PERFORMANCE OF PLASTIC WASTE IN ASPHALT MIXTURE THROUGH DRY PROCESS

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ABSTRAK

Plastik telah menjadi sebahagian daripada gaya hidup kita hari ini. Ia digunakan untuk apa-apa keperluan kehidupan seharian kita seperti pembungkusan, untuk melindungi tujuan, dan maksud perkhidmatan. Pengeluaran besar-besaran plastik akan menjadi baik kerana dapat menghasilkan pendapatan yang tinggi untuk industri. Terdapat beberapa percanggahan dalam industri plastik yang boleh menjadi bahan buangan dan memberi kesan buruk terhadap alam sekitar. Pelupusan plastik sisa nampaknya menjadi masalah utama di seluruh dunia sejak pengeluarannya mungkin tinggi disebabkan oleh permintaan yang tinggi. Secara logiknya plastic dicampur ke dalam campuran bitumin untuk pembinaan jalan berbanding membakar plastik buangan yang boleh menyebabkan pencemaran alam sekitar yang buruk. Hasil kajian terhadap plastik buangan yang dimasukkan ke dalam campuran asfalt telah dijalankan untuk menyiasat prestasi plastik sisa antara campuran asfalt yang diubahsuai dan campuran asfalt konvensional dan untuk mengkaji peratusan optimum bahan buangan plastik yang ditambah dalam campuran asfalt. Kajian ini menggunakan beberapa ujian untuk mengenal pasti prestasi plastik buangan dalam campuran asfalt. Ujian Marshall, ujian modulus yang berdaya tahan dan ujian rayapan dinamik telah dilakukan dengan mengambil tiga sampel setiap peratus plastik iaitu 0%, 5%, 7% dan 9%. Untuk ujian modulus berdaya tahan, pada 25 ° C campuran asfalt konvensional menunjukkan hasil terbaik dibandingkan dengan campuran asfalt yang diubahsuai di mana-mana peratusan plastik buangan ditambah. 7% daripada plastik ditambah adalah hasil tertinggi sebelum ia menurun apabila 9% plastik sisa ditambah. Pada 40 ° C hasilnya agak tidak konstan yang mana ia meningkat dan menurun pada setiap peringkat peratusan. Untuk ujian rayapan dinamik, campuran asfalt optimum adalah 9% di mana ia menunjukkan hasil yang lebih besar berbanding dengan peratusan lain yang terdapat dalam plastik buangan. Ini menunjukkan bahawa prestasi plastik buangan dalam campuran asfalt diubahsuai mempengaruhi keputusan setiap ujian yang telah dilakukan. Campuran asfalt yang optimum adalah berbeza pada setiap ujian yang dijalankan. Dapat disimpulkan bahawa peratusan tambahan plastik boleh memberi hasil yang lebih besar berbanding campuran asfalt konvensional.

Kata kunci: plastik sisa, peratusan optimum, modulus berdaya tahan, modulus creep

ABSTRACT

Plastic have become part of our today's lifestyle. It is used for any needs of our daily life such as packaging, for protecting purpose, and serving purpose. The mass production of plastic would be good as its can produce a high incomes for the industries. There are some contradict in plastic industries which it can be a waste material and give the bad effect in environment. The disposal of waste plastic seems to be a major problem worldwide since the production of it may be high due to the high demand. Plastic is a non-biodegradable and it mainly consists of low-density polytethylene. Furthermore, it is logically to be mixed into the bituminous mixes for road construction rather than burning the waste plastic that can lead to the bad environmental pollution. The researched of the waste plastic added into the asphalt mixture had been carried on to to investigate the performance of waste plastic between modified asphalt mixture and conventional asphalt mixture and to study the optimum percentage of plastic waste added in asphalt mixture. This study used several test to identify the performance of the waste plastic in the asphalt mixture. Marshall test, resilient modulus test and dynamic creep test had been done by taking three samples of each percentage of plastic which is 0%, 5%, 7% and 9%. For the Resilient Modulus test, at 25°C the conventional asphalt mixture show the best result compared to the modified asphalt mixture at any percentage of waste plastic added. 7% of plastic added is the highest result before it decreased when 9% of waste plastic is added. At 40°C the result quite not constant which it increased and decreasing at every stage of percentages. For the dynamic creep test, the optimum asphalt mixture is at 9% where it shows greater result compare to the other percentage of the waste plastic added. This shows that the performance of the waste plastic in modified asphalt mixture influence the result of every test that had been done. The optimum modified asphalt mixture is different at every test conducted. It can be concluded that the percentage of plastic added may give the greater result compare to the conventional asphalt mixture.

