha Wagaw Entitled: **Evaluation on the performance of Brick Dust as a filler material for Hot Asphalt Mix design** ; and recommended that it be accepted as fulfilling the thesis requirement for the degree of master of science in Highway Engineering.

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DECLARATION

I, the undersigned, declare that this thesis entitled "**<u>Evaluation on the Performance of Brick Dust as a Filler Material in Hot Asphalt Mix design in Jimma Zone</u>**" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been dually acknowledged.

Candidate:

Mr. Fisseha Wagaw

Signature_______________

As Master research Advisors, we hereby certify that we have read and evaluate this Msc research prepared under our guidance, by Mr. Fisseha Wagaw entitled: **<u>Evaluation on the Performance of Brick Dust as a Filler Material in Hot Asphalt Mix design in Jimma Zone.</u>** We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

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Eng. Anteneh Geremew	____________________	_____/_____/____
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ABSTRACT

Construction of highway pavement involves huge outlay of investment. A precise engineering design may save considerable investment; as well as reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard – pavement design and the mix design. This study emphasizes on the bituminous mix design considerations. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions of material combinations and finalizes the best one. This often involves a balance between mutually conflicting parameters.

A bituminous paving mixture is a mixture of coarse aggregate, fine aggregate and bitumen mixed in suitable proportion to result strong and durable mix with stand traffic load. In this paving mix, normally stone dust and cement are used as filler material.

One of the main problem in the construction of bituminous paving mixture is the insufficiency amount of filler from crushing stone aggregate and cement supply is low. A study has been carried out in this research to explore the use of Brick dust as filler material for the bituminous mixture.

From this point of view, the prime aim or main objective of this research is to evaluate the performance of brick dust as fillers in Hot Asphalt Mix design, according to the test procedure specified by ASTM.

Several specimens of hot asphalt mixture were prepared according to ASTM D 1559 using aggregate blend with brick filler and aggregate blend without brick filler. The aggregate blend made by using Job mix formula to obtain the percentage of mix material, for aggregate blend without brick G-1 32%, G-2 23% and G-3 45% for Aggregate blend with brick filler G-1 30%, G-2 18%, G-3 45% and G-4 7%; where G-1 Coarse Aggregate 3/4, G-2 Coarse Aggregate 3/8, G-3 Fine Aggregate, and G-4 brick filler.

The result of Marshall test on mix design of hot asphalt mixtures, for the wearing coarse were conclude that, the hot asphalt mixes with these brick fillers result in satisfactory Marshall Properties when compared with bituminous mixes not blend with brick filler, with its optimum asphalt content of 5.1% and 5.4% (by weight of total aggregate) respectively, the Specimens with blend with brick filler lead to produce asphalt mixture with higher Marshall stability, lower flow, lower void filled by asphalt and lower void in total mix comparing with specimens not blend with brick filler.

Hence, brick dust can totally replace stone dust and cement filler in bituminous paving mix, so it is recommended to use brick dust as filler material in bituminous paving mix, it may save considerable investment; as well as reliable performance of the in-service highway can be achieved.

Keyword: Aggregates, Brick Filler, Bituminous paving mix, Hot Mix Asphalt, Marshall Mix Design, Optimum Content.

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ACRONYMS

AASHTO	American Association of State Highways and Transport Officials
AC	Asphalt Concrete
ASTM	American Standard for Test Method
ATPB	Asphalt Treated Permeable Base
BC	Binder Content
BS	British Standard
CBPD	Cement by Pass dust
CBR	California bearing ratio
DC	Data Collector
DEC	Data Entry Clerk
DGA	Dense Graded Asphalt
DGM	Dense Graded Mix
ERA	Ethiopian Roads Authority
ERCC	Ethiopian Road Construction Corporation
HMA	Hot Mix Asphalt
HMAC	Hot Mix Asphalt Concrete
JiT	Jimma Institute of Technology
JMF	Job Mix Formula
Mb	Mass of Binder in Specimen
NP	Non PI
OGFC	Open Graded Friction Course
OGM	Open Graded Mix
OPC	Ordinary Portland Cement
Pb	Total Asphalt Binder content
PI	Personnel Investigator
RA	Research Assistant
RSDP	Road Sector Development Program
SMA	Stone Mastic Asphalt
VMA	Void in Total Mix
VTM	Void in Mineral Aggregate

CHAPTER ONE

INTRODUCTION

1.1. General

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The present study is related to the mix design considerations.

Hot mix Asphalt used in the surface layer of road and airfield pavements. The mix is composed usually of aggregate and asphalt cements. Some types of asphalt mixes are also used in base course. The design of asphalt paving mix, as with the design of other engineering materials is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure.

A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) Resistive to fatigue and permanent deformation (iv). Environment friendly, (v) economical and so on A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one (Construction of hot asphalt pavement, manual series No. 22. second edition)

Road usually show excessive failures at an early stage of the pavement life. A major step in the improvement of the existing performance of roads starts with modification of mix design. The strength, cost and stability of asphalt mixtures are influenced by several features together with gradation of aggregated and types and amount of filler materials. The filler plays a major role in the properties and behavior of bituminous paving mixtures (IlanIshai, et al, 1980).

The mechanical properties of bituminous road pavement depend decisively upon the properties of its filler-bitumen (Huschek, et al, 1980).For modification of asphalt paving materials, the high quality additives are quite expensive for the mass production of bituminous mixtures, a solution to this problem can be obtained by considering the influence of natural mixture ingredients, such as filler (IlanIshai Research Question, Joseph Craus, 1980).

Mineral fillers were originally added to dense-graded HMA paving mixtures to fill the voids in the aggregate skeleton and to reduce the voids in the mixture (Brian D. Prowell, et al, 2005). Filler used in the asphalt mixture are known to affect the mix design, especially the optimum asphalt content. Fillers not only fill voids in the coarse and fine aggregates but also affect the aging characteristics of the mix. Generally, the aggregate materials those are finer than 75 μm in size is referred to as filler. The use and the application of mineral filler in asphalt mixtures are intended to improve the properties of binder by reducing the binder's inherent temperature susceptibility *(*IlanIshai, et al, 1980).

The term (filler) is often used loosely to designate a material with a particle size distribution smaller than #200 sieves. The filler theory assumes that "the filler serves to fill voids in the mineral aggregate and thereby create dense mix", (I.Abdulwahhab, 1981).

Filler particle are beneficial because of increased resistance to displacement resulting from the large area of contact between particles. It was found that fillers increase comp active effects required to compact specimens to the same volume or air void content. The function of mineral filler is essentially to stiffen the binder.

According to various studies, the properties of mineral fillers especially the material passing 0.075 mm (No. 200) sieve have a significant effect on the performance of asphalt paving mixture in terms of deformation, Fatigue cracking, and moisture susceptibility (Kandhal, et al, 1998). Various conventional materials such as cement, lime, granite powder are normally used as filler in asphalt concrete mixture in other world.

Cement, lime and granite powder are expensive and are used for other purposes more effectively. With the economic point of view, my present investigation has been taken in order to study the performance of asphalt concrete mixture with Brick dust in hot asphalt mix.

1.2. Statement of the problem

Filler is one of the components of asphalt concrete mixture. It plays a significant role on the characteristics and performance of the asphalt concrete mixtures (Anderson et al., 1992). Fillers have traditionally been used in asphalt mixtures to fill the voids between the larger aggregate particles. The influence of different types of fillers on the properties of asphalt concrete mixture varies with the particle size, shape, surface area, surface texture and other properties (Bahia et al., 2011).

One of the main problems in the construction of asphalt paving mixture is the insufficiency of amount of fillers from crushing of stone aggregates and cement supply is low. Therefore, it is important to come across an alternative type of filler materials. This study was focus to investigate the performance of brick as filler in hot asphalt mix on the Marshall properties of asphalt paving.

1.3. Research Question

1. What is the property of Brick as filler in hot asphalt mix design?
2. What are the potential effects of using Brick filler in hot asphalt mix design within the study area?
3. What will be the outcome when we compare with the ERA standard specification?

1.4. Objective of the study

1.4.1. General Objective

- The general objective of study is to evaluate the performance of Brick dust as a filler material in Hot Asphalt mix design.

1.4.2. Specific objectives

- To identify the properties of brick as a filler.
- To examine the effect the brick as a filler on the properties of the asphalt mixture.
- To compare the Brick filler with the Standard Specification of ERA.

1.5. Scope of the study

The scope of study is to evaluate the performance (flow, stability, void filled by bitumen, void in total mix, density, optimum binder content) of the brick filler is going be used as a filler material in asphalt concrete mix design. This study done using the reuse of brick after molding and drying then crushing or waste material of brick

1.6. Significant of the Study

Asphalt pavements are a crucial part of our nation's strategy for building a high performance transportation network for the future. The continuing rapid growth in traffic demand, along with the increase in allowable axle loads, necessitates the improvement of the highway paving materials.

The aim of highway authorities was to provide safe, cost-effective, hard and smooth pavements that are capable to carry the anticipated loads. In order to achieve this aim many studies have been conducted to select the materials.

- So around Jimma zone there is the abundance of the material (brick) which may be used as filler and it can be minimize the cost we offer for other Filler material like Cement, Stone dust.
- Owners, contractors and consultants was benefit from the study as a source of information for Highway projects, in case of Jimma city and Zone and further for Ethiopia.
- Other researchers were using the findings as a reference for further research on Brick dust filler for asphalt mix design.
- The study was provide lessons that will help the concerned body can come up with appropriate measures to address problems resulting from using Brick dust and compared with other fillers in marshal mix design.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Various studies have been conducted on the properties of HMA using minor changes on the ingredients of the mixture. In general the main objectives of the researches were to understand in a better way the characteristics of Brick dust as a filler on bituminous mixtures and evaluate the effects of constituent ingredients on the performance.

The research herein with concentrates and builds on the Marshal Properties of HMA mixtures prepared using Brick fillers. This evaluation on the subject matter was conducted by comparing the traditional crushed stone mineral filler verses Brick Dust fillers. There are well-established literature below that indicate limestone filler (P-No. 200 sieve) being under practice on HAM performance, but not for the Brick Dust as mineral filler.

2.2. Theoretical Review

A number of studies have been made on use of different types of fillers in various types of paving mixes which are presented briefly below. Although the filler particles are small in size, it is well documented that filler exerts a significant effect on the characteristics and performance of asphalt concrete mixture. Good packing of the coarse aggregates, fine aggregates, and filler provides a strong backbone for the mixture (Zulkati et al., 2011).

In general, type of filler, type of stabilizer, amount of stabilizer affect not only optimum bitumen content (OBC) of paving mixes but also affect the property like Marshall stability, tensile strength, retain stability of mixes. Also OBC of dense graded mix is less than stone matrix asphalt (Brown and Mallick, 1994). An investigation on property of eight different types of mineral filler materials in Europe indicated that the filler quality does not affect the performance of mixture (Mogawer and Stuart, 1996).

Filler acts as one Waste marble dust obtained from shaping process of marble blocks and lime stone used as filler in hot mix asphalt and optimum bitumen content was determined by Marshall Test and it showed good result (Karaşahin and Terzi, 2007*)*.

Similarly a comparative study was done on SMA by taking basic oxygen slag as aggregate with PG 76-22 modified bitumen and lime stone as filler and chopped polyester fiber as stabilizer and SMA without fiber; concluded that modified SMA is superior compared to conventional SMA (Wu et al., 2007).

Four types of industrial by-product wastes filler namely, limestone as reference filler, ceramic waste dust, coal fly ash, and steel slag dust increases the stiffness and fatigue life of Stone Mastic Asphalt (SMA) Mixtures (Muniandy and Aburkaba, 2011).

Waste glass power as mineral filler on Marshall property of bituminous by comparing with bituminous where lime stone, ordinary Portland cement was taken as filler with varying content (4-7%). Optimum glass power content was found 7%. By using glass power as filler in bituminous its stability increases up to 13%, flow value decreases, density also decreases as compare to bituminous contains lime stone and cement filler of the major constituents in asphalt paving mixture (Jony et al., 2011).

Fillers not only fill voids in the coarse and fine aggregates but also affect the aging characteristics of the mix. Generally, the aggregate materials those are finer than 75 µm 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 binder, fly ash, or other suitable mineral matter (Road and Paving Materials, section 4, volume 04.03, 2003*)*. In an asphalt-concrete mixture the filler, whether artificial or natural, may stiffen the asphalt-concrete, extend the asphalt cement and affect the work ability and compaction characteristics of the mix (Andersone et al., 1982). Filler imparts a considerable importance on the properties of asphalt-concrete mixture. The amount of filler influences the optimum asphalt content (Hyyppa., 1964).

The work ability during the operation of mixing and compaction of asphalt-concrete mixture are consequential property of asphalt-filler mastic also affected by filler materials (A.Zulkati et al., 2012). Filler provides better resistance to micro cracking so that it can increase the fatigue life of asphalt-concrete mixture (Kim, Little and Song et al., 2003).

Structural characteristics of asphalt-concrete mixture are improved by using hydrated lime and phosphogvypsum as filler material (T.Sudhakaran et al. 2011). Significant improvement in fatigue life of the asphalt-concrete mixtures can be obtained by using fly ash from oil shale (Asi and A.Assaad. 2005). Waste cement dust as filler on the asphalt-concrete mixture enhances the mechanical properties of the mix, and the laboratory results indicate that the cement dust can totally replace limestone powder in the asphalt paving mixture (Ahmed and Othman. 2006).

The use and the application of mineral filler in asphalt mixtures are intended to improve the properties of binder by reducing the binder's inherent temperature susceptibility (Tunnicliff, 1962). Mineral fillers play a dual role in asphalt mixtures, first ; they act as a part of the mineral aggregate by filling the voids between the coarser particles in the mixtures and there by strengthen the asphalt mixture , second ; when mixed with asphalt , fillers form mastic , a high-consistency binder or matrix that cement slager binder particles together ; most likely a major portion of the filler remains suspended in the binder while a smaller portion becomes part of the load bearing framework (Harris and Stuart , 1995).

The type and amount of filler used in hot asphalt mixtures would be affecting the properties of the mixes .The use of industrial and by – products wastes as replacement of mineral fillers in asphalt mixtures to enhance the properties and performance of asphalt concrete pavements (Harris B.M and Stuart K.D, 1995).

Filler is one of the components of asphalt concrete mixture. It plays a significant role on the characteristics and performance of the asphalt mixtures (Anderson et al., 1992).For modification of asphalt paving materials, the high quality of additives are quite expensive for the mass producing of bituminous mixture, a solution to this problem can be obtained by considering the influence of natural mixture ingredient such as filler (Crasu et al. (1981) investigate the role of fillers in long term durability of bituminous concrete mix.

Chari and Jacob (1984) studied the influence of lime and stone dust fillers o fatigue performance of bituminous concrete mixes. Among the two filler lime was found to have substantial influence on the fatigue properties, although static strength remained more or less same for both the fillers. Suhaibani et al. (1992) investigate the effect of filler type and content on rutting potential of bituminous concrete.

Fwa and Aziz (1995) performed a series of testes to arrive at an acceptable bituminous mix using incinerator residue as a partial replacement for the aggregate in Singapore. Baig and Wahhab (1998) investigated the effectiveness of using hematite (rock wool natural fibers) as filler in improving the performance asphalt concrete pavement, and to compare hematite with lime (as filler) modification mixes and the conventional asphalt mix containing crushed stone filler. Lime modifies mixes showed better resistance to fatigue and rutting than other mixes.

Taha Et al. (2002*)* used Cement by pass dust (CBPD), a byproduct of Portland cement industry as filler in their study. Three different asphalt concrete mixtures were prepared using lime and 5 and 13% CBPD substitution for lime or fine aggregate. They found that the substitution of 5% CBPD for lime will essentially produce the same optimum binder content as the control mixture without any negative effect on the asphalt concrete properties. However, the use 13% CBPD for lime and fine aggregate will require higher optimum asphalt content and will produce an uneconomical mix. Karasahin and Terzi (2007) used marble dust as a filler material in asphalt concrete mixes. The marshal and plastic deformation test showed that lime stone dust and marble dust gave almost the same results. Marble dust had higher values of plastic deformation and hence was suggested for low traffic volume roads.

Different types and quantity of filler have an effect on the performance of asphalt-concrete mixture. Filler provides batter resistance to micro cracking so that it can increase the fatigue life of asphalt concrete mixture. Various conventional materials such as cement, lime, granite powder are normally used as filler in asphalt concrete mixture in other world. Cement, lime and granite powder are expensive and are used for other purposes more effectively. With the economic point of view, my present investigation has been taken in order to study the performance of asphalt concrete mixture with Brick dust and compare with conventional filler materials.

2.3. Components of mix and Functions.

2.3.1. Aggregate Type and Quality Selection

The properties of aggregates are very important to the performance of hot mix asphalt (HMA) pavements. Often pavement distress such as rutting, tripping, surface disintegration, and lack of adequate surface frictional resistance can be attributed directly to improper aggregate selection and use. Thus, care has to be made while selecting the mineral aggregate and all quality test assurance has to be conducted to confirm whether they satisfy a definite project specification.

