EFFECT OF CRUDE PALM OIL (CPO) AS AN ADDITIVE IN THE ASPHALT MIXTURE

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ABSTRAK

Terdapat pelbagai jenis kaedah yang digunakan untuk menghasilkan Hot Mix Asphalt (HMA) untuk jalan perkerasan jalan seperti Marshall Mix Design, Hveem Method dan kaedah terbaru yang disebut Superior Performing Pavement Asphalt atau Superpave. Terdapat banyak masalah yang timbul berkaitan dengan penjagaan kesihatan pekerja di tapak pelepasan dan pelepasan haba dan bau. Pelepasan haba dan bau semasa penempatan adalah berbahaya kepada orang ramai berhampiran tapak pembinaan dan yang paling terjejas adalah pekerja pembinaan. Selain itu, PAH iaitu Polycyclic Aromatic Hydrocarbon di mana pelepasan asap yang paling berbahaya boleh didapati semasa proses pencampuran Hot Mix Asphalt (HMA). PAH mengandungi karsinogenik, mutagenik dan teratogenik yang boleh membahayakan kesihatan. Menyelamatkan penggunaan tenaga pasti membantu dalam pelepasan gas rumah hijau dan pemuliharaan sumber semula jadi. Kajian ini dijalankan untuk menentukan potensi Minyak Sawit Mentah sebagai campuran dalam campuran aspal untuk mengurangkan suhu pencampuran Hot Mix Asphalt. Di samping itu, kajian ini juga memberi tumpuan kepada penilaian sifat-sifat mekanik spesimen (minyak sawit mentah) dalam Kaedah Rekaan Mix Marshall. Pelepasan jalan yang fleksibel yang akan dibina dengan menambahkan 0.3% daripada CPO ke campuran asfalt campuran panas boleh diperbaiki dari segi mengurangkan haba dan pelepasan gas berbahaya tanpa menjejaskan kebolehkerjaan, ketahanan, kestabilan dan kekuatan HMA. Semua ujian yang berkaitan telah dijalankan di makmal lebuh raya untuk mengumpul data dan menentukan sifat Marshall HMA. Semua maklumat yang berkaitan dengan prosedur, proses dan teknik yang digunakan untuk menghasilkan HMA dengan tambahan MSM akan dijelaskan secara terperinci dalam kajian ini. Maklumat dan garis panduan yang digunakan untuk mendapatkan dan mengira semua sifat bahan untuk HMA untuk memastikan campuran yang dihasilkan akan memenuhi keperluan dan kriteria untuk Marshall Mix Design juga akan dimasukkan. Hasilnya, kajian ini tidak berjaya mencapai matlamat utamanya iaitu sama ada CPO atau suhu adalah punca kegagalan dalam nilai VFA. Atas sebab ini, lebih banyak penyelidikan dan kerja percubaan perlu dilakukan untuk menilai prestasi bahan pada sifat fizikal dan kimia asfal dan aditif (CPO).

ABSTRACT

There are various types of method used to produce Hot Mix Asphalt (HMA) for the road pavement such as Marshall Mix Design, Hveem Method and the latest method called Superior Performing Asphalt Pavement or Superpave. There are many problems arise related to healthcare of the workers on paving site and emissions of heat and odor. Emission of heat and odour during placement are dangerous to the public near the construction site and most affected is the construction workers. Moreover, PAH which is Polycyclic Aromatic Hydrocarbon where the most dangerous fumes emission can be found during mixing process of Hot Mix Asphalt (HMA). PAH contains carcinogenic, mutagenic and teratogenic in which can be hazardous to health. Saving energy consumption surely helps in emission of greenhouse gases and conservation of natural resources. This study was conducted to determine the potential of Crude Palm Oil as an additive in asphalt mixture in order to lower the mixing temperature of Hot Mix Asphalt. In addition, this study also focuses on the evaluation of the mechanical properties of the specimens (crude palm oil) in the Marshall Mix Design Method. The flexible road pavement that to be constructed by adding 0.3% of the CPO into hot mix asphalt mixture can be improved in terms of reducing heat and emission of hazardous gaseous without affecting the workability, durability, stability and the strength of the HMA. All of the related tests were conducted in the highway laboratory to collect data and determine the Marshall properties of HMA. All the information which related to procedures, processes and techniques used to produce HMA with additional of CPO will be explained detailed in this study. The information and the guideline used to obtain and calculate all the properties of the material for HMA to ensure the mixture produced will meet the requirement and criteria for the Marshall Mix Design also will be included. As a result, this study was not successfully achieved its main objective which is, either CPO or the temperatures are the causes of the failure in VFA values. For this reason, more research and experimental work needed to be done to evaluate the material performance on the physical and chemical properties of asphalts and the additive (CPO).

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The oil palm industry in Malaysia started 80 years ago in a modest way. The government has spent almost RM350 million for the replanting process of oil palm in order to control its quality. The purpose is to increase the production of Crude Palm Oil (CPO). CPO can be used in pavement as an additive which have many benefits for the pavement performance and also helps a lot in energy saving. Increasing of energy cost has triggered the development of alternative binders to modify and enhance the asphalt binders (John, 2012).

Warm Mix Asphalt (WMA) is now being proposed as an alternative for the conventional asphalt as it can be produced at low temperature of about 105˚C to 135˚C. It has been observed that most of the alternative binders contain somehow similar to those of conventional asphalt binders. However, the binders have their own variability in the aspect of properties. In order to ensure that the binder behaviour brings the positive effect to the asphalt itself, it is important to carefully design the asphalt mixtures.

Using Crude Palm Oil (CPO) as an additive in asphalt pavement could reduce mixing time, compaction temperatures, aging, and stiffening characteristics of the asphalt pavement itself. For this reason, more research and experimental work needed to be done to evaluate the material performance on the physical and chemical properties of asphalts.

1.2 Problem Statement

Emission of heat and odour during placement are dangerous to the public near the construction site and most affected is the construction workers. Moreover, PAH which is Polycyclic Aromatic Hydrocarbon where the most dangerous fumes emission can be found during mixing process of Hot Mix Asphalt (HMA). PAH contains carcinogenic, mutagenic and teratogenic in which can be hazardous to health. Saving energy consumption surely helps in emission of greenhouse gases and conservation of natural resources.

1.3 Objective

The objectives of the study are:

- To determine the potential of 0.3% of the content of Crude Palm Oil (CPO) from the total mix design and three different mixing temperature in which at lower than the standard HMA. The mixing temperature of 150˚C, 160˚C and 170˚C is to prepare standard specimens of asphalt concrete in determination of stability and flow in Marshall apparatus.
- To determine whether the volumetric properties of modified Hot Mix Asphalt (HMA) comply with all the parameter set by PWD Malaysia's Standard Specification for Road Works (JKR/SPJ/2008-S4) mix design can be comply.

1.4 Scope of Study

The scopes of this study are:

- The aggregate and bitumen used in this mix design must be evaluated first. There are two (2) tests to be conducted on the aggregates which are, Los Angeles Abrasion Test and Specific Gravity of Aggregates. There are two (2) tests that have to be conducted on the asphalt which are, Softening Point Test and Penetration Test.

- Marshall Method shall be applied in order to investigate the effect of Crude Palm Oil (CPO) as an additive in asphalt mixture. The study will be done with two (2) stages and the total samples of Hot Mix Asphalt produced is 30 samples. The first stage involves of producing 15 ordinary samples of Hot Mix Asphalt in order to find the Optimum Asphalt Content (OAC). Then, another 15 samples of Hot Mix Asphalt with three (3) different mixing temperatures and an adequate quantity of Crude Palm Oil which should be added in the samples respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Marshall Mix Design is popular and applied for the design of Hot Mix Asphalt (HMA). Warm Mix Asphalt also produced using the same method like HMA except the binder. HMA used fresh bitumen meanwhile WMA used modified binder. In this study Marshall Mix Design method is used to investigate the effects of Crude Palm Oil (CPO) as an additive for the asphalt mix. The CPO is extracted from palm nut kernel.

The purpose of Crude Palm Oil (CPO) is as an additive in the Hot Mix Asphalt in which it acts as energy saver and producing a new asphalt mix so called Warm Mix Asphalt. According to Asphalt Institute, WMA is a modified HMA mixture that is produced, placed, and compacted at 10 – 40˚C lower than the conventional HMA mixture, which is temperature range of 135˚C to 180˚C. WMA has been claimed as an environmental technology with many benefits like less burner fuel needed to heat the aggregates, reduction on polluting emissions and lower emissions at the asphalt plants (Hidayah M.K., 2012).

2.2 Flexible Pavement

A road pavement is made of layers of chosen and processed materials that is placed on the subgrade or basement soil. The main structural function of a pavement is to support the loads applied to the roadway and distribute them to the underlying subgrade. Subgrade is an improved soil which is compacted using either roller or vibraplate. Road pavement is divided to two (2) types of pavement which are rigid and flexible pavement (Lavin, P., 2003).

The flexible pavement is designed to withstand the cumulative effects of climate and heavy traffic. The structure maintains contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction and cohesion for stability. For a certain period, the subgrade is protected, safety and comfort of road users are kept within tolerance limit.

Normally in Malaysia practice, flexible pavements are designed to last twenty years, allowance being created within the design traffic growth year by year together with 2% growth annually. A road is depended on workmanship of the workers in order to achieve its design life period and capacity. All the materials, equipment and machineries are of the required standards to design specification. Flexible pavement consists of layers of surface course, base course, sub base and subgrade in which must comply to JKR/SPJ/2008-S4

2.3 Hot Mix Asphalt (HMA)

Hot Mix Asphalt (HMA) is the most commonly used in Malaysia for highways, interstates and roads due to its flexibility, weather resistance and ability to repel water. What is Hot Mix Asphalt (HMA)? There are three components of HMA which are mixing, placing and compacting (Lavin, P., 2003).