Keywords: *waste plastic, optimum percentage, resilient modulus, creep modulus*

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
BS EN	British Standard
CO	Carbonyl Index
HMA	Hot Mix Asphalt
JKR	Jabatan Kerja Raya
PMB	Polymer Modified Bitumen
PEM	Porous European Mix
UTM	Universal Testing Machine
VFA	Void in Filled Asphalt
VMA	Void in Mineral Aggregate
VTM	Void in Total Mix

CHAPTER 1

INTRODUCTION

1.1 Research Background

Plastic have become part of our today's lifestyle. It is used for any needs of our daily life such as packaging, for protecting purpose, and serving purpose. The mass production of plastic would be good as its can produce a high incomes for the industries. There are some contradict in plastic industries which it can be a waste material and give the bad effect in environment. Plastic non-biodegradable so that it is not eco-friendly but it still user friendly. Today, there are a billion tonnes of plastic are being used and it seems to be increase day by day even though there are a lot of country which are banning the use of plastic waste due to the environment friendly policies. They also have a very long lifetime and burning of plastics waste under uncontrolled conditions and it also lead to generation of hazardous air pollutant depending upon the type of polymers and additives used. But instead of looking at the bad side of the waste plastic, it is actually can be very useful in other development such as road construction. The presence of waste plastic seems to lead to an environmental pollution, but with the previous and further studies, it can be the additive for the bitumen for the road construction. Many of the countries are looking forward in order to enhance and improve their properties of road pavement and construction and in term of cost saving, waste plastic seems to be the right choice to be implement into the road construction experiment.

Over the past two decades, traffic volumes have increased rapidly and the demanding from pavement engineers, stronger and long lasting pavements have also increase. New methods of pavement design are being developed and experimentally conducted to improve the performance of roads. New materials, one after another, are being used to replace the old ones to improve the strength, economy, aesthetics and durability. One of the productive ways is to use the waste plastics in bituminous road construction industries. Today, the waste plastics is enormous available, as the plastic materials have become very useful part of the daily life. If not recycled, their present disposal is either by land filling or by incineration. Both these processes either land filling or by incineration have certain impact on the environment in term of pollution. Under this circumstance, an alternate use for the waste plastics is the need of the time.

Plastic bag is non-biodegradable but most of it is recyclable. The recycled products are more environmentally harmful than the first manufactured ones because every time plastic is recycled it is subject to high intensity heat. This can make it to deteriorate and lead to effect the environment. That is why it is a must to determine the effective way to deal with this non-biodegradable waste in order to ensure the environment in always in 'go-green' mode. The experimentation at some places indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give greater strength, higher resistance to water and better overall performance vary with the period of time. Use of higher percentage of plastic waste reduces the need of bitumen by 10% and it leads to the saving of cost. It also increases the strength and performance of the road as a lot of previous studies have been conducted and proven

1.2 Problem Statement

The disposal of waste plastic seems to be a major problem worldwide since the production of it may be high due to the high demand. Plastic is a non-biodegradable and it mainly consists of low-density polytethylene. Furthermore, it was logically to be mixed into the bituminous mixes for road construction rather than burning the waste plastic that can lead to the bad environmental pollution. The laboratory test had been performed in order to conduct on these bituminous mixture. From the previous studies, it was shows that plastic waste improves the performance of bitumen when it was added into bitumen. The usage helps to improve the performance of the road pavement which also reduces the rutting effect.