The study conducted by (Kim, et al., 1992) disclosed that aggregate type has a significant effect on the fatigue resistance and permanent deformation of asphalt mixtures.

Aggregates are deemed to give the mixture stability after various traffic loads, resistance to wear due to abrasive action of traffic, and still resistant to frost action. Thus, to obtain a mixture having good performance, evaluation of various mineral aggregate physical properties is essential.

2.3.1.1. Aggregate Classification

Aggregate for HMA are generally classified according y to their formation is divided into three general types: sedimentary, igneous, and metamorphic. (ERA manual, 2002)

Sedimentary: Sedimentary rocks are formed in layers by the accumulation of sediment (fine particles) that deposited by wind and water, it may contain:

- Mineral particles or fragment (in case of sandstone and shale)
- Remains or products of animal (certain limestone)
- Plant (coal)
- End product of chemical action or evaporation (salt, gypsum)
- Combination of these types of material

Igneous: Igneous rock consists of molten material (magma) that has cooled and solidified. There are two types: extrusive and intrusive. (ERA manual, 2002)

Extrusive igneous rock is formed material that has poured out onto the earth's surface during the volcanic eruption or similar geological activity. Because exposure to the atmosphere allows the material to cool quickly, the resulting rock has a glass-like appearance and structure. Rhyolite, andesite and basalt are example of extrusive rock. Intrusive rock form from magma trapped deep within the earth's crust. Trapped in the earth, the magma cools and hardens, slowly, allowing a crystalline structure to form. Examples of igneous rock are: granite, diorite and gabbro. Earth movement and erosion process bring intrusive rock to the earth's surface where it is quarried and used. (ERA manual, 2002)

Metamorphic: Metamorphic rock is generally sedimentary or igneous rock that has been changed by intense pressure and heat within the earth. Because such formation processes are complex, it is often difficult to determine the exact origin of a particular metamorphic rock. Many types of metamorphic rock have a distinct characteristic feature; the mineral are arranged in parallel planes or layers. Splitting the rock along its planes is much easier than splited. Example of foliated rock is gneisses, schist (formed from igneous material) and slate (formed from shale, a sedimentary rock). (ERA manual, 2002)

2.3.1.2. Aggregate Sources

Aggregate for HMA are generally classified according to their sources, they includes Natural aggregate, Processed aggregates and synthetic rock aggregate.

Natural Aggregate: Natural aggregates are those used with little or on processing. They are made up of particles produced by natural erosion and degradation, such as the action of wind, water, moving ice and chemicals. The shape of individual particles is largely a result of erosion. Glaciers, for example, often produced rounded boulders and pebbles. Similarly, flowing water produces smoothly rounded particles. The two major types of natural aggregate used in pavement constructions are gravel and sand. Gravel is usually defined as particles 6.35 mm (1/4 in) or larger in size. Sand is defined as particles smaller than 6.335 mm but larger than 0.075 mm (No. 200), Pericles smaller than 0.075 mm are mineral filler (ERA manual, 2002).

Gravels and sands are further classified by their source. Materials quarried from an open pit and used without further processing are referred to as pit run materials. Similarly, materials taken from stream banks are referred to as bank-run materials.

Processed Aggregate: Processed aggregate have been quarried, crushed and /or screened in preparation for use. There are two basic sources of processed aggregate: natural gravel that is crushed to make them more suitable for use in HAM, and fragments of bedrock and large stones that must be reduced in size. Rock is crushed for three reasons:

- To reduce the size and improve the distribution and range (gradation) of particle size.
- To change the surface texture of the particles from smooth to rough.
- To change particles shape from round to angular.

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries (ERA manual, 2002)

The mineral aggregates used in this research were the manufactured one and subjected to various tests in order to assess their physical characteristic and suitability of the road construction. The aggregate were obtained from ERCC quarry and crusher site located in Unkulu of Ana Mana. In order to obtain a representative samples for testing, all coarse and fine aggregates were riffled in accordance with AASHTO/ASTM/BS.

2.3.1.3. Aggregate gradation and Size

An aggregate's particle size distribution, or gradation, is one of its most influential characteristics. It determines almost every HMA properties including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance, and resistance to moisture damage (Bouchard, 1992).

This makes gradation the primary factor in the asphalt mix design. Matthews and Monismith investigated a study to evaluate aggregate gradation on the creep response of asphalt mixtures and pavement rutting estimates. They have used both methods of measuring rutting performance (stabilometer and creep tests). From their study, it was indicated that mixtures with aggregate particles size distribution around the mid band of gradation limits, termed as “medium graded”, provide significantly better resistance to rutting than the mixtures with aggregate gradation below the mid band of aggregate gradation, termed as “coarse graded”. However, (Kim et al. 1992) have showed that changing the proportions of fine and coarse aggregates with the same nominal maximum aggregate size did not affect the permanent deformation significantly. This was verified by Kandhal and Allen that from their study on rutting potential of both coarse and fine graded mixtures. The statistical analysis of the test data revealed that there is no significant difference between the rutting resistance of coarse and fine graded super pave mixtures.

A) Coarse aggregate

Coarse Aggregate Should produces by crushing sound, unweathered rock or natural gravel. The specifications for the aggregates are similar to those for granular base course. The aggregate must be clean and free of clay and organic material; the particles should be angular and not flaky. Gravel should be crushed to produce at least two fractured faces on each particle. Aggregates for wearing course must also be resistant to abrasion and polishing. Highly absorption of bitumen must be taken into account in the mix design procedure.

B) Fine aggregate:

Can be crushed rock or natural sand and should be clean and free from organic impurities. It shall be fraction passing 600 microns and retained on 75 microns sieve and its function is to fill up the voids of the coarse aggregate.

C) Fillers

Mineral fillers can be crushed rock fines, Portland cement or hydrated lime to assist the adhesion of the bitumen to aggregate and fill up the void. It should be inert material which pass 75 micron sieve. However, addition of mineral fillers has dual purpose when added to asphalt mixtures.

A portion of the mineral filler that is finer than the asphalt film thickness mixed with asphalt binder forms a mortar or mastic and contributes to improved stiffening of mix. This modification to the binder that may take place due to addition of mineral fillers could affect asphalt mixture properties such as rutting and cracking. The other portion of fillers larger than the asphalt film thickness behave as a mineral aggregate and serves to fill the voids between aggregate particles, thereby increasing the density and strength of the compacted mixture.

Mineral fillers have a significant impact on the properties of HMA mixtures. Mineral fillers increase the stiffness of the asphalt mortar matrix. Mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures. Generally filler plays an important role in properties of bituminous mixture particularly in terms of air voids, voids in mineral aggregate. Different types of mineral fillers are used in the SMA mixes such as stone dust, ordinary Portland cement (OPC), slag cement, fly Ash, hydrated lime etc.

Mustafa Karasahin et al. (2006) used waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall Test and showed good result. Yongjie Xue et al. (2008) utilized municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler in stone matrix asphalt mixtures. They made a comparative study of the performance of the design mixes using Super pave and Marshall Mix design procedures.

2.3.2. Asphalt binder

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix. The characteristics of bitumen which affects the bituminous mixture behavior are temperature susceptibility, visco-elasticity and aging. The behavior of bitumen depends on temperature as well as on the time of loading. It is stiffer at lower temperature and under shorter loading period. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. Though at low temperature it behaves like an elastic material and at high temperatures its behavior is like a viscous fluid.

Asphalt binder is material having a wide range of consistency from fluid to hard and brittle for flexible pavement construction. Asphalt binders are most commonly characterized by their physical properties. This is because an asphalt binder's physical properties directly describe how it will perform as a constituent in Asphalt mix. Different quality tests were carried out on asphalt cement during this study to assess its physical properties through various laboratory steps.

2.4. Common types of premix

The main types of premix are asphaltic concrete, bitumen macadam and hot rolled asphalt. Each type can be used in surfacing or base courses. Their general properties and suitable specification described below. (Hot Asphalt Mix Manual, 2nd edition)

2.4.1. Asphaltic Concrete

Asphalt concrete (AC) is a dense, continuously graded mix which relies for its strength on both the interlock between aggregate particles and, to a lesser extent, on the properties of the bitumen and filler. The mix designed to have low air voids and low permeability to provide good durability and good fatigue behavior but this makes the material particularly sensitive to errors in proportioning, and mix tolerance are therefore very narrow. (Hot Asphalt Mix Manual, 2nd edition)

Hot mix asphalt concrete (commonly abbreviated as HMAC or HMA) is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300 °F(roughly 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt, and the asphalt cement at 200 °F (95 °C). Paving and compaction must be performed while the asphalt is sufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as those on major highways, racetracks and airfields. (Hot Asphalt Mix Manual, 2nd edition)

Warm mix asphalt Concrete (commonly abbreviated as WMA) is produced by adding zeo-lites waxes, asphalt emulsions, or sometimes even water to the asphalt binder prior to mixing. This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols and vapors. Not only are working conditions improved, but the lower laying-temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The usage of these additives in hot mixed asphalt (above) may afford easier compaction and allow cold weather paving or longer hauls. (Hot Asphalt Mix Manual, 2nd edition)

Cold mix asphalt concrete is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. While in its emulsified state the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMAC. Cold mix is commonly used as a patching material and on lesser trafficked service roads. (Hot Asphalt Mix Manual, 2nd edition)

Cut-back asphalt concrete is produced by dissolving the binder in kerosene or another lighter fraction of petroleum prior to mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to work and compact. After the mix is laid down the lighter fraction evaporates. Because of concerns with pollution from the volatile organic compounds in the lighter fraction, cut-back asphalt has been largely replaced by asphalt emulsion. (Hot Asphalt Mix Manual, 2nd edition)

2.4.2. Bitumen Macadam

This one is closed graded bitumen macadam are continuously graded mixes similar to asphaltic concrete but usually with a less dense aggregate structure. They have developed in the United Kingdom from empirical studies and are made to recipe specifications without reference to a format design procedure. Their suitability for different condition and with different materials may be questioned but, in practice, numerous materials including crushed gravels have been used successfully. (Asphalt Institute, 2001)

2.4.3. Bituminous Surfacing

This is particularly important for surfacing laid on granular base courses. Mixes which are designed to have good durability rather than high stability are flexible and are likely to have “ sand” and bitumen contents at the higher end of the permitted ranges. In areas where the production of sand- sized material is expensive and where there is no choice but to use higher stability mixes, additional stiffening through then aging and embrittlement of the bitumen must be prevented by applying a surface dressing (Asphalt Institute, 2001).

2.5. Hot Mix Asphalt

HMA is a mixture of coarse and fine aggregates and asphalt binder. HMA, as the name suggests, is mixed, placed and compacted at higher temperature. HMA is typically applied in layers, with the lower layers supporting the top layer. They are Dense Graded Mixes (DGM), Stone Matrix asphalt (SMA) and various Open graded HMA (National center for asphalt Technology, 1996).

2.5.1. Dense-Graded Mixes

This type of bituminous concrete is a well-graded HMA has good proportion of all constituents are also called Dense bituminous macadam. When properly designed and constructed, a dense graded mix is relatively impermeable. Dense-graded mixes are generally referred to by their nominal maximum aggregate size and can further be classified as either fine-graded or coarse graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes. It is Suitable for all pavement layers and for all traffic conditions. It offers good compressive strength. Materials used are Well-graded aggregate, asphalt binder (with or without modifiers)

2.5.2. Stone Matrix Asphalt (SMA)

Stone matrix asphalt (SMA), sometimes called stone mastic asphalt, is a gap-graded HMA originally developed in Europe to maximize rutting resistance and durability in heavy traffic road. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resists permanent deformation. The stone skeleton is filled with mastic of bitumen and filler to which fibers are added to provide adequate stability of bitumen and to prevent drainage of binder during transport and placement. Typical SMA composition consists of 70−80% coarse aggregate, 8−12% filler, 6.0−7.0% binder, and 0.3 per cent fiber. The deformation resistant capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes (National center for asphalt Technology, 1996).

2.5.3. Open-Graded Mixes

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands. The two most typical open-graded mixes are:

- Open-graded friction course (OGFC). Typically 15 percent air voids and no maximum air voids specified.
- Asphalt treated permeable bases (ATPB). Less stringent specifications than OGFC since it is used only under dense-graded HMA, SMA or Portland cement concrete for drainage.

OGFC – Used for surface courses only. They reduce tire splash/spray in wet weather and typically result in smoother surfaces than dense-graded HMA. Their high air voids reduce tire road noise by up to 50%.

ATPB – Used as a drainage layer below dense-graded HMA, SMA. Material used aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers). OGFC is more expensive per ton than dense-graded HMA, but the unit weight of the mix when in-place is lower, which partially offsets the higher per-ton cost. The open gradation creates pores in the mix, which are essential to the mix's proper function. Anything that tends to clog these pores, such as low-speed traffic, excessive dirt on the roadway can degrade performance (Hot Asphalt mix manual, 2nd edition)

2.6. Properties of Hot Mix Asphalt (HMA)

The main objective of asphalt concrete mixture design is to determine an economical blend or mix of stone aggregate, sand and fillers such as brick dust gives a mix having or possess the following characteristics.

- Sufficient mix stability to satisfy the demands of traffic without displacement.
- High resistance to deformation
- High resistance to fatigue and the ability to withstand high strains i.e. they need to be flexible.
- Sufficient stiffness to reduce the stresses transmitted to the underlying pavement layers.
- Sufficient void in total compaction mix to allow for a slight amount of additional compaction and traffic loading without flushing bleeding and loss of stability yet low enough to keep out harmful air and moisture.
- Sufficient work ability to permit sufficient placement of the mix without segregation.

2.6.1. Stability

Stability is defined as the resistance of the paving mix to deformation under traffic load. Two examples of failure are:

(i) Shoving - a transverse rigid deformation which occurs at areas subject to severe acceleration

(ii) Grooving - longitudinal ridging due to channelization of traffic. Stability depends on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen. Sufficient binder must be available to coat all the particles at the same time should offer enough liquid friction. However, the stability decreases when the binder content is high and when the particles are kept apart. A stability value that is too high produces a pavement that is too stiff and therefore less durable.

The stability of mixture depends on internal friction and cohesion. Interparticle friction among the aggregate particles is related to aggregate characteristics such as shape and surface texture. Cohesion result from the bonding ability of the asphalt, proper degree of both Interparticle friction and cohesion in a mix prevent the aggregate articles from being moved past each other of extracted by traffic. Table 2.1 list some causes and effects of insufficient stability.

Table 2.1: Causes and Effects of pavement Instability

Causes	Effects
Excess asphalt in mix	Wash boarding, rutting and flushing or bleeding
Excess medium size sand in mixture	Tenderness during rolling and for period after constriction , difficulty in compacting
Rounded aggregate, little or no crushed surface	Rutting and channeling

Source: Hot Asphalt Mix Manual, 2nd edition

2.6.2. Durability

The durability of an asphalt pavement is the ability to resist factor such as aging of the asphalt, disintegration of the aggregate, stripping of the asphalt film from aggregate, and the resistance of the mix against weathering and abrasive actions. Weathering causes hardening due to loss of volatiles in the bitumen. Abrasion is due to wheel loads which causes tensile strains. Typical examples of failure are (i) pot-holes, - deterioration of pavements locally and (ii) stripping, loss of binder from the aggregates and aggregates are exposed. Disintegration is minimized by high binder content since they causes the mix to be air and waterproof and the bitumen film is more resistant to hardening. A lack of sufficient durability in a pavement can have several causes and effects as shown in Table 2.2.

Table 2.2: Causes and Effects of pavement Durability

Causes	Effects
Low Asphalt content	Dryness or raveling
high void content through design or lack of compaction	Early hardening of asphalt followed by cracking or disintegration
Water susceptible (hydrophilic) aggregate in mixture	Asphalt film strips rom aggregate leaving an abraded, reveled or mushy pavement

Source: Hot Asphalt Mix Manual, 2nd edition

2.6.3. Impermeability

Impermeability prevents the passage of air and water into or through the asphalt pavement. This characteristic is related to the void content of the compacted mixture, and much of the discussion on voids in mix design relates to impermeability. Even though void content is an indication of the potential for passage of air and water through a pavement, the character of these voids is more important than the number of voids. Although impermeability is important for durability of compacted paving mixtures, virtually all asphalt mixtures used in highway construction are permeable to some degree. This is acceptable as long as it is within specified limits. Causes and effects of poor impermeability values in dense graded HMA are shown in table 2.3

Table 2.3: Causes and Effects of pavement Permeability

Causes	Effects
Low Asphalt content	Thin asphalt films will cause early aging and raveling
High voids content in design mix	Water and air can easily enter pavement, causing oxidation and disintegration
Inadequate compaction	Will result in high voids in pavement, leading to water infiltration and low strength

Source: Hot Asphalt Mix Manual, 2nd edition

2.6.4. Workability

Workability describes the ease with which a paving mixture can be placed and compacted. Mixture with good workability are relatively easy to place and compact, those with poor work ability are difficult to place and compact. And it can be improve by changing mix design parameters, aggregate source, or gradation. Mixtures that can be too easily worked or shoved are referred to as tender mixes. Tender mixes are too unstable to place and compact properly. They are often caused by:

- A shortage of mineral filler
- Too much medium-size particles
- Too much moisture in the mix

Although not normally a major contributor to workability problems, asphalt does have some effect on workability. Because the temperature of the mix affects the viscosity of the asphalt, a temperature too low will make a mix unworkable, and a temperature that is too high may make it tender. Table 2.4 lists some of the causes and effects to workability of paving mixtures.

