ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Effects of Different Fillers on the Mechanical Properties of Hot Mix Asphalt

Case Studies: Gambela – Itang - Jikawo Road Project

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering)

By

Nigatu Wudineh

Advisor

Professor Alemayehu Teferra

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Approved By Board Of Examiners:

Alemayehu Teferra (Prof.)	____________________	____________
Advisor	**Signature**	**Date**
Bikila Tekilu (Dr.)	______________________	_____________
Internal Examiner	**Signature**	**Date**
Henok Fikire (Dr.)	____________________	____________
External Examiner	**Signature**	**Date**
Essayas G/Yohanse (Dr)	____________________	____________
Chairman	**Signature**	**Date**

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AASHTO	American Association of State Highway and Transportation Officials
a.s.l.	above sea level
ASTM	American Society for Testing of Materials
CBPD	Cement by pass dust
AC	Asphalt Cement
ERA	Ethiopian Roads Authority
F/B	Fines to bitumen ratio
HMA	Hot Mix Asphalt
JMF	Job-Mix Formula
OBC	Optimum binder content, percent by total weight of mixture
Pa	Percent air voids in mixture %.
Pbe	Effective asphalt content in the mixture %
Pb	Asphalt content, percent by total weight of mixture.
Pba	Absorbed asphalt, percent by weight of aggregate.
Ps	Aggregate content, percent by total weight of mixture.
P-200	The percentage by weight of aggregate passing through Sieve No. 200
$P_{77}\ ^{0}F$	The penetration value of asphalt cement, in units of 0.25mm.
SHRP	Strategic Highway Research Program
Va	Volume of air voids in percent
Vb	Volume of bitumen in percent
VFA	Voids filled with asphalt %.
VMA	Voids in internal aggregate %.
RHS	Right Hand Side
LHS	Left Hand Side

ABSTRACT

Asphalt concrete road construction is a crucial part of the Growth and Transformation Plan (GTP) of Ethiopia for building a high performance transportation networks for its economic development. Currently many asphalt concrete road construction activities are taking place, especially on trunk and main access roads.

In this study the effect of different types of mineral fillers and their proportion at a given filler percentage by total weight of the mixture in hot mix asphalt concrete performance are investigated and alternative filler proportions are proposed for the construction of asphalt concrete pavement for Gambella –Itang –Jikawo road and it will serve as a guide to use alternative fillers for construction of asphalt concrete pavement in Ethiopia.

Investigation was made to adjust the Job Mix Formula using different filler proportion under the project specification. The mineral fillers, with given percentages by total weight of the mixture, used in this study were crushed stone, Pagag Sand, Cement and Marble dust passing 0.075mm sieve. After determining the optimum bitumen content with Marshall Stability test a number of trial mixes have been performed using the Marshal Mix design procedure to arrive at asphalt concrete mixtures that fulfill the Marshal criteria. The effects of each mineral filler type on Marshal Properties of the asphalt mixtures at a given optimum asphalt content 5% were evaluated and possible basis for such difference in properties was discussed.

Results of this study indicate that the addition of cement and marble dust to asphalt concrete as filler has produced relatively the same comparable Marshall properties. However, the Marshall Stability property obtained from replacement of these fillers was not good as compared with Pagag sand (natural sand).

It can be concluded that Pagag sand replacement up to 50% in the mixture shows acceptable air voids, Marshall Stability and flow values and maximum VMA values. However, from the VFA values we can understand that the replacement of Pagag sand by more than 10% shows a decrease in values below the specification limit as the result of air voids increases when the Pagag sand in the mixes increases that indicate the mixture needs more than 5% asphalt content which is not economical.

The use of cement 50% from the total proportion of design filler content (8.06%) in the mixture satisfies all the Marshall Properties. However, increasing the more than 50% replacement in the mixture test result shows it fulfills the Marshall properties under the project specification except the stability requirement. It is also observed that the Marshall Stability values obtained from cement filler is not uniform when we increase the replacement proportion. This may be due to creation of stabilization that leads to shrinkage cracking or asphalt stiffening effect. Since the cement filler Marshall Stability property obtained is not uniform, it would be difficult to give an explanation on this property based on this laboratory investigation only.

The results of this research work may be used as basis for further detail investigation on the effects of mineral fillers especially cement and marble dust on Marshall Stability and Flow properties of hot mix asphalt.

CHAPTER 1: BACKGROUND

1.1 Introduction

The government of the Federal Democratic Republic of Ethiopia (FDRE) has been focusing on improving its national road network in order to connect existing and potential agricultural production areas, industrial corridors with markets and international corridors as major component of its development policy. However, it has been observed that failure of the constructed asphalt concrete road, had occurred within short period before their expected design life, in some roads after few months of completion and others delayed from the contract period during construction due to shortage of HMA ingredients. One of the ingredients, filler which has less amount in the asphalt mixture, has significance on the performance and difficult to get from crushing of aggregates (basalt). It is one of the reasons for the failure and the cause of delays of asphalt road projects. Consequently, it costs additional budgets for maintenance of the roads and cost overrun due to extended time to finish projects which brings a negative impact on the government budget and nation economy. It has been noticed that the premature distress like fatigue cracking and permanent deformation (rutting) and the delays encountered in many road projects is the effect and shortage of fillers production. Even though it is known that the shortage of filler in the construction industry exists in our country, alternative filler proposals are not investigated in depth.

In accordance with the overall road sector strategy, the Ethiopian Roads Authority has allocated sufficient budget to finance payments for the construction of the Design and Construct Project of Gambella – Itang – Jikawo Road upgrading Project. The scope of the project is to upgrade the existing gravel road to all weather asphalt road linking Gambella and Jikawo. This portion forms part of the trunk route connecting Gambella with South Sudan.

In July 2006, Ethiopian Roads Authority (ERA) has tendered the project for selection of the design and build (DB) Contractor. However, this selection has failed and later on the Ethiopian Roads Authority has decided to implement the Gambella –Itang – Jikawo Road design and construction by force account. ERA force account has no design capacity and thus the design service (the Design and Supervision Consultant) has to be procured. As a result, the recruited Consultant (CORE Consulting Engineers Plc) has agreed to undertake both the design and the construction supervision services simultaneously. Thus, ERA's force account [currently, Ethiopian Road Construction Corporation, ERCC] and CORE Consulting Engineers Plc are assigned as Contractor and Supervision Consultant and hence agreement was signed on April 17, and 13, 2007 respectively. Subsequently, the service and works have commenced on May 09 and 15, 2007 respectively. Even if, the contract awarded for three years period, the road has been completed 2015 after more than six years, owing to critical shortage of construction materials, particularly filler material.

1.2 Background of the problem

Asphalt Concrete road construction in many parts of Ethiopia, especially south western part of Ethiopia suffers shortage of asphalt concrete ingredient (mineral fillers). On the other hand some of the constructed hot mix asphalt roads in Ethiopia fail early after opening to traffic due to premature distress. One of the Projects which have highly suffered from shortage of mineral fillers is the Gambella – Itang – Jikawo road which is focus of this thesis. Many researchers in developed countries have conducted various researches on the effect of fillers in hot mix asphalt to produce mixes with better resistance to permanent deformation (rutting), fatigue cracking and stripping of HMA. On the other hand, it has been noticed that the premature distresses like fatigue cracking, permanent deformation (rutting) and stripping of HMA, and the delay encountered and associated time and cost overrun due to shortage of fillers are not investigated in depth in Ethiopia.

There are different fillers which are used in hot mix asphalt to improve the mechanical properties of asphalt concrete in developed countries. Limestone dust, hydrated lime, Portland cement is some of the fillers which are used to impart greater stability and strength in the construction of asphalt concrete. However, there are no alternative fillers recommended in our country to improve or modify the quality of asphalt concrete roads.

The aim of this thesis is to study the effect of different filler combinations (crushed stone, cement and marble dust along with natural sand (Pagag Sand)) in the performance of HMA and to recommend the Marshall properties results of these fillers when we use as alternative fillers in the future. It is expected that this thesis result will serve as a base to use combined fillers for effective HMA mix design and minimize possible delays and associated cost caused by filler shortage in asphalt concrete road projects. Moreover, making use of combined fillers (cement and marble dust) minimizes the environmental deterioration caused by blasting of quarries during the production of rock dust and disposal of wastes (marble dusts) on lands and rivers from marble factories.

Attempt has been made to analyze the performance of different filler proportion by determining the job mix formula under the project specification using the Marshall Mix Design Method. The study focuses on Gambela-Itang-Jikawo road upgrading project which has highly suffered from filler shortage. Laboratory investigations on the Marshall properties of asphalt concrete mixtures have been made for different filler combination and selected grading was considered for further investigation when one type of filler is increased by 5%, 10, 25, 50, and 75% using constant bitumen content.

1.3 General Objective

- The main objectives of this research work is to determine the effect of filler type and content on the mechanical properties of asphalt concrete paving mixtures and especially to study the effect of cement, marble and Pagag sand proportion of mineral fillers on the properties of asphalt mixtures.

1.4 Specific Objective

- Specific objective of this study is solving the filler problem in the project by investigating the possible cost effective hot mix asphalt design using different filler proportion which produces mixtures that will perform satisfactorily under project specification. Using marble waste as filler we can minimize environmental degradation and by recommending the optimum percentage of crushed dust, Pagag sand, cement and marble dust as filler material in hot mix asphalt mixture under the project specification's on Marshall Properties.

1.5 Scope and Limitation

The research reported herein focuses on asphalt concrete characteristics such as the Marshal Properties under project Specification of Gambella – Itang Jikawo Road project. The materials selected for this study were collected from Gambela-Itang- Jikawo Road Project quarry and crusher site located at km 31 +000 LHS, Portland cement filler from market and Marble dust filler from Ethiopian Marble Industry found in Addis Ababa.

1.6 Organization of the Thesis

This thesis is composed of five chapters:
In the first chapter a general background of the road network and cause of failure and delay of asphalt roads due to the shortage of filler, type and nature of the project, under study and the final objective of the thesis work are discussed.

The second chapter focuses on the literature review and concentrates and builds on the Marshal Properties of fillers in HMA mixtures. Here discussion is made about the basic procedure of hot mix asphalt design and pavement materials and finally fillers.

The third chapter deals with the mix design selection and experimental investigation especially comparison of laboratory test results with project specification and effect of different filler proportion on Marshall Criterion. This chapter also elaborates the roles of the hot mix asphalt materials and structural properties in pavement performance.
The fourth chapter deals with assessments of test results which were obtained from laboratory tests and finally conclusions and recommendations are presented in the fifth chapter.

CHAPTER 2: LITERATURE REVIEW

2.1. General

Evaluation of hot mix asphalt properties by applying minor changes in the basic ingredients has been tried in the past by many researchers. The main objective of their research were to understand and investigate the characteristics and effect of the constituent ingredients on the performance of bituminous mixture [3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 15 16, 17, 18, 19]. From analysis of their data researchers pointed out that the improvement of asphalt concrete performance starts with modification of the mix design, better understanding of the characteristics of the mineral aggregates and the bitumen type.

The review begins with an overview of the different constituent ingredients of HMA, or asphalt aggregate interaction, with emphasis given to the role of fillers characteristics on the asphalt performance. This is followed by a concise summary of the dependence of hot mix asphalt performance on the mineral filler characteristics. The objective of the literature review is to identify the current knowledge about different hot mix asphalt ingredients with particular attention to mineral fillers which play a dominant role in asphalt mix design by affecting the air void in addition to stability and stripping.

2.2 Hot Mix Asphalt (HMA) Design

HMA mix design process consists of a series of procedures and/or tests followed by or executed to select aggregates, aggregate gradation, binder type and content, additive/modifier type and content to produce a bitumen-aggregate mix that satisfies specific requirements. It should be noted that the purpose of mix design is to formulate a mix of aggregates and binder which is both the most economical and at the same time has resistance to deformation and cracking, be durable over time, resist to water damage, provide a good tractive surface, and yet be inexpensive, readily made and easily placed by selecting a unique design asphalt content that will achieve a balance among the these desired properties [2].

2.3 Performance Related Aggregate Properties

Aggregate is the major structural component in HMA which makes up 90-95% of the mixture by weight and 85% by volume [15]. The American Society for Testing and Materials (ASTM) defines aggregate as a granular material of mineral composition such as sand, gravel, shell, slag, or crushed stone, with a cementing medium to form mortar or concrete, or alone as in base course or railroad ballast. Aggregates for HMA are usually classified by size as coarse aggregates, fine aggregates, or mineral fillers. ASTM also defines coarse aggregates as particles retained on a No.4 (4.75mm) sieve, fine aggregate as that passing through a No.4 sieve(4.75mm) and mineral filler as material with at least 70 per cent passing a No. 200 (0.075mm) sieve [ASTM, 2003].

The most important properties of HMA like stability, durability, stiffness, fatigue resistance and stripping are related to the aggregate physical properties and gradation. Aggregates for HMA are generally required to be strong, sound, and properly graded; to have clean surface without deleterious materials; consist of angular particles with low porosity and appropriate absorption for asphalt cement. Therefore, the quality and physical properties of this material has a large influence on the mix performance so that care has to be given in the mix design of asphalt pavement.

Research has shown that aggregate characteristics such as particle size, shape, and texture influence the performance and serviceability of hot mix asphalt pavement [3]. Another study conducted by [16] on the effect of aggregate type and gradation on permanent deformation were evaluated under test combination by changing asphalt type, asphalt content, air voids content, temperature, and applied stress level. The test result was analyzed using statistical analysis and graphical comparison of data. Their test results show that aggregate type has significant effects on fatigue resistance and permanent deformation of asphalt concrete, indicating better performance from the mixtures comprised of aggregates with rough surface texture and an angular shape. The study also indicate that coarse gradation, meaning a larger proportion of coarse aggregate with the same nominal maximum aggregate size compared to medium gradation, did not show significant effect on permanent deformation. Analysis conducted by Strategic Highway Research Program (SHRP) also disclosed that aggregate gradation and properties are among the main factors that influence the stability of hot mix asphalt (HMA). According to the SHRP study outputs, the properties that contribute to rutting to some extent for asphalt concrete (AC) are coarse aggregate size and shape properties.