1.3 Objective

The objective of this study are:

I. To investigate the performance of waste plastic between modified asphalt mixture and conventional asphalt mixture.

II. To study the optimum percentage of plastic waste added in asphalt mixture.

1.4 Scope of Research

This research was to analyze the properties of waste plastic bags used in order to get the optimum bitumen content for every waste plastic added in an asphalt mixture and to investigate the performance between the modified asphalt mixture and conventional asphalt mixture. The waste plastic was collected from the area around university campus and being shred afterwards. The aggregate used AC14 and the grade of bitumen used was 60/70. There are several Standards that have been used for this research which it complies with JKR, ASTM, and BS EN. This research had been conducted with several experiment which are Marshall Mix Design, Dynamic Creep Test, Resilient Modulus Test and Marshal test. All test will come out with 3 samples each which are samples containing 0%, 5%,7% and 9% addition of waste plastic.

1.5 Significance of Research

This research can solve the problem of abundance of waste plastic that lead to environment pollution by mixing it into the bitumen for the road construction. Waste plastic can increase the performance of the bitumen yet improved the quality of the road construction. The production of this asphalt mixture gave the advantages for the industry in term of cost as the waste plastic can be getting in lower price. The rapidly growth of the plastic industry yet became a serious problem when there was no experimental conduct of it on how to make it more useful even after being used.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will briefly describe the material, compound and method used in the present study for the performance of waste plastic in asphalt mixture by using dry process. It is also included the result of the study by the previous researched.

Plastic can be simply said as the most important material in daily life. The usage of plastic is quite big in all country around the world. The disposal of plastics seems to be a big problem worldwide. Since it was a non-biodegradable products so it lead to environmental pollution such as water pollution which it was proven by the previous researched that a lot of plastic bag found at the bottom of the sea and have effect the marine's life. It was indirectly effected human health as well which people will consume fish or any other marine life that have been polluted by the chemical in the plastic. Many of the scientists have their different analogy about the solution about the disposal problem of plastic waste. The most relevant one is by adding the waste plastic into the road construction, or to be more specific, in the asphalt mixture. A lot of experiments have been done by the older researchers which the performance of the asphalt mixture after being add with waste plastic were gave the positive impact to the asphalt itself and also the industry. This way will indirectly solve the issue of waste plastic disposal if the road construction industry set the enforcement of these modified asphalt mixture (Turnbull et al.,2016).

The usage of plastic was increasing and the production of it is more or less about 300 million tonnes by 2010 annually (Thompson et al., 2009). After a few studied have been done, it was proved that the existing of waste plastic would resulting the bad effect for the wildlife and also for human. The disposal of waste plastic should be done in a creative way which it can avoid the bad effect to human and wildlife. Several perspective have been consider regarding this issue such as putting the waste plastic into another industry; like a road construction industry, instead of being disposal using a conventional way (Atkinson et al.,2010). This more or less reduced the problem of disposal of waste plastic yet will increase the advantages of the other industry.

Plastic disposal problem had been a great issues in several country which it lead to the environment problem. The unsuccessful disposal program has caused some of the country into the disaster. For example, in Bangladesh, there were very serious flooding issues that caused by the blockage of drains and the result was the country have banned the plastic bag permanently (Njeru, 2006). It shows that how critical the waste plastic could be if it not being disposed perfectly. That's not stopped here, there are a lot of upcoming issues regarding to the environmental problem by the waste plastic such as health problem. It was reportedly caused the malaria disease due to the mosquito spreading their habitat through the waste plastic as their shelter.