In mixing, the process involved is, combination of approximately 95% stone, sand, and gravel mixed together with bituminous binders. The bitumen acts as an adhesive, gluing the aggregates into each other and became denser and act as a stone framework supporting the composite layer (Hamim et al., 2012). There are various types of mixing plants over the years in which made the flow of aggregate and asphalt through these plants are similar except for the method of proportioning and mixing (Lavin, P, 2003). It is called HMA because not only because it is mixed hot, it also must remain hot for the paving and compaction for repair or installation. This need for the asphalt to remain warm while paving and compaction is performed is one of the reasons so much paving is done in the summer.

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2.4 Carbon Emissions

A highway is a product that can comprehensively evaluate the entire construction process from its input or output of energy and carbon emissions. Carbon sources or carbon emission sources are formed in the pavement structure within the boundary of the pavement system, including a series of intermediate products and the unit process of collection. Through data acquisition, the degree of influence and the system boundaries can be reasonably identified. Asphalt pavement construction was divided into two parts, namely, asphalt mixture production and asphalt mixture construction. Asphalt mixture production includes aggregate stacking, aggregate supply, asphalt heating, aggregate heating, and mixture mixing. The construction of asphalt mixture was divided into asphalt mixture transportation, asphalt mixture paving, and compaction of asphalt mixture. Based on the carbon source investigation in these stages, statistics and calculation of asphalt mixture carbon emissions were conducted.

2.4.1 Carbon Emission Sources

With a good pavement performance and a capacity satisfying the requirements of various pavement structure layers, hot mix asphalt has been widely used in Malaysia. Generally, traditional hot mix asphalt is used in pavement construction, which emits large quantities of CO2, CH4, and N2O (Deng and Cheng, 2002; Wang et al., 2003). This material is part of the high-carbon emission model, and is considered as an element of the carbon emissions disaster area of the highway industry, which is unfavourable to the development of a low-carbon economy. The production, construction, and carbon flow are shown in Figure 1.

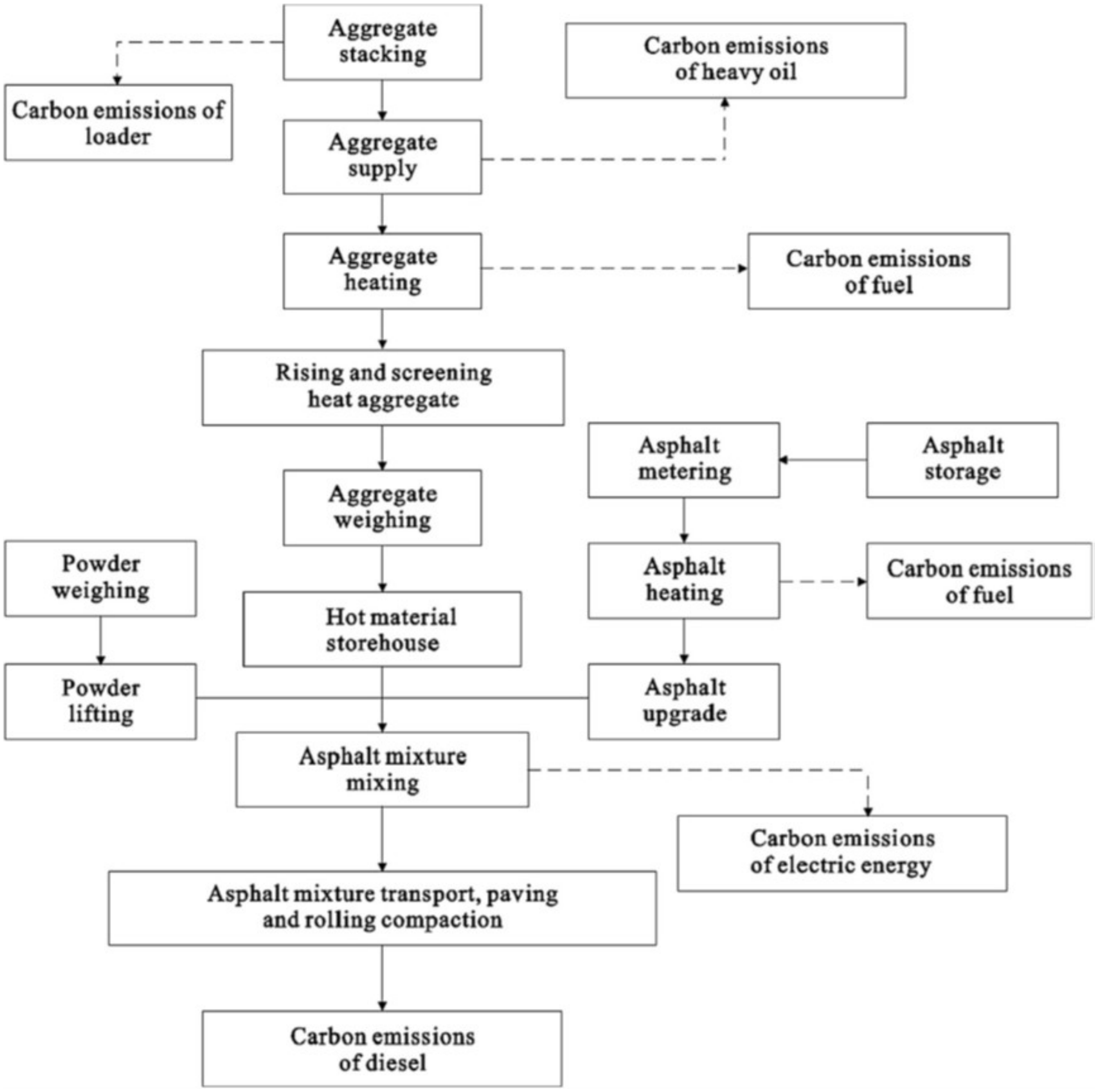


Figure 2.4.1: Production and construction process of asphalt mixture.
Source: www.sciencedirect.com

1. Aggregate Stacking

Aggregate is transported and piled by a loader at a specific location in the mixing station. The main energy source consumed during this process is diesel oil. Therefore, the main content of the investigation is the energy consumption unit mass of aggregate during this process by loading machine.

2. Aggregate Supply

In the thinning process, the aggregate is transferred to a cold aggregate bin by the loader. The main energy source consumed is fuel oil of the loader. Hence, to investigate fuel consumption, the production power of the asphalt mixing station with the loader collocation is considered, and the inclusion of each type of loader is specified in the questionnaire. The main targets of the investigation are the workload and fuel consumption of different types of machines per unit time.

3. Aggregate Heating

The aggregate conveyed from material field has a specific water content, which requires a drying step. Asphalt mixture is mixed under a high temperature and thus the aggregate needs to be heated to a high temperature (generally 160ºC). Drying and heating the aggregates are achieved by using a drying drum. The main energy consumptions are heavy oil and natural gas. Thus, the main parameters investigated are the consumption of energy per unit time, matching amount of production per unit time, and asphalt mixing station power.

4. Asphalt Supply

Before being transferred to a mixing pot, the asphalt binder must be heated in an asphalt storage tank to reach the correct temperature while maintaining a sufficiently low viscosity. Thus, mixing the asphalt binder with a dried aggregate is good. Heating the asphalt binder is achieved mainly through a thermal heating fluid, with heating temperature generally between 150ºC and 170ºC. Hence, the main content of the research in this phase is the energy consumption per unit time.

5. Asphalt Mixture Mixing

Asphalt mixture mixing mainly includes aggregate lifting by material hoist, vibrating screen for screening, aggregate weighing, blending and other processes. In these processes, electrical energy is the major consumption, which is related to the power of asphalt mixing stations. Therefore, the main parameter in this stage is electrical energy consumption per unit time corresponding to the produced power.

6. Asphalt Mixture Transport

The mixed asphalt mixture should initially be transported from the mixing site to the paving site by the transport vehicle, all of which involve consumption of diesel. Hence, in this stage, transport vehicle load and corresponding fuel consumption are investigated.

7. Asphalt Mixture Paving

The use of a paver is dependent on the width, thickness, cross slope and longitudinal slope. This type of machinery consumes large amounts of fuel. Hence, unit time consumption and spreading amount of the paver are investigated in this stage.

8. Asphalt Mixture Rolling Compaction

Asphalt pavement rolling is an effective method of improving the comprehensive performance of asphalt pavement. In this process, diesel oil is the main energy source. The main contents of the survey are roller fuel consumption per unit time and unit time workload. The entire production and construction stage of asphalt mixture is an interrelated process. The production condition of each stage should match the capacity of the asphalt mixing plant and serve as a starting point to investigate energy consumption through either a direct or indirect method.

2.5 Green Technology in Malaysia

Green Technology definition is a developed environmental friendly product and processed without disturbing the environment and conserves natural resources. The Malaysian government had identified green technology as the main growth area under the National Green Technology Policy in 2009. The implementation of Green Technology is expected to minimise and reduce the negative impact of all human activities towards natural environment and resources. According to the policy, major improvement of the Green Technology was established based on four key areas as the following (Garber and Hoel, 2001):

i) Energy Sector

Green technology is applied in power generation and also in the energy supply side management that include co-generation by the industrial and commercial sectors. This policy has also emphasised all Energy Utilisation Sectors including the demanding side of the management programmes.

ii) Building Sector

The Green Technology is adopted in the construction management, maintenance and also the demolition of buildings.

iii) Water and Waste Water Management Sector

Adoption of the Green Technology in the construction management, maintenance and demolition of buildings.

iv) Transportation Sector

Incorporation of the Green Technology in the transportation infrastructure and vehicles, in particular, biofuels and public road transport.