Table 2.4: Causes and Effects of pavement workability

Causes	Effects
Large maximum-size particles	Rough surface, difficult to place
Excessive coarse aggregate	May be hard to compact
A mix temperature too low	Uncoated aggregate, not durable, rough surface, hard to compact
Too much medium-size sand	Mix shoves under roller, remains tender
Low mineral Filler	Tender mix, highly permeable
High mineral filler content	Mix may be dry or gummy, hard to handle, not durable

Source: Hot Asphalt Mix Manual, 2nd edition

2.6.5. Flexibility

Flexibility is the ability of an asphalt pavement to adjust to gradual settlements and movements in the subgrade without cracking. Since virtually all subgrade either settle (under loading) or rise (from soil expansion), flexibility is a desirable characteristic for all asphalt pavement. An open graded mix or one with high asphalt content is generally more flexibility than a dense graded mix or one with low asphalt content. Sometimes the need of for flexibility conflicts with the need for stability, so that trade-offs have to be made in selecting the optimum asphalt content.

2.6.6. Fatigue Resistance

Fatigue resistance is the pavement's resistance to repeated bending under wheel load (traffic). Research shows air void and asphalt viscosity have a significant effect on fatigue resistance. As the percentage of air void in the pavement increases, either by design or lack of compaction pavement fatigue resistance is drastically reduced. Likewise a pavement containing asphalt that has aged and hardened significantly has reduced resistance to fatigue.

The thickness and strength characteristics of the pavement and the support of the subgrade also have a great deal to do with determining pavement life and preventing load-associated cracking. Thick, well-supported pavements do not bend as much under loading as thin or poorly supported pavements do. Therefore, they have longer fatigue lives. Table 2.5 present a list of causes and effects of poor fatigue resistance.

Table 2.5: Causes and Effects of poor fatigue resistance.

Causes	Effects
Low Asphalt content	Fatigue cracking
High design Voids	Early aging of asphalt followed by fatigue cracking
Inadequate pavement thickness	Excessive bending followed by fatigue cracking
lack of compaction	Early aging of asphalt followed by fatigue cracking

Source: Hot Asphalt Mix Manual, 2^{nd} edition

2.6.7. Skid Resistance

Skid resistance is the ability of an asphalt surface to minimize skidding or slipping of vehicle tires, particularly when wet. For good skid resistance, tire tread must be able to maintain contact with the aggregate particles instead of riding on a film of water on the pavement surface (hydroplaning). A list of causes and effects relating to poor skid resistance is shown in table 2.6.

Table 2.6: Causes and Effects of poor skid resistance.

Causes	Effects
Excess asphalt	Bleeding, low skid resistance
Poorly textured or graded aggregate	Smooth pavement, potential for hydroplaning
Polishing aggregate in mixture	low skid resistance

Source: Hot Asphalt Mix Manual, 2^{nd} edition

2.6.8. Desirable properties

From the above discussion, the desirable properties of a bituminous mix can be summarized as follows:

- Stability to meet traffic demand
- Bitumen content to ensure proper binding and water proofing
- Voids to accommodate compaction due to traffic
- Flexibility to meet traffic loads, esp. in cold season
- Sufficient workability for construction

CHAPTER THREE

METHODOLOGY

3.1. Introduction

The goal of this study was to evaluate the Marshal Mix properties in the laboratory using Brick as main Filler mineral and comparing with traditional fillers namely crushed stone. This study is start from preparation and investigation the properties of the row material for the marshal mix. The material used for the mixture includes coarse aggregate, Fine aggregate, Mineral filler (Brick) and asphalt binder.

The above mentioned materials were subjected to various laboratory test in order to determine their physical properties whether they can meet common specification and to assure the quality assurance. The quality assurance test conduct on the aggregate is determination of the aggregate physical properties Toughness, Gradation, Abrasion, Durability, Soundness, Specific gravity and water absorption. For asphalt binder penetration test, ductility, durability, purity and specific gravity and for the filler material the study investigates the specific gravity and the PI. All test on aggregate; asphalt binder, brick filler, and compacted specimens were conducted according to respective ERA, AASHTO, ASTM, and BS testing standards.

3.2. Study Area

This research was conducted in Jimma zone; the capital of the Zone is Jimma town. It is located in Oromia Region, Southwestern Ethiopia of about 355 km from Addis Ababa. Jimma zone has 17 Weredas. They are (Kersa, Seka-Chekorsa, Mana, Goma, Dedo, Gera, shebe-sombo, Nada, Sekoru, Tiroafeta, Gumey, Sigmo, Setema, Chorabotor, Limu-seka, Limu-kosa, and Nono benja). Jimma Zone is known as a green gold coffee land. The city is located 7.6670 North latitude and 36.8330 East longitude and at an altitude range of 1,720-2011 Masl and experiencing an average annual rain fall amounting to 1503-1800 mm. The long wet period extends from late May to early June. In addition, July, August and September are months of rainy season. Most parts of the zone are bounded by three main rivers: Gibe, Didessa and Gojab. According to the 1997 National census, The 2007 Population and Housing Census of Ethiopia: Statical report for Oromiya Region

Page 8 the rural and urban population of Jimma is 2,486,155. About 49.7% of the rural inhabitants were females.

3.3. Research Design

The research design was formulated with problem identification which has been done through unstructured literature review and informal discussion with colleagues and professionals in the sector. The data and information sources were determined based on the formulated research design. On the basis of the data and information sources, the research instruments were decided; and available documentary sources relevant to the study were reviewed. The review includes books, journal, and internet sources.

3.4. Materials selection

Several materials were required for producing asphalt specimens. Since the main objective of the study was to investigate the performance of Brick as filler with respect to overall parameters asphalt pavement mix, it was important to evaluate not only Brick, but also various aggregate and binder sources.

The Row material used in this study, the crush stone coarse aggregate and fine aggregate are taken from ERCC quarry which the crusher site located in Unkulu of Ana Mana Jimma Zone. Where the Brick filler were collected one from Adiss Ababa Brick products processing share company located in Burayu and the second one is from local area of Jimmity brick product processing privet company located in Jimma. The asphalt cement of 85/100 penetration grade was obtained from Ethiopian Road Construction Corporation.

3.5. Tests and preparation Materials used

3.5.1. Mineral Aggregate

Aggregate also called to as rock, granular material, and min-mix asphalt. Typical aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete). By volume aggregate generally accounts for 92 to 96 percent of HMA and about 70 to 80 percent of Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements.

3.5.1.1 Sieve analysis

The particle size distribution, or gradation, of the constituent aggregate Table 3.1 is one of the most influential characteristics in determining how an HMA mixture will perform as a pavement material. Aggregate gradation influences almost every important HMA property including stiffness, stability, durability, permeability, workability, fatigue resistance, skid resistance and resistance to moisture damage (Roberts et al., 1996) The gradation of a combination of aggregates is one of the key aspects when studying the behavior of asphalt mixes (for instance, Chowdhury et al. 2001; Anderson and Bahia 1997; El-Basyouny and Mamlouk 1999). Specifications on gradation are aimed to assure that the designer chooses the best possible combination of materials to obtain desirable responses (e.g., stability, flux, voids, Young modulus, rutting resistance, permeability).Aggregate gradation are compared to a universal specification ASTM D 3515 shown below in Table 3.1.

The Job-Mix-Formula (JMF) for the aggregate particle size distribution that would be used for the preparation of mixtures before blending and after blending is shown in Table 4.1. And Table 4.2 Where keeps the coarse aggregate size distribution unchanged and varying distribution in the fines. The specified grading limits and that of obtained for this study are as shown in Table 4.1 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.

Table: 3.1 Composition of Asphalt paving Mixture specification ASTM D 3515

Mix Designation and Nominal Maximum Size of Aggregate								
Sieve Size		2in (50mm)	1 1/2in (37.5mm)	1in (25.0 mm)	3/4 in (12.5mm)	1/2 in (12.5mm)	3/8in (9.5 mm)	No. 4 (4.75 mm)
2 1/2"	63 mm	100	......	......	......	......	......	......
2"	50 mm	90 -- 100	100	......	......	......	......	......
1 1/2"	37.5 mm	......	90 --100	100	......	......	......	......
1"	26.5 mm	60 -- 80	......	90 -- 100	100	......	......	......
3/4"	19 mm	......	56 -- 80	......	90 --100	100	......	......
1/2"	12.5 mm	35 -- 65	......	56 -- 80	......	90 --100	100	......
3/8'	9.5 mm	......	......	......	56 --80	......	90 --100	100

No. 4	4.75 mm	17 -- 47	23 -- 53	29 -- 59	35 -- 65	44 --74	55 -- 85	80 -- 100
No.8	2.36 mm	10 -- 36	15 -- 41	19 -- 45	23 -- 49	28 --58	32 -- 67	65 -- 100
No. 16	1.18 mm	......	......	......	......	......	......	40 -- 80
No. 30	0.6 um	......	......	......	......	......	......	25 -- 65
No. 50	0.3 um	3 -- 15	4 -- 16	5 -- 17	5 -- 19	5 -- 21	7 -- 23	7 -- 40
100	0.15 um	......	......	......	......	......	......	3 -- 20
0.075	0.075 um	0 -- 5	0 -- 6	1 -- 7	2 -- 8	2 -- 10	2 -- 10	2 -- 10
Bitumen, Weight % of Total Mixture								
		2 -- 7	3 -- 8	3 -- 9	4 -- 10	4 -- 11	5 -- 12	6 -- 12

Source: Asphalt institution of Hot Mix Asphalt pavement Manual, series No. 22, second edition

3.5.1.2. Los Angeles Abrasion

The Los Angeles (L.A.) abrasion test is a common test method used to indicate aggregate toughness and abrasion characteristics. Aggregate abrasion characteristics are important because the constituent aggregate in HMA must resist crushing, degradation and disintegration in order to produce a high quality HMA.

Figure 3.1: Major equipment used in the L.A. abrasion test.

The L.A. abrasion test measures the degradation of a coarse aggregate sample that is placed in a rotating drum with steel spheres shown in Figure 3.3. As the drum rotates the aggregate degrades by abrasion and impact with other aggregate particles and the steel spheres (called the “charge”). Once the test is complete, the calculated mass of aggregate that has broken apart to smaller sizes is expressed as a percentage of the total mass of aggregate. Therefore, lower L.A. abrasion loss values indicate aggregate that is tougher and more resistant to abrasion.

3.5.1.3. Aggregate Crushing Value (ACV)

Aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied wheel load as compressive load. The standard aggregate crushing test shall be made on aggregate passing 12.5 mm AASHTO test sieve and retained 9.5 mm AASHTO.

3.5.1.4. Aggregate Impact Value

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to as lowly applied compressive load. With aggregate of aggregate impact value higher than 30 the result may be anomalous. Also, aggregate sizes larger than 12 mm AASHTO are not appropriate to the aggregate impact test. The standard aggregate impact test shall be made on aggregate passing a 12.5-mm AASHTO test sieve and retained on a 10.0 mm AASHTO test sieve.

3.5.1.5. Particle Shape and Surface Texture

Rounded particles create less particle-to-particle interlock than angular particles and thus provide better workability and easier compaction. However, in HMA less interlock is generally a disadvantage as rounded aggregate will continue to compact, shove and rut after construction. Thus angular particles are desirable for HMA (despite their poorer workability), while rounded particles are desirable for PCC because of their better workability (although particle smoothness will not appreciably affect strength) (PCA, 1988).These particles tend to impede compaction or break during compaction and thus, may decrease strength.

These particles have a lower surface-to-volume ratio than rough-surfaced particles and thus may be easier to coat with binder. However, in HMA asphalt tends to bond more effectively with rough-surfaced particles. Thus, rough-surface particles are desirable for HMA. The flat and elongated particle test is used to determine the dimensional ratios for aggregate particles of specific sieve sizes. This characterization is used in the super pave specification to identify aggregate that may have a tendency to impede compaction or have difficulty meeting VMA specifications due to aggregate degradation.

3.5.2 Asphalt Binder Selection and Test

Asphalt binders, sometimes referred to as asphalt cement binders or simply asphalt cement, are an essential component of asphalt concrete they are the cement that holds the aggregate together. Asphalt binders are a co-product of refining crude petroleum to produce gasoline, diesel fuel, lubricating oils, and many other petroleum products. Asphalt binder is produced from the thick, heavy residue that remains after fuels and lubricants are removed from crude oil. This heavy residue can be further processed in various ways, such as steam reduction and oxidation, until it meets the desired set of specifications for asphalt binders.

3.5.2.1. Asphalt Binder Selection

For demanding, high-performance applications, small amounts of polymers are sometimes blended into the asphalt binder, producing a polymer-modified binder. In general asphalts can be classified into three general types:

- Asphalt cement
- Asphalt emulsion
- Cutback asphalt

Cutbacks and emulsions are used almost entirely for cold mixing and spraying and will not use for hot mix asphalt mixture. Because of its chemical complexities, asphalt specifications have been developed around physical property tests, such as penetration, viscosity and ductility. These tests are performed at standard test temperatures, and the results are used to determine if the material meets the specification criteria.

Asphalt binders have been mixed with crushed aggregate to form paving materials for over 100 years. They are a very useful and valuable material for constructing flexible pavement worldwide. However, asphalt binders have very unusual engineering properties that must be carefully controlled in order to ensure good performance. One of the most important characteristics of asphalt binders that must be addressed in test methods and specifications is that their precise properties almost always depend on their temperature.

Asphalt binders tend to be very stiff and brittle at low temperatures, thick fluids at high temperatures, and leathery/rubbery semi-solids at intermediate temperatures. Such extreme changes in properties can cause performance problems in pavements. At high temperatures, a pavement with a binder that is too soft will be prone to rutting and shoving.

On the other hand, a pavement that contains a binder that is too stiff at low temperatures will be prone to low-temperature cracking. There is an extreme change in modulus that occurs in asphalt binders over the range of temperatures. Specifications for asphalt binders must control properties at high, low, and intermediate temperatures. Furthermore, test methods used to specify asphalt binders usually must be conducted with very careful temperature control; otherwise, the results will not be reliable.

Asphalt binders are also very sensitive to the time or rate of loading. When tested at a fast loading rate, an asphalt binder will be much stiffer than when tested at a slow loading rate. Therefore, time or rate of loading must also be specified and carefully controlled when testing.

3.5.2.2. Asphalt Binder Test

For this research experimental works bitumen of penetration grade 85/100 is used and collected from ERCC Ethiopian Road Construction Corporation. The main reason of using this grade is because of its common type of asphalt that widely use in most road projects in our country.

A) Penetration

The penetration test is an empirical measure of the hardness of asphalt at room temperature. The standard penetration test begins with conditioning a sample of asphalt cement to a temperature of 25 ^{o}C in a temperature controlled water bath. A standard needle is then brought to bear on the surface of the asphalt under a load of 100 gm. for exactly five seconds. The distance that the needle penetrates into the asphalt cement is recorded in units of 0.1 mm. The distance the needle travel is called “penetration” of the sample.

B) Flashpoint

The flashpoint of asphalt cement is the lowest temperature at which volatile gases separate from a sample to “flash” in the presence of an open flame. Flashpoint must not be fire point, the lowest temperature at which the asphalt cement will burn. The asphalt flashpoint is determined to identify the maximum temperature at which it can be handled and stored without danger of flashing.

The basic procedure for determining flashpoint is to gradually heat a sample of asphalt cement in brass cup while periodically moving a small flame over the sample. The temperature at which an instantaneous flashing of vapors occurs across the surface is the flashpoint.

C) Specific Gravity

Specific gravity is the ratio of the weight of any volume of a material to the weight of an equal volume of water both at specified temperature. There are two reasons that needed to know about the specific gravity of asphalt cement. One's asphalt expands when heated and contracts when cooled. This means that the volume of a given amounts of asphalt cement will be grater at higher temperatures than at lower ones. Specific gravity measurements provide a yardstick for making temperature volume correction. Second specific gravity of asphalt is essential in the determination of the effective asphalt content and the percentage of air voids in compacted mix specimens and compacted pavement.

D) Ductility

Ductility is a measure of how far a sample of asphalt cement can stretch before it breaks into two parts. It is used in the penetration and viscosity classification systems. It is measured by an "extension" test in which a briquette of asphalt cement is extended or stretched, at a specific rate and temperature. Extension is continued until the thread of asphalt cement joining the two halves of the sample breaks. The length in centimeters of the specimen at the moment breaks is the ductility.