The previous research found out that the waste plastic is the most relevant binder to be added in the bitumen as to increase the performance of the road surface (Buncher et al., 2014). Due to the high demand of user for the pavement, it required more strength and stability to absorb the demand. Polymer such as waste plastic can improve the performance of asphalt mixture at low, intermediate and high temperatures. At low temperature, it can increase the resistance of mixture to permanent deformation, thermal fracture and fatigue cracking. Besides, at high temperature, the plastic flow decreased and the shear modulus increase. They found out the road pavement life span increase even by the small amounts of polymers added. It is also can be used to lower the life cycle cost (Kalantar et al., 2012).

The addition of waste plastic for about 5%-10% weight of the bitumen had affected the used of the modified bitumen which it can improved the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, which improved the longevity and pavement performance (Dobry et al., 2011). Waste plastic can be softened at around 130°C and no gas evaluation at 130°C-150°C in the temperature range. The binding property will increase when it mixed with bitumen (Gawande et al., 2012).

Sultana. (2012) had done a research on Marshall Properties of the modified and unmodified mixtures. They prepared a different percentage of plastic (PP,LDPE) and bitumen to determine the Marshall properties by using plastic coat aggregate (PCA) and polymer modified bitumen (PMB). They placed the specimens in 60°C of water bath for half an hour and then loaded at a ratio of 50.8mm/min. They stability and flow values then recorded. The resulted were then being summarized in Table 1. It can be said that bituminous binder produce better resistance against permanent deformation due to the high stability.

Table 2.1 Stability Values for % of Plastic (Sultana, 2012)

% of plastic	**Plastic coated aggregate sample (PCA)**		**Polymer modified bitumen sample (PMB)**	
	PP	**LDPE**	**PP**	**LDPE**
0	12	12	12	12
4	12.13	17.42	11.8	13.38
6	12.45	18.51	13.15	15.61
8	13.38	20.04	12.43	18.648
10	13.34	19.17	12.52	17.08

Baghaee Moghaddam et al. (2014) in the journal shows that the waste PET had a great potential to be reused as modifier in asphalt mixture. PET modified asphalt mixture shows the improvement compare to the control mixture, and the higher amount of modified mixture with PET, the higher the resistance against permanent deformation. In previous research which the evaluation of different polymer modified asphalt was conducted, due to the high melting point of PET it was supposed that PET be the barrier of the mixing, was not suitable to be used in asphalt modification. But after all, the result shows that using PET as modifier can considered improved the permanent deformation characteristic of asphalt mixture. Improvement of permanent deformation characteristic of PET modified asphalt mixture can be referred to PET properties which is known as semi-crystalline material.

Due to the investigation the effect of the adding waste plastic on asphalt mixture performance, it showed that 0.2% of waste plastic added into HMA would enhance the performance. The added of 0.5% of waste plastic into HMA would be similar with the 0% added (control). The performance of HMA were poor when it mixed with 1% of waste plastic. Based on the result, utilizing 0.5% plastic waste by weight of aggregate in HMA would make flexible pavement design eco-friendlier and enhancing the sustainable, since the huge amount of plastic waste could not corporate well without effecting the performance of hot mix asphalt (Ahmad et al., 2017).

Kolla Aswani Chandh et al. (2013) plastic waste that added to the bitumen was strengthened the pavement by improving the properties like moisture absorption, reduce the bitumen content, penetration and softening point. By addition of this plastic to the bitumen, we can increase the life span of the pavement when compared to the BT Pavement without Polymer usage. Khodary et al. (2019) Plastic has the sticky nature which increases the Binding properties, which is useful for rapid setting of the pavements generally used in heavy traffic regions. By this the usage of Bitumen has reduced and was replaced by the polymer waste so as the cost of the pavement has been reduced the cost.