In addition to the four key areas, Malaysian government had announced the National Green Technology Policy Strategic Thrusts in 2011 to strengthening the green technology adoption. The Strategic Thrust consists of five thrust as the following:

i. Strengthen the institutional frameworks

ii. Provide Conducive Environment for Green Technology Development

iii. Intensify Human Capital Development in Green Technology

iv. Intensify Green Technology Research and Innovations

v. Promotion and Public Awareness.

Currently, many researchers are supporting the fourth thrust in order to help the government in achieving their goals towards implementing green technology in Malaysia. The fourth thrust claimed that the Research, Development, Innovation and Commercialisation (RDIC) is very crucial in creating new technologies, techniques and applications which would be able to reduce the cost of Green Technology and promote its usage. It is also stated that the Research, Development and Innovations (RDI) could be enhanced through (Garber and Hoel, 2001):

i. Provision of financial grants or assistance to public and private sector in RDIC;

ii. Implementation of Green Technology foresight;

iii. Establishment of an effective coordinating agency for RDI and Centre of Excellence or new research institute for Green Technology development.

iv. Enhancement of smart partnerships between the government, industries and research institutions; and

v. Establishment of strong linkages between local research institutions and regional and international centres of excellence in Green Technology RDI.

As from the perspective of pavement technologies, Warm Mix Asphalt (WMA) is one of the potential technologies that can be implemented by local authorities in supporting this green technology by replacing the conventional Hot Mix Asphalt (HMA) practice. Some of the countries are also strictly practising environmental regulations to increase the awareness among the contractors to transform from conventional HMA to the new technology of WMA. Currently, local authorities and public users in Malaysia are concerned on the issues of global warming and emissions of greenhouse gaseous which can affect the surrounding environment in the near future. Therefore, researchers and pavement industries have put their energy and efforts in implementing the WMA technology in order to reduce energy requirements during pavement construction for environmental benefits.

2.6 Warm Mix Asphalt (WMA)

Warm Mix Asphalt (WMA) is an asphalt that produced and used at a temperature around 20 – 40˚C lower than the HMA. WMA should be prepared based on the optimum binder content obtained from a sample of HMA. WMA provide lower production and application temperature which gives many advantages and benefits to all parties involved.

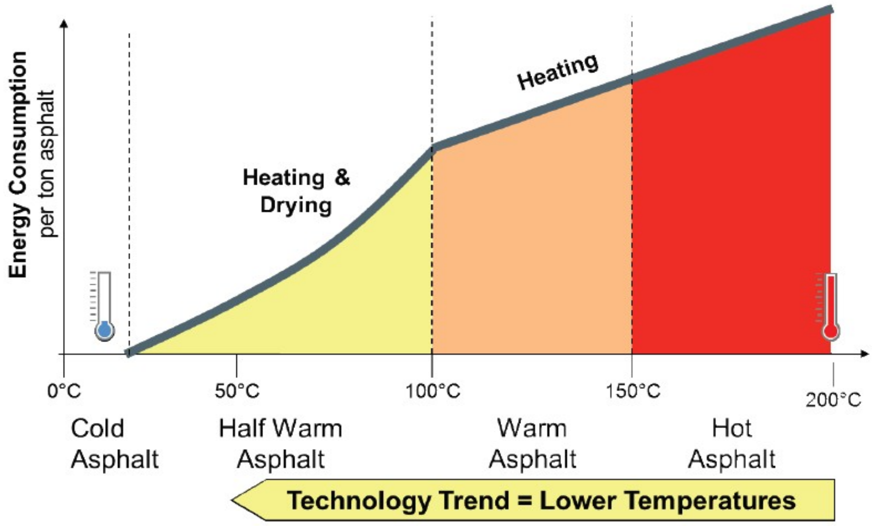


Figure 2.6: Classification by temperature range

Source: http://www.eapa.org/promo.php?c=202

European Asphalt Pavement Association (EAPA) stated that, the thermal and fatigue cracking resistance of the asphalt is improved and also decrease the ageing of the bitumen because of the lower production temperatures. The benefits of WMA can be described as follows:

- Environmental benefits
- Construction benefits
- Economic benefits

2.6.1 Environmental Benefits of WMA

The production of asphalt required a lot of energy throughout processes to obtain a perfect asphalt based on the design mix. The energy consumed during mixing process is about 60% of the total energy required for the construction of a certain road with a typical service life of 30 years (Abdullah et al., 2014). WMA is produced with lower production temperature compared to HMA, in which give most benefits in lower the emissions of fumes and odour to the public near the construction sites.

Moreover, this reduction of emissions is also beneficial to the asphalt workers that surely will exposed to the emissions instead of creating cooler working conditions compared to HMA. WMA helps in reduction of PAH which is Polycyclic Aromatic Hydrocarbon where the most dangerous fumes emission can be found during mixing process of HMA. PAH contains carcinogenic, mutagenic and teratogenic in which can be hazardous to health because the carcinogens are known as the agent of cancer, mutagens will damage the genes and teratogens will produce abnormalities in foetus (Abdullah et al., 2014).

2.6.2 Economic Benefits of WMA

The advantages of WMA in terms of economic benefits are in many aspect according to the type of energy used during production processes. The aspect can be divided to three aspects which are production, maintenance and pollution. The major impact to all asphalt producer is the energy consumption during production and maintenance in which means that any reduction of energy would mean a lot to them to save energy. In certain countries, there are road agencies that allocate some fund due to the tax for any construction that can produce lesser CO2 emission.

2.6.3 Construction Benefits of WMA

The technology of WMA gives advantages in manufacturing and paving operations. In manufacturing of WMA, because of the lower asphalt temperature, it results in less hardening of the bitumen and also reduce the thermal stress to the surrounding.

Cooling period of WMA is lesser in cold weather since it is close to the ambient temperature. It is to believe that the chance of construction period is to extended over the year since there is more time for paving and compacting. For this reason, it is possible to haul longer distances between pavement construction sites and the existing of asphalt plant (Abdullah et al,. 2014).

2.7 Crude Palm Oil (CPO)

Oil palm tree was introduced in Malaysia by the British in early 1870's. According to Malaysian Palm Oil Council (MPOC), the very first commercial planting of the oil palm tree took place is in Tennamaran Estate in Selangor. Currently, 4.49 million hectares of land in Malaysia is under oil palm cultivation, producing approximately 17.73 million tonnes of palm oil and 2.13 tonnes of palm kernel oil. Malaysia has been one of the largest producers and suppliers of palm oil in the world. During the production of crude palm oil, a large amount of waste materials has been produced such as palm oil fibres, shell and empty fruit bunches (Goh, B.H., Amiruddin, I., and Riza Atiq, A., 2006).

According to palm oil mills, oil palm fruits are transported and sterilised, stripped off the bunches and then crushed to extract the crude palm oil. The crude palm oil was collected in a tank, containing impurities which were also the waste materials of production of crude palm oil. An estimation was made according to the Malaysian Palm Oil Council (MPOC), for every 100 tonnes of fresh fruit bunches processed, 11 tonnes of palm oil husk, 6 tonnes of palm oil shell and 23 tonnes of empty fruit bunches were discharged from the mill.

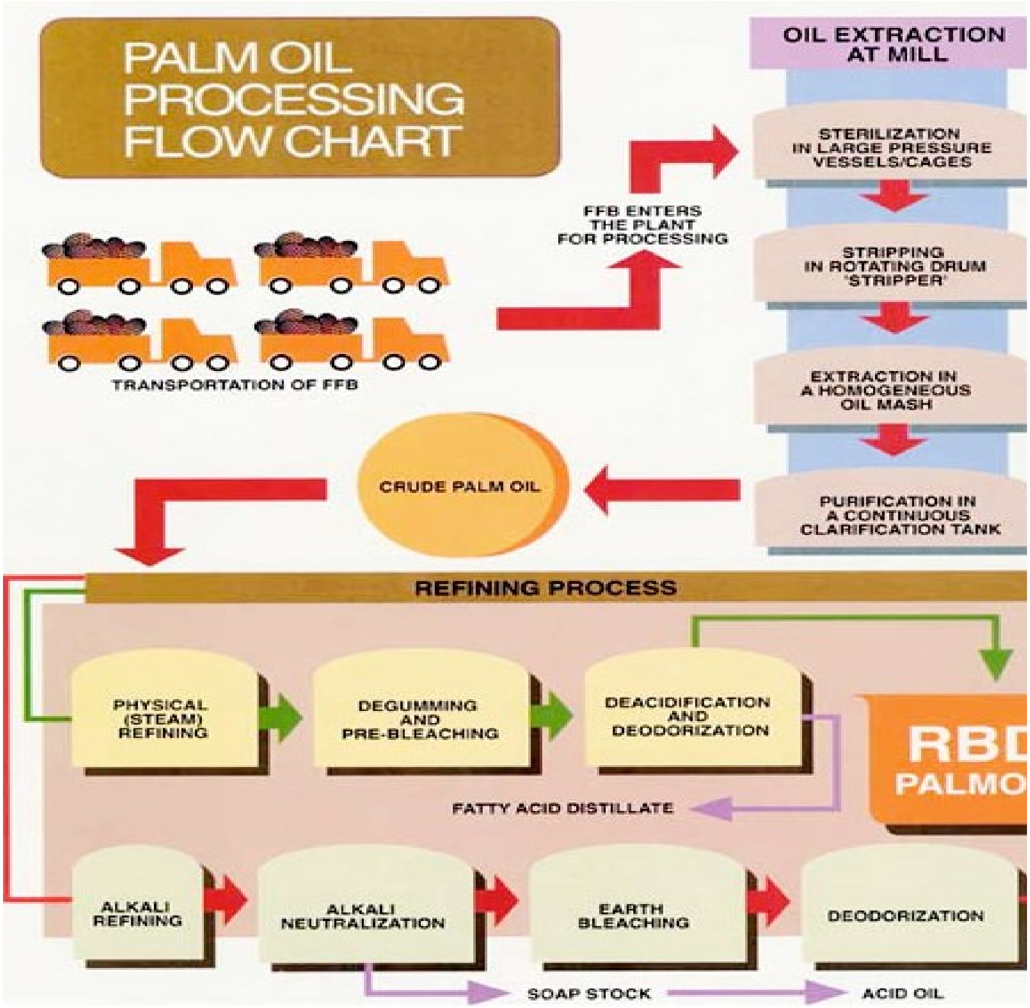


Figure 2.7: Processing Flow Chart of Crude Palm Oil.