Another study conducted by [25] disclosed that aggregate quality has a central role in the performance of hot mix asphalt concrete mixtures. The availability of good quality aggregate is of concern in many countries and he showed that upgrading and improvement of aggregate by cement coating technique (CCT) solves the aggregate depletion problem and availability of marginal aggregates. In his research the cement coating technique (CCT) addressed the surface texture of aggregate particles and improves the bond between the particles surface and asphalt binder. He used the hydrated Portland cement to shield the surface of the aggregate particles and he got the result which shows significant improvements achieved in permanent deformation, fatigue and moisture damage resistances.

Study also conducted by Frazier Parker and E. Ray Brown [34] showed that rutting varies geographically and that this variation is caused by quality of locally available aggregates. Areas which used crushed and angular natural sands are less susceptible to rutting. Conversely, smooth, rounded aggregate particles tend to slide past each other instead of locking together. If the aggregate provides a high degree of internal friction (Ø), the shear strength of the asphalt mixture will increase and, therefore, develop resistance to rutting. This is accomplished by selecting an aggregate that is angular, cubical, has a rough surface texture, and is graded in a manner to develop particle to particle contact [30].

2.4 Aggregate Gradation

Aggregate gradation is the distribution of particle sizes expressed as a percent of the total weight. Gradation is perhaps the most important property of an aggregate in addition to the aggregates properties. Almost all the important properties of HMA mixtures like stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance, and resistance to moisture damage are affected by gradation. Therefore, gradation is a primary consideration in asphalt mix design, and the specification place limits on the aggregate gradations that can be used in HMA mixtures. Gradation is determined by sieve analysis that is, by passing the material through a series of sieves stacked progressively smaller openings from top to bottom, and weighing the material retained on each sieve. Aggregate gradations are described as dense (well graded), open (uniformly-graded), and gap-graded. In general, the two factors relating to aggregate gradation having the most influence on VMA are density, or the ability of the aggregate particles to pack together, and the aggregate surface area. From the many investigators [35] proposed one of the best known gradations for maximum density. The equation for Fuller's maximum density curve is

$$P=100\,(d/D)^{n} \qquad (2.1)$$

Where P is the total percent passing or finer than the sieve and
D is the maximum size of the aggregate.
d is the diameter of the sieve size in question,

Studies by Fuller and Thompson showed that maximum density can be obtained for aggregate when n=0.5. In the early 1960s, the Federal Highway Administration introduced an aggregate grading chart which is convenient for determining the maximum density line and for adjusting aggregate grading based on the Fuller gradation equation using a 0.45 exponent. [11] Demonstrated that an aggregate having a gradation that produces a straight line on a 0.45 power gradation graph will have the maximum achievable density, and subsequently, as shown by [23], the lowest air void content and the lowest VMA in an HMA mixture. Deviating from the maximum density line in either the fine or the coarse direction will tend to increase the VMA of the compacted mixture. It is believed that, the gradation that gives the densest packing provides enhanced stability and reduces void space in the mineral aggregate through increased interlocking between mixture particles. However, gradations of maximum density may not provide enough voids in the aggregate. There must be sufficient air void space in HMA to permit enough asphalt cement to be incorporated to provide adequate film thickness for maximum durability while still leaving some air space in the mixture to avoid bleeding and/or rutting. Therefore, deviations from the maximum density curves are necessary in order to increase the total voids in the mineral aggregate (VMA). VMA is an important parameter and minimum values of VMA are required and suggested by most pavement agencies depending on the maximum nominal aggregate size of the mixture design. The requirement for minimum VMA is necessary to ensure that there are sufficient voids in the aggregate to allow enough asphalt cement to be added to provide a durable mix and sufficient air void to maintain stability.

The study on the effect of aggregate gradation on the creep response of asphalt mixtures and pavement rutting estimate by [16] using granite aggregate and AR 4000 and AR 8000 (American asphalt designation) asphalt was conducted for preparation of the specimens by kneading compaction, Hveem stabilometer, and simple creep tests (unconfined) for their performance evaluation purpose, two type of aggregate gradation (13mm maximum size medium gradation and 13mm maximum size coarse gradation) and investigation of rut depths were predicated for a total of 15 cases consisting of 4 temperature condition, 2 aggregate gradations and 2 measuring performance. From their test results they concluded that the conclusions drawn from their study were:

- The medium graded mixture provided significantly better performance in rutting than coarse graded mixture, and

- Temperature has more influence on rutting than the aggregate grading

During the design of asphalt concrete mixture, care has to be taken by the designer while determining maximum aggregate size in a mixture. In HMA mixtures, instability may result from excessively too small maximum particle sizes; and poor workability and/or segregation may result from excessively large maximum particle sizes [7]. Maximum aggregate sizes for surface mixes and binder course mixes vary from 9.5mm to 19mm and 19mm to 38mm respectively [34].

2.5 Surface Area

The aggregate surface area is one important property that affects the amount of asphalt needed to coat the aggregate. The total surface area of an aggregate mixture is dependent primarily on the gradation. Aggregate gradations that deviate above the maximum density line are defined as “fine” while those that deviate below the maximum density line are “coarse”. An analysis of Equation for surface area indicates that as particle diameter decreases, the surface area per unit mass increases. Using this equation, a simple estimate of surface area can be determined for the purpose of comparing different aggregate gradations [24]. It should be noted that the results of this equation are approximate.

$$S_A = \sum S_{af,\,No.} \; P_{No.} \quad \text{in kg/m}^2 \qquad (2.2)$$

Where

S_A	is surface area or m^2/kg
$S_{af,\,No.}$	is the surface area factor for sieve number $_{No.}$ and
$P_{No.}$	is the percentage passing by weight that sieve

2.6 Asphalt Binder

Asphalt grade and characteristics are critical to the performance of the asphalt pavement. Three methods, based on penetration, viscosity and performance are used to classify asphalt cements into different standard grades. The penetration grading of asphalt cement and viscosity grading are specified in ASTM D946 and D3381 respectively [35].

Another mixture property that must be evaluated is asphalt content. The asphalt content of HMA is very important to ensure satisfactory performance. A HMA mixture with low asphalt content is not durable, and one with high asphalt content is susceptible to bleeding and become unstable. The actual asphalt content directly affects mixture properties, such as asphalt film thickness, voids, stability (Hveem or Marshall), and Marshall Flow. Therefore, it is important to monitor asphalt content, but it is really these mixture properties that need to be controlled. The design procedure also includes a density-voids analysis of the compacted specimens to determine the percent air voids and percent voids filled with asphalt (VFA). After determinations, the specimens are tested at 60^0C, and the Marshall stability (maximum load observed in the test) and flow (deformation corresponding to the maximum load) are obtained [1].

The basic steps that are followed in determining the optimum asphalt binder are:

- Make several trial mixes with different asphalt binder contents
- Compact these trial mixes in the laboratory
- Run several laboratory tests to determine key sample characteristics
- Pick the asphalt binder content that best satisfies the mix design objectives.

Data resulting from these mix evaluations are plotted in a series of curves (Fig. 2.1);

- Asphalt binder content vs. density. Density will generally increase with increasing asphalt content, reach a maximum, then decrease
- Asphalt binder content vs. Marshall stability
- Asphalt binder content vs. flow.
- Asphalt binder content vs. air voids. Percent air voids should decrease with increasing asphalt binder content.
- Asphalt binder content vs. VMA. Percent VMA should decrease with increasing asphalt binder content, reach a minimum, then increase.
- Asphalt binder content vs. VFA. Percent VFA increases with increasing asphalt binder content.

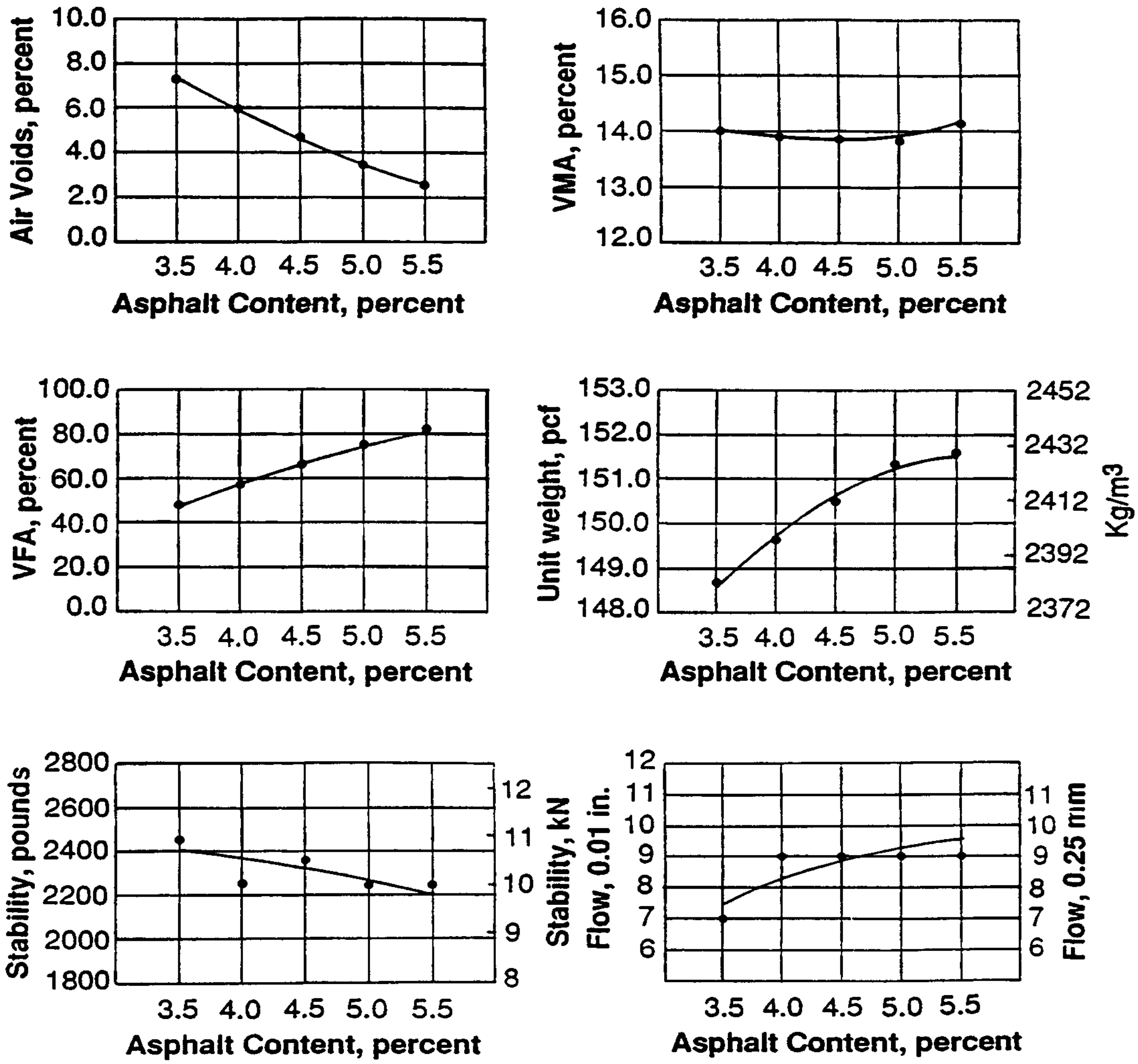

Figure 2.1: Typical Test Property Curves for a Hot Mix Asphalt Paving Mixture by the Marshal Method

A better method of selecting the Marshall Design binder content is to examine the range of binder contents over which each property is satisfactory, define the common range over which all properties are acceptable, and then choose a design value near the centre of the common range. If this common range is too narrow, the aggregate grading should be adjusted until the range is wider and tolerances become less critical [12].

It is important to know that aggregate gradation is directly related to optimum asphalt content. The finer the mix gradation, the larger surface area of the aggregate and the greater the amount of asphalt required to uniformly coat the aggregates. Conversely, because coarser mixes have fewer totals aggregate surface area, then require less asphalt.

The volumetric analysis is calculated from the values for bulk specific gravity (G_{sb}) and theoretical specific gravity (G_{mm}). The values for these specific gravities are determined using AASHTO T166 and AASHTO T209, respectively. The volumetric parameters are the voids in the mineral aggregate (VMA), voids in total mix (VTM), voids filled with asphalt (VFA), and the dust-to-binder ratio. For Marshall mix designs, an additional parameter for stability and flow [2].

2.7 Mixture Volumetric Composition

The volumetric properties of a compacted asphalt mixture provide indications of the potential performance of the mixture as a pavement. Therefore, understanding the volumetric composition of asphalt concrete and the ability to perform a volumetric analysis are two of the most important skills that any designers must master in order to develop effective asphalt concrete mix designs. This part of the research presents the volumetric analysis from the values of bulk specific gravity (G_{sb}) and theoretical specific gravity (G_{mm}) [2].

2.7.1 Bulk Specific Gravity

The bulk specific gravity of a mixture refers to the specific gravity of a specimen of compacted mixture, including the volume of air voids within the mixture. It is equivalent to the mass of a given specimen in grams, divided by its total volume in cubic centimeters. The bulk specific gravity test on the freshly compacted specimens may be performed as soon as when they have cooled to room temperature.

To determine the bulk specific gravity of dense graded mixture, the compacted specimens are extruded from the mold, cooled to room temperature, and the dry weight recorded. Each specimen is then immersed in water at 25° C for three to five minutes, and the immersed weight is recorded. The specimen is removed from the water, surface dried by blotting with a damp cloth, and the surface dry weight recorded in air (AASHTO T166 – Method A) or ASTM D 2726 [9].

