A STUDY ON COMPARISON BETWEEN SUBSTITUTION OF POLYETHYLENE/PLASTIC MIX AND ORDINARY MIX WITH VARIOUS PERCENTAGES OF BITUMEN

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SITI ROBIAH BINTI ARSHAD

Thesis submitted in fulfillment of the requirements
for the award of the
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Special dedicated to

My beloved parents;

Arshad Bin Man and Aminah Binti Hashim

Thank you for pray, endless love and unstoppable supports. Love both of you!!

And all my housemates,

Nurul Atikah, Nur Fathin Nadhirah, Nur Asyikin, Nurul Amira, Nur Hasbazilah and Nur Idayu

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ABSTRAK

Asfat digunakan dalam penurapan jalan kerana ia sangat ekonomi dan memenuhi aspek pembinaan jalan seperti kualiti yang bagus, permukaan yang boleh mencengkam ,tidak mengeluarkan bunyi and penyelenggran yang menjimatkan.Walau bagaimanapun, penggunaan asfat mempunyai kelemahannya seperti mudah mengeras semasa cuaca sejuk dan melembut semasa cuaca panas di samping mudah retak. Selain itu, kuantiti dan kapasiti trafik pengguna jalan raya semakin meningkat dari masa ke semasa yang merupakan penyebab pavemen menjadi teruk dan rosak. Kesesakan trafik dan beban yang tinggi oleh kenderaan juga merupakan . Oleh itu, untuk mengurangkan kerosakan dan kecacatan, struktur jalan atau pavemen perlu diimprovasi. Eksperimen ini akan diubah suai dengan campuran bitumen dengan plastik atau polietilena dengan menggantikannya dengan pelbagai peratusan. Jumlah sampel ialah 30 sampel dan disediakan di makmal dengan kaedah, perkakas dan mesin yang betul. Sampel yang disediakan terdiri daripada Marshall Mix Design kaedah. Sampel direka adalah mengikut standard aggregat 14 (ACW 14) dengan menggunakan JKR Standard. Julat kandungan bitumen adalah 4- 6% daripada berat jumlah agregat. Plastik atau polietilena akan digantkan dengan bitumen 4-8% daripada berat kandungan bitumen. Plastik atau polietilena boleh meningkatkan kebolehkerjaan pavemen, ketahanan dan menjmatkan bitumen yang digunakan. Tambahan pula, ia memberikan kekuatan ikatan di antara agregat dan menyediakan turapan yang kualiti tinggi untuk masa depan. Penemuan ini memberikan struktur mesra alam sekitar, yang menggunakan plastik kitar semula dan menyelamatkan bajet untuk pembinaan lebuh raya dan penyelenggaraan. Pada masa akan datang, diharapkan penyelidikan ini boleh menggalakkan penemuan-penemuan baru yang akan dijalankan dalam cara yang berbeza dan penggunaanya.

ABSTRACT

Asphalt use in road pavement because it's very economical and fulfilled the roadway design requirement such as good riding quality, good skid resistance surface, quiet surface and low maintenance. However, consumption of asphalt has some weaknesses, as it become brittle and hard in cold weather and soft in hot weather hence it easy to crack. Besides that, an increase in traffic volume or capacity of the road users year by year is the one of the reasons of the pavement crack, defect and damage. Hard traffic and high loading weight by vehicles are also contributed to the pavement's failure. Hence, to reduce the damage and defect, an improvised road or pavement structure is needed. This experiment will look into modified-bitumen where plastic or polyethylene will substitute the asphalt in various percentages. A total of 30 samples were prepared in laboratory with the proper method, apparatus and machines. The samples were prepared based on the production method of Marshall Mix specimens. The samples designed according to requirement for the aggregate course wearing 14 (ACW 14) by using JKR Standard. The range of bitumen content is 4- 6% from the weight of total aggregates. The plastic or polyethylene will substitute with the bitumen 4-8% from the weight of bitumen content. The plastic or polyethylene can improve the workability, durability and save the bitumen used. Furthermore, it gave the good binding to aggregates and provide the high quality pavement for future. This finding gave the eco environmental friendly structure, which is the recycle plastic are used and save budget for the highway construction and maintenance. In the future, hopefully this finding can encourage new research to be conducted in the different ways and usage.

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LIST OF SYMBOLS

%	Percentage
ρ_w	Density of water
G_{mb}	Bulk specific gravity of mix
G_{mm}	Maximum theoretical specific gravity of mix
P_b	Asphalt content, percent by weight
G_{se}	Effective specific gravity
kN	Kilo Newton
mm	Millimeter
et.al	Others
W	Weight

LIST OF ABBREVIATIONS

ASTM	American Section of the International Association for Testing Material
JKR	Jabatan Kerja Raya
APM	Asphalt- polyethylene/plastic mix
SBS	Styrene-butadiene
EVA	Ethyl vinyl acetate
PE	Polyethylene
HPE	Hard polyethylene
LPE	Low polyethylene
VTM	Total voids in mix
VMA	Voids in mineral aggregates
VFA	Voids filled with aggregates

CHAPTER 1

INTRODUCTION

1.1 Background Study

Asphalt is sticky, black and highly viscous liquid or semi-solid form of petroleum that also known as bitumen. It may be found in natural deposits or may be a refined product; it is a substance classed as a pitch. The primary use (70%) of asphalt/bitumen is in road construction, where it is used as the glue or binder mixed with aggregate particles to create asphalt concrete. The other main uses for bituminous waterproofing products, including production of roofing felt and for sealing flat roofs. The terms asphalt and bitumen are often used interchangeably to mean both natural and manufactured forms of the substance. Naturally occurring asphalt/bitumen is sometimes specified by the term "crude bitumen". Bituminous binders are widely used by paving industry. The main constituents of bituminous concrete (BC) are aggregate and bitumen. Asphalt is use in the pavement road because it is very economical and achieved the standard road design requirement which are good skid resistance and low maintenance cost.

However, consumption of the asphalt has some weaknesses like hard in cold weather but soft in hot weather. The tropical weather in Malaysia is give the bad impact to the texture and chemical characteristics of asphalt that will cause crack due to weather change from hot to cold. The initiative to reduce the road failure, an improvised asphalt concrete is needed in the road pavement structures. There are many additives material can be used to replace the content of asphalt such as vehicle's tire or other form of plastic material. The biggest wastage of plastic material is plastic bag used in most groceries business. So, in order to reduce the environment problem of the plastic material, plastic bag has been seen as the best material to replace asphalt.

The most common plastic are called polyethylene (PE) or polyethylene. According to WorlCount journal, the plastic material used was around 5 trillion plastic bags a year worldwide and the United States (US) alone throws away enough plastic bottles in a week to encircle the world 5 times and only 1 to 3% of all plastics used are recycled. Its common use is in packaging industries such as plastic films, geo-membranes, plastic bags and containers including bottles where the most plastic material are being used is plastic bags . Plastic bag is easy to get and to process compare to plastic bottles and etc. Moreover, the plastic use in the road pavement can reduce the percentage of asphalt use and the cost of material. Central Road Research Institute (CRRI) state that plastic such as plastic bags mixed with bitumen or rubber will improves the quality and life of roads. This is because the melting point plastic bag –bitumen mixes is high. This innovative technology not only strengthened the road construction but also increased the road life (N.Rokdey et al 2015). Figure 1 shows the pavement layer where the plastic-asphalt mix will be added. The plastic-asphalt mix will be added into the binder course at surface course. The thickness of for all layer is equal to ordinary pavement layer.

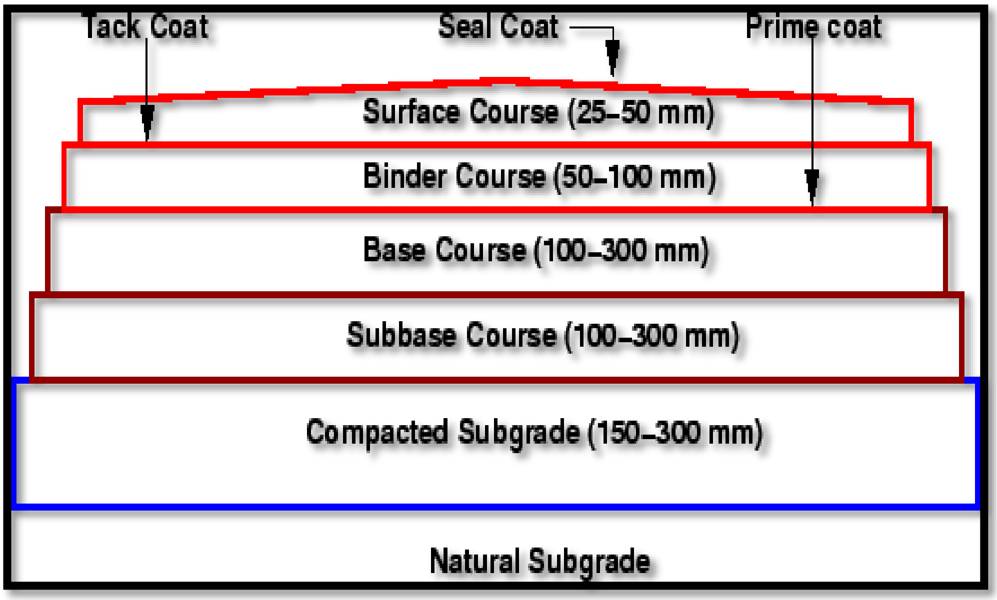


Figure 1-1 Percentage Voids in Total Mix (VTM) for 6% substitution of polyethylene

1.2 Problem Statement

After few years of the construction, some roads in Malaysia ~~a~~ serious distresses have appeared on roads, and thus changed the conditions of the pavement to a failed state, although the road did not achieve its design life period yet, and was designed according to the design manuals. One of the reasons is because of the heavy loading from the vehicles or rapid increasing of the road users in Malaysia. According to Statistics from Ministry of Transport Malaysia, the road user increase 3.5% from year 2009 to 5% 2010 and is expected to maintain its increment for the next 10 years. When the road users are increases, the loading in the road will be increased and the pavement have a problem if the pavement cannot support the high loading or volume (Sulyman, 2014).