CHAPTER 3

METHODOLOGY

3.1 Introduction

There are several methods that can be applied to prepare the hot mix asphalt which primary used in road pavement construction. Each method has its own procedure. In this project, Marshall Mix Design Method had been applied in preparing the hot mix asphalt. Even though the Marshall Mix Design is a conventional method but in Malaysia this method is still being practiced as a primary procedure. This is because the testing equipment used in the Marshall Mix Design is cheaper than other method such as MATTA Tester (Asphalt Institute, 1997). The Public Work Department (PWD) used this method as a guideline to prepare the mixture that will be used in pavement construction. Besides that, all contractors also should meet the requirement stated by the PWD.

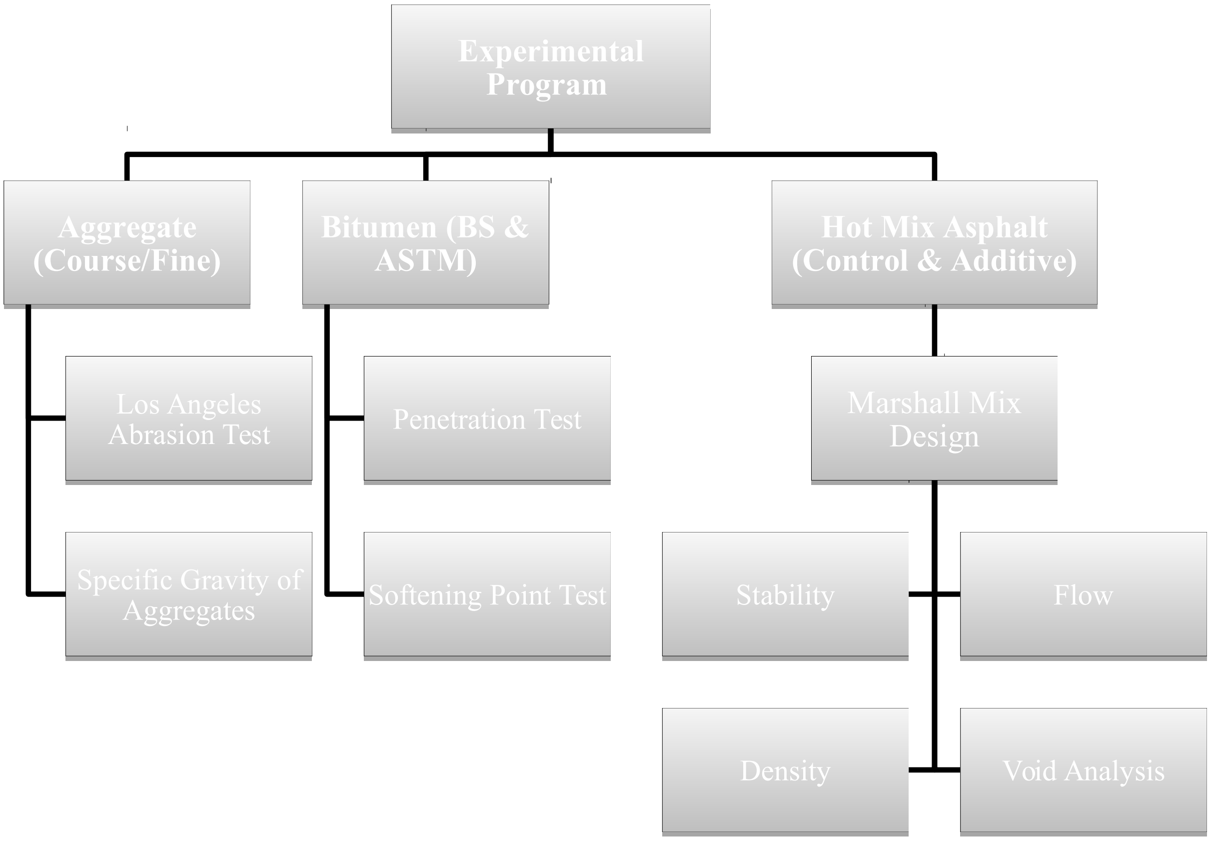
Hot Mix Asphalt (HMA) can be defined as paving materials consist of a combination of aggregate that are uniformly mixed and coated with asphalt cement. The aggregate and asphalts are combined in an asphalt mixing facility, continuously or in batch-mode. These two main components are heated to proper temperature, proportioned, and mixed to produce the desired paving material. After the plant mixing is complete, the hot-mix is transported to the paving site and spread with a paving machine in a partially-compacted layer to a uniform, smooth surface. While the paving mixture is still hot, it is further compacted by heavy self-propelled rollers to produce a smooth, well-consolidated course of asphalt concrete (Asphalt Institute, 1997).

3.2 Scope of Method

The scope of method for this study is focusing on how to develop the interpretation of test data. There are several graphs obtained from the laboratory test. All of the graph will be used in order to determine the design asphalt content of the mix (Asphalt Institute, 1997). The graphs will show the value of flow and density of the samples. The achievement of this study can be determined by making a comparison between the results from the testing specimens (Crude Palm Oil) and the control sample, which the control result should meet the requirement of PWD. Marshall Method shall be carried out in order to determine the potential of CPO as an additive in the asphalt mix. The test data for the control sample will be used as an indicator for evaluation process (Ratnasamy, and Radin, U., 2001).

3.3 Experimental Design

In order to achieve the objectives, there are various types of laboratory test to be conducted exactly. The methodology can be summarized by the flow chart as shown in Figure 3.1 below:



3.4 Evaluation of Material

The procedure of the Marshall Method starts with the preparation of the specimens. Sieve analysis was conducted in order to get the desired grading aggregate. In this study, CPO are used 0.3% of the total mix design. The weight of 3.6 grams is obtained and to be used for all samples with additive. This preliminary step in material preparation is to meet the physical requirement of the study specifications. Lastly, for density and voids analyses, the bulk specific gravity of all aggregates and the specific gravity of the asphalt cement are determined.

3.4.1 Asphalt Testing

For this purpose, the asphalt will be tested in order to check whether it is suitable or not for the experimental usage. There two (2) tests that should be conducted on the asphalt which are Penetration Test and Softening Point Test.

3.4.1.1.1 Penetration Test (ASTM Standard Test Designation D5 – 97)

The objective of this test to measure the consistency of the higher values of penetration indicates softer consistency. Bitumen sample in a container is heated in a range temperature of 80˚C to 90˚C for 30 minutes. Stir the sample constantly until it became completely fluid and free from air bubbles. Then, pour the bitumen sample into penetration cylinder (55mm diameter and 35mm deep), filling to 3mm of rim. After that, the specimens are left to cool at room temperature for one (1) day. Then, the samples are placed in water bath for 25˚C for one (1) hour for smaller one (1) and two (2) hours for larger one.

Next, the samples are placed in transfer dish which contains water with temperature 25˚C. Penetration needle is placed by touching the surface of asphalt and the penetrometer is set to zero (0) as show in Figure 3.5. Needle is loaded with 100gram weight and is allowed to penetrate the asphalt cement for five (5) seconds. Then, the depth of penetration will be measure by using the following formula:

Penetration value = (P1 + P2 + P3) / 5

where: P = penetration reading at different points

Figure 3.4.1.1: Automatic Penetrometer

3.4.1.1.2 Softening Point Test (ASTM Standard Test Designation D36 – 86)

The objective of this test is to indicate the tendency of the material flow at elevated temperature. Firstly, hot asphalt is poured into the ring and cooled at room temperature for about 30 minutes. Then apparatus is levelled as shown in Figure 3.6. the ring is then placed on the ring holder. The temperature in water bath is maintained at 5 ± 2˚C for 15 minutes. Next, forceps are used to place the asphalt with each ball-centring guide. Bath liquid is stirred and heated to 5 ± 2˚C per minutes to ensure it is increasing uniformly. Then, temperature is noted just after the ball is passed and dropped to the bottom of the beaker. The formula to be used for this test is as follows:

Softening Point, R = (R1 + R2) / 2

3.5 Marshall Mix Design

For this study, the total samples that should be prepared for this Marshall Mix Design Test is 30 samples. 15 of them will be used as control sample which consist of aggregates and asphalt while the balance of the sample is testing specimen which consist of aggregates, asphalt and crude palm oil. Sieve analysis is conducted in order to obtain the desired grading aggregate. In this study, the 0.3% of crude palm oil obtain from total mix design is 3.6gram and is used for all samples.