The voids in an asphalt mixture are directly related to density and it is apparent that the bulk density increases as the amount of proportional mineral filler increases in the mixture up to some point and then decreases. This is due to an increased amount of mineral fillers will decrease the void in the mix and the greater amount of filler tend to push the larger particles apart and act as lubricating ball-bearings between these larger particles which subsequently lower the bulk density, while more binder is required to cover extra filler amounts added to the mix which is not economical, thus, density must be closely controlled to insure that the voids stay within an acceptable range [9].

2.7.2 Theoretical Maximum Specific Gravity

The theoretical maximum specific gravity (often referred to as maximum theoretical density and thus abbreviated (MTD)) is the HMA density excluding air voids. Thus, theoretically, if all the air voids were eliminated from HMA sample, the combined density of the remaining aggregate and asphalt binder would be the MTD. MTD is a critical HMA characteristic because it is used to calculate percent air voids in compacted HMA and provide target values for HMA compaction. MTD is determined by taking a sample of oven-dry HMA in loose condition (versus compacted condition), weighing it and then completely submerging it in a 25°C water bath. A vacuum is then applied for 15 minutes to remove any entrapped air. The sample volume is then calculated by subtracting its mass in water from its dry mass [13].

2.7.3 Voids in the Mineral Aggregate

The VMA (voids in the mineral aggregate) are defined as the inter granular void space between the aggregate particles in a compacted asphalt mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume. The VMA is calculated on the basis of the bulk specific gravity of the combined aggregate and is expressed as a percentage of the bulk volume of the compacted asphalt mixture. VMA is calculated by subtracting the volume of the aggregate determined by its bulk specific gravity from the volume of the compacted asphalt mixture [3].

VMA is an important factor for mixture design. Voids in the Mineral Aggregate must be sufficient to allow adequate effective asphalt which is not absorbed into the aggregate particles) and air voids for its durability purpose, and air space. The more VMA in the dry aggregate, the more space is available for the binder. Since a thick binder film on the aggregate particles results in a more durable asphalt mixture, specific minimum requirements for VMA are recommended and specified as a function of the aggregate size [21].

Minimum VMA values are required so that a durable binder film thickness may be achieved. Increasing the density of the asphalt mixture by changing the gradation of the aggregate may result in minimum VMA values with thin films of binder and a dry looking, low durability asphalt mixture. Therefore, economizing in binder content by lowering VMA is actually counterproductive and detrimental to pavement quality. Low VMA mixes are also very sensitive to slight changes in binder. If binder content varies even slightly during production, the air voids may fill with binder resulting in a pavement that flushes and ruts [21].

VMA is most affected by the fine aggregate fractions which pass No. 200 sieve. The reason for this is that these particles tend to be absorbed by the binder film. Since they take up volume, there is a tendency to bulk (extend) the binder resulting in a lower VMA [21].

2.7.4 Air Voids in Compacted Mixture

AV (Air voids) are small pockets of air that exist within the asphalt binder and between aggregate particles expressed as percent of the bulk volume of the compacted paving mixture [1,3]. 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. To address this, HMA mix design seeks to adjust items such as asphalt content and aggregate gradation (the amount of material passing the No. 200 sieve in the asphalt mixture) to produce design air voids. Air void content is calculated from the mixture bulk and theoretical maximum specific gravity [2].

2.7.5 Voids Filled with Asphalt

Voids filled with asphalt (VFA) are the void spaces that exist between the aggregate particles in the compacted paving asphalt mixture that are filled with binder. VFA is expressed as a percentage of the VMA that contains binder.

Including the VFA requirement in a mix design helps prevent the design of asphalt mixture with marginally acceptable VMA. The main effect of the VFA is to limit maximum levels of VMA and subsequently maximum levels of binder content [2].

2.8 Marshall Stability and Flow

Stability is defined as the maximum compressive load carried by a compacted specimen tested at 60^0C at a loading rate of 50.8 mm/min. The Marshall Stability values can be increased by using “stiffer” or more viscous asphalt binder grade, aggregates that are more angular or a blend of all crushed aggregates and any material that can stiffen an asphalt binder will also increase the Marshall stability.

The flow is the vertical deformation of the compacted specimen from the start of the Marshall stability loading until the stability values begin to decrease. High flow values indicate an asphalt mixture that has plastic behavior and has the potential for permanent deformation, such as rutting or shoving, under traffic loading. Low flow values indicate a mixture that may have insufficient asphalt binder, which may lead to durability problems with the pavement. Low flow values may also indicate a mixture with a binder so stiff, that the pavement experiences low temperature or fatigue cracking. Marshall Flow is a function of the asphalt binder stiffness and the asphalt binder content of the mixture. It is obtained at the same time as the Marshal Stability test is conducted [7].

2.9 Moisture Susceptibility

Moisture susceptibility is the tendency of HMA toward stripping. The loss of integrity of an HMA mix through the weakening of the bond between the aggregate and the binder is known as stripping. One of the methods to prevent moisture susceptibility is proper mix design. The three mix parameters that are identified in the lab tests may influence stripping tendency are gradation, asphalt film thickness (asphalt content) and voids [22, 27, 30]. Gradation alone is probably not that important, although well graded mixtures tend to show fewer tendencies to strip than mixes with basically one size material. Gradation, as it relates to asphalt film thickness and the voids in a mix, is important. Mixes with finer gradations (surface mixes) tend to have larger asphalt film thicknesses and lower stripping tendency. Coarser gradations (base/binder mixes) tend to have smaller asphalt film thicknesses and greater stripping tendency [22, 27, and 30].

[17] Pointed out that inadequate surface drainage or sub-surface drainage is the primary contributor among many possible causes of stripping. Moisture can enter in different ways to the HMA pavement layers: by capillary action from the water table, run off from the road surface and seepage from surrounding areas are a few ways. If adequate drainage is not present, air voids in the HMA may become saturated with moisture, thereby increasing pressure and weakening the bond. Further Contributing factors such as air void above 8 percent, water can readily seep into the material, excessive dust coating on an aggregate can inhabit coating by asphalt and provide channel for water to penetrate, and inadequate drying of aggregate cause stripping [17].

If asphalt pavement does suffer from water sensitivity, serious distresses may occur. As a result, the asphalt pavement reduces in performance and increases in maintenance costs. To alleviate or control this problem, various liquid or solid anti-stripping additives have been developed, which can be used to promote adhesion between asphalt and aggregate. [21] Experimental studies of the physical and compositional properties of asphalt cement with anti-stripping additives demonstrated that anti-stripping additives tend to soften asphalt, reduce temperature susceptibility, and improve the aging characteristics of asphalt cement. [21] Stated also that the effect of an anti-stripping additive is asphalt specific.

Liquid anti-stripping agents and lime additives are among the most commonly used types of anti-stripping agents. The general practice regarding lime anti stripping additive is to add 1 to 1.5 percent lime by dry weight of aggregate to the mix. If an aggregate has more fines present, it may be necessary to use more lime additive due to the increased surface area of the aggregate. Three forms of lime are used: hydrated lime ($Ca(OH)2$), quick lime (CaO), and Dolomitic limes (both types S and N) [17].

Another Method of preventing moisture susceptibility of bituminous mixture is to upgrade and improve the available aggregates by cement coating technique (CCT). The CCT addresses the surface texture of aggregate particles and improves the bond between the particle surface and asphalt binder [25]. The concept of CCT is based on shielding the surface of the aggregate particle by hydrated Portland cement film.

2.10 The Effect of Mineral Filler on HMA

Several studies which demonstrated that the properties of the asphalt concrete are strongly influenced by the material passing the 0.075 mm sieve. This material is generally referred to mineral filler [3]. We can get filler material from rock dust derived from coarse and fine aggregate fractions and other materials such as lime, Portland cement, cement kiln dust, or fly ash, marble dust added to enhance the quantity and properties of filler in the mix. Mineral fillers can play a role as filler or as an extender. If the mineral filler acts like an extender it can produce flushing and rutting. The Marshall specifications limit the amount of mineral fillers by applying a maximum limit. In dense graded mixes, the proportion of filler is generally in the range of 4 to 6% by mass of the aggregates with a ratio by mass of filler to binder of between 0.6 and 1.2 based on the optimum asphalt content of the mix.

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 [22]. However, an early study made by Clifford Richardson, concluded that the role of the filler was more than void filling, implying that some sort of physical –chemical interaction occurred [4]. Portion of filler larger than the asphalt film thickness serves to fill the voids between aggregate particles, thereby increasing the density and strength of the compacted mixture, while particles finer than the asphalt film thickness become suspended in the asphaltic binder forming a mastic and adsorb asphaltic components, thereby increasing the viscosity of the binder and, consequently, toughness of the mix.

Parker, F. and Brown, E. R., Investigated in their research on Marshal Stability tests using 60/70 grade bitumen and mineral fillers such as stone dust, marble, and limestone on bituminous mixes. Generally, the test result pointed out that the Marshal Stability of all mixes was improved with addition of fillers [9]. This attributes to the fact that as filler content in the mix increases, lower air voids can be achieved.

The conclusions that he draws from his study were:

- The determination of optimum asphalt content was influenced by the amount of fillers, where better results be obtained at 5 to 7.5% filler content.
- Mixture prepared by using marble dust as compared to lime and stone dust shows higher values of compressive strength and modulus of elasticity.
- From low temperature tensile strength test, mixes prepared using marble dust exhibited higher values of tensile strength. From this result one can draw better performance can be achieved by using marble dust filler in bituminous mixtures when compared with other fillers..

Performance of asphalt mixture such as permanent deformation, fatigue cracking and moisture susceptibility of HMA are influenced by the physical properties of mineral filler. An investigation was carried out to identify which P-200 material are not most related to performance of asphalt paving mixture by characterization test. The study was conducted using super pave shear test, Hamburg wheel tracking and AASHTO T283 for evaluating permanent deformation, fatigue cracking and moisture susceptibility respectively. In the study, a mixture containing 12 different type of P-200 materials and filler to asphalt ratio were used and from the summary of statistical analysis of the test data, the Authors disclosed that the following important characteristics of mineral filler are most related to the performance of asphalt mixture

- The rutting potential of asphalt mixture is not affected by any P-200 characteristics when 0.8 filler to asphalt ratio used.
- Good correlation were obtained between rutting potential and gradation indicators (fitness modulus D10, D30 D60 and specific surface area) in 1.5 filler to asphalt ratio, i.e. the finer P-200 material, the more it modifies the asphalt binder and stiffens the HMA mix.
- In 0.8 and 1.5 filler asphalt ratio, there were no significant correlation between material properties of fatigue factor and P-200 sieve size.
- Significant effect has been observed during the analysis on the stripping characteristics of HMA mixtures due to fineness of P-200 materials (especially D10). This is because of that the smaller the size of P-200 (especially the smaller D10 size), the more the binder is being stiffer and/or extended. Stiffer asphalt binder in the mix provides stiffer mixture and extended asphalt binder increases the asphalt content in the mix. This will subsequently increase the resistance to stripping.

The laboratory evaluation conducted by two researchers [18] on the strength of asphalt mixture shows, increased substantially when the fine aggregate was changed from rounded sand to crushed fine aggregates that regardless of the type of coarse aggregate.

The Marshall Method of mix design reported that mix durability has also been related to the amount of fine "dust or dirt" particles in the mixture [2]. Excessive fine lowered the quality of the asphalt film on the aggregate. Depending on the size of these particles, the mix may be stiffer or tenderer.

Study conducted on the effect of filler type especially Portland cement and lime stone (in order to compare the effect of different types and ratios of mineral filler on the strength properties) on Marshall stability and retained strength of asphalt concrete found that cement filler resulted on higher values of retained strength [11].

Research in Saudi Arabia was conducted on the effect of mineral fillers type and content on properties of asphalt concrete using lime stone dust, hydrated lime, and Portland cement to identify the premature failures. Controlled mix were prepared using lime stone dust at content 3, 5.5, and 8% by total weight of aggregate mixes in which lime stone dust was replaced by either hydrated lime or portland cement with percentage of 1, 2, and 3% by total weight of aggregate [32]. Mixes at their optimum asphalt content for various type and contents of filler were tested for indirect tensile strength, resilient modulus, and wheel trucking test to measure the rut depth and got the following results:

- Replacement of limestone dust by hydrated lime has caused a significant increase in softening point of the mastic, whereas, replacing with cement has little effect on it.
- For high filler contents (5.5% and 8%) mixes containing hydrated lime replacing lime stone dust acquire higher optimum asphalt contents, higher air voids, and lower unit weights than those containing Portland cement. The differences in optimum asphalt content, air voids, and unit weight increase with the filler content.

- The VMA values of mixes are not sensitive to Portland cement replacement.
- Replacing part of lime stone dust by hydrated lime or Portland cement enhance the resistance of the mixes to rutting. The rut depth increases as the percentage replaced increases. Highest values were recorded for mixes made with 8% lime stone dust partially replaced by three percent hydrated lime, while the lowest values were found for those made with 5.5% lime stone dust.
- Mixes with high contents of lime stone dust (5.5% and 8%) showed a decrease in unit weight with increasing percent replaced by hydrated lime.
- Increasing the amount of replacement of lime stone by either hydrated lime or Portland cement shows that the resilient modulus values of the mixes are decreasing, but the Hveem stability is not affected by the type of filler used in the mixes.

Another study conducted on the effect of waste cement dust as mineral filler on the mechanical properties of hot mix asphalt by using 0%, 25%, 50%, 75% and 100% cement dust content by weight of the limestone mineral filler showed that an enhancement in Marshall and mechanical properties of asphalt concrete mixtures observed [33]. Their Marshall testing results have also indicated that an increase in the stability, unit weight and a decrease in the flow, voids ratio and voids in mineral aggregates revealed when the percentage of cement dust content increases. When replacement of lime stone by cement increases the tensile strength and unconfined compression strength of the properties also increased. The optimum cement dust ratio was found to be 100% of the used mineral filler. Hence, cement dust can totally replace lime stone mineral filler in asphalt paving mixtures [33].