There are various types of distresses occur in the road pavement, not only due to an increase of road users or heavy traffic load, but also due to construction method or because of the usage of not quality materials. These situations will ~~which~~ lead to a failure states of pavement. Thus it is very important to study these types of distresses, where distresses are very important factor for the pavement design, and for estimating the road life. Distresses can be divided into five types, pavement cracks, patching and pothole, surface deformation, surface defect, and miscellaneous distresses. Another challenge of road design in Malaysia is the weather change that also can caused the failure on the road pavement. The asphalt cannot withstand drastic weather changes because of it is soft in hot environments but hard in cold environments.

Any improvement in the property of the binder is the needed. According to the excessive production of the waste plastic bags, the initiative to use the plastic bags as good modifier for bitumen is proposed. Environmental Development in Malaysia stated there is no solution in sight for the plastic menace as the material is still freely issued, then carelessly discarded, each day. This application may reduce the productivity of natural resources as well as reduce the energy consumption of material production and all its associated pollution. The performance studies carried out on the roads constructed in Tamil Nadu indicated satisfactory performance with good skid resistance, good texture value, stronger and less amount of progressive unevenness over a period of time. The experimentation carried out by Centre Road Research Institute also indicated the using plastic material will give better stability value, indicating higher strength, less flow and more air voids. The characteristics of polyethylene or plastics bag which is one of plastic type is very good binder between the aggregates (Al-Hadidy A.I., Yi-qiu Tan , 2009) .By using plastic waste such as plastic bags in mix will help reduction in need of bitumen by around 10%, increase the strength and performance of road, avoid use of anti-stripping agent, avoid disposal of plastic waste by incineration and land filling and ultimately develop a technology, which is eco-friendly (Ms.Apurva Chavan, 2013). The previous study by Ms.Aspurva Chavan state that by using plastic in road pavement will increase the compression strength and bending strength compare to ordinary pavement.

Therefore, the experiment to determine the potential of plastic as additives in asphalt pavement will be conducted in this research. It is expected that bitumen-plastic mixes will help to increase the film thickness in the aggregate that can prevent cracking, bleeding and reduce noises. The successful of this research will produce a bitumen-plastic mix having high strength of pavement which will also help to reduce the waste plastic bags time by time.

1.3 Objectives of the Study

The objectives of this project are listed as below:-

- ✓ To identify the binding properties of waste plastic bag (polyethylene) as binding agent in hot mix asphalt.
- ✓ To produce sets of plastic added asphalt mixes by substituting various percentages of asphalt in ordinary asphalt mixes.
- ✓ To compare the strength of ordinary asphalt mixes and plastic added asphalt mixes.

1.4 Scope of Study

1. The plastic bags were obtained from the plastic recycled dustbin elsewhere in Kuantan and it is limited to grocery plastic bags only.

2. The percentages of plastic used is between 8-10 percent from the normal percentage of asphalt quantity.

3. 30 samples will be prepared for this research. There are 15 samples act as control samples which are common asphalt mixes will be used and the rest will be plastic-asphalt mix samples.

4. Marshall Stability, strength compression and water bath test are the laboratory testing that will be conducted to achieve the objectives.
5. The procedures to obtain the strength of the samples will be refer the laboratory manual UMP and the material standard will be using JKR Specifications 4.1.4.2 and ASTM or BS standard.

1.5 Significant of Study

This research is important to solve two problem which are the problem of road and environmental problems. Both issues can be solved by recycle and reuse the waste plastic bags to produce the plastic-asphalt mix before add with aggregates. Finally, the plastic-bitumen mixes can be use in the road construction by adding into sub base or surface course pavement layers. Then, this mixes will reduce the cost of the bitumen, develop environmental friendly structure, and increase the road life by reduce the failure on road.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The asphaltic pavement is an important asset for developing country such as Malaysia. Nowadays, Malaysia weather is leading to the distress on asphalt pavement and leaving the big potholes. Then, the properties of asphalt which is its will soft on hot environment and brittle on cold environment will give the drastic changes on asphalt characteristics due to the climate changes. A quality piece of pavement, especially at the surfacing layers ensures smooth riding and reduces the possibility of unnecessary road accidents (Yaacob et al, 2013). In addition, when hard traffic and high loading weight will give the effect for pavement material such as cracking, fatigue cracking and rutting at high temperature, causing its quality and performance in pavement of the road decrease (Al Maamori, 2014). The maintenance is needed year by year to reduce the road accidents and give the comfortable journey to the road users. The properties of ordinary asphalt mix such as permeability, skid resistance, good drainage, soundness and workability is depends on the quality of material pavement surface. A few of failure modes of the asphalt pavement are rutting, cracking, potholes, bleeding, slippage cracking and etc. The cracking is caused by shrinkage of asphalt pavement due to daily temperature cycling. Typically caused by an ability of the asphalt pavement that contract and expand because of environmental temperature. It allows moisture infiltration and give roughness to pavement surface (Erlingsson, 2013). Next, the alligator cracking will be end of the potholes that caused by the despression on the pavement surface that penetrate all the way through the asphalt layers down to the base course. Slippage or half – moon shaped that generally having two end pointed into direction of traffic caused by braking or turning wheels. This happened because of the low strength surface mix or poor bonding the mixes. The modified asphalt mixes will increase the strength performance of pavement and reduce maintenance cost.

2.2 Modification of Asphalt Mixture

Asphalt modification is contrasting option to improve the quality and life of asphalt. Change can consolidated or include the added substances in the asphalt. There are different of material that can use to make the new asphalt mixture, for example, thermoplastic polymers, different sort of polymers, thermo set, catalyst for substance reaction, crumb rubber, reinforce specialists and aging inhibitors. This is can enhance the asphalt innovation as well as it can decrease the request of the crude materials. But not all the modifier is at present utilized as a part of the asphalt on account of the cost and the required. The frequency of clients changes fundamentally relying upon the promoting of modifier, experience of contractual workers, offices and cost (Bahia, 2006).

2.2.1 Use of waste polyethylene in bituminous concrete mixes

Temperatures and loading rates which diverse look like climatic and loading conditions that can decrease the workability of asphalt. Shukla and Jain (1984) depicted that the impact of wax in bitumen can be diminished by including EVA (Ethyl Vinyl Acetate), aromatic resin and SBS (styrene-butadiene) in the waxy asphalt. The addition of 4% EVA or 6% SB or 8% resin in waxy bitumen viably diminishes the weakness to high temperatures, seeping at high temperature and fragility at low temperature of the mixes. The discoveries of the reviews led by the Shell Research and Technology Centre in Amsterdam demonstrated that the rutting rate is enormously decreased subsequently of SB adjustment of the binder .The asphalt concrete utilizing polyethylene modified binder were more impervious to permanent deformation at elevated temperature (Dennings and Carswell (1981). Sibal et al. (2000) assessed flexural fatigue life of asphalt concrete altered. Fatigue life and creep properties of the polymer modified mixes expanded altogether when contrasted with unmodified asphalt (Goodrich,1998) .The Indian Roads Congress Specifications Special Publication: 53 (2002) demonstrate that the time period and age of next restoration might be stretched out by half in case of surfacing with adjusted bitumen when contrasted with unmodified bitumen.

There are two processes that can lead to create the set of Asphalt-polyethylene Mix (APM) samples which is wet mixing process and dry mixing process. The wet mixing process where the small pieces of plastic bag (polyethylene) is blended with the asphalt at elevated temperature before blending with the hot aggregates. The specific rate of small portion of plastic bag is replaced the quantity of asphalt and reduce the aggregates used is dry mixing process.The major contrasts between these procedure the time that devoured to mix the plastic material. The wet procedure require more vitality to mix the plastic with the asphalt and the greatest rate is around 8% just and it can used the other reused material, for example, elastic and containers plastic at any size, type and shape. The dry procedure mixing, the substance of the waste plastic can utilize over 15% and just appropriate to waste plastic material.

2.3 Recent applications

A 25 km asphalt-polyethylene mix (APM) was laid in Bangalore, India. This street superior smoothness, uniform conduct and less rutting as compared to a conventional asphalt pavement which was laid at same time, which started creating "crocodile crack" before soon after. The procedure has additionally been affirmed, in 2003 by the CRRI (Central Road Research Institute Delhi). Polyethylene as one kind of polymers is utilized to examine the potential prospects to enhance asphalt mixture properties. (Mohammad T. Awwad et al.2007).

2.4 Engineering properties

Some of designing properties of APM that are specific interest when waste plastic material (low density polyethylene) is utilized as a part of granular base application. The ability of waste plastic pack that are utilized as added substances in asphalt configuration will improvised the a few properties of the asphalt building, for example, compacted density and ductility.

2.4.1 Compacted density

The utilization of waste plastic and waste elastic tire in development of streets draws out a superior execution. Since there is better authoritative of bitumen with plastic and tire. The recurrence of voids is additionally diminished because of expanded holding and region of contact amongst polymers and bitumen (Rishi and Supriya,2014).

2.4.2 Ductility

The properties of this adjusted asphaltic blend were contrasted with that of conventional asphaltic blend. It was noticed that penetration and ductility values of adjusted bitumen was diminishing with the expansion in extent of the plastic added substances, up to 12 % by weight (Justo., Veraragavan, 2012).

2.4.3 Flow

Various plastic wastes like, high density polyethylene, if added to asphalt concrete increases physical and mechanical properties of road. If binder used in hot mixes asphalt is prepared by mixing the HDPE by 4%,6% and 8% then, flows increases with increasing the HDPE content, no evolution of any toxic gases as maximum temperature of 180ºC and 10%, increase the strength and performance of roads. Variation of stability with bitumen and waste HDPE at mixing 30°C temperature (Hinisliog Sinan and Agar Emine ,2004).

2.5 Benefit using the waste plastic/polyethylene bag

One of the main advantages of using PAM in road pavement is can improve asphalt resistance to surface initiated cracks, the reduction of fatigue cracking, the reduction of temperature susceptibility, improve durability as well as the reduction in road pavement maintenance.

2.5.1 Reduced demand of waste plastic/polyethylene

The use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics. Use of plastic bags in road help in many ways like easy disposal of waste, better road and prevention of pollution and so on (Vasudevan and Rajasekaran,2007).

2.5.2 Reduced demand of cost maintenance

Collins et al. (1991) and Baker (1998) indicated modified asphalt mixes have longer lives than ordinary asphalt mixes. The addition of polymer to ordinary asphalt also increases its resistance to change of temperature and cracking. So, the cost maintenance that need for every year maintenance will reduce because of the life time for pavement is increases.