E) Solubility

The solubility test measures the purity of asphalt cement. A sample is immersed in a solvent to dissolve the asphalt. Impurities such as salt, free carbon and non-organic contaminants do not dissolve. These insoluble impurities are filtered out of the solution and measured as a proportion of the original sample.

F) Softening point

Softening point test may be classed as a consistency test in that it measures the temperature at which the bituminous materials reach a given consistency as determined by the test conditions while it is applicable to semi-solid materials and is useful in characterizing bitumen.

The test was performed by forming a sample in a brass ring, cooling it in a melting ice bath and then placing the sample within the ring in a 5 °C water bath. After placing a steel ball on a sample surface, the water bath temperature was raised at the rate of 5 °C per minute. The temperature at which the sample sagged under the weight of the steel ball and touches the bottom of the container surface 2.5 cm below the sample was the softening point temperature.

3.5.3. Mineral Filler

The fillers used the current study namely crushed stone and crushed brick. Their physical properties, which are believed to be major suspects of affecting the bituminous mixture property such as gradation parameters and plasticity index, were determined. The work had done show in figure 3.4. The brick dust collected from crushing and sieving the brick.

Figure 3.2; working the property of Brick filler, PI and Specific gravity

3.6. Asphalt Mix design

In the production of hot mix asphalt, asphalt and aggregate are blended together in precise proportion. The relative proportions of the materials determine the physical properties of the materials determine the finished pavement. There are three commonly used design procedures for determining suitable proportion of asphalt and aggregate in a mixture. They are Marshall Method, the Hveem method, and the Super pave system method.

3.6.1. Objective of Mix Design

The design of asphalt mix is largely a matter of selecting and proportioning materials to obtain the desired properties in the finished construction. The overall objective of the design procedure is to determine an economical blend and gradation of aggregates (within the limit of project specification or research specifications) and asphalt that yield a mix having:

- Sufficient asphalt to ensure a durable pavement
- Adequate mix stability to satisfy the demands of traffic without distortion or displacement
- Void content high enough to allow for a slight amount of additional compaction under traffic loading without flushing, bleeding, and loss of stability, yet low enough to keep out harmful air and moisture.
- Sufficient workability to permit efficient placement of the mix without segregation.

The selected mix design is usually the one that best meets all of the established criteria. It should be accomplished with well trained personnel using the proper materials and calibrated equipment and following the specified procedures. For this study the Marshall Mix Design method for HMA mixtures was used to identify the optimum asphalt binder contents for all mixtures.

3.6.2 Marshall Mix Design

The Marshall method of designing paving mixtures was developed by Bruce Marshall he is Bituminous Engineer with the Mississippi State Highway Department. 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 method is used for both laboratory design and field control.

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) high and 102 mm (4 in.) internal diameter. A series of specimens, each containing the same aggregate blend but varying in asphalt content from 4 % to 6 % with increment of 1/2 % is prepared using a specific procedure to heat, mix and compact the asphalt aggregate mixture.

The procedure for the Marshall method starts with the preparation of test specimens, and steps preliminary to specimen preparation are:

- All material proposed for use of meet the physical requirement of the project specification.
- Aggregate blend combination meets the graduation requirements of the project 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.

There was a significant amount of testing conducted throughout the progression of this study and there were several procedures followed for mix design, sample preparation, sample conditioning, and physical testing. The laboratory sampling plan consisting of preparing both brick blend aggregate and non-brick blend aggregate the control samples. The following flow chart show the procedure of asphalt mix design.

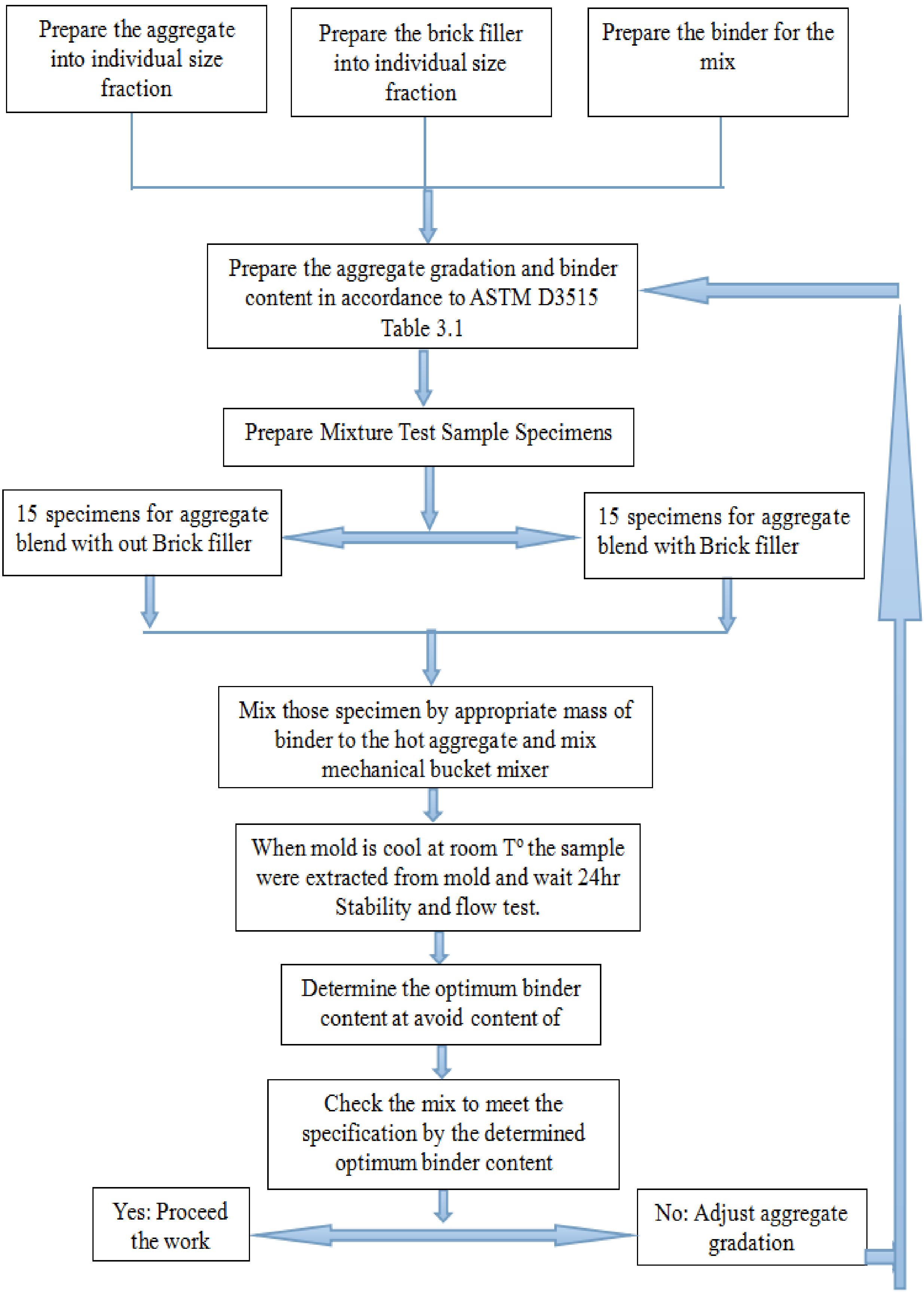

Figure 3.3: Flow chart of the Marshall Asphalt mix design

3.6.3. Specimen Preparation

In determining the design asphalt content for a particular blend or gradation of aggregate by the Marshall method, a series of test specimens is prepared for a range of different asphalt contents so the test data curve show well defined relationships. The steps recommended for preparing Marshall Test specimens are:

A) Prepare number of Specimens.

Preparing Marshall Specimens using the Marshall procedures for individual specimens are necessary. Dry and sieve aggregates into sizes (preferably individual sizes) and store in clean salable containers. Separate enough material to make 2 (types of aggregate) × 15 (samples for five bitumen and three samples for each bitumen) = 30 specimens of approximately 1200 gm each.

B) Preparation of Aggregate

There are two types of aggregate is one the normal aggregate which the study used as control without blending with brick filler and the second one is the mixed or blending aggregate with brick filler shown in figure 3.4 Next weigh out aggregate for each conditions of specimens placing each in a separate container and heat to mixing temperature determined from the asphalt property. Then heat sufficient asphalt cement to prepare the total specimens on each step. Asphalt contents should be selected at 1/2 % percent increments with at least two asphalt contents above "optimum" and at least two below "optimum."

Figure 3.4: Preparation of aggregate for specimen of Marshall Test.

C) Determination of Mixing and compacting temperature.

It is necessary to mix asphalt cement and aggregate until all the aggregate is coated. It is helpful to work on a heated table. Mixing can be mechanical mixer shown in figure 3.5. Also it is essential to check temperature of freshly mixed material; if it is above the compaction temperature, allow it to cool to compaction temperature; if it is below compaction temperature, discard the material and make a new mix.

The temperature to which the asphalt must be heated to produce viscosities of 170 ± 20 centistokes kinematics and 280 ± 30 centistokes kinematic shall be established as a mixing temperature and compaction temperature, respectively.

Figure 3.5: Checking Mixing Temperature

D) Preparation of Mold and Hammer

Thoroughly clean the specimen mold assembly and face of compaction hammer and heat them on the hot plate to a temperature between 95 ^{o}C and 150 ^{o}C (200 ^{o}F and 300 ^{o}F).as shown in figure 3.6. And place a piece of filter or waxed paper, in the bottom of the mold before the mixture is placed in the mold.

Figure 3.6 Preparations of Hammer and Mold

E) Preparation of mixtures

Weight into separate pans for each test specimen in the amount of each size fraction required to produce a batch that will result in compacted specimen 63.5 ± 1.227 mm (2.5 ± 0.05 in) in height, this is normally 1200 gm. (1.2 kg). Place the pan in the oven and heat to a temperature not exceeding 28 ^{o}C above the mixing temperature specified in (c). From the crater in the dry blended aggregate weight the required amount of asphalt binder into the mixture in accordance with the calculated batch weight, then mix the aggregate and the asphalt binder with mechanical mixer as quickly and thoroughly as possible to yield a mixture having a uniform distribution of asphalt as shown in figure.

Figure 3.7; Preparation of Mixtures

F) Packing the Mold

Place a paper disk and entire batch shown in the figure to the mold, spade the mixture vigorously with a heated spatula 15 times around the perimeter and 10 times over the interior. Smooth the surface to a slightly rounded shape as shown in figure 3.8. The temperature for the compaction should be within the limit of compaction temperature, otherwise it shall be discarded.


Figure 3.8: A) Packing the mold B) Compaction of specimens

G) Compaction of Specimens

Place a paper on top of the mix and place the mold assembly on the compaction pedestal in the mold holder. As specified according to the design traffic category these studies used by the maximum traffic flow of 75 blows with the compaction hammer using free fall of 457 mm. Then remove the plate and collar and reverse and reassembly the mold, apply the same number of compaction blows to the face of the reversed specimen as shown in figure 3.8. After compaction remove the base plate and the paper disks allow the specimen to cool in air until no deformation will result overnight as shown in figure 3.9.


Figure 3.9: A) Packing the mold and Compaction of specimens allowed cooling

3.6.4. Mixture characteristics and behavior

When a sample paving mixture is prepared in the laboratory, it can be analyzed to determine its probable performance in a pavement structure. The analysis focuses on four characteristics of the mixture and the influence those characteristics are likely to have on mix behavior. They are:

- Mix Density
- Air Void
- Void in the mineral aggregate
- Asphalt content

Mix Density

The density of the compacted mix is its unit weight or the weight of a specific volume of mix. Density is particularly important because high density of the finished pavement is essential for lasting pavement performance. In mix design testing and analysis, density of the compacted specimen is usually expressed in kilograms per cubic meter (kg/m3). It is calculated by multiplying the bulk specific gravity of the mix by the density of water [(1,000 kg/m^3) (62.43 lbs. /ft^3].

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. The bulk specific gravity of an asphalt concrete mixture can be determined using either laboratory compacted specimens or cores or slabs cut from a pavement.
The standard procedure for determining the bulk specific gravity of compacted asphalt concrete involves weighing the specimen in air and in water. The following formula is used for calculating bulk specific gravity of a saturated surface-dry specimen:

$$G_{mb} = A/(B - C)$$ .... Eq. 3.1

Where:
G_{mb}= 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, and

C = Mass of the specimen in water, g

The specimen density and the maximum theoretical density, both of which are determined in the laboratory, are each used as standards to determine if the density of the finished pavement meets specification requirements.

A) Air voids

Air voids are small pockets of air between the coated aggregate particles in the final compacted HMA. Air void content does not include pockets of air within individual aggregate particles, or air contained in microscopic surface voids or capillaries on the surface of the aggregate. A certain percentage of air voids is necessary in the finished HMA to allow for a slight amount of compaction under traffic and a slight amount of asphalt expansion due to temperature increases. The allowable percentage of air voids in laboratory specimens is between 3 percent and 5 percent for surface and base courses, depending on the specific design.

The durability of an asphalt pavement is a function of the air void content. Therefore designing and maintaining the proper air void content in HMA and other mix types is important for several reasons. When air void contents are too high, the pavement may be too permeable to air and water, resulting in significant moisture damage and rapid age hardening. When air void contents are too low, the asphalt binder content may be too high, resulting in a mixture prone to rutting, bleeding and shoving.
Determining air void content is one of the main purposes of volumetric analysis. Unfortunately, there is no simple direct way to determine the air void content of an asphalt concrete specimen. Air void content is determined by comparing the specific gravity (or density) of a compacted specimen with the maximum theoretical density of the mixture used to make that specimen.

Density and air void content are directly related. The higher the density is the lower the void in the mix will be, and reversal. Job specifications usually require the pavement compaction achieve an air void content of less than 8 percent and more than 3 percent. Air void content is calculated from the mixture bulk and theoretical maximum specific gravity:

$$Va = \left[100\left[1 - \left[\frac{Gmb}{Gmm}\right]\right]\right]$$ .... E.q 3.2

Where

V_a = Air void content, volume %

G_{mb} = Bulk specific gravity of compacted mixture

G_{mm} = Theoretical maximum specific gravity of loose mixture

B) **Voids in the Mineral Aggregate** (VMA)

It is the inter-granular void spaces that exist between the aggregate particles in a compacted paving mixture. VMA includes air voids and spaces filled with asphalt. VMA is a volumetric measurement expressed as a percentage of the total bulk volume of a compacted mix.

VMA represents; the space that is available to accommodate the effective volume of asphalt (i.e., all of the asphalt except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the mixture. The more VMA in the dry aggregate, the more space is available for the films of asphalt. The durability of the mix increases with the film thickness on the aggregate particles. Therefore, specific minimum requirements for VMA are recommended and specified as a function of the aggregate size.

Minimum VMA is necessary to achieve an adequate asphalt film thickness, which results in a durable asphalt pavement. Increasing the density of the gradation of the aggregate to a point where below minimum VMA values are obtained leads to thin films of asphalt and a low-durability mix. Therefore, economizing in asphalt content by lowering VMA is actually counter-productive and detrimental to pavement quality. Table 3.7 shows specification for VMA in ERA manual.

Table 3.2: Void in the mineral aggregate (ERA manual)

Nominal maximum particle size (mm)	7.5	28	20	14	10	5
Minimum void in mineral aggregate, %	12	12.5	14	15	16	18

$$VMA = (Va - Vbe) \qquad \text{E.q 3.3}$$

Where

VMA =Voids in the mineral aggregate, % by total mixture volume

Va = Air void content, % by total mixture volume

Vbe = Effective binder content, % by total mixture volume

C) Binder Content

Binder content is one of the most important characteristics of asphalt pavement mix. Use of the proper amount of binder is essential to good performance in asphalt concrete mixtures. Too little binder will result in a dry stiff mix that is difficult to place and compact and will be prone to fatigue cracking and other durability problems. Too much binder will be uneconomical, since asphalt binder is, by far, the most expensive component of the mixture and will make the mixture susceptible to rutting and shoving.