Previous work by [20] on granite and marble dust as filler in asphalt concrete indicated that the addition of marble and granite dust to asphalt concrete can make properties comparable to the conventional asphalt concrete mixes with stone dust as filler. In addition Rheological tests conducted on filler-asphalt mastic revealed that granite dust showing the highest resistance to rutting of this filler. On the other hand optimum binder content of a mix reduces with increase in marble dust in the mix. This shows that this filler acts as bitumen extender also. Other results of Marshall Tests, creep tests and moisture susceptibility tests also indicate that marble dust and granite dust can be successfully utilized as filler in bituminous construction. The application of these materials in road construction will alleviate the problem of their disposal and environmental pollution.

In order to gain higher density and strength in asphalt cement mixes it is needed to add some mineral filler. Its job is to fill the void in the aggregate and the filler increasing the density of the mix. The Mineral filler also affects the asphalt content as result of greater total surface area of the aggregate blend. Small increases in the amount of filler in a gradation can literally absorb much of the asphalt binder, resulting in a dry, unstable mix. Small decreases have the opposite effect. To avoid bleeding of the pavement and loss of stability, it is also necessary to control the amount of asphalt used. The choice of filler will be determined by availability and cost together with the need to impart specific qualities such as improved stiffness or reduced moisture sensitivity.

Conducted investigation in Dubai on the quality and quantity of locally produced filler (passing sieve No. 200) on asphalt mixtures. Samples were prepared having ordinary Portland cement, (OPC), hydrated lime, and sodium silicate in addition to the six mineral fillers (Gambro origin) and one lime stone filler [31]. Using the Marshall Test procedure the optimum binder content 4% was considered for comparative study from the range (3.5-4.5) which represents the bitumen content range by different specifications used in Dubai. They have also carried out the grading of each mineral filler using ASTM D422, tests which are used for determining the gradation of fine soil, Atterberg Limits, surface area, specific gravity and voids in the compacted fillers, micro structural analysis (chemical and physical) including bitumen cement properties(penetration, softening point, kinematic viscosity at 135 degree Celsius, and penetration index “P.I”). The quality of each type of filler was studied by adding different fillers to bitumen at two filler to bitumen ratios (0.5 and 1.5 by weight). From their test data, they have made the following conclusion.

- For selected mixes using selected binder and fillers 4 fillers were chosen based on different specific gravity of filler one local source filler and OPC representing a higher specific gravity range where as from one site Gabbros origin and hydrated lime shows medium specific gravity and lower specific gravity respectively.

- The Marshall parameters (%VFB, %VTM, %VMA and bulk specific gravity) were not affected significantly by changing the type of filler at specific filler content.

- All type of mineral filler used in Dubai Emirate have minimal stiffening effect when we see the role of binder extender. However, selection of a filler type to improve the binder stiffening property under extremely high temperature is extremely critical. Fillers which show more stiffening effect should address to the permanent deformation problem.

- Hydrated lime fillers have shown superior stiffening properties when compared with other filler types.

- When 0.8 ratio of hydrated lime to bitumen used the softening point increases from 51.7(for AC 60/70) to 79.4, the penetration (0.1mm) decrease from 57 to 23 at 25 degree Celsius and the PI increase from -0.78 to +2.0.

- Active filler is added mainly to provide early strength development to support traffic as well as faster dry back of the compacted layer. Limited research (32) has shown that optimum Portland cement contents on FDR-FA projects in California are likely to be between 1.0 and 2.0 percent by mass of the dry crushed material. Their study has shown that in general the active filler content should always be less than the asphalt binder content.

- In their research they have pointed out that Portland cement contents higher than 2.0 percent was not used because of the risk of creating a stabilized material that will be prone to shrinkage cracking. Having mentioning some concern about cracking associated with the use of Portland cement contents higher than 1.0 percent in their research they found some research on a limited number of material types that showed Portland cement at rates of up to 2.0 percent in combination with foamed asphalt cement did not behave in the same manner as material treated with 2.0 percent cement and no foamed asphalt (i.e., similar to a Type A cement-treated base material). Laboratory specimens with 2.0 percent Portland cement and varying quantities of asphalt binder up to 4.0 percent showed no evidence of shrinkage. These findings, along with limited microscope analysis, support the conclusion that performance of materials with a combination of the two additives is different from the performance with either of the additives alone, and that Portland cement contents of up to 2.0 percent can be considered, provided that appropriate material assessments are undertaken. Active Filler Application Rates Portland cement contents of 1.0, 1.5, and 2.0 percent and/or hydrated lime contents of 2.0, 2.5, and 3.0 percent by mass of the dry material are used as a starting point together with an untreated control (i.e., asphalt binder with no active filler). Generally active filler contents must not exceed the asphalt binder content determined as in their research. If the test results indicate that both active fillers provide satisfactory performance, the design engineer should select according to cost, availability, and local experience.

CHAPTER 3: EXPERIMENTAL INVESTIGATION

3.1 Project Location

The project is located in Gambella National Regional State. The starting point of the project is Gambella, located at 34^0 35’ E Longitude, 8^o14’ N Latitude and Elevation of 480 m, above mean sea level (msl) and is 770 km from Addis Ababa along Addis - Jimma - Bedele - Gore road. It then terminates at Jikawo town located at 33^o 46’ E Longitude and 8^o22’ N Latitude at an elevation of 413 m, above msl.

The Location map of the project road is shown in Fig 3.1 and 3.2.

Figure 3.1 Location Map of Ethiopia the Road Project (EMA, 1:50 Mercator projection Map)

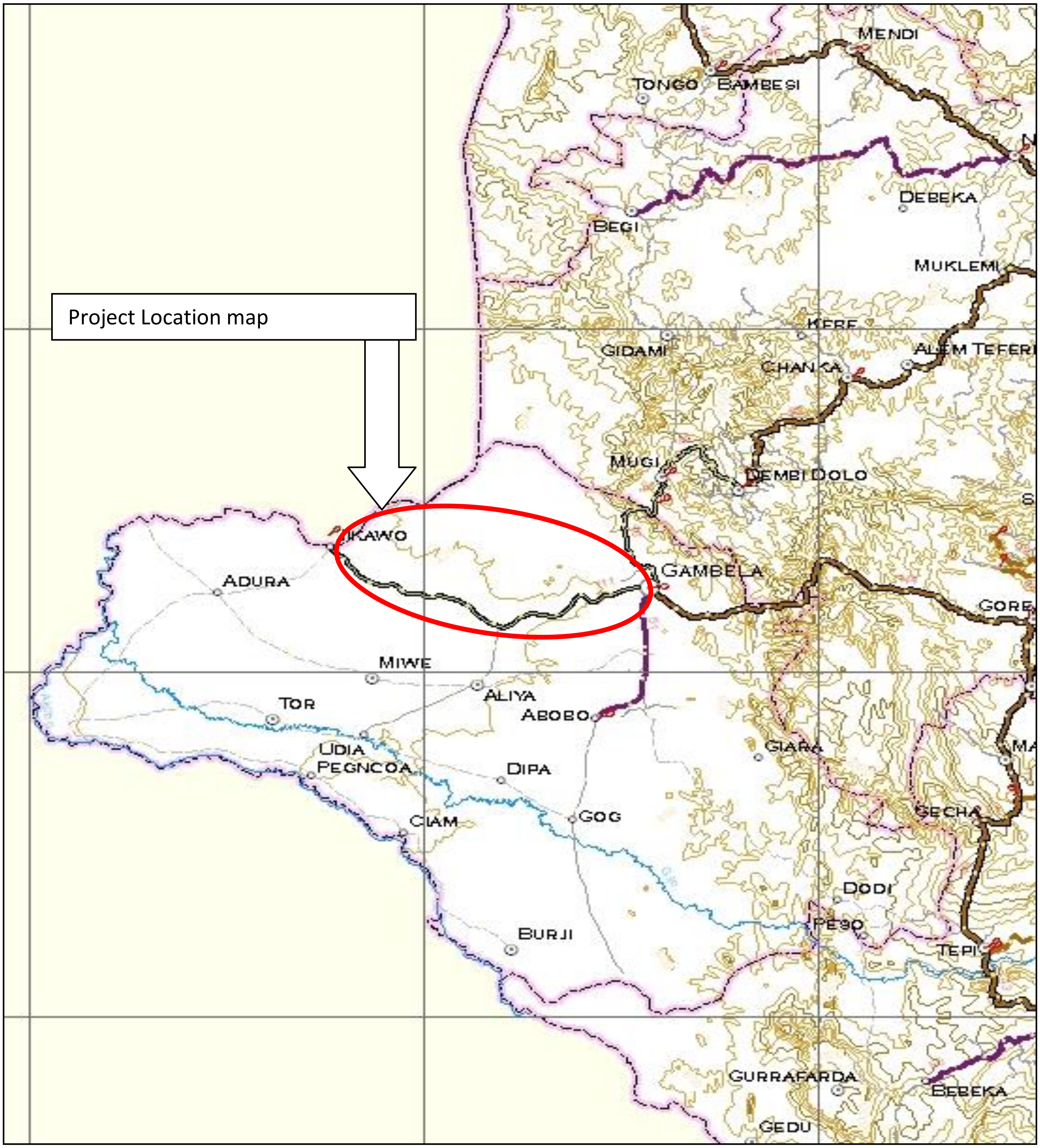

Figure 3.2 Location Map of the Project (Gambella – Itang –Jikawo Road project)

3.2 Physiography of the Project

i) Topography

The Gambella – Itang – Jikawo road project, which is the study area, is a Federal all weather gravel road DS 6 (according to ERA Design Standard 2002) located in the Gambella National Regional State and is considered as one of the main link roads in the region running predominantly through flat terrain parallel to Baro River on the right hand side, about 7km offset for certain length of the project. The road lies in areas that are covered by woodland and wooden grassland mixed with some trees and shrubs. The road topography starts at an elevation of about 480 m above msl at Gambella and falls gradually to an elevation of 413 m at Jikawo.

ii) **Climate of the Area**

In reference to Ethiopian Metrological maps the minimum and maximum temperature ranges from 22 to 47ºC with humidity greater than 1.0 and the mean annual rainfall of the area ranges between 1000 mm to 1400 mm. The project area is classified as Kola or warm [4].

Table 3.1: Mean Monthly Rainfall, Maximum and Minimum Temperature of the project (Gambella – Itang –Jikawo Road project)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Rainfall, (mm)	1	1	25	50	100	100	150	150	150	100	25	10
Max. Temperature (ºC)	35	40	40	35	35	30	30	35	30	35	35	35
Min. Temperature (ºC)	20	20	25	20	20	20	20	20	20	20	20	20

3.2.1 General Information About The Project Progress And Filler Problem of Gambela-Itang-Jikawo

3.2.1.1 The Manufacturing of Asphalt

The Contractor of the subject project, Ethiopian Roads Construction Cooperation (ERCC) has started the asphalt production on November 10, 2010 by purchasing the crushed stone dust from Chinese Contractor (China Jingaxi Cooperation for International Economy and Technical Cooperation) of the Metu-Gore road rehabilitation project, as the Contractor does not have the special dust mill (cone crusher). The project continues with this dust until January 31, 2012 for its asphalt production. When the Chinese Contractor completed and demobilized their dust mill from Metu-Gore project, the project has been in problems due to shortage of crushed dust filler for quite some time. Then the project management had made intensive efforts to find alternative fillers for the project. As a solution, the Contractor had found to use the natural sand (pagag sand) as filler which is available at the project area. The size of this natural sand is found in the range of 0 and 1.18mm sieve of which certain portion is less than 0.075mm (filler). However, due to the size limitation of this sand (0-1.18mm), it needs intensive sieving to get the required filler amount for the asphalt production. Therefore using this Pagag sand as filler source only and to continue the asphalt construction was not economical and it will be time consuming.

The project under consideration has no dust crusher to crush dust for the production of asphalt. The solution which was proposed to overcome the problem of dust was to use alternative fillers like cement and marble dust. Some studies revealed that cement and marble dust have comparable results with crushed stone filler in hot mix asphalt concrete. However, their effect on the performance of asphalt concrete varies when changing the type and aggregate gradation, the filler to asphalt ratio changes, type and proportion of filler.

3.3 Mix Design selection

Mix design is an important step in achieving well-performed asphalt pavement. In many cases, the cause of poorly-performing pavements has been attributed to poor or inappropriate mix design or to the production of a mixture different from what was designed in the laboratory. The Asphalt Institute advises that when developing a specific mix design, it is often necessary to make several trial mixes to find one that meets all the design criteria. It also adds that for preliminary or exploratory mix design it is advisable to start with a blended aggregate gradation that approaches the median of the specification limits [2]. Based on this principle, initial trial mixes are established with aggregate gradation that approaches the median of the project specification. In the Job Mix Formula different fillers by percents are added to satisfy the filler proportion in the mix and to determine cost effective filler combination using Marshall Mix design method. The gradation adjustment in the Job Mix Formula produces the filler content by total weight of aggregate of 6.72, 7.05 and 8.06%. The optimum asphalt content was determined by choosing the median of the percent air void limits, which is 3-5 percent for all the selected gradation using the method proposed by Asphalt Institute design method. Thus, all the calculated and measured mix properties for asphalt content at the given range of air voids (3-5%) were determined and then evaluated by comparing them to the Marshal Mix Design criteria shown in Table 3-8. Then after, an asphalt content that optimizes all the project specification values was selected as optimum asphalt content for respective mixes and the results are presented in subsequent section of this chapter.

Further investigation was done using the selected filler content of 8.06% at the optimum asphalt content with partial replacement of Pagag sand, cement and marble dust increasing proportionally in the mix by 5%, 10%, 25%, 50%, and 75%. In order to accommodate the increased quantity one type of filler by (5%, 10, 25, 50, 75%), an equal proportions of filler from the other fillers was decreased.