2.6 Summary

In this modification asphalt is asphalt-plastic mixes that coated over aggregate. This increases the contact surface area at the interface and ensures better bonding between asphalt and aggregates. The coating of plastic reduce the air voids spaces between the aggregates. This is will prevents oxidation of bitumen and the moisture absorption by entrapped air. The road can withstand heavy traffic, high loading and show better service life. This study will have a positive impact on the environment as it will reduce the volume of plastic waste to be disposed and prevent environment pollution. It will not only reduce the waste material but will develop a technology, which is environmental friendly.

CHAPTER 3

METHODOLOGY

3.1 Introduction

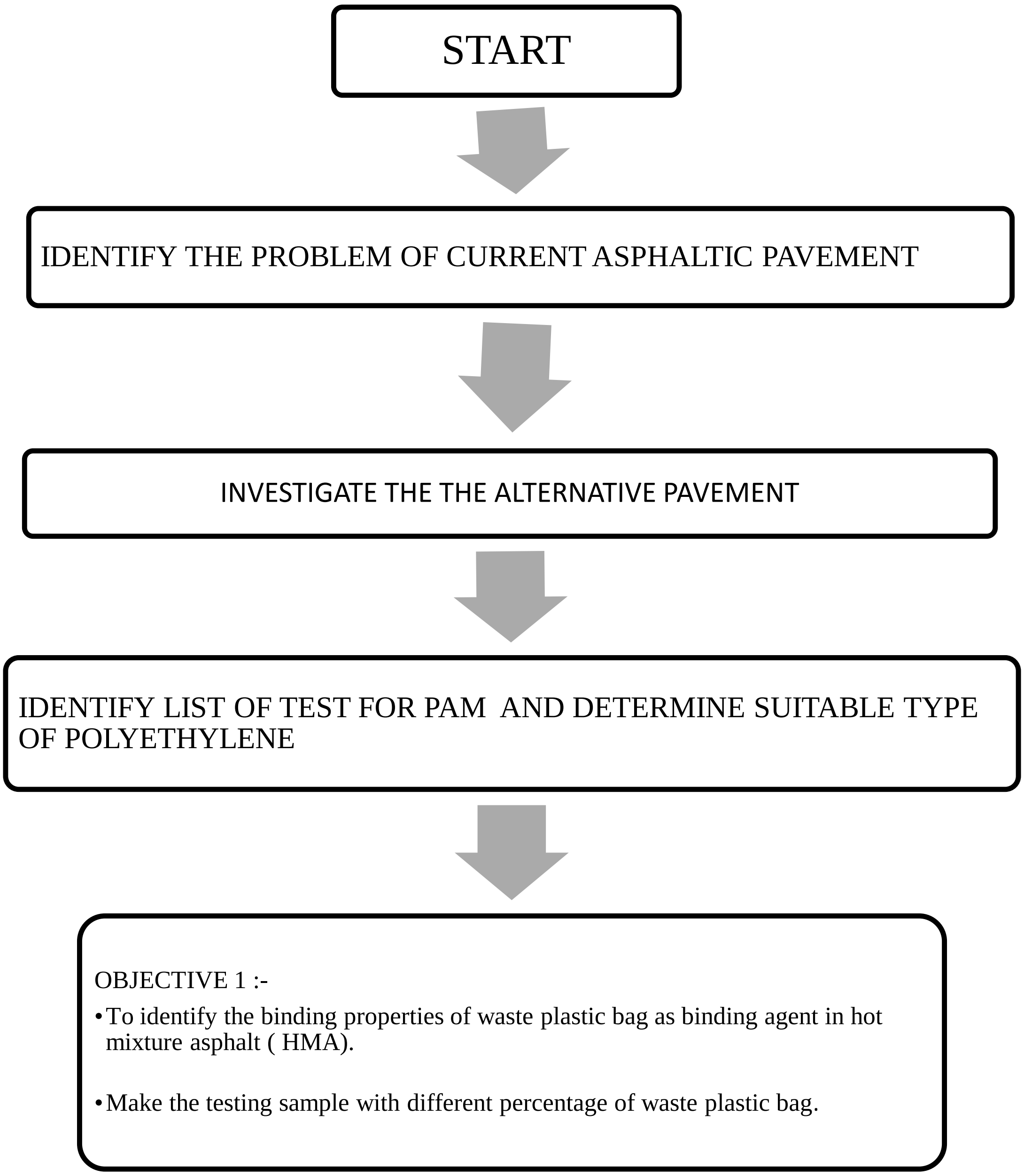
A few methods is expected to accomplish the objectives of the review which is the binding property of plastic waste. The literature review from the previous researcher showed that the plastic waste utilized as a part of the asphalt restrains great binding property. The aggregates was heated to around 170^{o}C and the shredded plastic waste (size) between 2.36mm and 4.75mm) was included plastic got mollified and covered over the aggregates. The mix of the aggregates and plastic was compacted. The samples was hard and indicated compressive quality at least 130Mpa and the binding strength of 500 strength 500kg/cm^2. The polymer coated aggregates was absorbed water for 72 hours. There was no stripping at all and the plastic material is sticks well with the surface of aggregates.

3.2 Preliminary studies

The study on binding property promoted a study on preparation of plastic waste mixes and it is the suitability of properties of the asphalt-plastic blend for the road pavement construction. The plastic waste blending material have a few step which are preparation of blend. In this step, the polyethylene plastic bag were cut 4.75mm sieve and retaining at 2.36mm sieve were collected. These small pieces of plastic were added slowly into the hot bitumen at temperature around 170-180^{o} C. The mixture was stirred for 20-30 minutes. The blend with different percentage of plastic give the difference softening point reading. The higher of percentage of plastic material added, higher the softening point reading. The penetration test conducted to determine the hardness of the asphalt mixture. The increasing plastic material in asphalt, the decreasing of penetration value. Ductility is decreasing by addition of plastic waste into asphalt. The decreasing in ductility value may be due to interlocking of polymer molecules with asphalt. The Marshall Stability Test result the plastic-asphalt blend has higher strength compared to ordinary mixture, which is approximately 1200kg.

3.2.1 Research Flow Chart

PHASE 1



PHASE 2

PREPARE THE CONSTANT SAMPLES AND WASTE PLASTIC BAG

OBTAIN THE WASTE PLASTIC BAG IN PLASTIC RECYCLED DUSTBIN

FIND THE METHOD TO MAKE WASTE PLASTIC BAG INTO SMALL PIECES

OBJECTIVE 2:-

To produce set of plastic added plastic mixes by substituting various percentges of asphalt in ordinary asphalt mixes

LIST OF TEST FOR ASPHALT-PLASTIC MIX

-Density and void analysis

-Marshall Stability

RECORD THE DATA

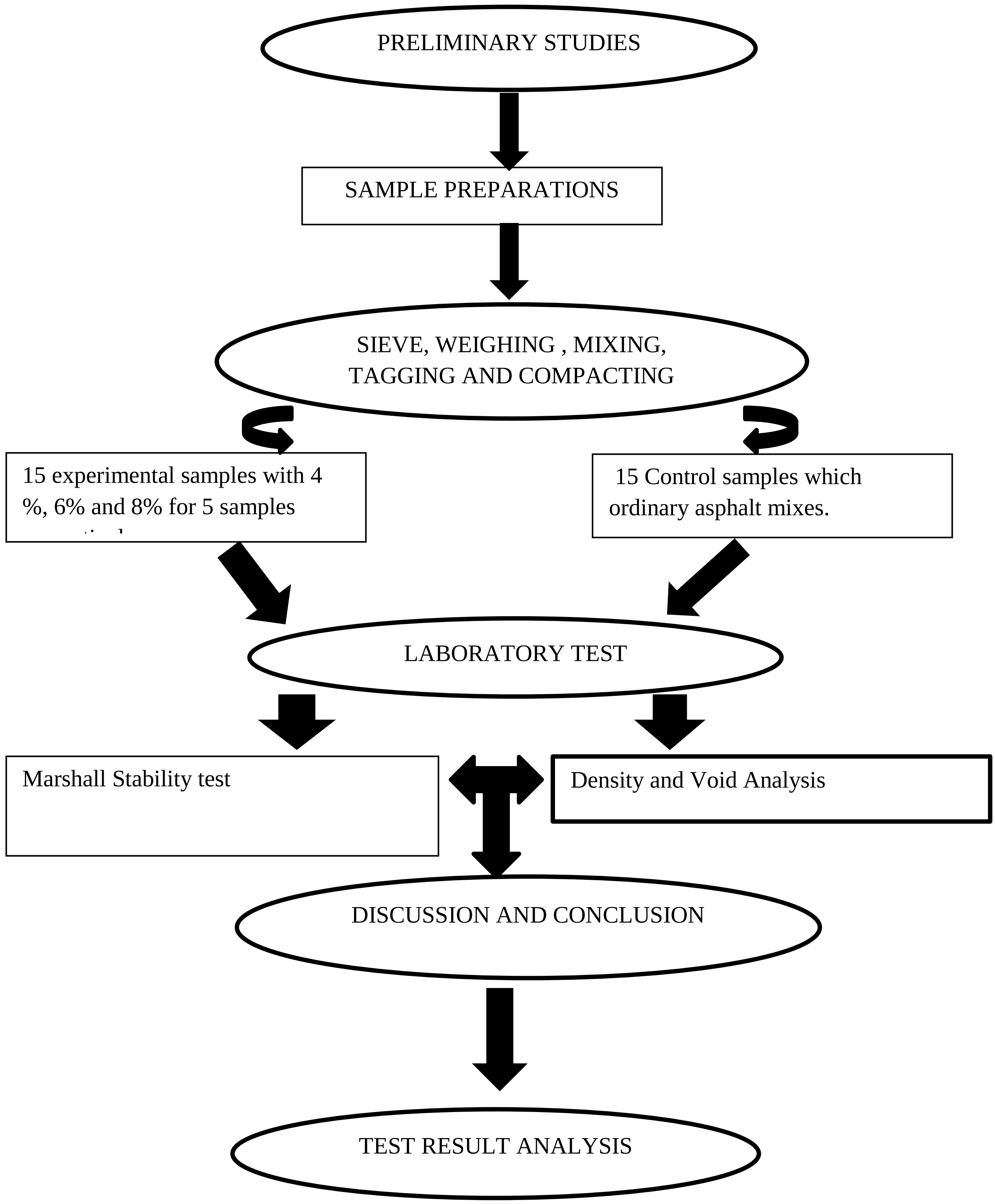
OBJECTIVE 3 / OUTCOME

To compare the strength of ordinary asphalt mixes and plastic added asphalt mix

The research started with identify of the problem pavement in Malaysia. The characteristics of asphalt mixture and design of mixture. A few journal was collected to show the problem and disadvantages of the current pavement in Malaysia. The other factor such as weather and quality of material are considered. Then, investigation of the alternative solution to solve the problems in the eco-friendly environmental ways. The previous study indicated a few solution to solve the pavement problems but the used plastic bag (polyethylene) was choose because of the excessive of the waste in Malaysia according to the journal and articles. In this research by literature reviews, the binding property of the plastic bag (polyethylene) can determined the suitability of the material as additives in pavement. To find the binding property of plastic bag (polyethylene), the preparation of samples with the different percentages of plastic bag is required. The laboratory tests such as compaction test, density and void analysis, and Marshall Stability test are conduct to determine the binding properties, ductility and hardness of the asphalt-plastic samples to compare with the ordinary asphalt mixture.