Firstly, grade the aggregate according to the BS standard and heated at 135˚C and a sufficient amount is weighed (about 1200g) for sample preparation that need to be placed in a mould. After that, the required quantity of asphalt is weighed out and heated to a temperature 160˚C. Then, the aggregate is heated in the oven to a temperature not higher than 28˚C above the binder temperature.

After that, weighing the bitumen based on the percentage of the design bitumen using balance 5kg capacities. A crater is formed in the aggregates, the binder poured in along with the crude palm oil and mixing carried out until all the aggregates are coated. The mixing temperature is controlled for every different temperature used by using thermometer. The thoroughly cleaned mould is heated in an oven to a temperature between 130˚C.

The mould is 101.6mm diameter by 76.2mm and provided with a base plate and extension collar. The inside surface of mould is wiped with grease. A piece of filter paper is fitted in the bottom of mould and the whole mix poured in three layers. Then, the layer is compacted with tamping rod for 25 blows each layer in order to avoid honeycomb mix. After that, compact the sample to Marshall Compactor Test for 75 blows at top and bottom. After the compaction process, the sample is allowed to cool in air until no deformation occurs when removing from the mould.

The specimen is then carefully removed from the mould by extruder. Before the testing process, the specimen is measure and weighed in air and water (for volume determination). If the asphalt mix consists of an open (porous) texture, then weighing in water will lead to error in volume. The specimen is then marked and stored for stability and flow measurements.

After that, the sample is heated in the boiling water to a temperature 60 ± 2˚C for at least 30 minutes. It is important to ensure that the testing head will be put into oven before using it. After 30 minutes and the testing apparatus are ready, remove the sample from the boiling water and place it at the testing apparatus. Adjust the testing head in appropriate way then start the process until the failure occurs. The point of failure is defined by the maximum load reading obtained. Both stability and flow testing shall be completed in within seconds after the samples are removed from the boiling water.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the result from the lab test will be analysed. The requirement from Public Work Department (PWD) will be used as a guideline in order to analyse the result. The design of specimens is based on Specification for Road Work (JKR/SPJ/2008-S4) and at the same time Superpave Method as published by the National Asphalt Paving Association is adopted in the design. Before the sample could be produced, all the materials used have been tested first in order to ensure it is suitable for usage. Materials that need to be tested are aggregate and asphalt (Ratnasamy, and Radin, U., 2001).

This chapter presents all the experimental results obtained and discussed in order to achieve the aim of the study which is to investigate the effect of Crude Palm Oil (CPO) as additive in asphalt mixture. The properties of the binders with and without the additives were measure under specific temperatures which are for controlled sample is 160°C while for the modified samples are at 150°C, 160°C, and 170°C. The additive, CPO, was in a sealed container at room temperature in order to prevent from oxidation and premature aging and was kept safe in the laboratory. The properties of modified asphalt mixture were evaluated and compared with the properties of controlled sample.

4.2 Aggregate Test Results

All the results data are obtained and tabulated. Then the results will be analysed in order to get desired value for evaluation process.

4.2.1 Los Angeles Abrasion Test

The objective of this test is to ascertain the degradation of aggregates by abrasion and impact. The test is an important tool to measure the hardness of aggregates that are recommended for highway projects. The test also will determine the quality of the aggregate. The soft aggregates will be quickly ground to dust, whilst the hard aggregates are quite resistant to crushing effect. After the test was carried out, the result obtain can be shown in Table 4.2.1 below:

Aggregate Size (mm)	Weight of Sample (g)		Loss (g)
	Before	After	
14 – 12.5	2500	3560.3	1230.7
12.5 – 9.5	2500	3560.3	

Table 4.2.1: Result of L.A Abrasion Test

Percent Loss = [(weight loss) / (total weight of sample)] x 100%

= (1230.7 / 5000) x 100%

= 24.61%

The results obtained meet the requirement of PWD where the value of percent loss should be not more than 30%.

4.3 Asphalt Test Results

All the results data are obtained and tabulated. Then the result will be analysed in order to get the desired value for evaluation process.

4.3.1 Penetration Test (ASTM Standard Test Designation D5-97)

This test will cover determination of the penetration of semi-solid and solid bituminous materials. The needles, containers and other condition described in this test method provide for penetration up to 500. The objective of this test is to measure the consistency of the bitumen. Higher values of penetration indicate softer consistency. The result obtained from the test is shown as in Table 4.3.1 below:

No. of Penetration	Pan 1 (Larger)	Pan 2 (Smaller)
1	98	91
2	87	116
3	93	87
Average	93	98

Table 4.3.1: Results of Penetration Test

Penetration value (1) = (98 + 87 + 93) / 3 = 93

Penetration value (2) = (91 + 116 + 87) / 3 = 98

The result obtained meet the requirement of Public Work Department (PWD) where the value of Penetration Test should be in range between 80-100.

4.3.2 Softening Point (ASTM Standard Test Designation D36-86)

This test will cover the determination of the softening point of bitumen range from 30°C to 150°C using ring ball apparatus immersed in distilled water (30°C to 80°C). The objective of this test is to indicate the tendency of the material flow at elevated temperature. The result obtained from this test is as shown in Table 4.3.2 below:

Test	1	2	Average
Softening Point (°C)	49.60	52.80	51.20

Table 4.3.2: Result of Softening Point Test

The result obtained met the requirement of Public Work Department (PWD) where the value of Softening Point Test should be not less than 48 and not more than 54.

4.4 Marshall Mix Design Results

Binder (%)	Weight in air (g)	Weight In water (g)	Bulk Density (g/mm)	Stability (kN)	Flow (mm)	VTM (%)	VMA (%)	VFA (%)
4.0	1326.600	720.400	2.142	7.925	3.459	8.102	16.420	50.656
4.0	1307.300	720.400	2.189	7.023	3.101	6.057	14.559	58.399
4.0	1246.300	632.300	1.981	8.014	3.631	14.996	22.689	33.908
Average			2.104	7.654	3.397	9.718	17.889	47.654
4.5	1276.800	702.500	2.168	9.560	3.884	6.343	15.817	59.896
4.5	1255.900	684.300	2.134	9.258	3.548	7.829	17.153	54.356
4.5	1374.300	755.700	2.139	10.016	3.376	7.603	16.949	55.145
Average			2.147	9.611	3.603	7.258	16.64	56.467
5.0	1278.800	709.400	2.181	12.016	3.845	5.197	15.784	67.071
5.0	1257.900	699.500	2.193	13.100	4.010	4.649	15.297	69.607
5.0	1230.900	688.100	2.205	13.835	4.098	4.138	14.843	72.119
Average			2.193	12.984	3.984	4.661	15.308	69.599
5.5	1250.400	696.200	2.213	10.805	3.982	3.167	14.985	78.864
5.5	1294.800	719.200	2.225	10.021	3.839	2.658	14.537	81.718
5.5	1297.300	728.700	2.264	9.493	3.830	0.921	13.012	92.926
Average			2.234	10.106	3.884	2.249	14.178	84.803
6.0	1270.200	707.800	2.243	7.855	3.107	1.244	14.308	91.304
6.0	1259.600	698.400	2.236	9.271	3.822	1.547	14.570	89.384
6.0	1288.300	718.400	2.248	7.924	3.657	0.991	14.088	92.968
Average			2.242	8.350	3.529	1.261	14.322	91.219

Table 4.4: Result of Marshall Tests

The purpose of Marshall Mix Design Tests is to determine the optimum bitumen content (OBC) of the design mix for AC14 and compacted using 75 blows of the Marshall hammer. Data from the Marshall tests were used to plot six parameters which are Stability, Flow, Density of Mix, Percent Voids Total in Mix (VTM), Percent Void in

Mineral Aggregates (VMA) and Void in Mineral (VFA). All this values are calculated and the results obtain from the Marshall test are shown as below:

1) Calculate the Maximum Specific Gravity (Gmm) using the following equation:

$$\text{Gmm} = \frac{(C-A)}{(C-A)-(D-B)}$$

A = Weight of Container in air

B = Weight of Container in water

C = Weight of Container and Sample in air

D = Weight of Container and Sample in water

2) Calculate the Bulk Specific Gravity of each specimen using the following equation:

$$\text{Bulk Specific Gravity (BSG)} = \frac{A}{B-C}$$

A = Weight of specimen in Air

B = SSD Weight of specimen in Air

C = Weight of specimen in Water

3) Calculate the average Bulk Specific Gravity of the mix (Gmb) using the following equation:

$$\text{Gmb} = \frac{BSG\,specimen\,1 + BSG\,specimen\,2 + BSG\,specimen\,3}{3}$$

This value, Gmb, will be used to determine air voids (VTM) of the mixture.

4) Determine the voids in total mix (VTM) using the following formula:

$$VTM = 100 \text{ x } \quad 1-(\frac{Gmb}{Gmm})$$

Gmb = bulk specific gravity of mix

Gmm = maximum specific gravity of mix (Rice)

This VTM value will used to determine density and VFA.