The current asphalt mixture had some major problem in the density where the previous researched found out that the density must be increase in order to get better due to the high demand of traffic in the future. Researched found out that asphalt mixture still need to be increase the performance in form of the density because it would affected the pavement when there are increasing of traffic demand (Associates, 1988). Previous study at Arkansas found out that the density should be more than 2.1 percent while the void must above 2.5 percent to prevent rut.

Kandhal, (2016) Late years, an increasing number of states are determining the utilization of antistripping (AS) specialists. Based on the visual observation, they found out that there is a need for future research to improve the HMA asphalt. They claimed that the demand on the past year would be so different with the future demands. Hence the further study need to be done. There is a need to recognize the issue appropriately with the goal that choices are not made dependent on visual perceptions of some segregated upset regions. Outer variables as well as set up properties of the HMA asphalts can prompt untimely stripping in HMA asphalts. Brown et al. (1997) Recommendations for easing the issues related with these variables have been given. An analytical system dependent on scientific experience has been prescribed for use by the indicating organizations and industry to build up stripping as an issue on a particular undertaking or state.

Free et al. (2018) As of late, there have been perceptions and reports of blend sturdiness related execution issues. While the genuine reason for these issues have not been completely researched, it was felt that "dry" blends are the general reason, with contributing elements being too high a plan gyration level extreme reuse for instance reused black-top asphalt or reused black-top shingles, lacking blend particular or improper blend type determination, and so forth. Much of the time the reason is likely a mix of a few variables. An ongoing study directed of Oldcastle Materials working organizations, found that most revealed asphalt bothers that were seen inside the most recent 5 years, were sturdiness relate. Rutting was just announced by 7% of the respondents, which underpins the generally held conviction that rutting is definitely not a noteworthy execution issue with the present blends. While rutting still may happen, it is presumably the situation of a blend generation issue, development related issue, or a lacking basic structure, and not one coming from the blend structure itself (Testin et al., 2011).

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2.2 Aggregates

Aggregate are the common materials used in development industry such as road construction, building, agricultures and others. Aggregate can be either natural or manufactured. An aggregate can be extracted from the crushing of the large rock formation by the excavation and it was called a natural aggregate. Natural aggregate consists of crushes stone, sand and gravel are one of the most abundant natural resources. While manufacturing aggregate is often the product of other manufacturing industries such as slag or specialty rock that is produced to have a particular physical characteristic not found in the natural rock.

Physical properties of aggregate are the most readily apparent aggregate properties and it have the most direct effect on how an aggregate performs as either a pavement material constituent or by itself as a base or subbase material.

Generally, aggregate should be hard and tough enough to resist crushing, degradation and disintegration from any associated activities including manufacturing, stockpiling, compaction and consolidation. Aggregate that are not adequately resistant to abrasion and polishing will resulted the premature structural failure and/or a loss of skid resistance.

2.3 Plastic

Plastic commonly used as a binder nowadays. In this study, waste plastic bag was used as stabilizing additive to improve performance of the asphalt mixture.

2.4 Bituminous Binder

Bitumen is a material that can act as a binder to the aggregate, fines and stabilizer in asphalt mixture. Bitumen is treated as a viscoelastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. Bitumen is an effective binder for most road surfacing applications and mainly used in spray seals and asphalt. It is of petroleum origin and have a thermoplastic material. It is produced from the crude petroleum oil and its properties of chemical inertness, water resistance and natural adhesion make it a correct material for a many of application. Road construction requires a variety of bitumen grades with strict quality specifications. This research required a bitumen grade 60/70. Some of the bitumen properties are:

- The bitumen must not be highly temperature susceptible: the mix should not become too soft or unstable during hottest weather and should not become to brittle during cold weather.
- The viscosity of bitumen should be adequate at the time of mixing and compaction. This can be done by using of emulsion of suitable grades or by heating the bitumen and aggregates prior to mixing.
- Adequate affinity and adhesion between the bitumen and aggregate used in the mixture.