3.3 Outline methodology

3.3.1 Experimental flow chart



3.4 Sample preparations

To prepare standard specimens of asphalt concrete for the determination of stability and flow in the Marshall apparatus and to determine density, percentage air voids and percentage of aggregate voids filled with binder. A few testing will carried out for the asphalt mix, which includes are Density and Void analysis (ASTM D2726), Marshall Stability and Flow Test (ASTM D1559). 30 samples will be prepared for this research. There are 15 samples act as control samples which are common asphalt mixes will be used and the rest will be plastic-asphalt mix samples.

Table 3-1 Design Bitumen Contents (JKR/SPJ/1988)

GRADE	PERCENTAGE
ACW 10	5.0 – 7.0%
ACW 14	4.5 – 6.5%
ACW 20	4.5 – 6.5%
ACW 28	4.0 – 6.0%

Table 3-2 Number of total samples

	4% of PE	6% of PE	8% of PE	0% of PE (ordinary mix)
4.0% of bitumen	1	1	1	3
4.5% of bitumen	1	1	1	3
5.0% of bitumen	1	1	1	3
5.5% of bitumen	1	1	1	3
6.0% of bitumen	1	1	1	3
Total	5	5	5	15
Total samples	30 samples			

3.4.1 Sieve analysis to achieve proper aggregate gradation

Sieve analysis was carried out to find the suitable aggregate gradation for the mixes. The aggregates were sieved according to Jabatan Kerja Raya (JKR) standard gradation graph to meet specifications. The proposed gradation for the samples was designed according to the gradation graph analysis. The passing aggregates must be within the limit of standard. Proper gradation can produced a better and suitable pavement for the road users. Table 3.3 shows the proposed gradation for the control sample without any improvised.

Table 3-3 Calculation of Marshall Mix Design for Ordinary Samples

Sieve size (mm)	Passing weight (%)	Selected gradation (%)	Average weight of passed aggregates (%)	Weight of aggregates (g)
20	100	100.0	0	0
14	95 – 100	87.5	12.5	150.0
10	80 – 90	79.0	8.5	102.0
5	68 – 80	62.0	17.0	204.0
3.35	52 – 72	53.5	8.5	102.0
1.18	45 – 72	37.5	16.0	192.0
0.425	45 – 62	23.5	14.0	168.0
0.150	17 – 30	11.5	12.0	144.0
0.075	10 – 16	7.0	4.5	54.0
Pan	4 – 10	0	0	0
Total				1116.0
Filler (1200g – 1116g)				84.0 (cement)

Table 3-4 Calculation of Bitumen Content

Percentage of bitumen content (%)	Weight of bitumen (g)
4.0	50.0
4.5	56.54
5.0	63.16
5.5	69.84
6.0	76.50

Calculation weight of bitumen according to percentage:

$$\frac{n}{100} \times (\ 1200 + b) = b$$

n = percentage of bitumen content

b = weight of bitumen content

The weighted of every sample is 1200g include weight of filler but no include the bitumen or plastic/polyethylene (PE). The total weight of bitumen for 15 experimental samples is 854.49g.

3.5 Sample preparation procedures

3.5.1 Marshall Mix Design

The samples preparation consists of the production of the Marshall Mix Design specimen. The total number of samples is 30 samples and it will be prepared in the laboratory with the proper method, apparatus and machines. The procedures are including the sieve of samples, mixing, weighting, compaction, and others according the ASTM standard. The apparatus and machines were used during the sample preparations are as following:

Figure 3-1 Mould with 101.6mm and 76.6mm high

Figure 3-2 Drying oven (140 – 170^{o} C)

Figure 3-3 Weighing

Figure 3-4 Water bath

Figure 3-5 Marshall Compression machine

Figure 3-6   Marshall compactor

Figure 3-7   Sieve shaker

3.6 Density and Void Analysis Calculation Formula

1) Bulk Density

Bulk Density, $d = G_{mb}\ x$

$$G_{mb} = [W_D / (W_{SSD} – W_{SUB}]$$

Where:

d = *Bulk density* (g/cm^3)

G_{mb} = *Bulk specific gravity of the mix*

ρ_w = *density of water* ($1\ g/cm^2$)

W_D = *Mass of specimen in air (g)*

W_{SSD} = *Surface dry mass (g)*

2) Voids in Total Mix (VTM)

$$VTM = [1- (d/TMD)]\ x\ 100$$

$$TMD = G_{mm}\ x\ \rho_w$$

$$G_{mm} = \{1/[((1- P_b)/G_{se}) + P_b / G_b]\}$$

Where:

D = *bulk density*

ρ_w = *density of water* ($1g/cm^2$)

G_{mm} = *Maximum theoretical specific gravity of the mix*

TMD = *Maximum theoretical density (g/cm^3)*
P_b = *asphalt content, percent by weight of the mix*
G_{se} = *effective specific gravity of the mix*
G_b = *specific gravity of asphalt cement*

3) Voids in the Mineral Aggregates (VMA)

$$VMA = 100 \times \{1- [G_{mb}(1- P_b) / G_{sb}]\}$$

Where:

G_{mb} = *bulk specific gravity of the mix*

P_b = *asphalt content, percent by weight of the mix*

G_{sb} = *bulk specific gravity of the aggregate*

4) Marshall Stability and Flow of bituminous mixture

To measure the resistance to plastic flow of cylindrical specimens of an asphalt paving mixture loaded on the lateral surface by means of the Marshall Apparatus. The method is suitable for mixes containing aggregates up to 25mm maximum size.

3.7 SUMMARY

At the end of the last work, 15 samples with the five different bitumen content designed according to JKR standard. The percentage of bitumen for 15 samples are 4.0% - 6.0% are produced and 15 samples of improvised bitumen produced. A few testing will be carried out for this sample are Density and Void Analysis (ASTM D2726) and Marshall Stability and Flow Test (ASTM D1559). Based on the result, all samples compared with the samples with the polyethylene content with the different percentage of substituted.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The data was collected is the standard laboratory test. All the data are recorded to conclude the project outcome. The result of the control samples were compared to the experimental sample to determine its properties and other effects. The results from the experiment were presented in the graph and other collection method. These methods give a clear view of the result where discussion can be made easily. The purpose of the study is determine the properties of polyethylene in improving it effectiveness to substitute with Hot Mix Asphalt (HMA) in terms of air voids, stability, flow, and stiffness. In this chapter, all the results were presented in the table and graphs format.

4.2 Result of Marshall Mixture Mix, Marshall Stability and Flow Test for Control Samples

Table 4-1 Weighing, Marshall Stability and flow Result

Bitumen content(%)	No. of sample	Height (mm)	Weight (g)			Marshall stability (kN)	Flow (mm)
			Air	Water	SSD		
4	1	70.04	1244.1	679.0	1246.6	13.735	3.504
	2	72.11	1231.1	669.5	1235.9	10.062	5.400
	3	69.87	1246.4	680.5	1248.6	14.275	3.612
Average						12.690	4.172
4.5	1	71.55	1217.5	687.5	1221.1	16.755	4.350
	2	71.18	1217.8	667.8	1220.8	13.785	4.750
	3	70.69	1216.8	680.5	1250.5	13.670	4.960
Average						14.740	4.686
5.0	1	71.50	1241.8	680.5	1250.0	20.015	4.680
	2	71.01	1244.5	687.5	1251.8	16.137	5.040
	3	71.28	1244.9	679.1	1252.0	13.570	4.460
Average						16.574	4.727
5.5	1	70.95	1277.8	687.4	1283.0	16.069	4.925
	2	70.55	1259.8	703.1	1268.7	16.137	4.690
	3	71.01	1243.4	677.4	1250.7	23.100	5.080
Average						18.435	5.016
6.0	1	73.00	1259.7	681.4	1268.5	18.120	5.746
	2	72.96	1312.6	716.6	1321.0	23.100	5.096
	3	72.56	1270.6	711.0	1275.3	16.105	4.206
Average						19.108	5.016

Table 4.1 showed the data of weight at air, water and surface dry in gram unit. Then, the Marshall stability and flow that were recorded by Marshall Compacter machine.

4.3 Density and Voids of Control Samples

4.3.1 Bulk Density (g/mm^3)

Table 4-2 Bulk Density (g/mm^2) control samples

Bitumen Content (%)	No. of sample	Marshall Stability (kN)	Flow (mm)	Bulk Density (g/mm^2)
4	1	13.735	3.504	0.002192
	2	10.062	5.400	0.002173
	3	14.275	3.612	0.002194
4.5	1	16.755	4.350	0.002282
	2	13.785	4.750	0.002202
	3	13.670	4.960	0.002135
5.0	1	20.150	4.680	0.002181
	2	16.137	5.040	0.002205
	3	13.570	4.460	0.002173
5.5	1	16.069	4.925	0.002142
	2	16.137	4.690	0.002227
	3	23.100	5.080	0.002168
6.0	1	18.120	5.746	0.002146
	2	23.100	5.096	0.002172
	3	16.105	4.206	0.002252

Table 4.2 showed the bulk density that was determined by simply formula and the data was simply determined by weighing in the air and water.