5) The percent density of each test specimen can be determined by the following formula:

$$Density = 100 - VTM$$

6) Determine the voids in the mineral aggregate (VMA) using the following formula:

$$VMA = 100 - [\frac{Gmb \, x \, Ps}{Gsb}]$$

Gmb = bulk specific gravity of mix

Ps = Percent stone (100 – Pb from Ignition Method)

Gsb = bulk specific gravity of aggregate

7) Determine the voids filled with asphalt (VFA) using the following formula:

VFA = (VMA – VTM) x 100

4.5 Optimum Asphalt Content

In order to obtain homogeneous mix and to achieve the required standards for attaining the quality and characteristics for pavement construction based on the JKR/SPJ/2008-S4, which are the average of bulk specific gravity, stability, flow, VFB and VIM obtained be plotted separately against the bitumen content and a smooth curve drawn through the plotted values.

The mean optimum asphalt contents were determined by averaging five bitumen contents so determined as follows;

I. Peak of curve taken from the stability graph,

II. Flow equals to 3mm from the flow graph,

III. Peak of curve taken from the bulk specific gravity graph,

IV. VFB equals to 75% for wearing course, from the VFB graph,

IV. VIM equals to 40% for wearing course from the VIM graph.

The results are shown below:

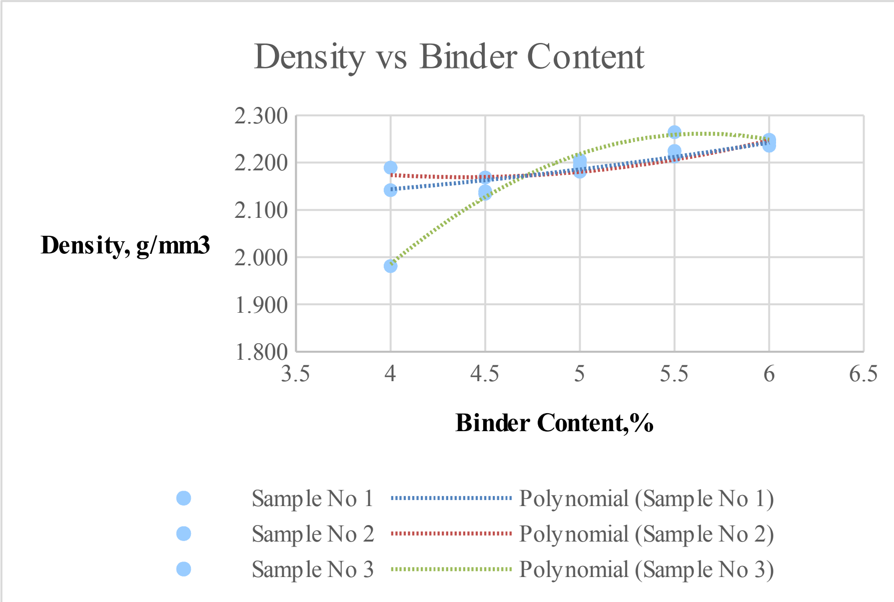


Figure 4.5.1: Density vs Binder Content

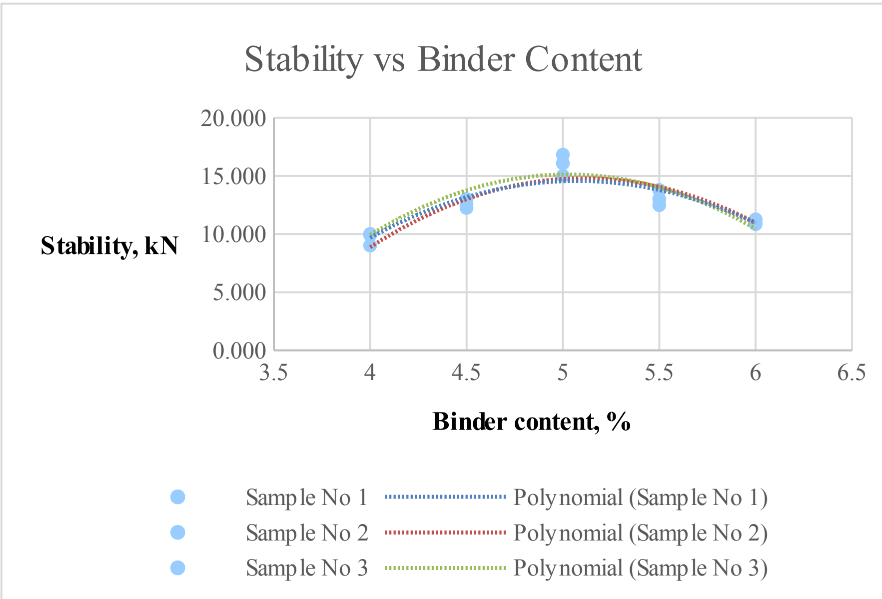


Figure 4.5.2: Stability vs Binder Content

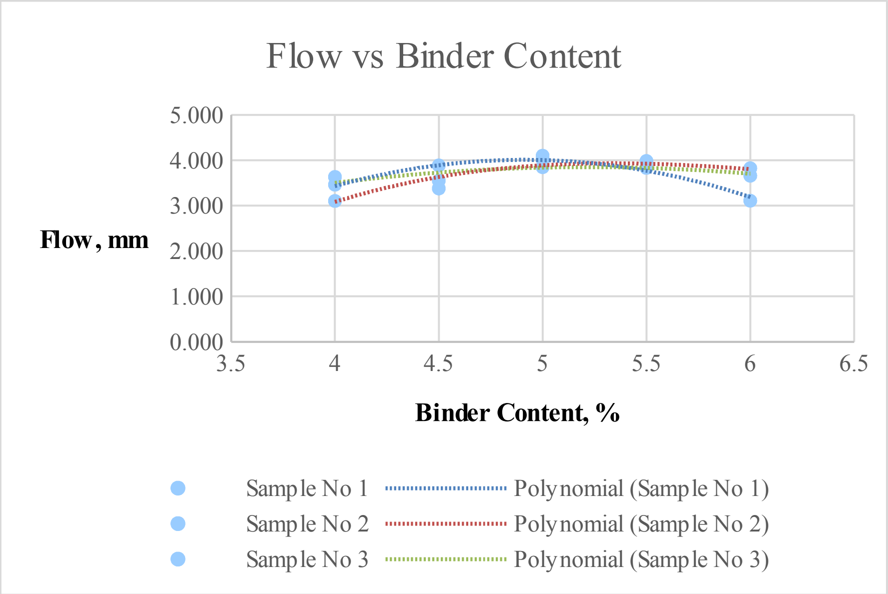


Figure 4.5.3: Flow vs Binder Content

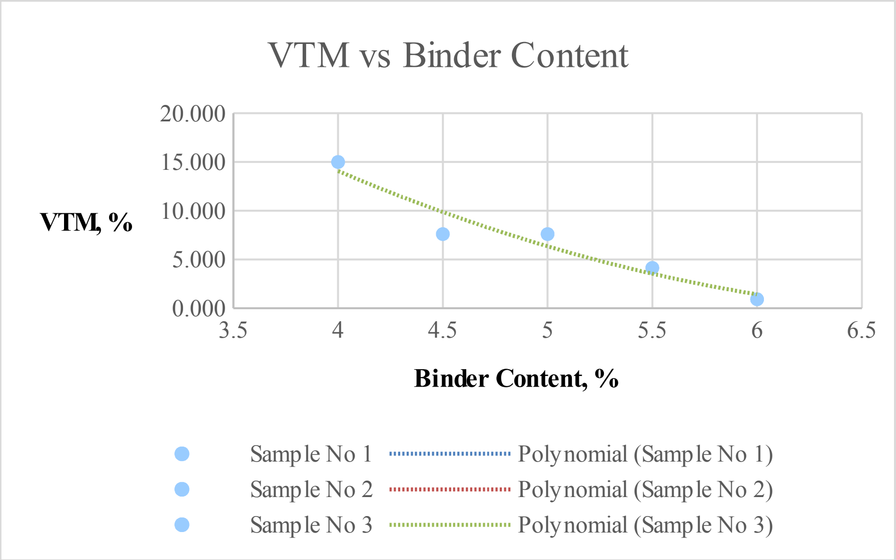


Figure 4.5.4: VTM vs Binder Content

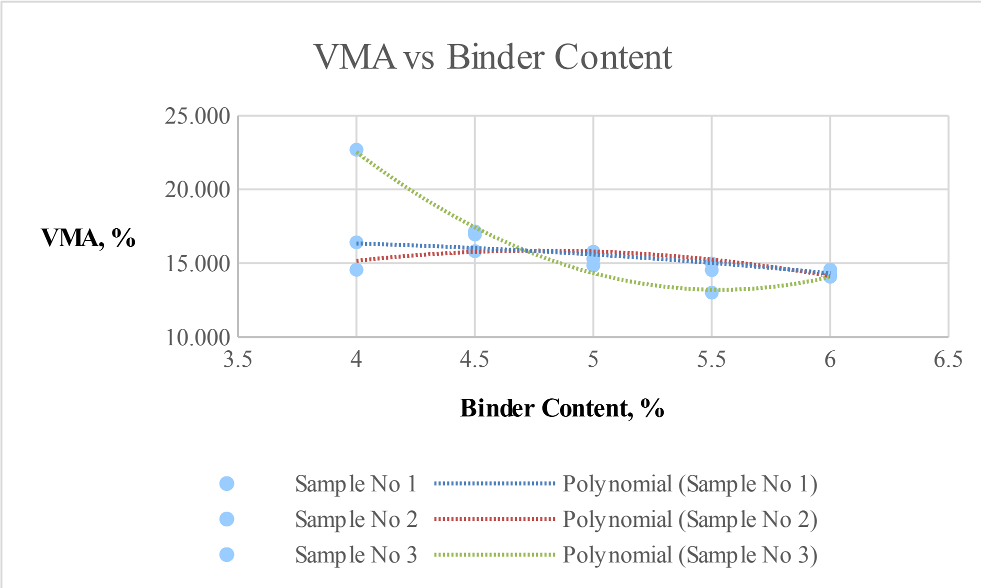


Figure 4.5.5: VMA vs Binder Content

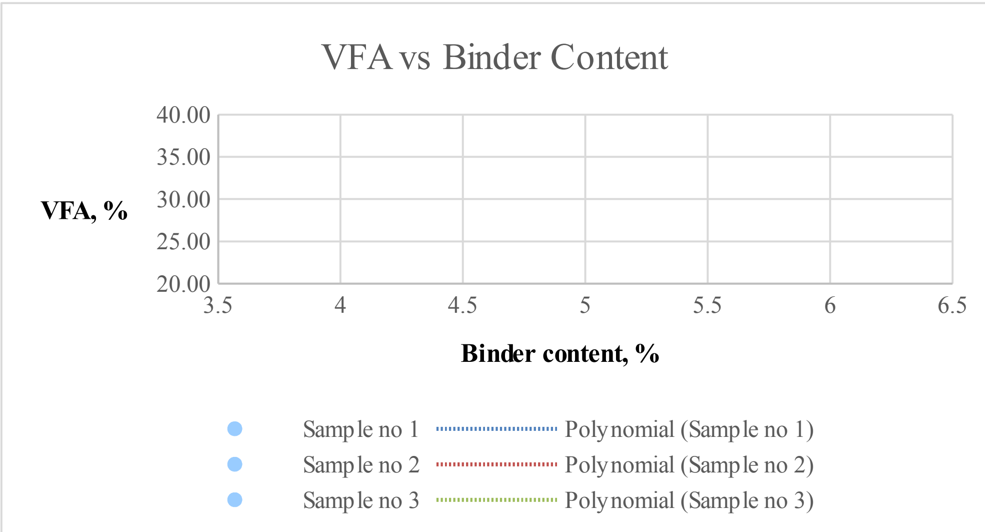


Figure 4.5.6: VFA vs Binder Content

From the graphs, volumetric properties of Marshall Specimens are obtained at varying indicating the mean of optimum asphalt content of 5.0% based on the JKR/SPJ/2008-S4 with respect to the mean optimum content as followed maximum stability curve which is laid at 5.0% bitumen content, flow equals to 3mm from the flow at 4.0% bitumen content, maximum bulk specific gravity at 5.5% bitumen content, VFA equals to 75% at 5.5% bitumen content, VTM equal to 4.0% at 5.0% bitumen content.