The mixes were prepared using crushed dust and Pagag sand, and crushed dust, Pagag sand and cement and crushed dust, Pagag sand, cement and marble dust at filler contents of 6.72, 7.05 and 8.06% respectively, by the total weight of mix. These contents cover the filler range which fulfills the project specifications. All Job-Mix-

Formula (JMF) for the aggregate particle size distribution that would be used for the preparation of mixtures are shown in Table 3-2 [4].

Table 3.2 Aggregate Gradation used for various Filler Contents

Percent Filler in Mix	**6.72%**	**7.05%**	**8.06%**	**Specification Limits**
Sieve Size (mm)	**Total Percentage Passing**			
1" (25.0mm)	100.00	100.00	100.00	100
¾" (19mm)	90.53	92.47	92.33	85-100
½" (14 mm)	79.04	81.60	81.24	71-84
3/8" (9.5mm)	68.10	72.75	72.23	62-76
No. 4 (4.75mm)	52.17	52.70	51.81	42-60
No. 8 (2.36mm)	34.28	34.83	34.69	30-48
No. 16 (1.18mm)	22.22	23.32	23.87	22-38
No. 30 (0.60mm)	15.75	16.46	17.42	16-28
No. 50 (0.30mm)	12.19	12.07	13.13	12-20
No. 100 (0.15mm)	9.18	8.72	9.68	8-15
No. 200 (0.075mm)	6.72	7.05	8.06	4-10

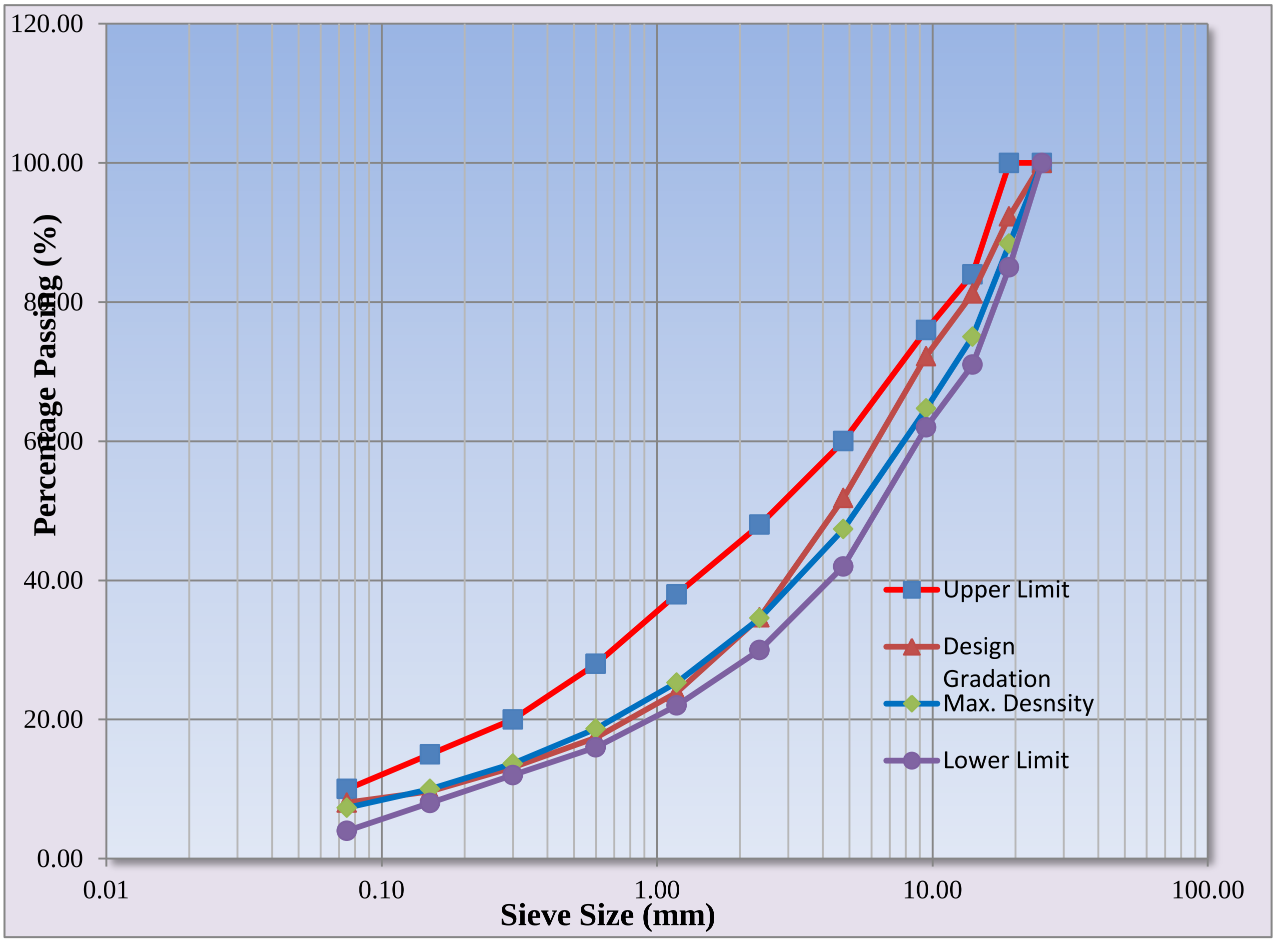

Figure 3.1 Selected Gradation Curve

3.4 Material Characteristics

In the design and construction of HMA mixtures, selection, proportioning and characterization of individual material is very important to obtain the desired quality and properties of finished mix. Coarse and Fine aggregate materials used in the study were collected from the project crusher site which is found at km 31+ 000 LHS from Gambela to Jikawo, marble from Ethiopian marble industry at Addis Ababa, Ordinary Portland Cement (OPC) from market and Pagag sand (natural sand) from natural source from pagag at border of Ethiopian and South Sudan. The 60/70 penetration grade bitumen was also collected from the market.

These ingredient materials are tested in the laboratory in order to determine their physical properties and establish whether they can meet the project specifications or not. The conducted quality tests include: gradation, Los Angeles abrasion, soundness, flakiness, aggregate crushing value, asphalt affinity, specific gravity and water absorption tests. However, the coarse and fine aggregate used water absorption is more than the specification requirement due to shortage of quarry sites. I have also used this aggregate source to conduct the laboratory, since my research work is project based and the Standard Technical Specification of ERA allows the water absorption for coarse and fine aggregate maximum of 2%. The results are shown in Table 3.3:

Table 3.3 Aggregate physical properties

S/N	Test description		Test Method	Result	Specification Requirements of the Project (ERA Manual)
1	Cleanliness and Deleterious materials,%		AASHTO T176	-	< 5 passing 0.075mm
2	Aggregate crushing Value		BS 812-110	16	<25
3	Los Angeles Abrasion		AASHTO T96	16.25	< 30
4	Durability and soundness, %	Sodium test	AASHTO T104	-	< 12%
		Magnesium test			<18%
5	Particle shape, Flakiness, %		AASHTO T176	30.1	< 45%
6	Aggregate Polishing Value		AASHTO		<50%
7	Water absorption, %		ASTM C 127	1.75	<2%
8	Specific Gravity (Bulk)	i. Coarse Aggregate	AASHTO T85	2.541	-
		ii. Fine Aggregate	AASHTO T84	2.628	-
9	Affinity for Asphalt (Coating and Stripping), %		AASHTO T-182	100	>95%
10	Absorption	i. Coarse aggregate	BS 812-105.2	1.262	<1%
		ii. Fine Aggregate	BS 812-105.2	2.136	<1.5%

3.4.1 Mineral Aggregate characteristics

The coarse and fine aggregate particles were separated into different sieve sizes and proportioned to obtain the desired gradation for bituminous mixtures which is given in the ERA Technical Specifications and the Particular Technical Specification of the Contract and described under Section 6400 which is shown in the above Table 3.2 last column.

3.4.2 Asphalt Binder

60/70 penetration paving grade bitumen was recommended by the specification to prepare filler-bitumen mixtures and was utilized for the preparation of asphaltic mixtures. The properties of the 60/70 binder specification requirement like penetration, flash point, ductility, purity and specific gravity tests were performed and test results are given in Table 3.4:

Table 3.4 60/70 Asphalt Binder Physical Properties and Test Results

No.	Test Description	Test Method	Test results	Specification Requirement
1	Water content (%)	AASHTO T55	Nil	Nil
2	Penetration 25°C,100 gm , 5 sec.	AASHTO T49	65	60 – 70
3	Flash Point, ^{o}C	AASHTO T48	586	Min 232
3	Loss on Heating (%)	AASHTO T47	-0.3	Max 1
5	Ductility, (25^{0}C , 5 cm/min)	AASHTO T51	100*	100
6	Softening point (Ring &ball)	ASTM D-36	52	>46
7	Specific Gravity at 25^{0}C (kg/m^{3})	AASHTO T228-06	1020	1010

3.4.3 Physical Properties of Mineral Filler

When an asphalt mixture is designed, it is essential to check if the solid particles are adequately coated with asphalt cement to maintain the required performance. This verification is mainly based on the surface area, $S_{A,}$ expressed in square meters per kilogram of dry solids (m^2/kg). 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 [24]. The filler fraction has the highest contribution to the surface area. As can be seen from the results, as the filler content increases in the aggregate proportion, the specific surface area will also increase.

The usual methods to determine $S_{A,}$ are approximate, and often based on experience with local crushed rock materials. Hveem developed a simple method to calculate the asphalt mixtures with surface area factors which are related to a given sieve size, and are to be multiplied by the total percentage of aggregate passing that sieve. You refer section 2.5 about the surface area factor.Hveem [24] also defined values of $S_{af, No.}$ for sieves No. 4, 8, 16, 30, 50, 100, 200 as being 0.41, 0.82, 1.64, 2.87, 6.14, 12.29, 32.77 m^2/kg respectively. The surface area for fines is 32.77m^2/kg.

The mineral fillers, used the current study namely crushed stone, Pagag sand, cement and marble dust, are all materials passing No. 200 sieve. Their physical properties, which are believed to be major suspects of affecting the bituminous mixture property [18], such as gradation parameters and plasticity index were determined as shown in Table 3-5 and 3.6.

Table 3.5 Grain size Analysis of Fillers

Sieve size in mm	Crushed Dust	Pagag Sand	cement	Marble Dust	Remarks
4.75	100	100	100	100	
2.36	100	100	100	100	
1.18	100	99.9	100	98.9	
0.60	99.89	98.6	100	98	
0.30	97.97	97.5	100	97.1	
0.15	83.4	95.5	100	95.4	
0.075	59.27	94.5	96.88	88.4	
0.033	55.5	90.5	NA	78.1	
0.022	51.67	68.6	NA	72.2	
0.013	47.65	54.5	NA	66.7	
0.009	45.93	47.5	NA	-	
0.007	40.83	33.3	NA	-	
0.003	37.45	20.5	NA	-	
0.001		10.1	NA	-	

NA* Not Applicable

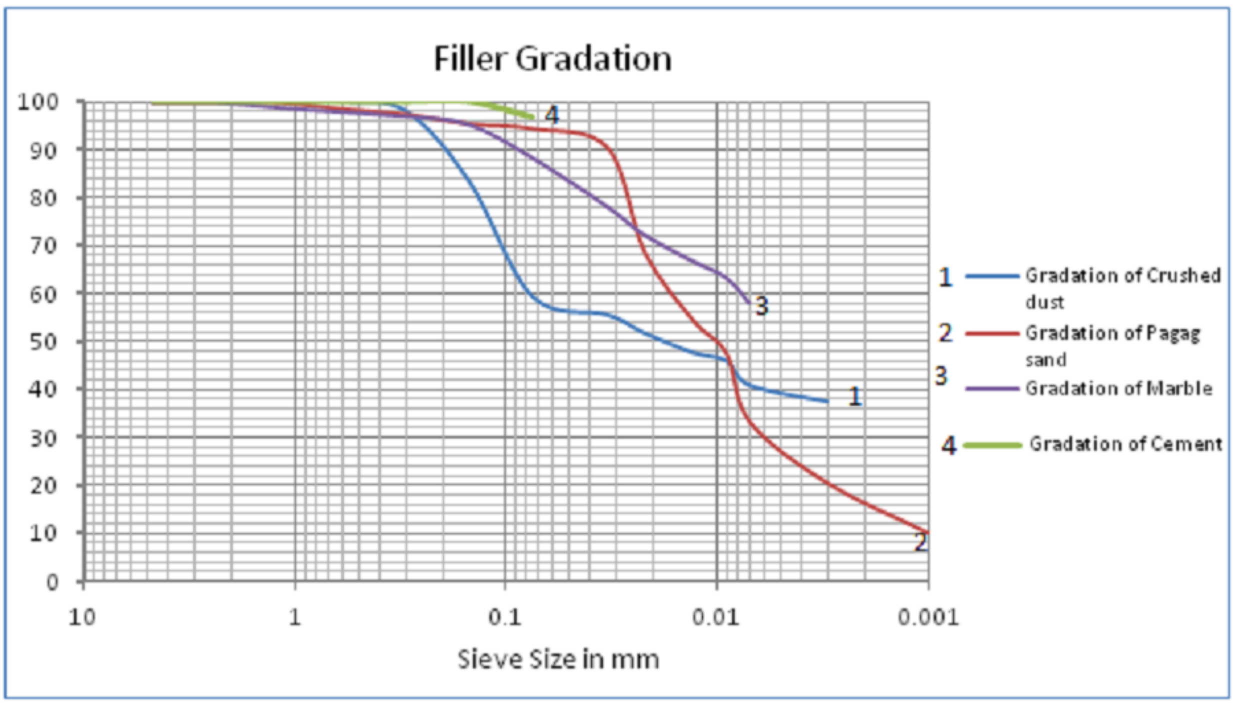

Figure 3.3 Fillers Gradation

Table 3.6: Physical Properties of Mineral fillers

No.	Test	Filler Type			
		Crushed Dust	Pagag Sand	Cement	Marble Dust
1	Specific Gravity	2.823	2.591	2.936	2.873
2	% Passing sieve No.200 ASTM C117	5.16	11.98	100	88.44
3	Surface area (m^2/kg)	41.42	50.25	56.94	54.36
4	Plasticity Index	NP	NP	NP	NP

The fineness indicator is calculated by dividing 100 the sum of the percentage of filler retained on a standard series sieve (75, 50, 30,20,10,5,3 and 1 micron).