4.3.2 Voids in Total Mix (VTM) for Control Samples

Table 4-3 Percentage of Voids in Total Mix (VTM) for Control Samples

Bitumen Content (%)	No. of sample	Marshall Stability (kN)	Flow (mm)	Bulk Density (g/mm^3)	TMD (g/mm)	VTM (%)
4	1	13.735	3.504	0.0022	0.002422	9.16
	2	10.062	5.400	0.0022	0.002422	9.16
	3	14.275	3.612	0.0022	0.002422	9.16
4.5	1	16.755	4.350	0.0022	0.002400	8.33
	2	13.785	4.750	0.0022	0.002400	8.33
	3	13.670	4.960	0.0022	0.002400	8.33
5.0	1	20.150	4.680	0.0022	0.002374	7.33
	2	16.137	5.040	0.0022	0.002374	7.33
	3	13.570	4.460	0.0022	0.002374	7.33
5.5	1	16.069	4.925	0.0021	0.002352	6.46
	2	16.137	4.690	0.0021	0.002352	6.46
	3	23.100	5.080	0.0021	0.002352	6.46
6.0	1	18.120	5.746	0.0021	0.002331	5.62
	2	23.100	5.096	0.0021	0.002331	5.62
	3	16.105	4.206	0.0021	0.002331	5.62

The percentage of air voids in the mix was determined by firstly calculated the maximum theoretical density (zero voids) TMD. The highest and lowest value air voids for overall samples was 9.16% and 5.62% respectively.

4.3.3 Voids in the Mineral Aggregates

Table 4-4 Percentage of Voids in the Mineral Aggregates (VMA) for Control Samples

Bitumen Content (%)	No. of sample	Marshall Stability (kN)	Flow (mm)	Bulk Density (g/mm^3)	TMD (g/mm)	VTM (%)	VMA (%)
4	1	13.735	3.504	0.0022	0.002422	9.16	20.00
	2	10.062	5.400	0.0022	0.002422	9.16	20.65
	3	14.275	3.612	0.0022	0.002422	9.16	19.93
Average							20.19
4.5	1	16.755	4.350	0.0022	0.002400	8.33	19.12
	2	13.785	4.750	0.0022	0.002400	8.33	20.02
	3	13.670	4.960	0.0022	0.002400	8.33	22.45
Average							20.53
5.0	1	20.150	4.680	0.0022	0.002374	7.33	21.50
	2	16.137	5.040	0.0022	0.002374	7.33	20.64
	3	13.570	4.460	0.0022	0.002374	7.33	20.35
Average							20.83

5.5	1	16.069	4.925	0.0021	0.002352	6.46	23.35
	2	16.137	4.690	0.0021	0.002352	6.46	20.42
	3	23.100	5.080	0.0021	0.002352	6.46	22.49
Average							22.09
6.0	1	18.120	5.746	0.0021	0.002331	5.62	23.86
	2	23.100	5.096	0.0021	0.002331	5.62	21.94
	3	16.105	4.206	0.0021	0.002331	5.62	20.10
Average							21.97

The highest average value of voids in the mineral aggregates (VMA) for control samples was 22.09% with bitumen content 5.5% and the lowest average value was 20.19% with bitumen content 4.0%.

4.3.4 Voids Filled with Asphalt (VFA)

Table 4-5 Percentage of Voids filled with Asphalt (VFA) for control samples

Bitumen Content(%)	No. of sample	Marshall Stability (kN)	Flow (mm)	Bulk Density (g/mm^3)	TMD (g/mm)	VTM (%)	VMA (%)	VFA (%)
4	1	13.735	3.504	0.0022	0.002422	9.16	20.00	54.20
	2	10.062	5.400	0.0022	0.002422	9.16	20.65	55.64
	3	14.275	3.612	0.0022	0.002422	9.16	19.93	54.04
Average							20.19	54.63
4.5	1	16.755	4.350	0.0022	0.002400	8.33	19.12	51.34
	2	13.785	4.750	0.0022	0.002400	8.33	20.02	58.39
	3	13.670	4.960	0.0022	0.002400	8.33	22.45	65.90
Average							20.53	59.54
5.0	1	20.150	4.680	0.0022	0.002374	7.33	21.50	65.91
	2	16.137	5.040	0.0022	0.002374	7.33	20.64	64.49
	3	13.570	4.460	0.0022	0.002374	7.33	20.35	63.96
Average							20.83	64.79
5.5	1	16.069	4.925	0.0021	0.002352	6.46	23.35	72.33
	2	16.137	4.690	0.0021	0.002352	6.46	20.42	68.36
	3	23.100	5.080	0.0021	0.002352	6.46	22.49	71.28
Average							22.09	70.66
6.0	1	18.120	5.746	0.0021	0.002331	5.62	23.86	76.45
	2	23.100	5.096	0.0021	0.002331	5.62	21.94	75.50
	3	16.105	4.206	0.0021	0.002331	5.62	20.10	72.04
Average							21.97	74.66

Table above shows that the 6.0% bitumen content gave the highest average result for percentage voids in mineral aggregates (VMA) was 74.66% and lowest average value was 54.63% for 4.0% bitumen content.

4.4 Marshall Stability and Flows for Control Samples (ASTM D1559)

4.4.1 Marshall Stability for control Samples

Table 4-6 Marshall Stability for Control Samples (ASTM D1559)

Sample	Binder (%)	Average Height (mm)	Average Diameter (mm)	Volume Of The Sample (cm^3)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)
1	4.0	70.04	101.66	568.508	0.86	13.735	11.812
2		72.11	101.53	583.813	0.83	10.062	8.351
3		69.87	101.60	566.458	0.86	14.275	12.277
Average						12.691	10.813
1	4.5	71.55	101.61	580.192	0.83	16.755	13.907
2		71.18	101.63	577.419	0.83	13.785	11.442
3		70.69	101.29	569.614	0.86	13.670	11.756
Average						14.736	12.368
1	5.0	71.50	101.27	575.913	0.83	20.015	16.612
2		71.01	101.43	573.775	0.86	16.137	13.878
3		71.28	101.50	576.752	0.83	13.570	11.263
Average						16.574	13.918
1	5.5	70.55	101.47	570.508	0.86	16.069	13.819
2		70.57	101.53	571.345	0.86	16.137	13.878
3		70.60	101.64	572.827	0.86	23.100	19.866
Average						18.435	15.824
1	6.0	71.12	101.52	575.684	0.83	18.120	15.040
2		71.19	101.51	576.138	0.83	23.100	19.173

3		71.15	101.76	578.654	0.83	16.105	13.367
Average						19.108	15.86

The highest average value of Marshall Stability was 15.86 kN with bitumen content or percentage of binder 6.0% where as the lowest value was 10.813 kN with binder percentage was 4.0%.The load was applied to the specimen at the constant strain rate of 50.88mm/min according to ASTMD1559 until the maximum load was reached. The maximum force and flow at the force were read and recorded .Reference Table 1.0 taken from ASTM D1559:

Volume of specimen (cm^3)	**Approximate thickness of specimen (mm)**	**CHAPTER 5Correlation ratio**
200-213	25.4	5.56
214-225	27.0	5.00
226-237	28.6	4.55
238-250	30.2	4.17
251-264	31.8	3.85
265-276	33.3	3.57
277-289	34.9	3.33
290-301	36.5	3.03
302-316	38.1	2.78
317-328	39.7	2.50
329-340	41.3	2.27
341-353	42.9	2.08
354-367	44.4	1.92
368-379	46.0	1.79
380-392	47.6	1.67
393-405	49.2	1.56
406-420	50.8	1.47
421-431	52.4	1.39
432-443	54.0	1.32
444-456	55.6	1.25
457-470	57.2	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-552	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.8	0.86
574-585	71.4	0.83
586-598	73.0	0.81
599-610	74.6	0.78
611-625	76.2	0.76

Stability correlation ratio (from ASTM D1559)

4.4.2 Flows for Control Samples

Table 4-7 Flows for Control Samples

Bitumen content (%)	No. of sample	Height (mm)	Weight (g)			Flow (mm)
			Air	Water	SSD	
4	1	70.04	1244.1	679.0	1246.6	3.504
	2	72.11	1231.1	669.5	1235.9	5.400
	3	69.87	1246.4	680.5	1248.6	3.612
Average						4.172
4.5	1	71.55	1217.5	687.5	1221.1	4.350
	2	71.18	1217.8	667.8	1220.8	4.750
	3	70.69	1216.8	680.5	1250.5	4.960
Average						4.686
5.0	1	71.50	1241.8	680.5	1250.0	4.680
	2	71.01	1244.5	687.5	1251.8	5.040
	3	71.28	1244.9	679.1	1252.0	4.460
Average						4.727
5.5	1	70.95	1277.8	687.4	1283.0	4.925
	2	70.55	1259.8	703.1	1268.7	4.690
	3	71.01	1243.4	677.4	1250.7	5.080
Average						5.016
6.0	1	73.00	1259.7	681.4	1268.5	5.746
	2	72.96	1312.6	716.6	1321.0	5.096
	3	72.56	1270.6	711.0	1275.3	4.206
Average						5.016

Then, the highest and lowest average value for flow was 5.016mm and the 4.172mm respectively.

4.5 Density and Void Analysis for 4% Substitution of Polyethylene /Plastic

4.5.1 Weight for 4% substitution polyethylene /plastic

Bitumen content before substitute 4.0% of polyethylene/plastic (%)	Weight of bitumen before substitute 4.0% of polyethylene/plastic (%) , a	Weight of polyethylene/plastic content (g) , b	Weight of bitumen content (g) , (a – b)
4.0	50.00	2.00	48.0
4.5	56.54	2.26	54.54
5.0	63.16	2.53	60.63
5.5	69.84	2.80	67.14
6.0	76.50	3.06	73.44

Table 4-8 Weight of bitumen content after substitute with 4.0% polyethylene/plastic

4.5.2 Voids in total mix (VTM)

Table 4-9 Voids in Total Mix (VTM)

Sample	Binder (%)	Weight in (g)			Bulk Density (g/mm)	TMD (g/mm)	VTM (%)
		Air	Water	SSD			
1	4.0	1254.4	696.2	1258.1	0.00223	0.00246	9.14
2	4.5	1206.6	670.5	1207.0	0.00225	0.00244	7.79
3	5.0	1193.2	656.5	1196.0	0.00221	0.00242	6.22
4	5.5	1195.8	668.0	1197.1	0.00226	0.00241	5.68
5	6.0	1239.4	695.4	1240.1	0.00228	0.00239	4.60

For 4% substitution of polyethylene/plastic the highest value for air voids was 9.14% and the lowest value was 4.60%.