2.5 Dry Process

Dry process is quite not popular compare to the wet process but the function of the process there are several previous researched showed that the production of asphalt mixture by the dry process was logistically easier than wet process. In the dry process, the waste material is assumed to be a substitute for a small portion of the fine aggregate. The reaction between bitumen and waste material such as crumb rubber in the traditional dry process is negligible due to the following reasons which is larger crumb rubber particle size, higher crumb rubber content and no reaction additives (Junan Shen et al.,2017).

The larger molecule size (LMS) of extracted asphalt binders from the rubberized PEM and SMA in dry process, increased as the storage time increased. The ratio of bonding, carbonyl index (CO) of the binders extracted from rubberized Porous European Mix (PEM) in dry process increased as the storage time increased, but increase much quicker in the early than the late storage times (Junan Shen et al.,2017).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This nature of this study was based on experimental program. This study had focus on physical and mechanical properties of the bituminous mixture using waste plastic as additive. The process of experimental works of this bituminous mixture was shown in the first part of this chapter. Preparation and procedures of this bituminous mixture sample have also been included in this section. Testing considered in this research are describes in detail in this chapter.

3.2 Materials

3.2.1 Waste Plastic

Waste plastic bags are used for this research and it is being collected around university campus and being shred afterwards. Abundance of waste plastic that are not being dispose was collected in order to get the sufficient amount of waste plastic due to the demand of the research.

Figure 3.1 Shredded waste plastic

3.2.2 Aggregate

Aggregate use for this research is AC14. Table 3.1 shows the aggregate grading for AC14. The load bearing and the strength characteristic of the mixture have been contributes by almost of the weight of the aggregate in bituminous concrete mixtures. Hence, to ensure the good pavement, the physical properties and the quality need to be controlled. The aggregate's properties that should be put in the pavement are shown below.

I. Aggregates should have minimal plasticity. The presence of clay fines in bituminous mix may cause stripping problems. Clay lumps and friable particles should be limited to utmost 1%.

II. Resistance or durability to weathering should be measured by soundness of sulphate testing.

III. The ratio of dust to asphalt cement, by mass should be a not more than 1.2 & a not less than 0.6.

IV. It is recommended JKR to be used for determining the maximum specific gravity of bituminous concrete mixes.

Table 3.1 Aggregate Grading for AC14

Mix Type	Wearing Course
Mix Designation	AC14
BS Sieve Size (mm)	Percentage Passing by Weight
20.0	100
14.0	90 – 100
10.0	76 – 86
5.0	50 – 62
3.35	40 – 54
1.18	18 – 34
0.425	12 – 24
0.150	6 – 14
0.075	4 - 8

3.2.3 Bituminous Binder

Bitumen grade 60/70 was used to in this study in order to prepare the samples. Bitumen 60/70 means the range of 60 to 70 at standard test condition of penetration value which generally used as a paving grade. It has a thermoplastic property which caused the material to soften and high temperature and at lower temperature, it hardened.

3.3 Flowchart

This flowchart shows the process of experimental study of the use of plastic waste in the bituminous mixture in Figure 3.1