4.6 Crude Palm Oil (CPO) Effects on Asphalt Mixture

Addition of Crude Palm Oil (CPO) as an additive into the asphalt mixture resulting in many effects including volumetric properties of the bitumen itself. Another effect is the time taken for mixing process for three different temperatures are different from each other and from control sample. All the differences from modified sample (control + CPO) are compared with the control sample.

4.6.1 Bulk Density vs Modified Sample (CPO)

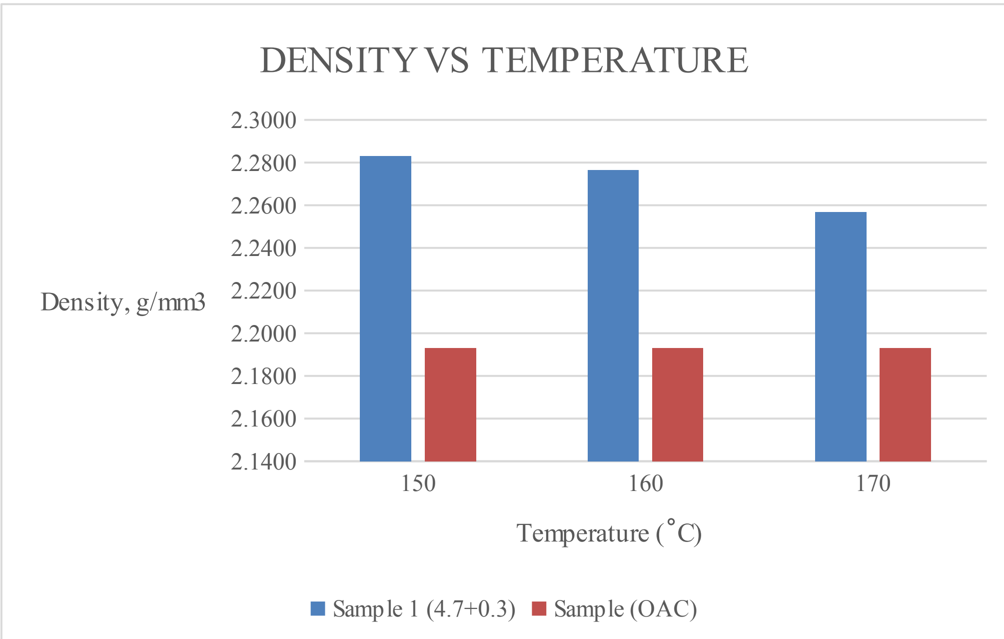


Figure 4.6.1: Bulk Density vs Modified Samples with three different temperatures.

Figure 4.6.1 shows the density of samples for control and additive for each three of the temperatures. The density obtained from three samples are vary from each other. The figure shows the value of bulk density for control sample is 2.193 g/mm at 5.0% binder. While for the modified sample, the highest value of bulk density obtained is 2.283 g/mm at 4.7% binder plus 0.3% CPO. The increasing of the density will increase the shear resistance hence improve.

4.6.2 VTM vs Modified Sample (CPO)

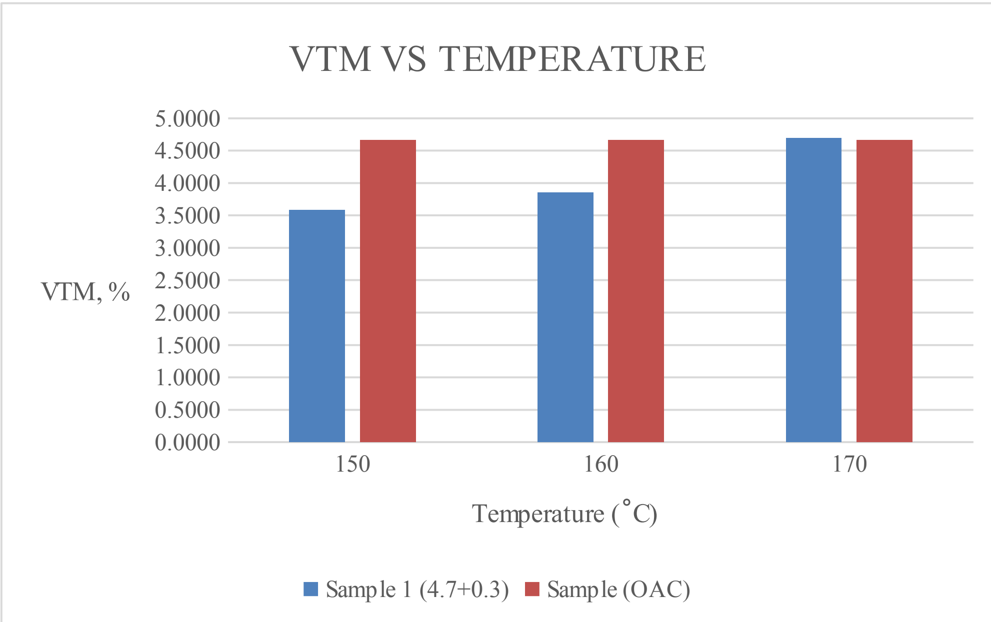


Figure 4.6.2: VTM vs Modified Samples with three different temperatures.

VTM is referring to Voids Total in Mix. Generally, the percent of voids content is decrease with increasing of percentage binder. Binder here refers to asphalt content itself. The results of three different temperatures vary from each other. Refer to Figure 4.6.2, the value of VTM for sample Optimum Asphalt Content (OAC) are 4.661% and it is complying to the specification of JKR/SPJ/2008-S4 which are in range of 3.0 – 5.0

%. The criteria here refer to VMA, VFA, Flow and Stability. All the criteria should meet the requirement before the evaluation of additive sample could be done. Additive sample refer to the sample that are contain 0.3% CPO. Refer to Figure, the value of VTM for modified sample (Sample 1) are varied from each other. All three values are complying with the Specifications of JKR/SPJ/2008-S4. As the temperature arise, the VTM percentage also increases. This is because the viscosity of the asphalt is reduced due to the additive.