4.5.3 Voids in Mineral Aggregates (VMA)

Table 4-10 Voids in Mineral Aggregates (VMA)

Sample	Binder (%)	Weight (g)			Bulk Density (g/mm)	TMD (g/mm)	VTM (%)	VMA (%)
		Air	Water	SSD				
1	4.0	1254.4	696.2	1258.1	0.00223	0.00246	9.3496	17.6668
2	4.5	1206.6	670.5	1207.0	0.00225	0.00244	7.7869	17.4870
3	5.0	1193.2	656.5	1196.0	0.00221	0.00242	8.6777	17.2818
4	5.5	1195.8	668.0	1197.1	0.00226	0.00241	6.2241	17.9502
5	6.0	1239.4	695.4	1240.1	0.00228	0.00239	4.6025	17.8311

Table 4.10 showed that the for voids in mineral aggregates is 17.9% and the lowest is 17.2818.

4.5.4 Voids filled aggregates

Table 4-11 Voids filled with Asphalt (VFA)

Sample	Binder (%)	Weight in (g)			Bulk Density (g/mm)	TMD (g/mm)	VTM (%)	VMA (%)	VFA (%)
		Air	Water	Surface Dry					
1	4.0	1254.4	696.2	1258.1	0.00223	0.00246	9.3496	17.6668	47.0781
2	4.5	1206.6	670.5	1207.0	0.00225	0.00244	7.7869	17.4870	55.4703
3	5.0	1193.2	656.5	1196.0	0.00221	0.00242	8.6777	19.2818	54.9954
4	5.5	1195.8	668.0	1197.1	0.00226	0.00241	6.2241	17.9502	65.3257
5	6.0	1239.4	695.4	1240.1	0.00228	0.00239	4.6025	17.8311	74.1884

4.6 Marshall Stability and flow for 4% substitution polyethylene/plastic

4.6.1 Marshall Stability and flow for 4% substitution polyethylene/plastic

Table 4-12 Marshall Stability 4% substitution polyethylene/plastic

Sample	Binder (%)	Average Height (mm)	Average Diameter (mm)	Volume Of The Sample (cm^3)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)
1	4.0	70.81	101.6	574.0793	0.83	12.054	10.0048
2	4.5	65.52	101.6	531.1916	0.96	12.060	11.2480
3	5.0	64.79	101.6	525.2732	0.96	12.969	12.4502
4	5.5	64.51	101.6	532.0032	0.96	13.971	13.4642
5	6.0	66.37	101.6	538.0828	0.93	15.292	14.2216

The highest Marshall Stability 14.2216 kN and the lowest was 10.0048 kN.

Table 4-13 Flow for 4% substitution polyethylene/plastic

Sample	Binder (%)	Volume Of The Sample (cm^3)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)	Flow (mm)
1	4.0	574.0793	0.83	12.054	10.0048	4.012
2	4.5	531.1916	0.96	20.050	19.2480	4.100
3	5.0	525.2732	0.96	12.969	12.4502	4.208
4	5.5	532.0032	0.96	12.921	12.4042	4.314
5	6.0	538.0828	0.93	15.292	14.2216	4.153

The highest value for the flow is 4.314mm and the lowest value is 4.012mm.

4.7 Density and Voids Analysis for 6% Substitution Polyethylene /Plastic

4.7.1 Weight of bitumen after substituted with 6% polyethylene/plastic

Table 4-14 Weight of bitumen after substituted with 6% polyethylene/plastic

Bitumen content before substitute 6.0% of polyethylene /plastic (%)	Weight of bitumen before substitute 6.0% of polyethylene/plastic (%) , a	Weight of polyethylene/plastic content (g) , b	Weight of bitumen content (g) , (a – b)
4.0	50.00	3.00	47.00
4.5	56.54	3.40	53.10
5.0	63.16	3.80	59.76
5.5	69.84	4.19	65.65
6.0	76.50	4.59	71.91

Table above showed the weight of bitumen after substituted with 6% polyethylene/plastic. The unit is in gram.

4.7.2 Voids in Total Mix (VTM)

Table 4-15 Percentage Voids in Total Mix (VTM) for 6% substitution of polyethylene

Sample	Binder (%)	Weight in (g)			Bulk Density (g mm)	TMD(g/mm)	VTM(%)
		Air	Water	SSD			
1	4.0	1200.0	670.1	1201.0	0.00226	0.00246	8.13
2	4.5	1209.1	682.4	1209.6	0.00229	0.00244	6.15
3	5.0	1214.8	685.5	1215.9	0.00229	0.00242	5.37
4	5.5	1217.5	690.8	1217.7	0.00231	0.00241	4.15
5	6.0	1219.2	693.5	1219.4	0.00232	0.00239	2.93

4.7.3 Voids in the Mineral Aggregates (VMA)

Table 4-16 Percentage Voids in Mineral Aggregates(VMA) for 6% substitution of polyethylene

Sample	Binder (%)	Weight (g)			Bulk Density (g /mm^3)	TMD(g/mm)	VTM(%)	VMA(%)
		Air	Water	SSD				
1	4.0	1200.0	670.1	1201.0	0.00226	0.00246	8.13	16.65
2	4.5	1209.1	682.4	1209.6	0.00229	0.00244	6.15	15.98
3	5.0	1214.8	685.5	1215.9	0.00229	0.00242	5.37	16.42
4	5.5	1217.5	690.8	1217.7	0.00231	0.00241	4.15	16.14
5	6.0	1219.2	693.5	1219.4	0.00232	0.00239	2.93	16.22

The highest VMA for 6% substitution of polyethylene 16.65% and the lowest value was 15.98%.

4.7.4 Voids Filled with Asphalt (VFA)

Table 4-17 Percentage Voids Filled with Asphalt (VFA) for 6% substitution of polyethylene

Sample	Binder (%)	Weight in (g)			Bulk Density (g mm)	TMD (g/mm)	VTM(%)	VMA(%)	VFA(%)
		Air	Water	SSD					
1	4.0	1200.0	670.1	1201.0	0.00226	0.00246	8.13	16.65	51.17
2	4.5	1209.1	682.4	1209.6	0.00229	0.00244	6.15	15.98	61.51
3	5.0	1214.8	685.5	1215.9	0.00229	0.00242	5.37	16.42	67.30
4	5.5	1217.5	690.8	1217.7	0.00231	0.00241	4.15	16.14	74.29
5	6.0	1219.2	693.5	1219.4	0.00232	0.00239	2.93	16.22	81.94

4.8 Marshall Stability and Flow for 6% substitution Polyethylene /Plastic

4.8.1 Marshall Stability and flow for 6% substitution Polyethylene /Plastic

Table 4-18 Marshall Stability for 6% substitution Polyethylene /Plastic

Sample	Binder (%)	Average Height (mm)	Average Diameter (mm)	Volume Of The Sample (cm³)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)
1	4.0	70.00	101.6	574.0293	0.86	22.054	18.253
2	4.5	65.02	101.6	530.1916	0.96	22.060	17.392
3	5.0	65.19	101.6	524.2732	0.96	20.969	17.424
4	5.5	64.51	101.6	530.0032	0.96	20.971	15.758
5	6.0	66.27	101.6	537.0828	0.93	20.292	11.220

The lowest value was 11.22kN and the highest value 18.25Kn for Marshall stability of 6% substitution polyethylene/plastic

Table 4-19 Flow for 6% substitution polyethylene/plastic

Sample	Binder (%)	Volume Of The Sample (cm³)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)	Flow (mm)
1	4.0	574.0293	0.86	22.054	18.253	4.002
2	4.5	530.1916	0.96	22.050	17.392	4.412
3	5.0	524.2732	0.96	20.969	17.424	4.598
4	5.5	530.0032	0.96	20.971	15.758	5.208
5	6.0	537.0828	0.93	20.292	11.220	5.235

The lowest value of flow was 4.00mm and the highest value was 5.235mm.

4.9 Density and Voids Analysis for Substitution 8% Polyethylene/Plastic

4.9.1 Weight of bitumen after substitution 8% polyethylene/plastic

Table 4-20 Weight of bitumen after substitution 8% polyethylene/plastic

Bitumen content before substitute 8.0% of polyethylene/plastic (%)	Weight of bitumen before substitute 8.0% of polyethylene/plastic (%) , a	Weight of polyethylene/plastic content (g) , b	Weight of bitumen content (g) , (a – b)
4.0	50.00	4.00	56.00
4.5	56.54	4.52	52.02
5.0	63.16	5.05	58.11
5.5	69.84	5.59	64.25
6.0	76.50	6.12	70.38

The table above showed the weight of bitumen content after minus with the polyethylene/plastic.

4.9.2 Voids in Total Mix (VTM)

Table 4-21 Percentage of Voids in Total Mix (VTM) for 8% substitution Polyethylene/Plastic

Sample	Binder (%)	Weight in (g)			Bulk Density (g/mm)	TMD (g/mm)	VTM (%)
		Air	Water	SSD			
1	4.0	1087.3	622.6	1092.6	0.00231	0.00246	6.0976
2	4.5	1138.5	656.5	1142.8	0.00234	0.00244	4.0984
3	5.0	1147.4	663.4	1149.1	0.00236	0.00242	2.4793
4	5.5	1204.9	697.8	1206.4	0.00237	0.00241	1.6598
5	6.0	1147.4	665.2	1148.9	0.00237	0.00239	0.8368

The highest value for VTM is 6.1% and the lowest value of VTM for 8% substitution of polyethylene.

4.9.3 Voids in Mineral Aggregates (VMA)

Table 4-22 Percentage of Voids in Mineral Aggregates (VMA) for 8% substitution Polyethylene /Plastic

Sample	Binder (%)	Weight in (g)			Bulk Density (g/mm)	TMD (g/mm)	VTM (%)	VMA (%)
		Air	Water	SSD				
1	4.0	1087.3	622.6	1092.6	0.00231	0.00246	6.0976	14.81
2	4.5	1138.5	656.5	1142.8	0.00234	0.00244	4.0984	14.15
3	5.0	1147.4	663.4	1149.1	0.00236	0.00242	2.4793	13.89
4	5.5	1204.9	697.8	1206.4	0.00237	0.00241	1.6598	13.96
5	6.0	1147.4	665.2	1148.9	0.00237	0.00239	0.8368	14.41

The highest value VMA was 14.81% and the lowest was 13.89% for 8% substitution polyethylene/plastic.