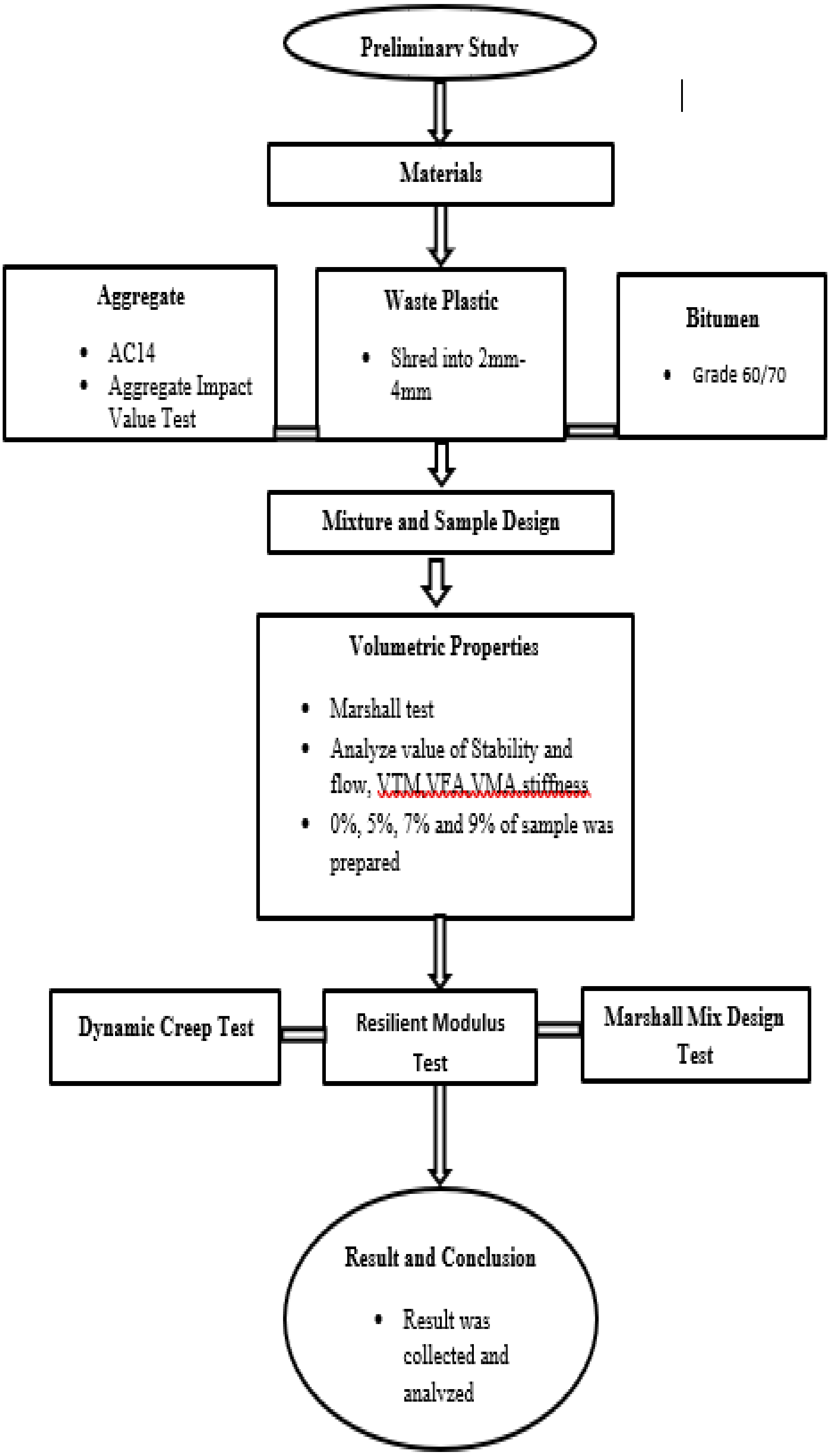

Figure 3.2 Project Methodology

3.4 Mix Design

Flexible pavement consists of major two materials. These two materials are aggregate and binder. The performance of pavement is greatly influenced by binder. Generally bitumen 60/70 is used as binder in pavement construction. The research work would require virgin bitumen, waste plastic and aggregate as raw materials. In order to study only the effect of waste plastic on binder and mixes other ingredients are kept same throughout the whole experiment process.

3.5 Dry Process

For the flexible pavement, hot stone aggregate 170°C is mixed with hot bitumen 160°C and the mix was used for road laying. The aggregate was chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen was chosen on the basis of its property. The quality of voids, moisture absorption and soundness was improve by the plastic coat aggregates.