Asphalt binder content can be calculated in four different ways: total binder content by weight, effective binder content by weight, total binder content by volume, and effective binder content by volume. Total asphalt content by volume is calculated as the percentage of binder by total mix mass:

$$Pb = 100\left[\frac{Mb}{Ms + Mb}\right] \qquad \text{E.q 3.4}$$

Where

P_b = Total asphalt binder content, % by mix mass

M_b = Mass of binder in specimen

M_s = Mass of aggregate in specimen

Total asphalt binder content by volume can be calculated as a percentage of total mix volume using the following formula:

$$Vb = \left(\frac{Pb * Gmb}{Gb}\right) \qquad \text{E.q 3.5}$$

Where

V_b = Total asphalt binder content, % by total mix volume

P_b = Total asphalt binder content, % by mix mass

G_{mb} = Bulk specific gravity of the mixture

G_b =Specific gravity of the asphalt binder

The absorbed asphalt binder content by volume is also calculated as a percentage of total mix volume:

$$Vba = Gmb\left[\left(\frac{Pb}{Gb}\right) + \left(\frac{Ps}{Gsb}\right) - \left(\frac{100}{Gmm}\right)\right] \quad \text{E.q 3.6}$$

Where

V_{ba} = Absorbed asphalt content, % by total mixture volume

G_{mb}= Bulk specific gravity of the mixture

P_b= Total asphalt binder content, % by mix mass

G_b= Specific gravity of the asphalt binder

P_s = Total aggregate content, % by mix mass = 100 – P_b

G_{sb}= Average bulk specific gravity for the aggregate blend

G_{mm}= Maximum specific gravity of the mixture

The effective asphalt by volume is found by subtracting the absorbed asphalt content from the total asphalt content:

$$Vbe = (Vb - Vba) \quad \text{E.q 3.7}$$

Where

V_{be}= Effective asphalt content, % by total mixture volume

V_b= Total asphalt binder content, % by mixture volume

$V_{ba,}$ = Absorbed asphalt content, % by total mixture volume

The effective and absorbed asphalt binder contents can also be calculated as percentages by weight, once the volume percentage has been calculated:

$$Pba = Pb - Pbe \quad \text{E.q 3.8}$$

$$Pbe = Pb\left(\frac{Vbe}{Vb}\right) \quad \text{E.q 3.9}$$

Where

P_{be} = Effective asphalt binder content, % by total mass

P_b = Asphalt binder content, % by total mass (see Equation 5-5)

V_{be} = Effective asphalt binder content, % by total mixture volume (see Equation 5-8)

V_b = Asphalt binder content, % by total mixture volume (see Equation 5-6)

P_{ba} = Absorbed asphalt binder, % by total mixture mass

D) Voids Filled with Asphalt

Voids filled with asphalt (VFA) are the percentage of inter-granular void space between the aggregate particles (VMA) that contains or is filled with asphalt. VFA is used to ensure that the effective asphalt part of the VMA in a mix is not too little (dry, poor durability) or too great (wet, unstable). The acceptable range of VFA varies depending upon the traffic level for the facility. Higher traffic requires a lower VFA, because mixture strength and stability is more of a concern. Lower traffic facilities require a higher range of VFA to increase HMA durability. A VFA that is too high, however, will generally yield a plastic mix. VFA is the effective binder content expressed as a percentage of the VMA:

$$\mathbf{VFA = 100\left(\frac{VMA - Va}{VMA}\right)} \qquad \text{E.q 3.10}$$

Where

VFA = voids filled with asphalt, as a volume percentage

VMA =Voids in the mineral aggregate, % by total mixture volume

Va = Air void content, % by total mixture volume

3.7. Test procedure

In Marshall Method of pavement mix design after preparation of test specimen, the next step is each compacted test specimen is subjected to these test and analysis those are listed below:

1. Bulk Specific gravity determination.
2. Stability and flow test.
3. Density and Void analysis.

The equipment required for the testing the specimen of the 102 mm (4 in.) diameter x 64 mm (2.5 in.) height is:

A) Marshall testing Machine:

It is compression testing device, designed to apply loads to test specimens through cylindrical segment testing heads (inside radius of curvature of 51 mm (2 in)) at constant rate of vertical strain of 51 mm (2 in.) per minute. Two perpendicular guide posts are included to allow the two segments to maintain horizontal positioning and free vertical movement during the test. It is equipped with a calibrated proving ring for determining the applied testing load, a Marshall stability testing head for use in testing the specimen, and a Marshall flow meter for determining the amount of strain at the maximum load in the test, the picture is shown in figure 3.10.

Figure 3.10: Marshall Stability and flow test machine

B) Water Bath

Water bath is at least 150 mm (6 in.) deep and thermostatically controlled to 60 $^{o}C \pm 1$ ^{o}C. The tank should have a perforated false bottom or be equipped with a shelf suspending specimens at least 50 mm (2 in.) above the bottom of the bath shown in figure 3.11.

Figure 3.11: Water bath

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. General

In this study, thirty sets of bituminous mixtures using different types of mineral fillers were evaluated using the Marshal Mix design method. These mixtures were prepared using crushed stone, and brick fillers with varying the content of asphalt binder by the total mixture and their effects on Marshal Properties were assessed.

Different researches made on the effect of fillers on bituminous mixtures, as reviewed in Chapter 2, revealed that type and amount of fillers affect the performance of HMA mixes. The test results obtained in this thesis research are discussed under subsequent sections.

4.2. Interpretation of Test Data

4.2.1. Aggregate Gradation of mix design

HMA is graded by percentage of different-size aggregate particles it contains. Table 4.1 illustrates HMA gradations without blending with brick dust filler which is the normal gradation used as a control for the study. Certain terms are used in referring to aggregate fractions: Course aggregate -G-1 ¾ inch, Coarse Aggregate -G-2, 3/8 inch, Fine Aggregate - G-3, Brick Mineral Filler & dust– G-4

Table 4.1: Aggregate Gradation and blending without Brick material

AASHTO Sieve Size mm	G-1 (26.2-13.2)	G-2 (13.2-9.5)	G-3 (9.5-4.75)	Blending Result	Specification		Median	JMF
					lower	upper		
26.5	100.0	100.0	100.0	100.0	100	100	100.0	100
19.0	96.4	100.0	100.0	98.8	85	100	92.5	98.9
13.2	32.6	99.9	100.0	78.4	71	84	77.5	80.9
9.50	5.2	83.0	100.0	65.7	62	76	69.0	70.1
4.75	2.7	12.8	95.1	46.6	42	60	51.0	54.4
2.36	2.4	7.0	60.9	29.8	30	48	39.0	38.0
1.18	2.2	5.6	36.7	18.5	22	38	30.0	24.9
0.600	2.1	4.7	22.4	11.8	16	28	22.0	17.1
0.300	1.9	4.1	14.4	8.0	12	20	16.0	12.3
0.150	1.8	3.7	10.0	5.9	8	15	11.5	9.4
0.075	1.7	3.3	7.7	4.8	4	10	7.0	7.4
Blending proportion	32%	23%	45%	100%				

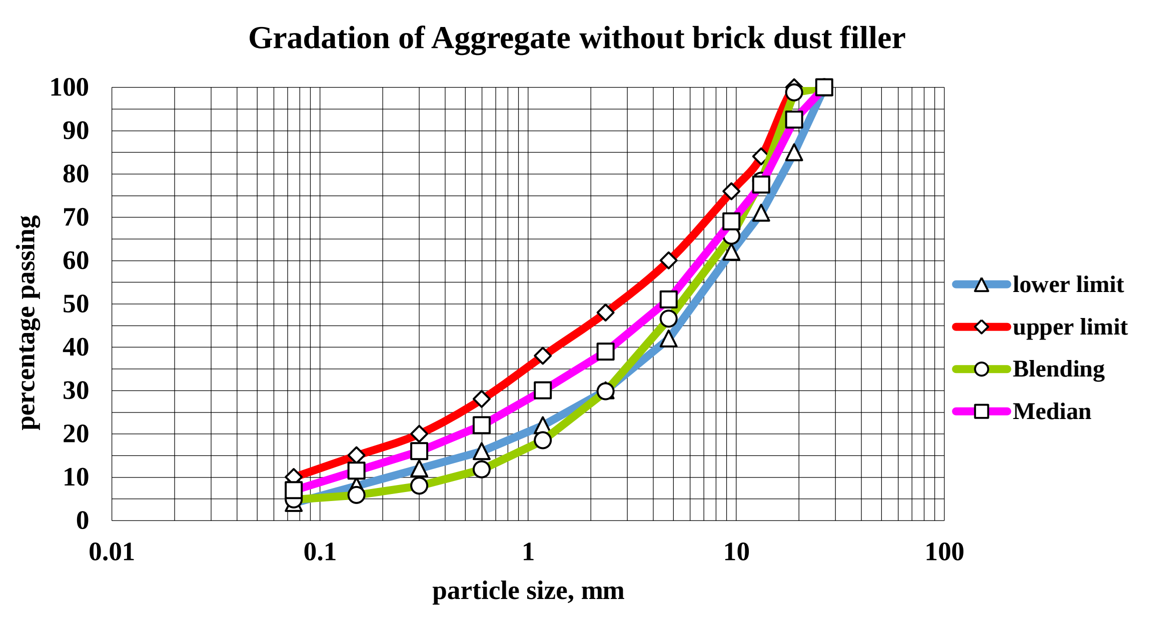

Figure 4.1: Gradation of aggregate blend before mixing with Brick material

Note: - Mineral filler and Mineral Dust occur naturally with many aggregates and are produced as a by-product of crushing many types of rock.

The above figure shows that the aggregate blend without brick dust filler for the Marshall Mixture preparation, which shows the blend G-1, 32%, G-2, 23%, and G-3, 45%. From the graph we conclude the blend needs somehow filler material to be in the specification lower and upper limit.

Table 4.2: Aggregate Gradation and blending with Brick material

AASHTO Sieve Size mm	G-1 (26.2-13.2)	G-2 (13.2-9.5)	G-3 (9.5-4.75)	G-4 (4.75-.075)	Blending Result	Specification		Median	JMF
						lower	upper		
26.5	100.0	100.0	100.0	100	100	100	100	100.0	100
19.0	96.4	100.0	100.0	100	98.9	85	100	92.5	98.9
13.2	32.6	99.9	100.0	100	79.8	71	84	77.5	80.9
9.50	5.2	83.0	100.0	100	68.5	62	76	69.0	70.1
4.75	2.7	12.8	95.1	100	52.9	42	60	51.0	54.4
2.36	2.4	7.0	60.9	95.0	36.0	30	48	39.0	38.0
1.18	2.2	5.6	36.7	85.4	24.2	22	38	30.0	24.9
0.600	2.1	4.7	22.4	74.2	16.8	16	28	22.0	17.1
0.300	1.9	4.1	14.4	58.4	11.9	12	20	16.0	12.3
0.150	1.8	3.7	10.0	50.1	9.2	8	15	11.5	9.4
0.075	1.7	3.3	7.7	44.6	7.7	4	10	7.0	7.4
Blending proportion	30%	18%	45%	7%	100%				

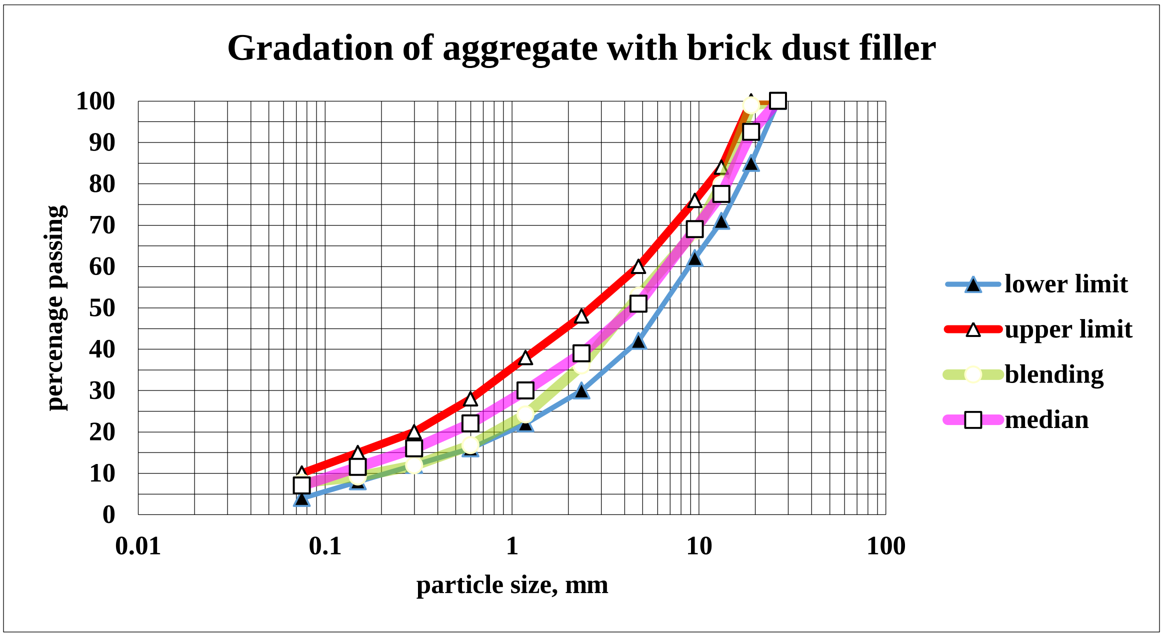

Figure 4.2: Gradation of aggregate blend after mixing with Brick material

To satisfy the specification the upper and lower limit by using job mix G-4. 7% was blend with aggregate of G-1, 30%, G-2 18%, G-3 45% gives us good aggregate blend for the Marshall mix design. The detail work for each aggregate gradation for this study, G-1, G-2, G-3, and G-4 are shown in Appendix A.

4.2.2 Aggregate Physical properties

To investigate the physical properties of the aggregates and their suitability in road construction, various tests were conducted and the results are indicated in Table 3-4. The specific surface area was determined, for each of the aggregate size distribution; by multiplying surface area factors by the percentage passing the various sieve sizes and adding together. As can be seen from the results, as the filler content increases in the aggregate proportion, the specific surface area will also increase.

The detail work for physical properties of aggregate show in Appendix B

Table 4.3: Aggregate Physical properties

No	Test Description	Test Method			Result	Specification requirements (ERA Manual 2002)
		ASTM	AASHTO	BS		
1	Los Angeles Abrasion, %	AASHTO T 96			18.8	< 30
2	Aggregate Crushing Value, ACV, %	BS 812 part 104			17.91	<25
3	Durability and Soundness, %	ASTM C 128			5.3	<12
4	Coarse Aggregate Specific Gravity (Bulk)(kg/m^3)	AASHTO T 85			2.72	N/A
5	Fine Aggregate Specific Gravity (Bulk)(kg/m^3)	AASHTO T 84			2.59	N/A
6	Coarse Aggregate Specific Gravity (Apparent)(kg/m^3)	AASHTO T 85			2.86	N/A
7	Fine Aggregate Specific Gravity (Apparent)(kg/m^3)	AASHTO T 84			2.87	N/A
8	Water Absorption, %	ASTM C 127			1.71	<2
9	Particle shape, Flakiness, %	BS 812, Part 110			20.1	<45

4.2.3. Asphalt Binder Test and Result

A series of tests including penetration, specific gravity, softening point, flash point, ductility, and solubility in carbon tetra chloride were conducted for the basic characterization properties of penetration grade asphalt. The test results are shown in Table 4.4, which complies with the requirement of ERA specifications

Table 4.4: Laboratory test result for Asphalt binder

No	**Test Description**	**Test Method**		**Result**	**Recommended Specification ERA for 85/100**
		ASTM	**AASHTO**		
1	Penetration 25 ^{o}c	D 5	T 49	90	85 － 100
2	Specific gravity (kg/m^3)	D 70	T 228	1023	1020±
3	Ductility, 25 ^{o}c (cm)	D 113	T 51	100+	100+
4	Solubility, %	D 2042	T 44	99.6	Min 99
5	Softening Point, ^{o}C	D 36	T 53	46	42 － 51
6	Loss on heating, %		T 47	23	Max 100
7	Flash Point, ^{o}C	D 92	T 48	562	Min 232

4.2.4 Brick dust filler

The fillers used the current study namely crushed stone and crushed brick. Their physical properties, which are believed to be major suspects of affecting the bituminous mixture property such as gradation parameters and plasticity index, were determined as shown in Table 4.5.

Table 4.5: Laboratory test result for Brick filler

No	Test Description	Test Method		Result	Specification requirements (ERA Manual 2002)
		ASTM	AASHTO		
1	Specific gravity (kg/m^3)	D 854 or C 88	T 100 or 104	**2.472**	N/A
2	PI, (Plastic Index)	D 423 or 424	T 89 or T 90	**NPI**	⩽ 4

4.3 Preparation of test Data

The first step in evaluation of test result from marshal design method is prepared the stability and flow values and void data:

4.3.1 Measuring the Stability

It is a processing of measuring the stability values from the standard 63.5 mm (2 1/2 in) thickness shall be converted to an equivalent 63.5 mm (2 1/2 in) value by means of conversion factor. The applicable correlation ratio to convert the measured stability values are set in Table 4.1. The conversion may be made on the basis of either measured thickness or measured volume.