4.9.4 Voids filled with Asphalt (VFA)

Table 4-23 Percentage of Voids filled with Asphalt (VFA) for 8% substitution Polyethylene /Plastic

Sample	Binder (%)	Weight in (g)			Bulk Density (g/mm)	TMD (g/mm)	VTM (%)	VMA (%)	VFA (%)
		Air	Water	SSD					
1	4.0	1087.3	622.6	1092.6	0.00231	0.00246	6.0976	14.81	58.83
2	4.5	1138.5	656.5	1142.8	0.00234	0.00244	4.0984	14.15	71.04
3	5.0	1147.4	663.4	1149.1	0.00236	0.00242	2.4793	13.89	82.15
4	5.5	1204.9	697.8	1206.4	0.00237	0.00241	1.6598	13.96	88.11
5	6.0	1147.4	665.2	1148.9	0.00237	0.00239	0.8368	14.41	94.19

Table 4.23 showed the percentage of VFA for 8% substitution polyethylene/plastic. The highest value was 94.19% and the lowest value was 58.83%.

4.10 Marshall Stability and Flow for 8% Substitution Polyethylene/ Plastic

4.10.1 Marshall Stability and flow for 8% substitution polyethylene / plastic

Table 4-24 Marshall Stability for 8% substitution polyethylene

Sample	Binder (%)	Average Height (mm)	Average Diameter (mm)	Volume Of The Sample (cm3)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)
1	4.0	59..22	101.6	524.544	0.96	24.239	23.269
2	4.5	61.35	101.6	516.436	1	23.963	23.963
3	5.0	60.88	101.6	522.111	1	18.557	18.557
4	5.5	63.13	101.6	539.947	0.93	15.375	14.299
5	6.0	60.6	101.6	523.003	0.96	12.504	12.004

Marshall Stability for 8% substitution polyethylene was showed table above. The highest value was 23.963kN and the lowest was 12.00kN.

Table 4-25 Flow for 8% substitution polyethylene/plastic

Sample	Binder (%)	Volume Of The Sample (cm3)	Height Correlation Ratio	Marshall Stability (kN)	Corrected Marshall Stability (kN)	Flow (mm)
1	4.0	524.544	0.96	24.239	23.269	4.211
2	4.5	516.436	1	23.963	23.963	4.532
3	5.0	522.111	1	18.557	18.557	5.040
4	5.5	539.947	0.93	15.375	14.299	5.328
5	6.0	523.003	0.96	12.504	12.004	5.319

Table above showed the flow for 8% substitution polyethylene/plastic. The lowest value was 4.211mm of sample number 1 and 5.319mm for sample number 5 and this is highest value.

4.11 Comparison between control and experimental samples in terms of Density, Air voids and Marshall Stability test

The comparison between control samples and experimental samples needed to confirmation the objectives for this study. The value for experimental sample must were recorded in the tables and graphs to give clear view about the outcomes.

4.11.1 Analysis of Air Voids (AV)

Air voids are the important factor to correlate results to performance of the asphalt pavement. The amount of the air affected the stability and the durability of the mix. If the air voids are low, rutting can occur and if the air voids too high, the mixes are permeable to air and water can cause premature cracking and raveling of the mix. A proper percentage of the air voids is necessary to prevent the pavement from flushing, shoving and rutting. It can be controlled by manipulating the binder content. The durability of and asphalt pavement is an function of the void content.

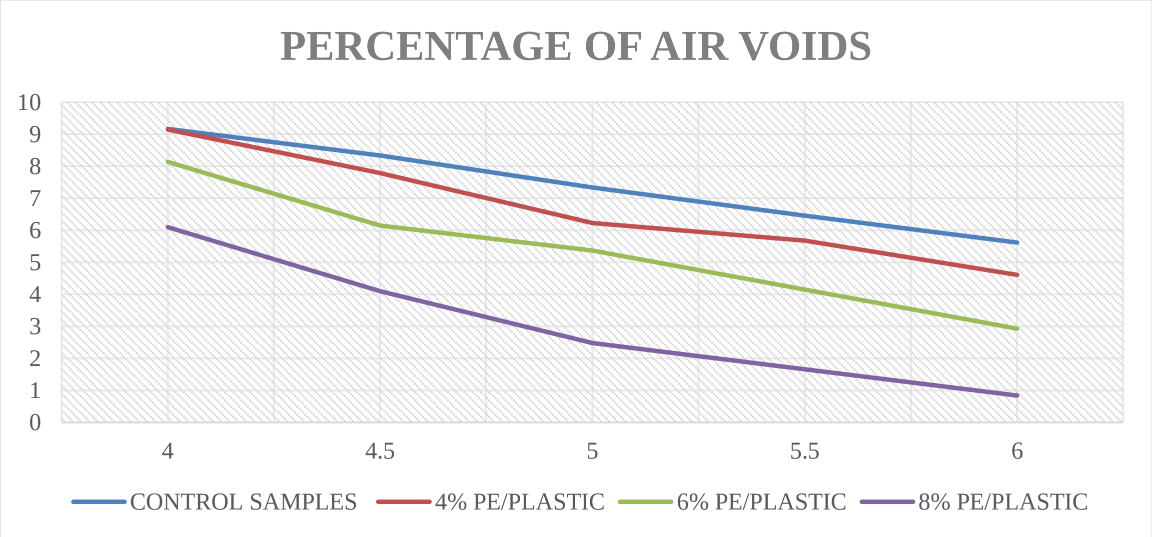


Figure 4-1 Percentage of Air Voids vs Percentage of Bitumen Content

The result of the void and density analysis were presented using the graphical method to compare the effect of the plastic/polyethylene. The graph were built using the mean value of experimental samples and the value of each sample for 4%,6% and 8%

polyethylene/plastic content . The result show the 8% of the polyethylene/plastic content in the mix was the less percentage of air voids. All the experimental sample air voids were less percentage than the control samples. At any bitumen content the air voids were less by substitute the certain percentage of polyethylene/plastic.

4.11.2 Analysis of Voids in the Mineral Aggregates (VMA)

The voids in mineral aggregates or VMA is the total volume of voids within the mass of sample with sample compacted. VMA is important to allow room for enough asphalt binder to make a durable. If the VMA is too large, an uneconomical amount of asphalt binder will required to reduce the mixture air voids to an acceptable level. This amount of asphalt binder in the mixture may also lead to mixture stability problems .As the nominal maximum particles size of the aggregates increase and the minimum VMA required decrease. This occurs because the total space between large aggregates particles is smaller than the voids space between small aggregates particles (Robert, 1991).

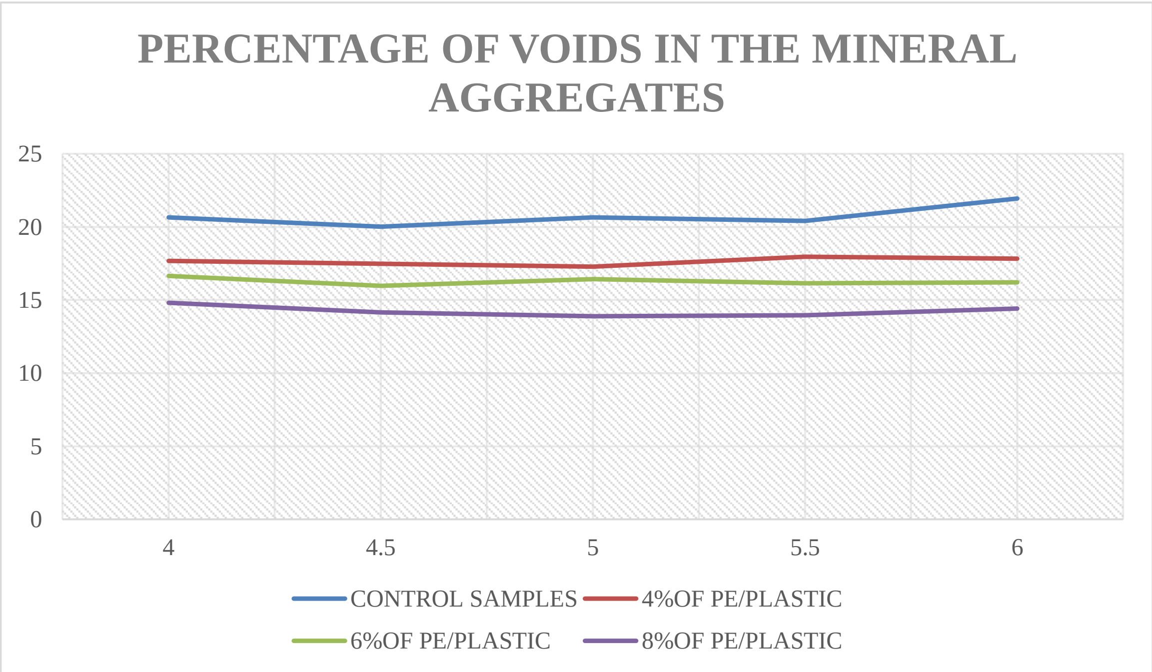


Figure 4-2 Percentage VMA vs Percentage bitumen content

Figure 4.2 shows the control samples has higher voids in mineral aggregates than experiment sample. It shows that the 8% polyethylene/plastic substitution has the highest value of VMA for all the bitumen content.

4.11.3 Analysis of Voids Filled with Asphalt (VFA)

It is percentage of the VMA ,VFA can limit the amount of VMA. VFA is purposed to avoid less durable HMA resulting from thin film of the binder on the aggregates particles in light traffic situations. Low air voids content may be very critical in term deformation. VFA requirement helps to avoid those mixes that are susceptible to rutting in heavy traffic situations.