3.5 Experimental Work (Marshall Tests)

3.5.1 Outlined Procedure of Marshall Test Method

The experimental works were started by determining the optimum asphalt content using the Marshall Mix Design method and with the compaction effort of 75 blows. The 75 blows compaction effort is taken from the Marshall criterion for heavy traffic which is suggested for asphalt concrete Mix design [20] and shown in Table 3.6.

Table 3.7: Suggested Marshal Mix Design Criteria MS-2 (Table 5.2)

Description	Light Traffic Surface and Base		Medium Traffic Surface and Base		Heavy Traffic Surface and Base	
	Min	Max	Min	Max	Min	Max
Compaction number of blows at each end of specimen	35		50		75	
Stability No.(N)	3336		5338		8006	
Flow, in 0.25mm	8	18	8	16	8	14
Percent Air Voids	3	5	3	5	3	5
Percent Voids in mineral aggregate (VMA) for 19mm nominal aggregate size and 4% air void	12	14	11	13	13	
Percent filled with Asphalt (VFA)	70	80	65	78	65	75

Tests were conducted in the laboratory to characterize the aggregate and mixture properties. The procedure for the marshal method starts with the preparation of tests specimens. The first step prior to specimen preparation is testing all the physical requirement of the project specifications if the material proposed for use meet the requirement or not. Then materials which fulfill the specification under gone aggregate blend combinations to meet the gradation requirement of the project specifications. For performing density and void analyses, the bulk specific gravity of all aggregate used in the blend and asphalt cement was determined and shown with the test result of the marshal properties in Appendix A. The Marshal method uses standard specimen of 64mm height by 102mm diameter [2].

3.5.2 Preparation of specimen

The preparation of aggregate involves drying the aggregate to constant weight at 105^{o}C to 110^{o}C and separate the aggregate by dry sieving into desired size fractions. Before the preparation of test specimens, mixing and compaction temperatures were determined. The determination of mixing and compaction temperature - the temperature to which the asphalt mix must be heated to produce viscosities of 170±20 centistokes kinematic for mixing and 280±30 centistokes kinematic for compaction was established by testing the asphalt cement viscosity at different temperatures and plotting the viscosity versus temperature relationship. Then preparation of the mixture starts by weighting into separate pans for each test specimen the amount of size fraction required producing a batch that will result in a compacted specimen 63.5±1.27mm in height. This will be normally being about 1.2kg. Then, these ingredients were mixed at a temperature of 135^{0}C, as previously determined. The percent by weight of asphalt content for all mixes was taken with respect to the total weight of the mixture. The mixture was then placed into the mould after placing a paper disk in the mould. Having placed the entire batch in the mould, spade the mixture vigorously with a heat spatula or trowel 15 times around the perimeter and ten times over the interior. Smooth the surface slightly rounded shape [2].

Compaction of the specimen will be done by placing a paper on the top of the mix and placing the mould assembly on the compaction pedestal in the mould holder. As specified according to the heavy design traffic category of the project and based on Marshall Mix Design criteria as shown in table 3.5, the mix was compacted using 75 blows of either side with the compaction hammer with free fall of 457mm. After compaction, the specimen were allowed to cool and removed from the mold by means of an extrusion jack or other compression device. Normally, specimens are allowed to cool overnight. In accordance with the Marshal procedure, each compacted test specimens were subjected to determination of unit weight, void analysis, and stability and flow tests. Then, plots were made to determine values of each respective specimen prepared using different types and proportion of mineral fillers as indicated in Appendix A [2].

Based on the requirements for Laboratory Design mix given by the ERA Technical Specification (the project specification) and the results obtained for the different fillers content are shown in the next Table 3.8 and the Marshal properties for different filler percentage each asphalt content are indicated in graphs and in Table-1A as given in Appendix-A.

Table 3.8 Range of Values for Laboratory Design Mix and Test Results for different filler Percentage

No.	Mix Requirements	Unit	Marshall Criteria Project Specification Range	Test Result for 6.72% Filler	Test Result for 7.05% Filler	Test Result for 8.06% Filler	Remark
1	Bitumen Content	(%)	4.6-5.4	5.1	5.0	5.0	
2	Marshall Stability	(KN)	Min 9.0	11	9.5	9.7	
3	Flow	(mm)	1.5-4	3.0	2.5	2.20	
4	Air Voids	(%)	3.5-4.5	4.7	4.6	5.6	
5	Voids in Mineral Aggregate	(%)	16-20	14	13.4	16.9	
6	Voids filled with Bitumen	(%)	65-75	67	65.9	67.1	
7	Filler / bitumen ratio by wt	-	1.2-1.8	1.47	1.41	1.6	

3.5.2 Partial Replacement of Fillers

In this study, fifteen sets of bituminous mixtures using different types and amount of mineral fillers were evaluated using Marshall Mix Design method. Theses mixtures were prepared using Pagag Sand, Portland cement and Marble dust fillers with varying the content by total mixture and their effects on Marshall Properties were assessed. The results of all Marshall Properties tests using the designed asphalt content of 5% are summarized in Table3.9 for mixtures with different replacement of filler content. The test results obtained in this research are discussed in the following sections. All results are shown for each specimen is average value of the three tests.

Table 3.9 Summary of the Partial Replacement of different Fillers in Asphalt Concrete mixtures at 5% bitumen content with 8.06%.

Marshall Property	**Filler Type**	**Partial Replacement of Filler (%)**				
		5%	**10%**	**25%**	**50%**	**75%**
Air Void %	Pagag Sand	5.3	5.5	5.7	6.1	6.4
	Cement	5.8	5.2	4.7	4.0	3.4
	Marble Dust	5.5	5.0	4.6	3.7	3.5
Marshall Stability (KN)	Pagag Sand	9.7	9.8	10.0	9.7	9.5
	Cement	7.7	8.0	7.7	9.6	5.8
	Marble Dust	8.4	8.2	7.8	7.7	8.2
Marshall Flow, (mm)	Pagag Sand	2.28	2.26	2.17	2.16	2.04
	Cement	2.11	2.39	2.27	2.37	2.59
	Marble Dust	2.39	2.59	2.46	2.58	2.56
VMA, (%)	Pagag Sand	16.5	15.9	15.6	15.1	14.5
	Cement	13.0	14.5	15.1	16.6	16.7
	Marble Dust	13.2	14.3	14.2	14.3	14.6
VFA, (%)	Pagag Sand	67.7	65.4	63.4	59.6	55.9
	Cement	55.2	63.9	69.1	75.8	79.7
	Marble Dust	58.8	65.0	67.5	74.2	76.4
Bulk Density (kg/mm^3)	Pagag Sand	2.286	2.292	2.294	2.30	2.308
	Cement	2.301	2.308	2.314	2.322	2.330
	Marble Dust	2.299	2.306	2.323	2.336	2.334

CHAPTER4: DISCUSSION OF TEST RESULTS

4.1 Introduction

This chapter provides the discussion of test results obtained from different type and proportion of mineral fillers using the Marshal Mix design method. Mixes at their optimum asphalt content for various types and contents of filler are tested for Marshall Properties and the results are summarized in chapter 3. The test results obtained in this research are discussed under subsequent sections.

4.2 Effect of Filler Type and Contents on Unit Weight

The usual trend in relation to the bulk density of the compacted mixture shows increasing the asphalt content and the amount of filler in a mix both increase the density of the mix up to certain limit and then decreases because of forming thicker films around the aggregates thereby pushing the aggregate particle further apart resulting in lower density. However, as it seen in the figure 4.1 below the bulk density curves do not show decrease as the filler content increases because the filler proportion increase was within the designed filler percentage.

From Table 3.9 and Figure 4.1, mixes made with all type of fillers (Pagag sand, cement, marble dust) exhibit nearly similar trend of increase in unit weight as filler content increases for mixes made with partial replacement of all filler proportions, regardless of the filler type, the unit weight obtained is relatively the same. It is shown that mixes made with cement and marble dust, the unit weight is almost identical results. This may be due to with cement and marble dust possessed a bit higher unit weight values of 2.314 kg/m^3, 2322 kg/m3 and 2323 kg/m^3, 2336kg/m^3 respectively.

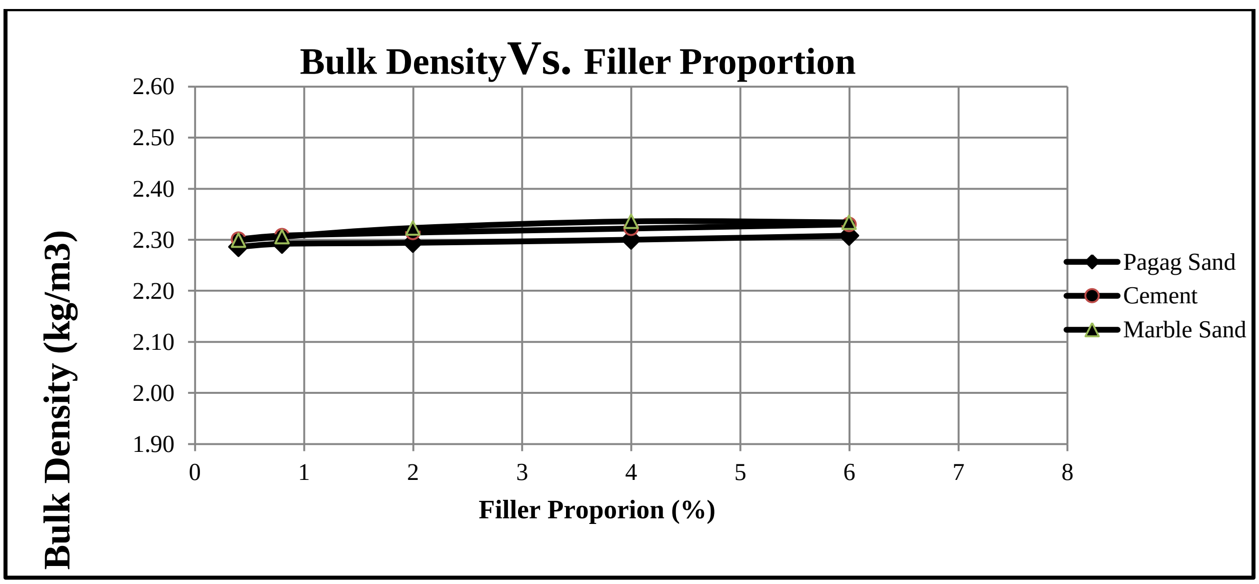

Figure 4.1 Effects of Filler Type and Content on Bulk Density

4.3 Effect of Filler Type and Proportion on Marshall Stability

Figure 4-2 shows the results of Marshall Stability as a function of varying the filler proportion and type. It is shown that for mixes made with cement, the stability increases with the increase of percentage up to 50% and then decreases when the proportion increases. This can be explained by the fact that adding a certain amount of dust improves the viscosity of the asphalt cement however, increasing beyond a certain limit it modifies the asphalt mixtures more by extending the asphalt binder, hence would rather give lower stability values. The result also indicates that there exists an optimum cement filler proportion that gives better stability. On the other hand, the stability values obtained by mixes made with Pagag sand is relatively higher than all mixes made with either cement or marble dust fillers. This can be related to coarser property of Pagag sand which may not modify the asphalt cement. For mixes made with marble dust, all the values are lower than the limits set by the project specifications. This abnormal feature of the marble dust may be due to high stiffening of the asphalt cement and extension of the binder making the mix appear to have excessive asphalt content. Therefore further investigation is required regarding the asphalt cement and marble dust extending property of the mixture when we are using marble and cement as combined filler.

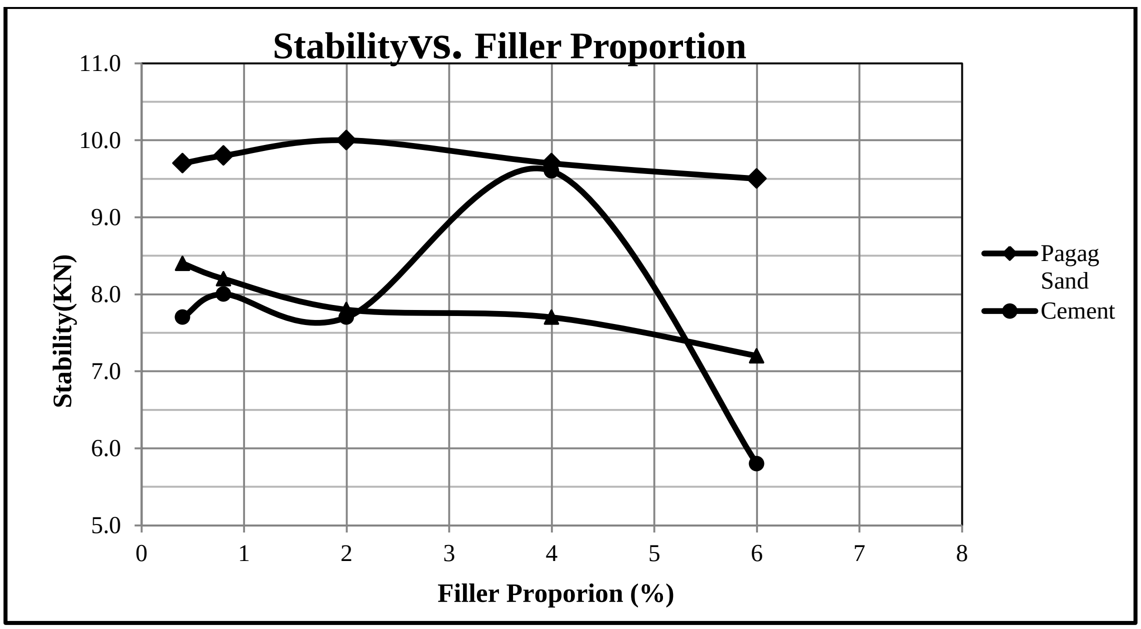

Figure 4.2 Effect of filler type and content on Marshall Stability

Further reason for better stability obtained by Pagag sand may due to the coarseness of Pagag sand as compared with the other two fillers which implies has less surface area and it needs less bitumen content which will contribute for greater stability up to certain percentage of filler content, where as cement has very fine from the other two fillers it may need much bitumen content to have a better stability than the other two. In addition the better stability obtained from Pagag sand may probably be the result of some filler may be added in relatively large quantities without stiffening the binder.