4.3.2 Measuring Flow Values

The flow values also read from the Marshall machine during the applied load fort stability check. So after reading the flow values the average the flow values and the final converted stability values for all specimens of given asphalt content listed in Table 4.2 for blend without Brick filler and Table 4.3 blend with Brick filler shown below

Table 4.6 Stability Correlation Ratios

Volume of Specimen cm^3	Approximate Thickness of Specimen		Correlation Ratio
	mm	in	
200 to 213	25.4	1	5.56
214 to 225	27	1 1/16	5
226 to 237	28.6	1 1/8	4.55
238 to 250	30.2	1 3/16	4.17
251 to 264	31.8	1 1/4	3.85
265 to 276	33.3	1 5/16	3.57
277 to 289	34.9	1 3/8	3.33
290 to 301	36.5	1 7/16	3.03
302 to 316	38.1	1 1/2	2.78
317 to 328	39.7	1 9/16	2.5
329 to 340	41.3	1 5/8	2.27
341 to 353	42.9	1 11/16	2.08
354 to 367	44.4	1 3/4	1.92
368 to 379	46	1 13/16	1.79
380 to 392	47.6	1 7/8	1.67
393 to 405	49.2	1 15/16	1.56
406 to 420	50.8	2	1.47
421 to 431	52.4	2 1/16	1.39
432 to 443	54	2 1/8	1.32
444 to 456	55.6	2 3/16	1.25
457 to 470	57.2	2 1/4	1.19
471 to 482	58.7	2 5/16	1.14
483 to 495	60.3	2 3/8	1.09
496 to 508	61.9	2 7/16	1.04
509 to 522	63.5	2 1/2	1
523 to 535	64	2 9/16	0.96
536 to 546	65.1	2 5/8	0.93
547 to 559	66.7	2 11/16	0.89
560 to 573	68.3	2 3/4	0.86
574 to 585	71.4	2 13/16	0.83
586 to 598	73	2 7/8	0.81
599 to 610	74.6	2 15/16	0.78
611 to 625	76.2	3	0.76

Source: Hot Asphalt Mix Manual, 2nd edition

It is possible while making the specimen the thickness slightly vary from the standard specification of 63.5 mm. Therefore, measured stability values need to be corrected to those which would have been obtained if the specimens had been exactly 63.5 mm. This is done by multiplying each measured stability value by an appropriated correlation factors as a given table above.

Gmb= Bulk specific gravity,

Gmm= Theoretical maximum specific gravity,

Va= Air Void in the total mix,

VMA= Voids in the mineral aggregate and

VFA = Void filled with asphalt

Table 4.7 Marshall Test result for Mix without Brick Filler

% AC	Bulk Volume, cc	Gmb	Gmm	Unit Weight Mg/m^3	% Air Void	% VMA	% VFB	Stability			Flow, mm
								Measured, div	Factor	Adjusted,KN	
4.0A	521.0	2.268	2.562	2.268	11.5	13.39	40.7	1252.0	1.04	12.98	3.40
4.0B	514.0	2.288	2.562	2.288	10.7	13.68	42.7	1265.2	1.04	12.14	4.00
4.0C	502.0	2.300	2.562	2.300	10.2	13.25	44.1	1361.0	1.04	11.37	3.30
Av		2.285	2.562	2.320	8.0	13.4	65.4			12.89	3.02
4.5A	517.5	2.289	2.562	2.289	10.6	13.17	44.4	1220.0	1	14.97	3.60
4.5B	515.5	2.290	2.562	2.290	10.6	13.03	44.3	890.0	1	10.92	3.85
4.5C	520.5	2.283	2.562	2.283	10.9	13.28	43.5	890.0	1	10.92	4.00
Av		2.287	2.562	2.383	6.2	13.25	68.1			12.10	3.12
5.0A	505.5	2.331	2.498	2.331	6.7	13.01	62.8	813.0	1	9.98	4.00
5.0B	510.0	2.303	2.498	2.303	7.8	14.00	58.9	1029.0	1	12.63	4.00
5.0C	516.0	2.316	2.498	2.316	7.3	13.54	60.6	1149.0	1	14.10	4.50
Av		2.317	2.498	2.386	5.2	13.52	73.8			11.40	3.21
5.5A	508.5	2.338	2.479	2.338	5.7	12.20	68.7	881.0	1.04	11.24	4.00
5.5B	515.5	2.305	2.479	2.305	7.0	14.35	63.8	783.0	1.04	9.99	3.52
5.5C	502.0	2.383	2.479	2.383	3.9	14.63	76.5	1060.0	1.04	13.53	4.00
Av		2.342	2.479	2.383	5.4	13.62	84.3			10.50	3.52
6.0A	510.0	2.320	2.448	2.320	5.2	14.26	73.0	806.0	1.04	10.29	4.80
6.0B	506.5	2.354	2.448	2.354	3.8	14.08	79.0	795.0	1.04	10.14	4.00
6.0C	508.0	2.368	2.448	2.368	3.2	14.59	81.8	610.0	1.04	7.78	5.00
Av		2.347	2.448	2.368	6.1	14.81	92.5			9.50	5.10

Table 4.8 Marshall Test result for Mix with Brick Filled

% AC	Bulk Volume	Gmb	Gmm	Unit Weight, Mg/m^3	Air Void %	VMA %	VFB %	Stability			Flow, mm
								Measured, div	Factor	Adjusted, KN	
4.0A	521.0	2.268	2.562	2.568	6.2	10.39	46.7	1252.0	1.04	14.98	3.48
4.0B	514.0	2.288	2.562	2.588	5.7	11.08	42.7	1417.0	1.04	17.08	3.40
4.0C	502.0	2.300	2.562	2.400	6.2	10.25	44.1	1361.0	1.04	16.37	3.30
Av		2.285	3.562	2.558	6	10.85	44.1			16.58	3.33
4.5A	517.5	2.289	2.562	2.579	5.06	10.17	43.4	1220.0	1	14.97	3.30

4.5B	515.5	2.290	2.562	2.590	5.6	10.03	43.3	890.0	1	16.92	3.25
4.5C	520.5	2.283	2.562	2.583	5.01	10.28	43.5	890.0	1	15.92	3.00
Av		2.287	2.562	2.587	5.1	10.31	43.5			15.93	3.28
5.0A	505.5	2.331	2.498	2.531	4.01	10.01	73.4	813.0	1	12.98	3.60
5.0B	510.0	2.303	2.498	2.603	4.1	11.00	74.5	1029.0	1	16.63	3.40
5.0C	516.0	2.316	2.498	2.586	4.01	10.54	72.2	1149.0	1	14.10	3.50
Av		2.317	2.498	2.595	4	10.61	73.3			14.53	3.49
5.5A	508.5	2.338	2.479	2.538	4.2	11.20	78.7	881.0	1.04	11.24	4.00
5.5B	515.5	2.305	2.479	2.505	4.5	11.35	73.8	783.0	1.04	10.99	3.52
5.5C	502.0	2.383	2.479	2.513	3.9	11.03	76.5	1060.0	1.04	13.53	4.00
Av		2.342	2.479	2.592	4.1	11.10	76.5			11.24	3.75
6.0A	510.0	2.320	2.448	2.520	6.2	13.26	80.0	806.0	1.04	11.19	5.80
6.0B	506.5	2.354	2.448	2.574	4.8	13.01	82.0	795.0	1.04	11.04	5.20
6.0C	508.0	2.368	2.448	2.548	4.2	13.19	81.8	610.0	1.04	11.18	5.61
Av		2.347	2.448	2.572	5.1	13.20	81.8			11.10	5.57

Gmb= Bulk specific gravity,

Gmm= Theoretical maximum specific gravity,

Va= Air Void in the total mix,

VMA= Voids in the mineral aggregate and

VFA = Void filled with asphalt

Table 4.9 Summary of Table 4.7 and 4.8 Marshall Test result for this study

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Asphalt Content %	Unit Weight, Mg/m3		Air Void, Va,%		VMA,%		VFB,%		Stability, KN		Flow, mm	
	A	B	A	B	A	B	A	B	A	B	A	B
4	2.32	2.558	8	6	13.40	10.85	65.4	44.1	12.89	16.58	3.02	3.33
4.5	2.383	2.587	6.2	5.1	13.25	10.31	68.1	43.5	12.1	15.93	3.12	3.28
5	2.386	2.595	5.2	4	13.52	10.61	73.8	60.6	11.4	14.53	3.21	3.49
5.5	2.383	2.592	5.4	4.1	13.62	11.10	84.34	76.5	10.5	11.24	3.52	3.75
6	2.368	2.572	6.1	5.1	14.81	13.20	92.45	81.8	9.5	11.10	5.1	5.57

Where A: - Mixture Blend without Brick Filler

B: - Mixture Blend with Brick filler

4.4. Analysis on physical properties of compacted HMA.

The application of brick filler on aggregate has noticeable effects on the important physical properties of HMA. The following section analyzes and discusses the result collected with in the laboratory under control conditions

4.4.1. Stability

Stability is generally a measure of the mass viscosity of the aggregate-asphalt cement mixture and is affected significantly by the angle of internal friction of the aggregate and the viscosity of the asphalt cement. Anything that increases the viscosity of the asphalt cement increases the Marshall stability

The addition of Brick filler in the asphalt mix reduces the deformation due to high temperatures, especially during its early life when it is most susceptible to rutting. Furthermore, the brick makes the HMA less sensitive to moisture effects by improving the aggregate asphalt bond. The detail table shown in appendix C

The addition of brick as a filler in the hot asphalt mix result void and asphalt content decrease. So decreasing of asphalt content due to addition of brick filler result good or high stability by avoiding wash boarding, rutting, flushing and bleeding effects caused by excess asphalt mix. Balancing of excess medium size sand in the mixture by adding brick filler to reduce tenderness during compaction which also result good stability for the mixture

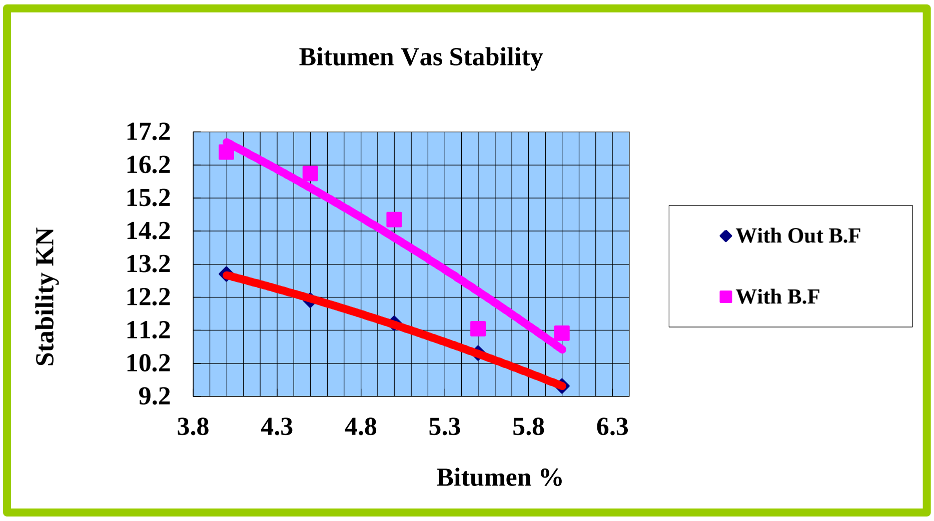

Figure 4.3: Stability Comparison of both

The stability test aims at measuring the mix resistance to deformation under load, so there is a natural tendency to think that if a certain stability value is good, and then much higher value mast better. From figure 4.3 shown illustrate that the addition of brick filler on the blend result increasing of stability than of blend without brick filler.

This may be due to making the brick dust filler and asphalt cement combination act as a more viscous binder thus increasing the Marshall stability. Therefore the brick filler stiffens the asphalt film and reinforces it. That means a mixture with brick dust filler good in the resistance of deformation than that of bend without brick filler.

4.4.2. Unit Weight (Density)

The density of the compacted mix is the unit weight of the mixture (the weight of a specific volume of asphalt mixture). Density is important because proper density in the finished product is essential for lasting pavement performance. Mix properties are required to be measured in volumetric terms as well as weight. The effect of brick filler content on the unit weight of compacted mixes is shown in Figure 4.4.

Mixes made with brick filler and without brick filler showed a trend of increase up to maximum and then decreases as the filler content increases. But the starting point of the unit weight different the mix with Brick filler start with Unit weight of 2.558 Mg/m^3 and the blend not mix with brick filler is start with unit weight of 2.32 Mg/m^3 ending with 2.572 Mg/m^3 and 2.368 Mg/m^3 respectively.

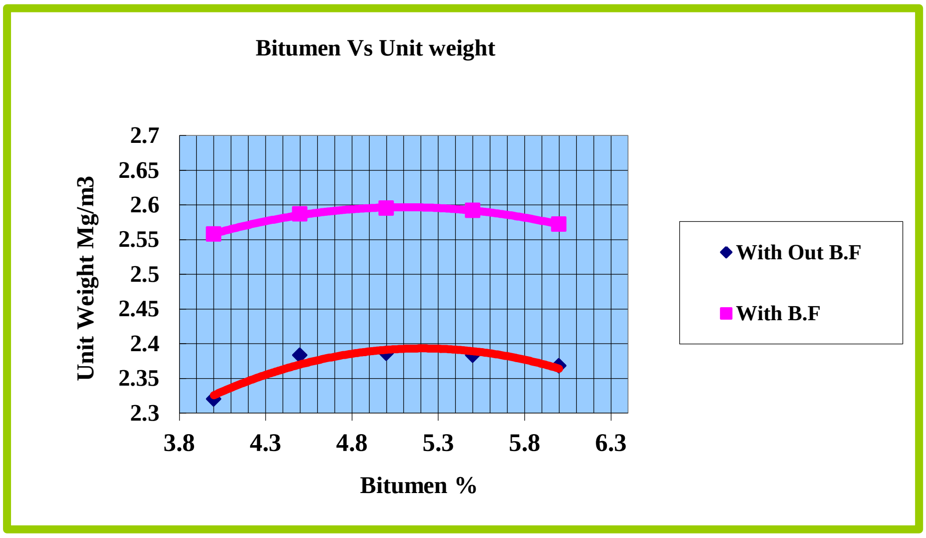

Figure 4.4: Unit Weight Comparison of both

This may be due to making the brick dust filler and asphalt cement combination act as a more viscous binder thus increasing the Marshall stability. Therefore the brick filler stiffens the asphalt film and reinforces it. This because while filler content increases in the mix it fills the voids hence increase unit weight. However, at higher content the mix becomes stiffer that needs greater compaction effort then consequently lower dense mixture obtained.

4.4.3. Voids in Mineral Aggregate (VMA)

VMA is the total volume of voids within the mass of the compacted aggregate. This total amount of voids significantly affects the performance of a mixture because if the VMA is too small, the mix may suffer durability problems, and if the VMA is too large, the mix may show stability problems and be uneconomical to produce. It is a common trend that, as filler content in the mixes increase, the voids in mineral aggregate decrease up to minimum value then increases at higher content.

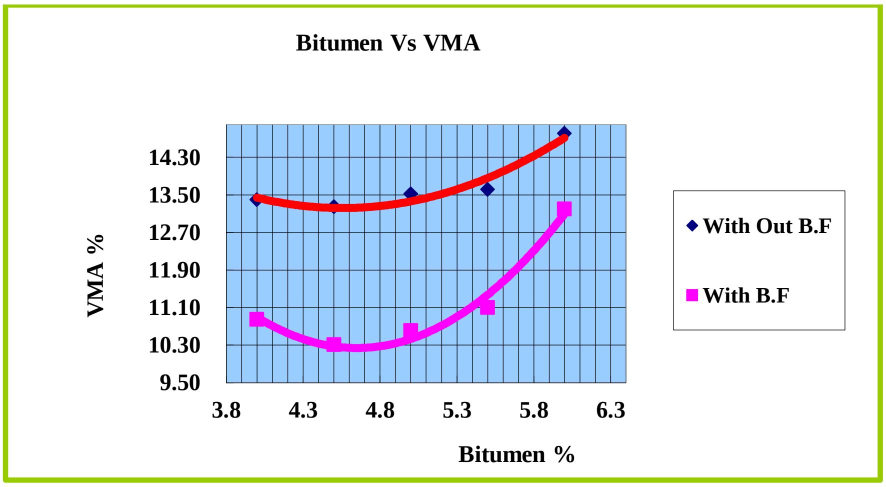

Figure 4.5: VMA Comparison of both

As can be seen from Figure 4-5, mixtures using both brick filler and crushed stone filler types exhibit same manner, but mixtures made using brick filler in the mid-range of the specification hence its durable and economical.

It is a common trend that, as filler content in the mixes increase, the voids in mineral aggregate decrease up to minimum value then increases at higher content. As can be seen from Figure 4.5, mixtures using both blend with brick dust filler and without brick dust filler types exhibit same manner,

It can be observed from Fig. 4.5 that VMA decreases by the addition of brick dust filler to the bituminous mixtures. This may be due to the decrease of bulk specific gravity as indicated by equation for VMA. But all the results are within the specification range which also supports the use of these brick dust as filler.

4.4.4. Voids Filled with Asphalt (VFA)

A void filled with asphalt (VFA) is the percentage of inter-granular void space between the aggregate particles (VMA) that contains or is filled with asphalt. Most specifications include percent VFA requirements range from 65 - 80 percent. Since VFA depends on both VMA and Va, the cumulative effects of these two variables are shown on Figure 4.4. The mix blend with brick filler is minimize the void filed with asphalt when its compare with asphalt mix without brick filler as shown in Figure 4. 6.