4.6.3 VFA vs Modified Sample (CPO)

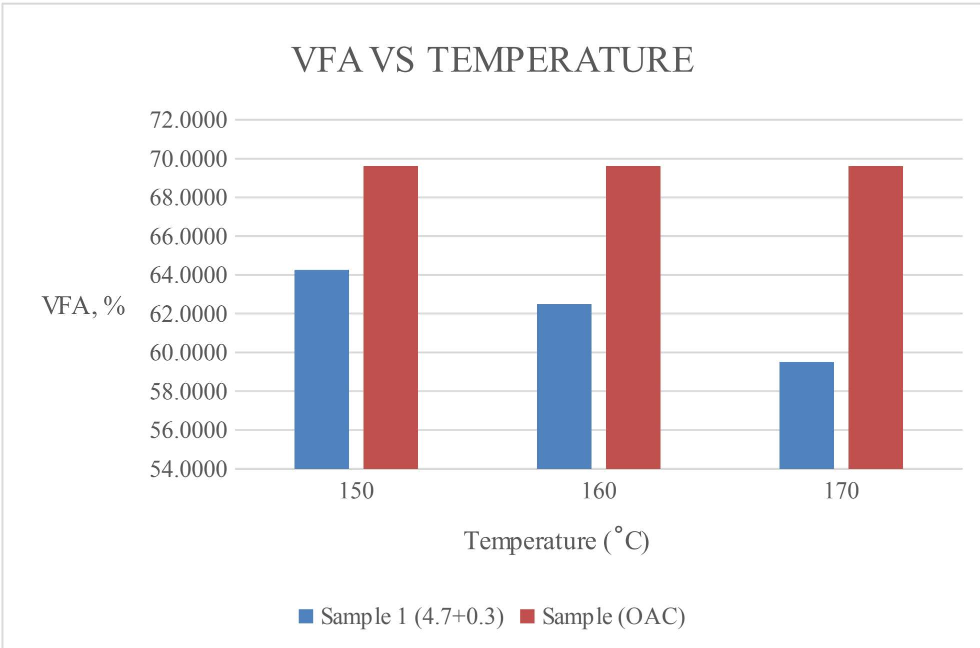


Figure 4.6.3: VFA vs Modified Samples with three different temperatures.

VFA means Voids Filled with Asphalt. The values of VFA are determined from the value of VMA and VTM. This means that the values of VFA are related with the VMA and VTM. The higher values of the VMA and VTM, the smaller values of the VFA can be obtained. Refer to Figure 4.6.3, the value of VFA for control is 69.59% and the modified sample are differing from each other and also the percentage of VFA is decreased as the temperature increased. These values did not meet the requirement of the specification. The control value meets the requirement and it is mean that this specification can be used as an indicator for additive sample because of the control sample is acceptable. It shows that the modified sample is not suitable for paving mix design. Hence the nominal maximum particle size for ACW14 is needed to recalculate and redesign the gradation of the aggregates in order to obtain the nominal maximum particle size that will differ from the first sieve.

4.6.4 Flow vs Modified Sample (CPO)

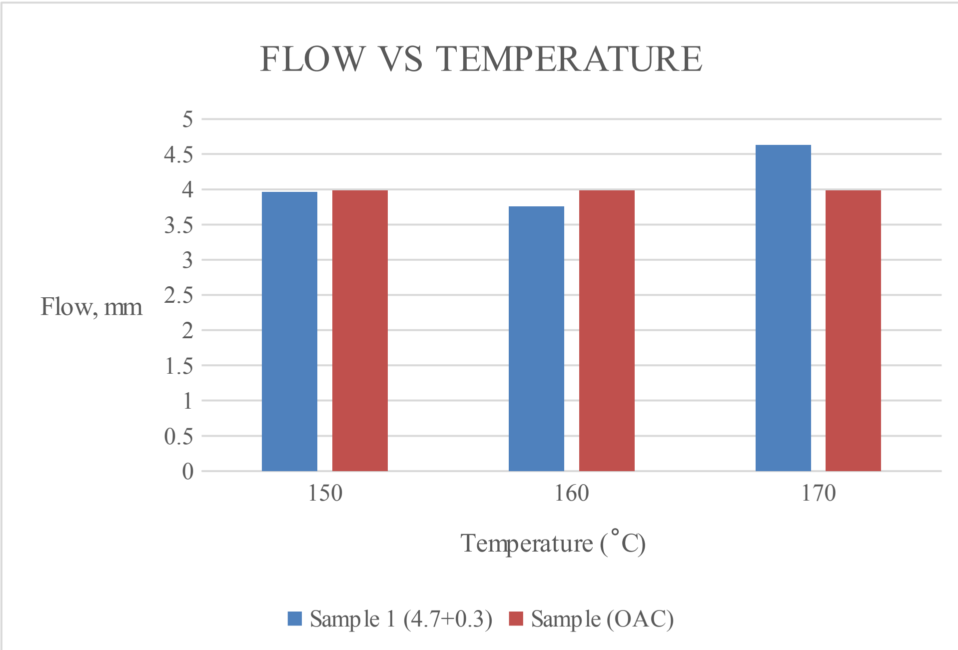


Figure 4.6.4: Flow vs Modified Samples with three different temperatures.

Figure 4.6.4 shows the flow of the samples for control and additive for three different temperatures with 0.3% of CPO. The flow is referring as the vertical deformation of the samples which is measure from start of loading to the point at which stability begin to decrease in hundredths of inch. The increasing of temperature gives the higher value of flow. Refer to Figure 4.5.4, the value of flow for control is 3.984mm which is complying to the specification JKR/SPJ/2008-S4 which are in range of 2.0mm – 4.0mm. It can be used as an indicator for modified sample because of the control value is acceptable. Figure 4.6.4 also shows the value flow of modified samples which are differing from each other. The value of modified sample at 170°C are slightly over the specification and the value is not acceptable for paving mix design.

4.6.5 Stability vs Modified Sample (CPO)

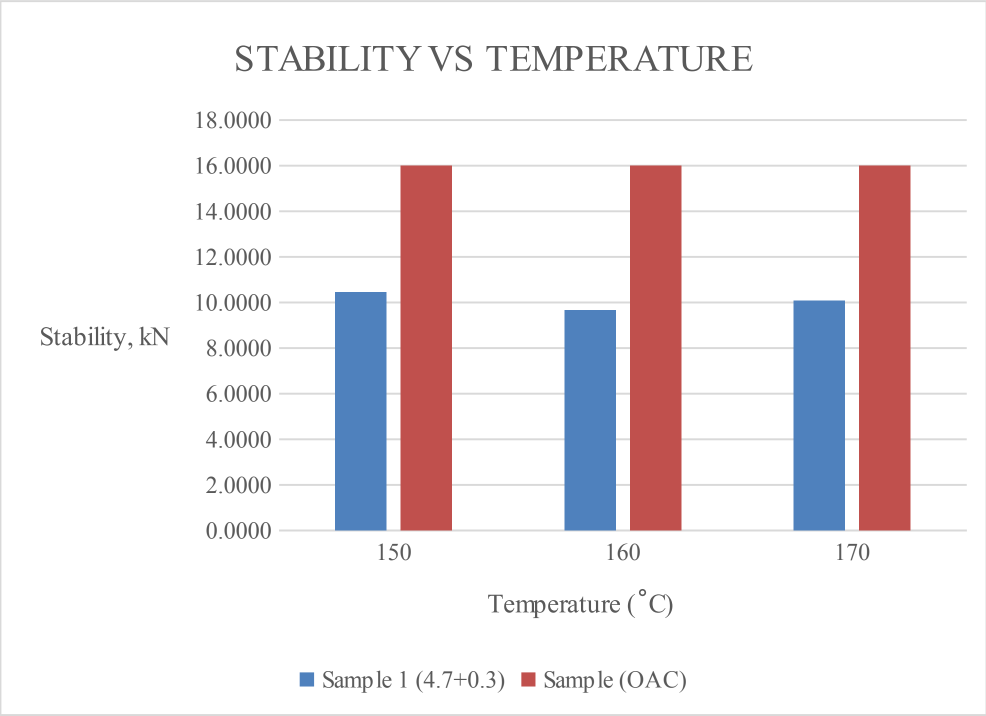


Figure 4.6.5: Stability vs Modified Samples with three different temperatures.

Figure 4.6.5 shows the value of Marshall Stability for control which are 15.98kN and the modified samples are differing from each other. All the values met the requirement of specification JKR/SPJ/2008-S4. The specification stated that the stability value for ACW14 should be more than 8kN.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

From the study that have been done, it is found that there is slightly failure to show that the potential of crude palm oil to be used as an additive in the asphalt mixture. This can be shown from the result and analysis of the Marshall Mix Design of the modified sample. A comparison between additive sample in terms of reducing heat and emission of hazardous gaseous without affecting the density, stability, flow, percentage air voids (VTM), percentage of aggregate voids filled with asphalt (VFA), and lastly percentage of voids in mineral aggregate (VMA) have been analysed to determine the potential of CPO as an additive in asphalt mixture. For this reason, more research and experimental work needed to be done to evaluate the material performance on the physical and chemical properties of asphalts and the additive (CPO).

Besides that, the second objective is to evaluate the mechanical properties of the specimens (CPO) from its density, stability, percentage air voids (VTM), percentage of aggregate voids filled with asphalt (VFA), percentage of voids in mineral aggregate (VMA) and flow. This objective cannot be achieved because of the value of VFA obtained from the experiments indicates lower value than the control sample and also did not meet the requirement of specification by Public Work Department (PWD). For this reason, the gradation limit for asphalt concrete need to redesign and recalculate to obtain a better design that could achieve the requirement PWD.

5.2 Recommendation

The main objectives of this study is not achieved then there are steps that must be improved in this study to ensure the asphalt mixture produced using CPO can give better results. In this study, CPO is used without knowing the properties of the CPO itself either could reduce the viscosity of the asphalt mix like other additives or could not. The CPO properties should have been studied so that value of CPO used can be measured without affecting the properties of normal Hot Mix Asphalt.

Another recommendation is to ensure the laboratory equipment is in good condition. The conventional machine must be replaced with the latest one. It is a waste to use the conservative machine in order to commercialize the product. These samples with additive have their potential to commercialize in construction sector in term of saving energy and reduce emissions.

Besides that, another method that can be used in order to get accurate results is by using the latest method called Superior Performing Asphalt Pavement (Superpave). This is because the testing equipment that has been used in this method is better than other method due to the machine which is fully automatic.

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