4.4 Effect of Filler type and Proportion on Voids in the Mineral Aggregate (VMA)

Figure 4-3 demonstrates the effect of filler type and replacement proportion on void in the mineral aggregate (VMA). In order to have adequate film thickness for a pavement, there must be sufficient space between the aggregate particles in the compacted pavement. This void space is referred to as Voids in the Mineral Aggregate (VMA). It must be sufficient to allow adequate effective asphalt and air voids. From the figure 4-3 VMA decreases as the amount of Pagag sand proportion increases. This is a common trend that, as filler content in the mixes increases the void in the mineral aggregate decreases up to minimum value and then increases at higher content. However, in Pagag sand, under the given proportion, it is not showing the minimum value and decreasing even if the proportion in the mixes increases. This may also be because of the filler proportions is within the design filler content. Increasing the Pagag sand proportion to 75% we can get comparable results when we are using 10% proportion of cement and marble dust. Particle size distribution curves also indicate that cement and marble dust is finer material than pagag sand.

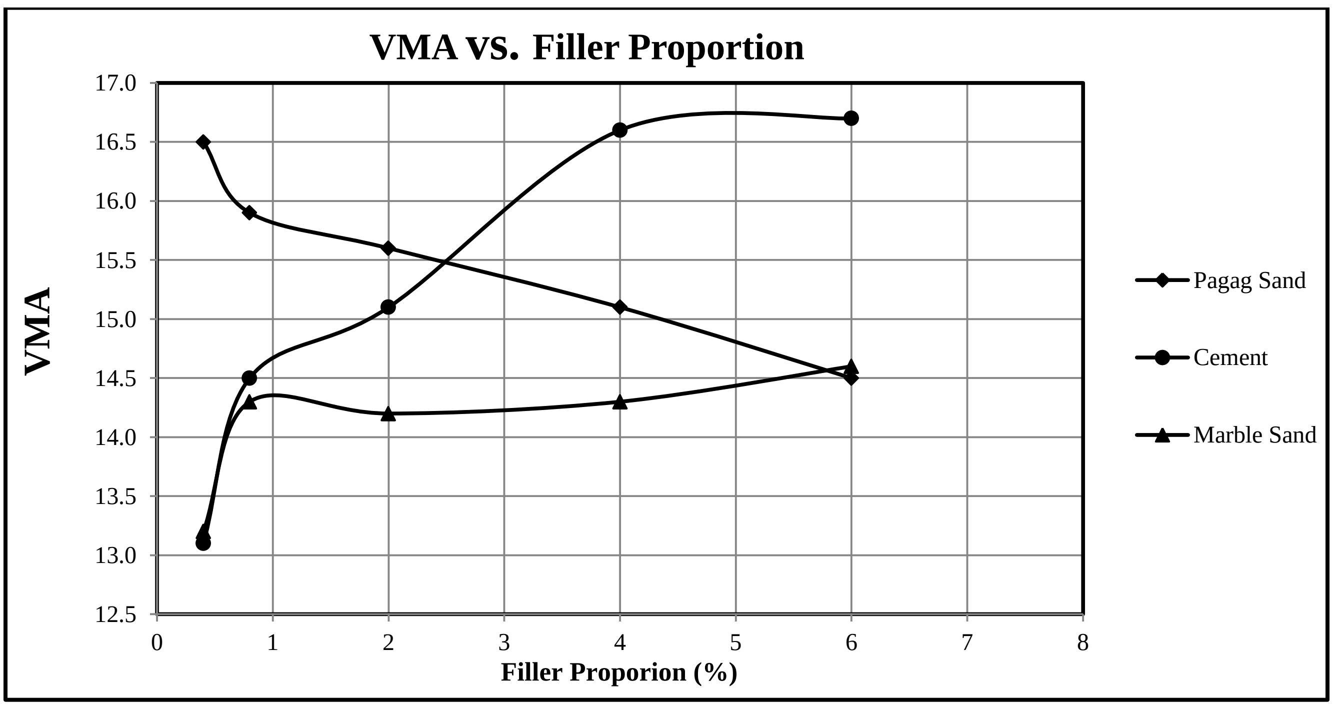

Figure 4.3 Effect of filler type and content on VMA

On the contrary, the result of the test indicates that when the proportion of Cement and Marble dust filler increases in the mixture VMA also increased. This is probably due to the fact that the total void space between small particles is greater than that between lager particles. For given effective bitumen content, the film thickness will be greater if the filler mixture coarser.

Using higher proportion of cement and marble dust fillers in the mixture resulted higher values of VMA and may suffer durability problem and since the mix may needs higher bitumen content to coat the mixture it may not be economical,. It is shown that at 5% and 10% proportion of cement and marble the mixture achieve VMA of 13, 13.2% and 14.5, 14.3% respectively, which is the minimum recommended value of ERA specifications for project. In HMA mixtures minimum VMA is necessary in order to accommodate enough asphalt content, so that aggregate particles can be coated with adequate asphalt film thickness. It is clear that all the VMA values are within the specification limit set by the project. Even though the VMA test result of cement and marble are within the project specification limits the stability problem may result from extending property of cement and marble on the asphalt binder.

4.5 Effect of filler type and proportion on Air Void

As can be seen from Figure 4.4 below the air void increases as the amount of Pagag sand replacement increases in the mixture within the given range of filler content. Using more Pagag sand as filler only may need higher asphalt cement to increase film thickness which is essential for durability. Replacement of Pagag sand more than 50% in the mixture shows an increase of the air voids beyond the specification limits on contrary it may also need high bitumen content more than 5% which is uneconomical. This may result from the coarser nature of Pagag sand as compared with the other two filler which may not extend the asphalt cement. However, with increasing cement and marble dust replacement in the mixture it has shown similar trend in decreasing in air voids. This is due to the fact that, cement and marble is finer than Pagag sand which may stiffen the binder and fills the voids.

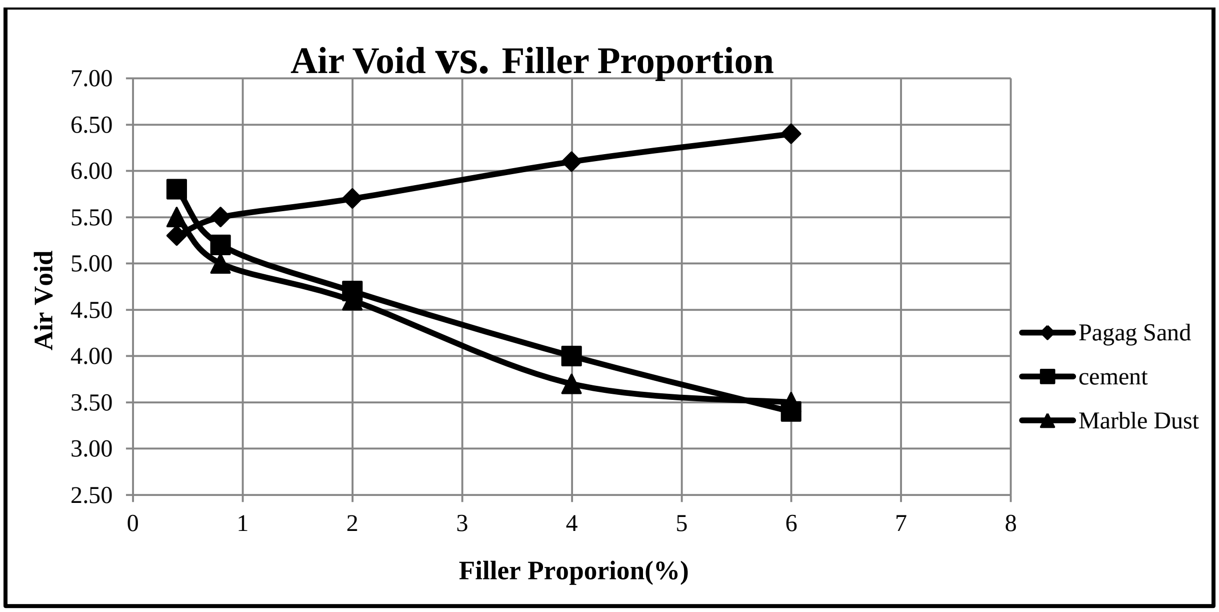

Figure 4.4 Effect of filler type and proportion on Air Void

4.6 Effect of filler type and proportion of the Marshall Flow property

From the findings of the laboratory test results as is shown in Figure 4.6, the Marshall Flow values obtained from replacement of marble dust filler resulted higher values as compared to cement and Pagag sand. This is the result of increasing the air void as the replacement proportion of dust increases that may extending the asphalt cement forming mastics and filling the void. The replacement of cement also shows the same trend as marble dust. When the replacement proportions of cement increases by more than 50% the flow values start decreases, however, the value is still within the specification limits. This may be due to the fineness of cement which can easily modify the properties of asphalt cement like the marble dust. This phenomenon did not work for the mixtures prepared using Pagag sand fillers. When the proportion of Pagag sand increased in the mixture the flow values decreases. This is probably because of more voids result, when the Pagag sand replacement increased in the mixture the air void also increased which can give better air void space for mixture without deformation.

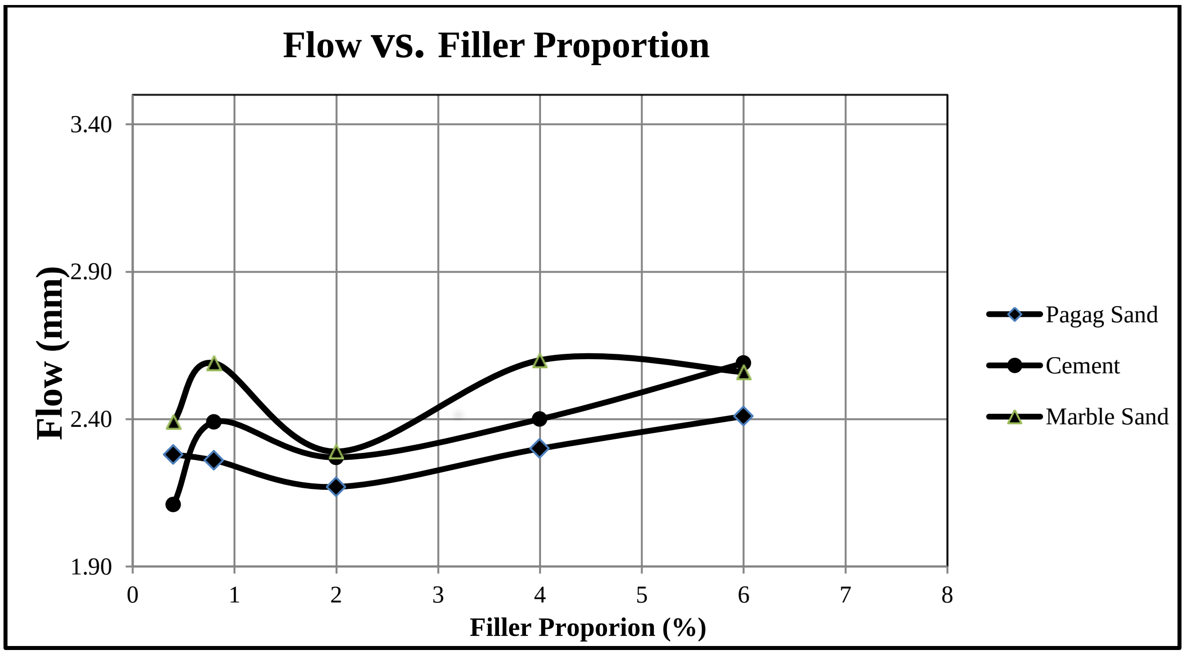

Figure 4.5 Effect of filler type and proportion on Marshall Flow

4.7 Effect of filler type and proportion on the VFA

Figure 4-6 shows effect of filler type and proportion on the voids filled with asphalt property of the mixture. From the figure the voids filled with asphalt values for mixes prepared by cement and marble dust are increased.

The Marshal Criteria set under the specification for VFA is 65% - 75%. The durability of mixes is related to the effective asphalt content in the mix. If the percentage of voids filled with asphalt is lower than the limit indicated, there will be less asphalt film around the aggregate particles which will be subjected to moisture and weather effect by easily oxidizes and detached from the aggregate particles and subsequently lower performance of the mixture. On the other hand, if the limit is exceeded, more voids are filled with asphalt than required for durability, however, it will face stability problem. From Table 4.1 and the above Figure 4.6, we see the VFA values obtained by preparing mixes with cement and marble dust, the VFA values increased as usual trend. The replacement of marble dust at 10%, 25%, and 50% and cement replacement at 25% and 50%

satisfy the specification limits. However, when more Pagag sand filler used in the mixture, the VFA values decreased. This can be related with the properties which are observed in air voids as the filler content increase in the mixture the value of air voids increased so that the mix needs more asphalt cement to fill the voids which is not economical.