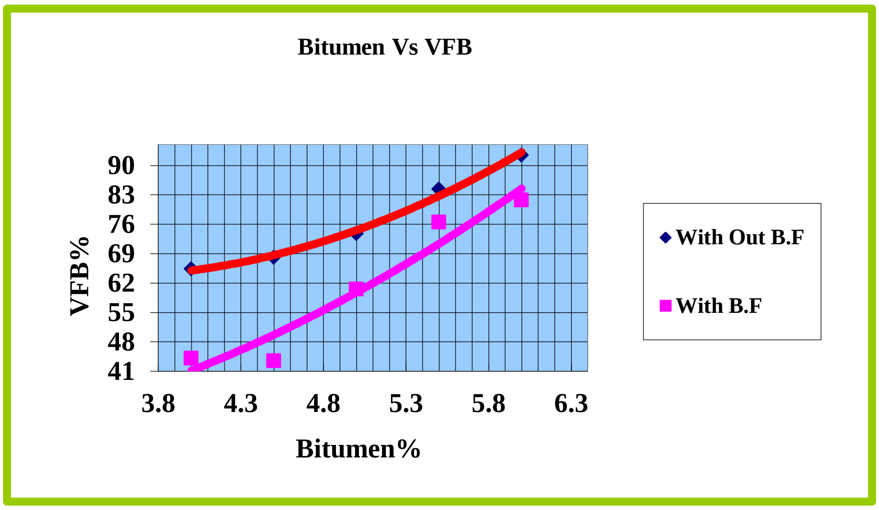

Figure 4.6: VFA, Comparison of both

VFB of mixtures decreasing after adding brick dust as filler into the mixture, as shown in Figure 4.6, VFB which represents the volume of the effective bitumen content in the mixture is inversely related to air voids and hence as air voids decreases, the VFB increases. But from the above result we conclude that addition of brick dust filler on the bituminous mixture change the trend from inverse to revers that means the addition of brick dust filler in the mixture result the decreasing of both air void and asphalt content this is because of the brick filler fill the void that occupied by air and asphalt.

4.4.5 Air Void in the mix (Va)

Air voids may be increased or decreased by lowering or raising the binder content. They may also be increased or decreased by controlling the amount of material passing the No. 200 sieve in the asphalt mixture. The more fines added to the asphalt mixture generally the lower the air voids. If a plant has a bag house dust collection system, the air voids may be controlled by the amount of fines which are returned to the asphalt mixture. Finally, the air voids may be changed by varying the aggregate gradation in the asphalt mixture.

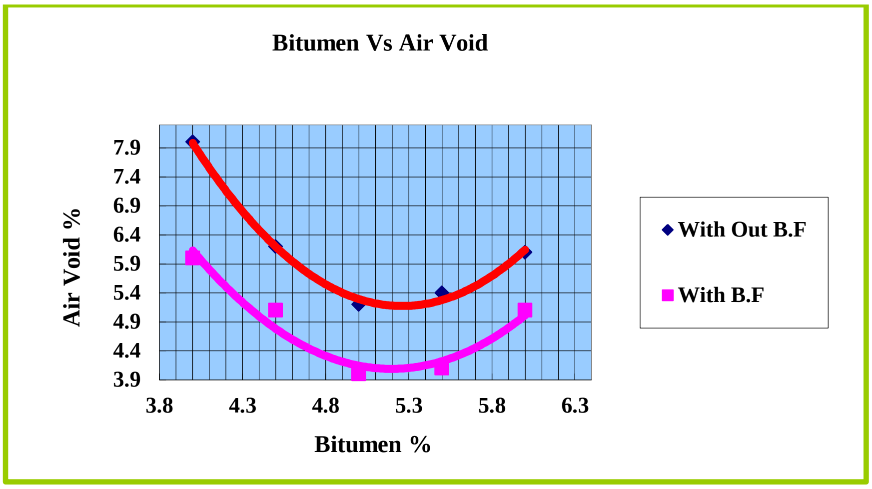

Figure 4.7: Air Void Comparison of both

Total void in the mix refers that the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the bulk volume of the compacted paving mixture. The asphalt mix done by mixing the Brick filler minimize the volume of total air between the coated aggregate than that of used by stone filler self. As shown in Figure 4.7.

4.4.6. Flow

Flow refers that the vertical deformation of the sample (measured from start of loading to the point at which stability begins to decrease) in 0.25 mm. High flow values generally indicate a plastic mix that will experience permanent deformation under traffic, whereas low flow values may indicate a mix with higher than normal voids and insufficient asphalt for durability and one that may experience premature cracking due to mixture brittleness during the life of the pavement.

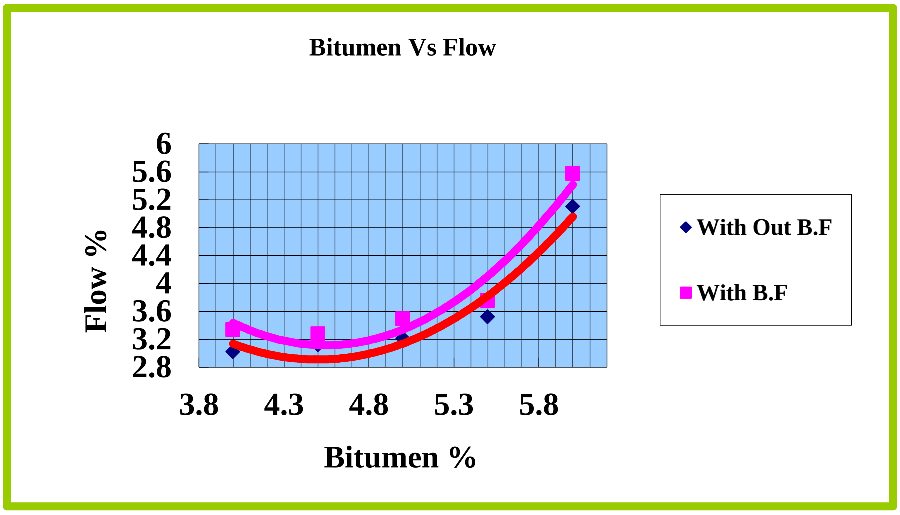

Figure 4.8: Flow Comparison of both

The flow value has a general trend of consistently increases with increasing asphalt content. For 75-blow Marshall designs that are used on high volume roads, the flow value is usually specified to be in the range of 2 – 4 mm. Figure 4.8 shows that the mix with Brick filler samples are increases in flow compared with the stone itself filler samples.

4.5. Optimum Asphalt Content Determination

It is considered that the effective asphalt content in the mixture determines the performance of mixtures. This can be explained as that it is the effective asphalt binder content that makes the asphalt film around the aggregate particles. If the asphalt film thickness around the aggregate particles is thick enough, various desirable characteristics such as better durability, more fatigue resistance, and higher resistance to moisture induced damage can be achieved from bituminous mixtures. But, there should be a maximum limit where up on an increase in temperature and loading, the asphalt content in the mix gets increased and results bleeding on the surface of paved road.

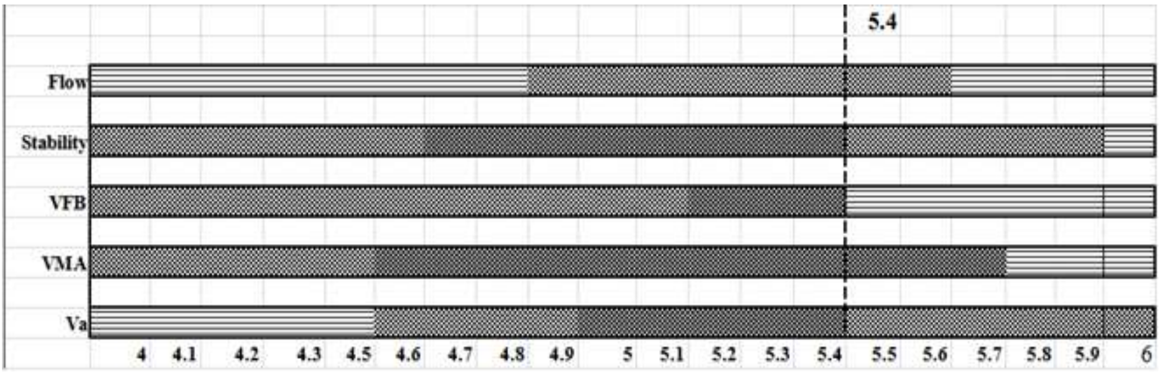

Figure 4.9: Determination of Asphalt content with mix not blend with Brick Filler

Figure 4.9 and 4.10 is plotted for the effective asphalt content that is present in mixes for mix which not blends with brick dust filler and blend with brick dust filler. The figure shows that there exists a common trend among the filler types with respect to their content in the mixture.

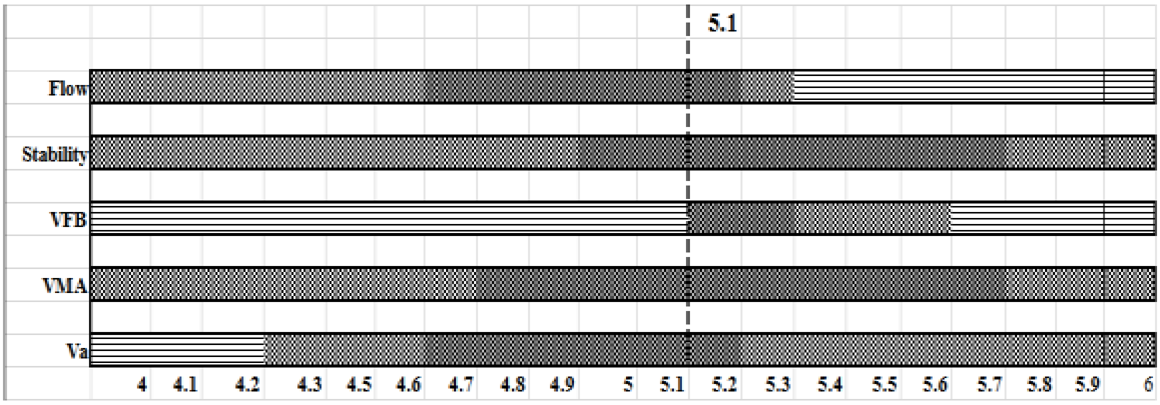

Figure 4.8: Determination of Asphalt content with mix with Brick Filler

That is, the effective asphalt content decreases as the filler content in the mix increases. This is probably because more voids will be filled with mineral filler as the filler content in the mix increases, which results lower total asphalt content, and hence lower effective asphalt. Besides, as the filler content in the mix increases, more asphalt will be absorbed by fine aggregates due to higher proportion of fines in the mix.

Table 4.10 Summary Marshall Test result of the study

Marshall Mix Property	**Flow (%)**	**Stability (KN)**	**VFB (%)**	**VMA (%)**	**Va (%)**	**Density (Mg/m^3)**	**OBC (%)**
Mix Criteria As per ERA Spec.	2 to 4	Min. 7 KN	70 to 85	10 to 16	3 to 6	-	4 to 10
Mix Without Brick Filler	3.5	9.65	79.21	13.42	5.2	2.39	5.4
Mix With Brick Filler	3.43	13.68	74.7	10.9	4.1	2.6	5.1
Comparison with specification	Ok	Ok	Fair	Fair	Ok	Ok	Ok

After measurement of stability and Flow from the prepared specimen using Marshall test (ASTM D 1559) it is common practice to select the design binder content by calculating the mean value of the binder contents for (a) maximum stability, (b) maximum density, (c) the mean value for the specified range of void contents and (d) the mean value for the specified range of flow values. The following two methods are commonly used to determine the optimum asphalt content from the plotted curves and determine the following properties:

- Stability
- Flow

- Air Void
- VMA
- VFB

Compare values from with criteria for acceptability given in Table 4.5. The properties of the mix design at this design binder content with recommended Marshall Criteria is then shown in Table 4.8 and Table 4.9. The detail work procedure of the Marshall Test method for this study is attached in Appendix C.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

This study evaluated the performance of brick dust as filler for HMA. Using standard testing procedures, aggregate was tested for all the necessary quality tests including specific gravity, absorption, abrasion resistance, void content, and gradation. Similarly important quality tests of bitumen were conducted in a laboratory and all the results were pass the necessary specifications.

The analysis also answers the question of whether brick is effective in increasing the performance the HMA mixtures irrespective of which application method is used. On the basis of test results and analysis obtained in a controlled laboratory, the following conclusions and recommendations are presented.

5.1 Conclusions

- The laboratory result for brick gives specific gravity and plastic index, satisfying the specification for using filler in hot asphalt mix, so brick can use as filler in hot asphalt mix design.
- For the mixture contain brick filler at content of 7% gives good gradation proportion for hot mix asphalt.
- The optimum asphalt content value were required to fulfill the Marshall requirement is 5.1% for mixture contain brick filler and were the mixture which not contain brick filler require optimum asphalt content value of 5.4%. Higher bitumen content is required in order to satisfy the design criteria when mix is not blend with Brick filler. This probably due to fact that there is higher asphalt absorption for fill the void
- Hot Asphalt Mix produced using blend with brick Filler performed better under load than HAM made with blend not mix with brick filler. Stability value of mixes prepared with brick filler with gives 13.68 KN and mix prepared without brick filler gives 9.65 KN with their optimum asphalt content.
- The void in mineral aggregate (VMA) values obtained indicate relatively decreasing trend due to additional of brick in the mixture i.e. for mixture blend with brick filler gives 10.9% and for mixture not blend with brick filler result 13.42%.

- Void filled with asphalt (VFA) values of mixture blend with brick filler result 4.1% and mixture not blend with brick filler gives 5.2% were found the max value of marshal criteria this is because of the void is filled by the brick dust filler.
- The flow and Air void in the mixture value obtained indicate decreasing trend due to the addition of brick dust as filler in the mixture than mixture not blend with brick filler to obtain maximum marshal criteria values.
- From this study, the test result obtained from mixture blend with brick filler and mixture not blend with brick filler or normal mix have relatively similarly trend. Besides better performance was obtained from mixture blend with brick filler. As a result this show us that brick filler can used as alternative filler type in hot asphalt mix to the widely used crushed stone.

5.2. Recommendation

- Most of the time the gradation of aggregate is not as need as specification and this problem always because of the shortage of filler material, the remedial action done for this problem is using conventional filler as addition those materials are either cement or lime or re crushing the stone fine material to get the stone dust. This will increase the project cost plus time instead of those above material if the contractors should use the brick filler it will be make the project Economical.
- From the above finding it is evident that brick filler can use as filler in hot asphalt mix and the result is with blend the aggregate with brick filler is good so the client should use this material as filler.
- Further modification in design mixes can result in utilization of brick as fillers in bituminous pavement thus partially solving the disposal of industrial and construction wastes respectively.
- For future research, it is recommended that detailed or in-depth investigation should be carried out on related project; compliance with quality of materials and construction methods in accordance with ERA Standard Specifications and investigate related material.