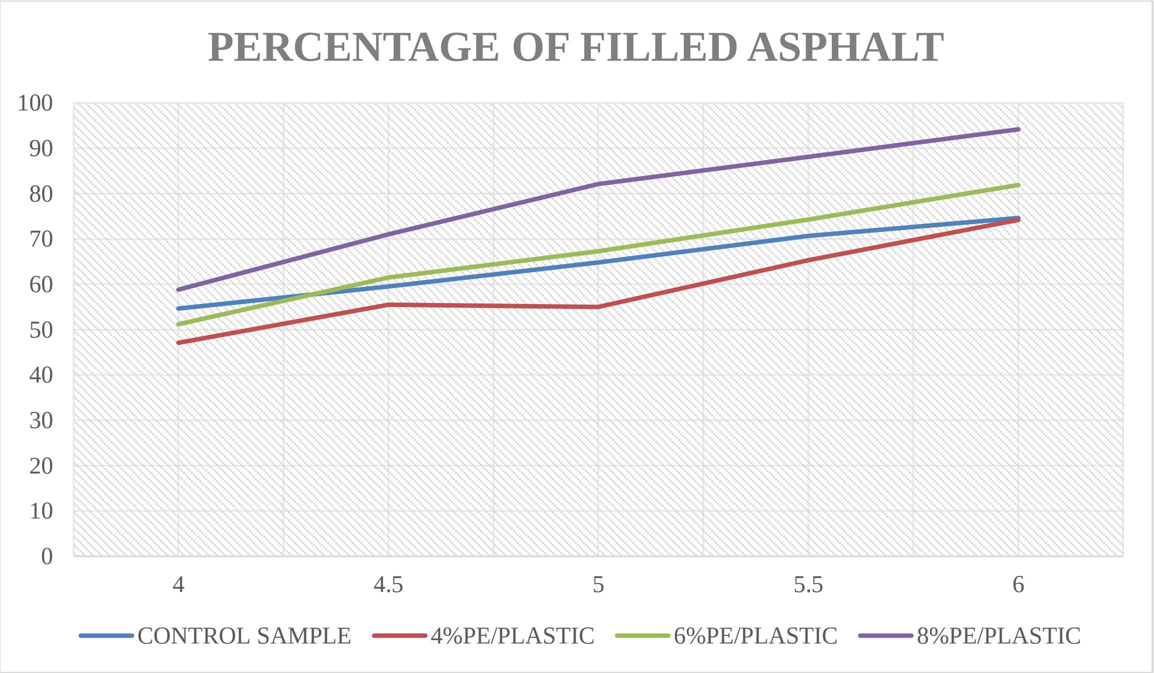


Figure 4-3 Percentage VFA vs percentage bitumen content

The graph above shows that only 8% and 6% polyethylene/plastic content have the higher value of VFA than the control sample. Then, the 4% polyethylene/plastic content was lowest value and lower than control value. This is caused by improper procedure during experiment or the 4% polyethylene/plastic contents not enough to compete with the bitumen mixture.

4.11.4 Analysis of Marshall Stability

The stability of the pavement is a ability to maintain the shape of the layers under repented loading .The pavement is considered unstable when it develop ruts, ripples, raveling and other sign of shifting the HMA. The stability should be adequate according requirement of traffic load of the area. It also depends on the frictional force between the aggregates characteristics such as shape, surface and particles.

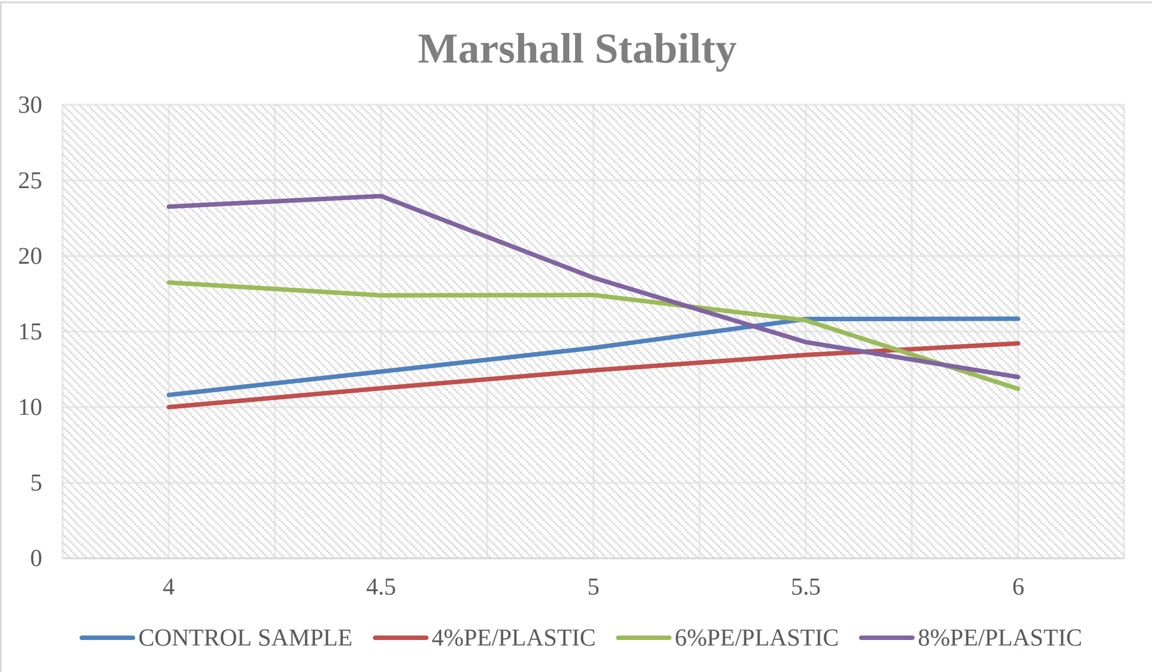


Figure 4-4 Marshall Stability (kN) vs percentage of bitumen content

Figure 4.4 shows that substituted bitumen with 4% polyethylene/plastic gave the result which is the stability was lower than control samples. At 4.5% bitumen content with 8% polyethylene/plastic content gave the highest value and higher than control samples. Then, 6% polyethylene /plastic content gave the highest stability value at 5.5% bitumen content.

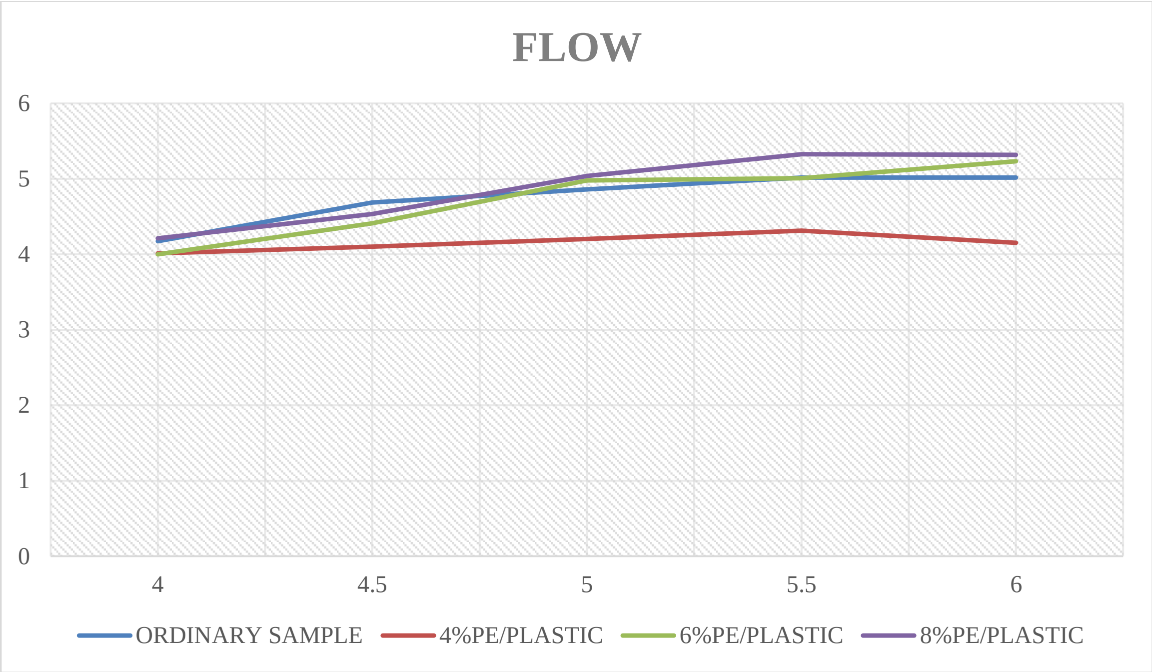


Figure 4-5 Flow vs percentage bitumen content

Figure 4.5 shows the flow against percentage of bitumen content. The highest flow 8% polyethylene/plastic content with 5.5% bitumen content. It shows that the 6% and 8% polyethylene/plastic content only can be replace with bitumen at certain percentages.

CHAPTER 5

CONCLUSION / RECOMMENDATIONS

5.1 Introduction

The last chapter of this study is the conclusion and recommendations. Both written regarding this study were obtained from the analysis of the experimental result. The conclusion for this study must be the objectives. Furthermore, appropriate suggestions and recommendations were proposed in this chapter.

5.2 Limitation of study

There were some major limitation of this study during this during cutting the polyethylene/plastic in detail plastic bag into smaller pieces. The problem is to cutting manually and produced the 15 samples that need to cut the large amount of plastic pieces although the weight needed for each sample was low value. Beside that, to mix plastic/PE also had problem because it will produce bad odour and smoke in the laboratory which it make difficulty to heat together and to clean it.

5.2 Suggestion for Future Research

In the future research in this field, it is can recommended that this project can use hard density polyethylene (HDPE) such as PVC, recycled plastic containers, plastic furniture and others. It also need the special shredding machine to make it into smaller pieces and the stability, bonding and density will be higher than using low density polyethylene (LDPE) . In future, the improvisation with HDPE maybe can give the higher value and better result to the pavement structure. The other objective for this study is to decrease the waste plastic so that, if the plastic is not give the better result than the pavement which is not improvise but same with the original pavement it can also save the bitumen used and decrease environment pollutions.

Uses the other waste product in experimental also needed to save the bitumen used for highway construction and maintenance. The other waste product that can be used are crumb rubber, crude palm oil and fly ash.

5.3 Conclusion

For this research, it was revealed that polyethylene/plastic able to increase the compression strength of the pavement hence improve the properties of the pavement but in the certain percentage. It also improve the workability, durability and provided high density of the Hot Mix Asphalt (HMA) .Beside that, it gave the pavement a better performance for future development. This finding also helps to save budget and this experimental don’t need the special chemical that need the higher cost. In future, hopefully this finding can encourage new research to be conducted in different ways and other waste products.

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APPENDIX A

The aggregates graded according to the ASTM or BS standard were over dried at 170^{o}C – 180^{o}C.

The required quantity of asphalt was weighted out and heated to a temperature of about 160^{O}C -165^{O}C

APPENDIX B

The bitumen poured and mixing carried out until the aggregates was coated by bitumen. The temperature constantly about 160 -170°C.

Sample were weighted at air, water and air again to find surface dry mass

APPENDIX C

The samples were immersed into water bath for 30 – 40 minutes with 60^{o}C.

The Marshall Stability Test