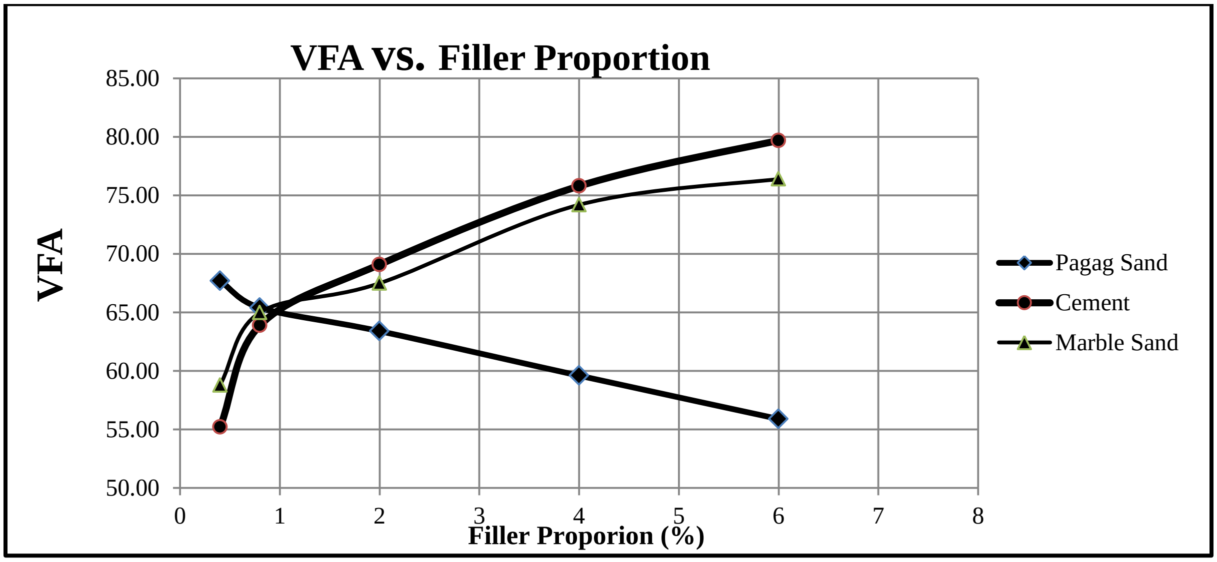

Figure 4.6 Effect of filler type and proportion on the VFA

Study conducted [18] to investigate the premature failure of newly constructed highway pavements in Saudi Arabia, on the effect of Marshall Stability as a function of varying filler content and type shows as Portland cement increases in Marshall Stability up to 8%. Comparable result is obtained in this research that mixes made with Portland cement or marble dust, the stability increases with the increase of up to 50% from the filler proportion; however, in this study it decreases when the proportion in the mixes increases more than 50%. The effect of both filler type and their contents on the unit weight in the compacted mixes due to the replacement of limestone by hydrated lime shows a trend of increase in the unit weight. However, the opposite trend was observed for mixes partially replaced by Portland cement. But in this study the partial replacement of mixes with either Portland cement or marble dust does not show a significant increase in their unit weight of in the compacted mixes. This may be due to the replacement proportions was not out of the control percentage of filler. In Saudi, with regard to air void the effect of replacement process depends partially on the total filler content. When the filler content increased from 3% to 8% the increased in air void shows an increase with128% as compared with 3% increase which is 30%. Whereas in this study with increasing cement and marble dust replacement in the mixture it has shown similar trend in decreasing in air voids. Since, the replacement proportion in this study is under control the content of filler we cannot observe the increase in the air void. In their research, they observed that when the replacement of limestone by hydrated lime or Portland cement up to 3% the Marshall Flow value which yields the minimum Marshall Flow value. In this study also shows when the replacement of the mixes by either Portland cement or Marble dust increases it shows an increase in the flow value. However, the result obtained is not out of the given project specification values stated under the contract.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the findings of the laboratory test results and review of literatures made on the effects of fillers on bituminous mixtures, the following conclusions are drawn:

- Pagag sand replacement up to 50% in the mixture shows acceptable air voids, Marshall Stability and flow values and maximum VMA values. However, from the VFA values the replacement of Pagag sand by more than 10% shows a decrease in values below the specification limit.

- Using 50% cement filler from the total proportion of design filler content (8.06%) in the mixture satisfies all the Marshall Properties. However, increasing the more than 50% replacement in the mixture test result shows it fulfills the Marshall properties under the project specification except the stability requirement. It is also observed that the Marshall Stability values obtained from cement filler is not uniform when we increase the replacement proportion. This may be due to creation of stabilization that leads to shrinkage cracking or asphalt stiffening effect. Since the cement filler Marshall Stability property obtained is not showing a defined trend, it would be difficult to give an explanation on this property based on this laboratory investigation only.

- Mixes prepared by partial replacement of marble dust at a given proportion produce values within the specification limit for air void, VMA, VFA and Bulk density. However, we get all test results for stability and Marshall Flow Values below the specification limits.

- It was found that mixes prepared by use of marble dust up to 25% replacement at given proportion produce values within the specification limit for air void, VMA, VFA and bulk density. In addition, the test results show that minimal use of marble dust filler in the mixture has better results for stability and flow as compared with higher replacement proportion.

- The addition of cement and marble dust to asphalt concrete as filler within the project specification has relatively the same comparable Marshall properties.

- From the Job Mix formula adjustment made and laboratory test results obtained, the project has used filler combination that resulted in better mixture properties on the given road project, i.e. using crushed stone, Pagag sand, cement and marble dust fillers. From the test results obtained, Pagag sand 2.5%, cement at 1.5% and marble dust 3.5% percent filler.

5.2 Recommendations:

Based on the conclusions above, the following recommendations are proposed:

1. Comprehensive laboratory study needed on the Marshall Stability and Flow of the mixes prepared by cement and marble dust to determine the relation between these fillers and the optimum bitumen content rather than using 5% bitumen content (specific for the project case) to see the stability and flow property changes.

2. Mixtures prepared with replacement of marble fillers show relatively similar trend as cement when compared to the Pagag sand. Nowadays, it is becoming common to use marble dust material as fillers in asphalt mixtures and researches show that it can be used in asphalt paving mixtures as an alternate to the widely used crushed stone. However, this study indicates that further investigation on the characterization tests for cement and marble fillers especially on Marshall Stability and flow properties in relation with the performance of asphalt concrete are needed. The investigation should also seek for its suitability in the asphalt mixtures as alternative mineral filler to the crushed stone. For cement and marble dust filler, in relation with the performance of asphalt concrete that would better simulate the actual field condition like stabilization and early shrinkage is important.

3. In this research, only Marshall properties under project specification is studied using Pagag sand, cement and marble dust; therefore, further investigations are required on the following areas.
    - Studies should be made by blending marble dust with cement using different Proportion with more percentage of marble dust replacement.
    - Detail study of durability of hot mix asphalt performance made by marble dust blended with cement or crushed dust shall be made.

4. Limits of filler content should be specified in the ERA current specification when combinations of fillers used and further investigation are to be carried out on cement and marble fillers with respect to Marshall Stability and flow values to be used widely as filler material.

Finally, the results and findings of this research work may be considered as indicative only for further studies as these findings are based on limited laboratory testing equipments and small number of samples. More elaborate sampling and using Hveem Stabilometer and gayratory compactor detail investigation shall be needed before concluding the performance of cement and marble dust as alternative filler in ERA standard technical specification for hot mix asphalt.

References

1. Zemichael Berehe Mehari, Effect of Different Types of Filler Materials on characteristics of Hot-Mix-Asphalt Concrete, 2000
2. The Asphalt Institute, Mix Design Methods for Asphalt Concrete and other Hot Mix Types, MS-2, Sixth Edition, 1995.
3. Roberts, F.L., P.S. Kandhal, E.R. Brown, Dah - Yinn Lee, and T.W.Kennedy. "Hot Mix Asphalt Materials, Mixture Design and Construction", NAPA Education Foundation Lanham, Maryland, 1991.
4. Engineering Report (2007), Design Document of Gambela-Itang Jikawo Road Project, ERA
5. Ducatz Ervin L. JR.," Aggregate Properties Related to Pavement Performance, "APT, Vol.58, pp.492-501, 1989.
6. Anderson, D. A. " INFLUENCE OF FINES ON PERFORMANCE ON ASPHALT CONCRETE MIXTURES"
7. Freddy L. Roberts, Prithivs. Kandal, E. Ray Brown " Hot Mix Asphalt Materials, Mixture design and Construction"
8. The Asphalt Institute, The asphalt Handbook, MS-4, 1989 Edition

9 Annual Book of ASTM Standards, Vol. 04.02, American Society for Testing and Materials, 1998.Meininger, Ed., American Society for Testing and Material, Philadelphia, 1992

10 Washington Asphalt Pavement Association, Inc. 2002, (http:/www.asphaltwa.com/wapa-web)

11 Goode, J.F. and Lufsey, L.S., "A New Graphical Chart for Evaluating Aggregate Gradations," Proceedings of the Association of Asphalt Paving Technologists, Vol. 31, 1962, pp. 176-207.

12 Freddy L. Roberts, Prithvi S-Kandhal, E Ray Brown "Hot Mix Asphalt Materials, mixture Design

13 Annual Book of ASTM Standards, Vol. 04.03, American Society for Testing and Materials, 1998.

14 Todd V Scholz, Durability of Bituminous paving Mixtures

15 Parker, F. and Brown, E. R., ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia, 1992, Analysis and modeling of Rutting for Long Life Asphalt Concrete Pavement and "Effects of Aggregate Properties on Flexible Pavements Rutting in Alabama," Effect of Aggregates and Mineral Fillers On asphalt Mixtures Performance,

16 Kim, Y.R., Kim, N., and Khosla, N.P., "Effect of Aggregate Type and Gradation on Fatigue and Permanent Deformation of Asphalt Concrete" "," Effect of Aggregates and Mineral Fillers On asphalt Mixtures Performance," ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia, 1992

17 Roberts et al.1996, " Laboratory Evaluation of moisture susceptibility Tests between asphlt binder and aggregate

18 ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing and Material, Philadelphia, 1992, " Effect of Aggregates and Mineral Fillers On asphalt Mixtures

Performance,”

19 Bruce A. Chadbourn Eugene L. Skok, Jr. Benita L. Crow Samantha Spindler “The Effect of Voids in Mineral Aggregate (VMA) on Hot-Mix Asphalt Pavements”

20 Eng.Noor M. Asmael, and Rajan Choudhary “ EFFECT OF MINERAL FILLER TYPE AND CONTENT ON PROPERTIES OF ASPHALT CONCRETE MIXES”

21 Bruce A. Chadbourn, Eugene L. Skok, Jr., Benita L. Crow and Samantha Spindler Minnesota Department of Transportation Office of Research Services “The Effect of Voids in Mineral Aggregate (VMA) on Hot-Mix Asphalt Pavements”

22 Ethiopian Roads Authority (ERA) Design Manual-2002

23 Nijboer, L.W., Plasticity as a Factor in the Design of Dense Bituminous Road Carpets, Elsevier Publishing, New York, 1948.

24 Hveem, F.N., "Mix Design Method for Asphalt Concrete”, MS-2, The Asphalt Institute, College Park, Md. 930-111, Alabama Highway Department, Montgomery, Alabama, January, 1987.

25 Fouad and M. Boyomy, Development and Analysis of cement coated Aggregate for Asphalt Mixture

26 Dukatz, E.L. and R.S. Phillips, "The Effect of Air Voids on the Tensile Strength ratio," Proceedings, Association of Asphalt Paving Technologist, Vol. 56, 1987.

27 Abrar Awol**. “**Using Marble Waste Powder in Cement and Concrete Production”

28 Abdulrahman Al-suahaibabi, Jamal Al-Mudaiheem, and Fahd Al- Fozan, “Effect of Filler Type and Content on Properties of Asphalt Concrete Mixes”

29 Hassan Y. Ahmed*, Ayman M. Othman** and Afaf A. Mahmoud*** “EFFECT OF USING WASTE CEMENT DUST AS MINERAL FILLER ON THE MECHANICAL PROPERTIES OF HOT MIX ASPHALT “

30 Kandhal, P.S., C.Y. Lynn, and F. Parker, Jr., NCAT Report No.98-2. Auburn University, AL., January 1998.Characterization Tests form Mineral Fillers elated to Performance of Asphalt Paving Mixtures.

31 Shahrour, A.M., and Saloukeh, G.B., “Effect of Quality and Quantity of Locally Produced Filler (Passing Sieve No. 200) on Asphaltic Mixtures in Dubi”, Effect of Aggregates and Mineral Fillers on Asphalt Mixtures Performance , ASTM STP 1147, Richard C.Meininger, Editor, American Society for Testing and Materials, Philadelphia, 1992.

32 JONES, D., Fu, P. and Harvey, J. 2008. Full-Depth Pavement Reclamation with Foamed Asphalt: Final Report. Davis and Berkeley, CA.: University of California Pavement Research Center. (UCPRC-RR-2008-07).

33 Kandhal et al. 1992; Kim et al. 1992, (Brown et al. 1989), Effect of Aggregate Gradation with Fuller Distribution on Properties of Sulfoaluminates Cement Concrete.

34 Frazier Parker and E. Ray Brown, “quality of Aggregate properties on Hot Mix asphalt.”

35 Fuller and Thompson, 1907, “ The Classical Aggregate Gradation Theory”

Appendix A

Sieve Analysis of Aggregate and their Gradation

Appendix B

- Asphalt Mix Design including Marshall test Result with 6.72% Filler Content
- Asphalt Mix Design including Marshall test Result with 7.05% Filler Content
- Asphalt Mix Design including Marshall test Result with 8.06% and the Test Results of the Replacement for Different Filler Proportion