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APPENDIX A

AGGREGATE GRADATION FOR THE STUDY

Table A1: G-1 (3/4) Course Aggregate Gradation trial

Trail one **Trial two**

Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	Average %
25.0	0.00	0.00	100.00	25.0	0.00	0.00	100.00	100
19.0	214.60	3.90	96.10	19.0	190.60	3.37	96.63	96.4
13.2	3420.30	62.09	34.02	13.2	3707.70	65.49	31.14	32.6
9.5	1599.10	29.03	4.99	9.5	1460.90	25.80	5.34	5.2
4.75	127.90	2.32	2.67	4.75	147.20	2.60	2.74	2.7
2.36	15.00	0.27	2.39	2.36	15.90	0.28	2.46	2.4
1.18	10.00	0.18	2.21	1.18	11.60	0.20	2.26	2.2
0.60	9.30	0.17	2.04	0.60	10.50	0.19	2.07	2.1
0.30	7.90	0.14	1.90	0.30	8.70	0.15	1.92	1.9
0.15	6.30	0.11	1.79	0.15	6.30	0.11	1.81	1.8
0.075	3.40	0.06	1.72	0.075	3.70	0.07	1.74	1.7
Pan	95.00	1.72	0.00	Pan	98.50	1.74	0.00	0.0
Total	5508.80			Total	5661.60			

Table A 2: G-2 (3/8) Course Aggregate Gradation trial

Trial one **Trial Two**

Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	% Average
25.0	0.00	0.00	100.00	25.0	0.00	0.00	100.00	100
19.0	0.00	0.00	100.00	19.0	0.00	0.00	100.00	100.0
13.5	7.20	0.23	99.77	13.2	0.00	0.00	100.00	99.9
9.5	522.60	17.05	82.71	9.5	509.00	16.71	83.29	83.0
4.75	2148.30	70.10	12.61	4.75	2139.50	70.25	13.04	12.8
2.36	179.40	5.85	6.76	2.36	179.30	5.89	7.15	7.0
1.18	41.20	1.34	5.42	1.18	42.40	1.39	5.76	5.6
0.60	26.20	0.85	4.56	0.60	26.40	0.87	4.90	4.7
0.30	17.80	0.58	3.98	0.30	18.50	0.61	4.29	4.1
0.15	13.90	0.45	3.53	0.15	13.40	0.44	3.85	3.7
0.075	16.10	0.53	3.00	0.075	7.50	0.25	3.60	3.3
Pan	92.00	3.00	0.00	Pan	109.70	3.60	0.00	0.0
Total	3064.70			Total	3045.70			

Table A 3: G-3 Fine Aggregate Gradation trial

Trial one				Trial Two				
Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	% Average
25.0	0.00	0.00	100.00	25.0	0.00	0.00	100.00	100
19.0	0.00	0.00	100.00	19.0	0.00	0.00	100.00	100.0
13.5	0.00	0.00	100.00	13.5	0.00	0.00	100.00	100.0
9.5	0.00	0.00	100.00	9.5	0.00	0.00	100.00	100.0
4.75	36.60	4.97	95.03	4.75	37.30	4.79	95.21	95.1
2.36	250.00	33.95	61.08	2.36	268.90	34.56	60.64	60.9
1.18	177.40	24.09	36.99	1.18	188.80	24.27	36.38	36.7
0.60	103.80	14.10	22.90	0.60	111.90	14.38	21.99	22.4
0.30	60.70	8.24	14.65	0.30	61.60	7.92	14.07	14.4
0.15	32.40	4.40	10.25	0.15	33.40	4.29	9.78	10.0
0.075	17.60	2.39	7.86	0.075	17.80	2.29	7.49	7.7
Pan	57.90	1.89	0.00	Pan	58.30	7.49	0.00	0.0
Total	736.40			Total	778.00			

Table A 4: G-3 Brick Filler Aggregate Gradation trial

Trial one **Trial Two**

Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	Sieve Size (mm)	Wt. of Sample Retained gm.	% Retained	% Pass	% Average
25.0	0.00	0.00	100.00	25.0	0.00	0.00	100.00	100
19.0	0.00	0.00	100.00	19.0	0.00	0.00	100.00	100.0
13.2	0.00	0.00	100.00	13.2	0.00	0.00	100.00	100.0
9.5	0.00	0.00	100.00	9.5	0.00	0.00	100.00	100.0
4.75	0.00	0.00	100.00	4.75	0.00	0.00	100.00	100.0
2.36	34.00	5.97	94.03	2.36	23.20	4.06	95.94	95.0
1.18	59.00	10.35	83.68	1.18	50.30	8.79	87.15	85.4
0.60	65.20	11.44	72.24	0.60	62.70	10.96	76.19	74.2
0.30	89.70	15.74	56.49	0.30	91.30	15.96	60.23	58.4
0.15	45.80	8.04	48.46	0.15	48.90	8.55	51.68	50.1
0.075	31.40	5.51	42.94	0.075	31.50	5.51	46.17	44.6
Pan	244.70	42.94	0.00	Pan	155.00	27.10	0.00	0.0
Total	569.80			Total	572.00			

APPENDIX B

PHYSICAL PROPERTIES OF AGGREGATE

Los Angeles Abrasion Test

Table B 1: Abrasion and Impact in the Los Angeles Machine

<table>
<tr><td colspan="2">Material type ;</td><td>Date sampled</td><td colspan="3">5/20/2016</td></tr>
<tr><td colspan="2">Source;</td><td>Date tested</td><td colspan="3">2405/2016</td></tr>
<tr><td colspan="6">Maximum Size Coarse Aggregate ; 20(19)mm</td></tr>
<tr><td rowspan="2">Passing</td><td rowspan="2">Retained on</td><td colspan="4">Grading</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>37.5 mm (1½ in.)</td><td>25.0 mm (1 in.)</td><td>1 250 ± 25</td><td></td><td></td><td></td></tr>
<tr><td>25.0 mm (1 in.)</td><td>19.0 mm (¾ in.)</td><td>1250 ± 25</td><td></td><td></td><td></td></tr>
<tr><td>19.0 mm (¾ in.)</td><td>12.5 mm (½ in)</td><td>1250 ± 10</td><td>2500 ± 10</td><td></td><td></td></tr>
<tr><td>12.5 mm (½ in.)</td><td>9.5 mm (⅜ in.)</td><td>1250 ± 10</td><td>2500 ± 10</td><td></td><td></td></tr>
<tr><td>9.5 mm (⅜ in.)</td><td>6.3 mm (¼ in.)</td><td></td><td></td><td>2500 ± 10</td><td></td></tr>
<tr><td>6.3 mm (¼ in.)</td><td>4.75-mm (No. 4)</td><td></td><td></td><td>2500 ± 10</td><td></td></tr>
<tr><td>4.75-mm (No. 4)</td><td>2.36-mm (No. 8)</td><td></td><td></td><td></td><td>5000 ± 10</td></tr>
<tr><td>Total</td><td></td><td>5 000 ± 10</td><td>5 000 ± 10</td><td>5 000 ± 10</td><td>5 000 ± 10</td></tr>
<tr><td colspan="2">Number of Revolution</td><td colspan="4">500</td></tr>
<tr><td colspan="2">Number of Steel Balls</td><td>12</td><td>11</td><td>8</td><td>6</td></tr>
<tr><td>37.5 mm (1½ in.)</td><td>25.0 mm (1 in.)</td><td>1257.6</td><td rowspan="4">3125</td><td rowspan="4">1880</td><td rowspan="4"><u>18.8</u></td></tr>
<tr><td>25.0 mm (1 in.)</td><td>19.0 mm (¾ in.)</td><td>1250.2</td></tr>
<tr><td>19.0 mm (¾ in.)</td><td>12.5 mm (½ in)</td><td>1251.2</td></tr>
<tr><td>12.5 mm (½ in.)</td><td>9.5 mm (⅜ in.)</td><td>1246</td></tr>
<tr><td>9.5 mm (⅜ in.)</td><td>6.3 mm (¼ in.)</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>6.3 mm (¼ in.)</td><td>4.75-mm (No. 4)</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>4.75-mm (No. 4)</td><td>2.36-mm (No. 8)</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Total</td><td></td><td>5005 gm.</td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Calculate the loss (difference between the original mass and the final mass of the test sample) as a percentage of the original mass of the test sample.</td></tr>
</table>

Aggregate Crushing Value Test

Table B2: Aggregate Crushing value

AGGREGATE CRUSHING VALUE (ACV)				
AGGREGEATE CRUSHING VALUE (ACV)				
Repre. Section :		Lab #		1
Visual Description :	SSD state	Sampling date :		20/05/2016
Purpose : for normal weight concrete mix design		Testing date :		24/05/2016
Specification Limits : For Normal weight concrete = 25% Max				
Smaller Aggregate Testing Size BS(14.0 – 10.0 mm) Or ASTM[12.5-9.5]				
Test No.			1	2
Mass of aggregate before test, passing 14.0(12.5)mm and retain 10.0(9.5)mm sieves		M_1 (g)	2843	2786.14
Mass of aggregate after compression, Passing 2.36mm sieves		M_2 (g)	509.2	499.01
ACV(%) = $(M_2/M_1)*100$			17.92	17.91
Average ACV(%) = $(Test_1 + Test_2)/ 2$			**17.91**	

Aggregate Impact Value Test

Table B3: Aggregate Impact value

S.No.	Weight of measure(gm.) a	weight of measure plus aggregates sample (gm.) b	Net weight of aggregates in the measure in g (A) =b-a	The fraction passing through 2.36mm ASTM Sieve in g (B)	The fraction retained on 2.36 mm ASTM Sieve in g (C)	Total Aggregate impact value
1	**783.2**	**1149.2**	**366**	**50**	**316**	**19.80**
2	**783.2**	**1133.2**	**350**	**48**	**302**	**19.30**
Average value (%)						**19.55**

Unit Weight of Aggregate Test.

Table B4: Aggregate unit weight

UNIT WEIGHT OF AGGREGATES AASHTO T19 ASTM C29							
1. Compacted Density for crashed coarse agg.							
Material type ;		Gravel Coarse agg.		Date sampled		5/20/2016	
Source;		Unkulu crushing site		Date tested		2405/2016	
ERCC @ JIMMA District				Sample no		2	
Maximum Size Coarse Aggregate ; 20(19)mm							
Trial No				1	2	3	Average
Mass of Container		A	Kg	4063.5	4063.5	0	
Mass of Container + Sample		B	Kg	8949.5	8905	0	
Mass of Sample		B - A	Kg	4886	4841.5	0	
Volume of Container		C	m3	3000	3000	0	
Unit Weight		(B - A) / C	Kg/m3	**1.629**	**1.614**		**1.621**

Specific Gravity & Absorption Test of Aggregate

AASHTO T84/T85

Table B5: Apparent and Bulk Specific Gravity of Fine Aggregate

Description			Test 1	Test 2	Test 3	Test 4	Test 5	Average
A. Mass of Oven Dry Sample in Air		g	484.6	484.3	487.6	487.7		
B. Mass of Saturated Surface Dry Sample in Air		g	502.1	502.7	502.6	503		
C. Mass of Flask + Water		g	732	728.4	732	728.4		
D. Mass of Flask + Water + Sample		g	1048.9	1042.7	1047.4	1044.6		
Absorption		(B - A)*100 / A	3.61	3.80	3.08	3.14		3.71
Test temperature , ^{o}C			23 ± 1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7

Apparent Specific Gravity	A / A - (D - C)	2.890	2.849	2.832	2.844	2.838	**2.87**
Bulk Specific Gravity	A / B - (D - C)	2.617	2.571	2.605	2.611	2.608	2.594
Bulk Specific Gravity (S.S.D basis)	B / B - (D - C)	2.711	2.668	2.685	2.693	2.689	**2.69**

Specific Gravity & Absorption Test of Aggregate

AASHTO T 84 / T 85

Table B 6: Apparent and Bulk Specific Gravity of 3/4 Course Aggregate

Description		Test 1	Test 2	Test 3	Test 4	Test 5	Average
A. Mass of Oven Dry Sample in Air	g	2549.2	2581.7				
B. Mass of Saturated Surface Dry Sample in Air	g	2593	2633				
C. Mass Sample in Water	g	1659.5	1679.5				
Absorption	(B - A)*100 / A	1.72	1.99				1.85
Test temperature ,oC		23 ± 1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7
Apparent Specific Gravity	A / A - C	2.87	2.86				**2.86**
Bulk Specific Gravity	A / B - C	2.73	2.71				2.72
Bulk Specific Gravity (S.S.D basis)	B / B - C	2.78	2.76				**2.77**

Specific Gravity & Absorption Test of Aggregate

AASHTO T84/T85

Table B7: Apparent and Bulk Specific Gravity of 3/8 Course Aggregate

Description		Test 1	Test 2	Test 3	Test 4	Test 5	Average
A. Mass of Oven Dry Sample in Air	g	2567.8	2540.5				
B. Mass of Saturated Surface Dry Sample in Air	g	2603.5	2633.5				
C. Mass Sample in Water	g	1655.5	1668				
Absorption	(B - A)*100 / A	1.39	3.66				2.53
Test temperature ,^{o}C		23 ± 1.7	23 ± 1.7	23 ±1.7	23 ± 1.7	23 ± 1.7	23 ± 1.7
Apparent Specific Gravity	A / A - C	2.81	2.91				**2.86**
Bulk Specific Gravity	A / B - C	2.71	2.63				2.67
Bulk Specific Gravity (S.S.D basis)	B / B - C	2.75	2.73				**2.74**

Determination of Flakiness Index

BS 812 Part 105.1

Table B8: Apparent and Bulk Specific Gravity of Fine Aggregate

Sieves Nominal Apperture Size, mm.	Mass of test portion (gm)	Mass of agg. passing on the flakiness gauge (gm)	Flakiness Index (%)	% in the total aggregate (%)	Weighted average for flakiness index %
13.2 - 19.0	1240.0	276.4	22.3	39.6	8.8
9.50 - 13.2	1254.0	173.4	13.8	40.0	5.5
6.3 - 9.50	640.0	198.1	31.0	3095.8	958.2
TOTAL WEIGHT	3134.0	647.9			963.8
FLAKINESS INDEX (%)	**20.1**				

APPENDIX C

MARSHALL MIX DESIGN METHOD

Table C 1: Marshall Properties for Mix without Brick Filler

Asphalt Content,%	Unit Weight, Mg/m3	Air Void, Va, %	VMA, %	VFB, %	Stability, N	Flow, mm
4	2.32	8	10.85	65.4	12.89	3.02
4.5	2.383	6.2	10.31	68.1	12.1	3.12
5	2.386	5.2	10.61	73.8	11.4	3.21
5.5	2.383	5.4	11.10	84.34	10.5	3.52
6	2.368	6.1	13.20	92.45	9.5	5.1

Table C 2: Optimum Asphalt Content Determination Mix Without Brick Filler

	BITUMEN	AIR VOID	VMA	VFB	STABILITY	FLOW	Unit weight
	4.0	8.0	10.8964	64.99	11.9228	3.14	2.33
	4.1	7.6	10.709249	65.55	11.769809	3.06	2.34
	4.2	7.2	10.553356	66.19	11.613276	2.99	2.35
	4.3	6.8	10.428721	66.93	11.453201	2.95	2.35
	4.4	6.5	10.335344	67.75	11.289584	2.92	2.36
	4.5	6.2	10.273225	68.67	11.122425	2.91	2.37
	4.6	5.9	10.242364	69.67	10.951724	2.92	2.38
	4.7	5.7	10.242761	70.76	10.777481	2.95	2.38
	4.8	5.5	10.274416	71.95	10.599696	2.99	2.39
	4.9	5.4	10.337329	73.22	10.418369	3.06	2.39
	5.0	5.3	10.4315	74.58	10.2335	3.14	2.39
	5.1	5.2	10.556929	76.03	10.045089	3.24	2.39
	5.2	5.2	10.713616	77.58	9.853136	3.36	2.39
	5.3	5.2	10.901561	79.21	9.657641	3.50	2.39
	5.4	5.2	11.120764	80.93	9.458604	3.65	2.39
	5.5	5.3	11.371225	82.74	9.256025	3.82	2.39
	5.6	5.4	11.652944	84.63	9.049904	4.01	2.39
	5.7	5.5	11.965921	86.62	8.840241	4.22	2.38
	5.8	5.7	12.310156	88.70	8.627036	4.45	2.38
	5.9	5.9	12.685649	90.87	8.410289	4.70	2.37
	6.0	6.1	13.0924	93.12	8.19	4.96	2.36
Asphalt Test Requirement	4 - 10 %	3-6%	10-16 %	70-85 %	Min. 7 KN	2-4 mm	-

Table C 3: Marshall Properties for Mix with Brick Filler

Asphalt Content,%	Unit Weight, Mg/m3	Air Void, Va,%	VMA, %	VFB,%	Stability, N	Flow, mm
4	2.558	6	13.40	44.1	16.58	3.33
4.5	2.587	5.1	13.25	43.5	15.93	3.28
5	2.595	4	13.52	73.3	14.53	3.49
5.5	2.592	4.1	13.62	76.5	11.24	3.75
6	2.572	5.1	14.81	81.8	11.10	5.57

Table C 4: Optimum Asphalt Content Determination Mix With Brick Filler

	BITUMEN	AIR VOID	VMA	VFB	STABILITY	FLOW	unit weight
	4.0	6.1	13.4384	41.13	16.884	3.43	2.56
	4.1	5.8	13.36583	42.73	16.618092	3.32	2.57
	4.2	5.5	13.3076	44.38	16.347208	3.23	2.57
	4.3	5.2	13.26371	46.09	16.071348	3.17	2.58
	4.4	5.0	13.23416	47.87	15.790512	3.13	2.58
	4.5	4.8	13.21895	49.70	15.5047	3.11	2.59
	4.6	4.6	13.21808	51.60	15.213912	3.11	2.59
	4.7	4.4	13.23155	53.55	14.918148	3.13	2.59
	4.8	4.3	13.25936	55.57	14.617408	3.17	2.59
	4.9	4.2	13.30151	57.65	14.311692	3.24	2.60
	5.0	4.1	13.358	59.79	14.001	3.33	2.60
	5.1	4.1	13.42883	74.7	13.685332	3.43	2.60
	5.2	4.1	13.514	75.5	13.364688	3.57	2.60
	5.3	4.1	13.61351	75.8	13.039068	3.72	2.60
	5.4	4.1	13.72736	78.5	12.708472	3.89	2.60
	5.5	4.2	13.85555	71.38	12.3729	4.09	2.59
	5.6	4.3	13.99808	73.88	12.032352	4.31	2.59
	5.7	4.5	14.15495	76.45	11.686828	4.55	2.59
	5.8	4.6	14.32616	79.07	11.336328	4.81	2.58
	5.9	4.8	14.51171	81.75	10.980852	5.09	2.58
	6.0	5.0	14.7116	84.50	10.6204	5.40	2.57
Asphalt Test Requirement	4 - 10 %	3-6%	10-16 %	70-85 %	Min. 7KN	2-4mm	