Plastic waste was cut into a size between 2 mm to 4 mm using shredding machine. Then the aggregate mix was heated to 170°C and being transferred to mixing chamber. Similarly, the bitumen was to be heated up to a maximum of 160°C. At the mixing chamber, the shredded plastic wasted was added over the hot aggregate. The plastic wasted aggregate then was mixed with hot bitumen.

3.6 Marshall Mixed Design

Marshall Mixed Design is a method to prepare standard specimen of asphalt concrete for the determination of stability and flow in the Marshall apparatus and to determine percentage air voids, percentage of aggregate voids filled with binder and the density. A few tested will be carried out for the asphalt mix, which includes Density and Void Analysis (ASTM D6927-06).

There were some basic method in Marshall Mix Design which is i) aggregate selection, ii) asphalt binder selection, iii) sample preparation, iv) stability determination, v) density and voids calculations and vi) optimum asphalt binder content selection.

For the aggregate selection, it was important to determine the physical properties of aggregate that consists of toughness and abrasion, durability and soundness, cleanliness and deleterious materials and particle shape and surface texture. It was also a necessary to determine the gradation and size and also the specific gravity and absorption. For the asphalt binder selection, this study required a bitumen of grade 60/70.

Like other mix design method, several trial on the aggregate-asphalt binder blends with different asphalt binder for each sample. The optimum asphalt binder content can be selected through the evaluating each trial blend's performance. As the result, it must contain a range of asphalt contents both above and below the optimum asphalt content. Based on the result of the optimum asphalt binder content, the samples are generally prepared at 0.5% by weight of increment, with no less than two samples above the estimated asphalt binder content and two below it.

Each sample then been heated to the anticipated compaction temperature and compacted with a Marshall hammer. There was some parameter of the compactor need to be followed which are the size of sample is 102 mm diameter cylinder 64 mm in height (correction can be made in every different sample). The tamper foot must be flat and circular with a diameter of 98.4 mm corresponding to an area of 76 cm^2. The compaction pressure is specified as 457.2 mm and free fall drop distance of a hammer assembly with a 4536 g sliding weight. The number of blows is generally 35,50 or 75 on each slide depending upon anticipated traffic load. The tamper foot strikes the sample on the top and covers almost the overall sample of top area. Then the sample was turned over and the procedure repeated.

Figure 3.3 Compactor Machine

3.7 Resilient Modulus Test

Resilient Modulus test is a basic material property used to identify unbound pavement materials. The stiffness of materials under different conditions, such as moisture, density and stress level were analyzed throughout this test. The input parameter to mechanistic-empirical pavement design method also need to be required. Mr is typically determined through laboratory test by measuring stiffness of a cylinder specimen subject to a cyclic axle load. Mr is a ratio of applied axle deviator stress and axle recoverable strain.

The repeated load indirect tension test for determining resilient modulus of bituminous mixture was conducted by applying compressive load with a haversine or other suitable waveform. The load was applied vertically in the vertical diametral plane of a cylindrical specimen of asphalt concrete. It was to measure the horizontal deformation of the specimen and with an assume Poisson's ratio, the resilient modulus can be calculated.

The load duration was the time for the specimen subjected to a cyclic stress pulse and while cycle duration is the time interval between the successive application of a cyclic stress. Or another common name also called as rest period. The loading device shall be a top loading, closed-loop electro-hydraulic testing machine with a function generator which capable of applying repeated cycles of a haversine-shape load pulse. The optical extensometer, non-contact sensors, or clamps attached to the specimen axial deformation is a load and specimen that response with measuring equipment.

Figure 3.4 UTM-25 Machine

3.8 Dynamic Creep Test

This is the method to access the resistance to permanent deformation or rutting. Marshall samples was used for the test which its dimension was similar to the specimen of indirect tensile resilient modulus test. The test was conducted in accordance BS EN 12697-25.

The prepared samples were conditioned at 40°C for about 2 h to 3 h. Repeated load was applied for 3600 cycles for 40 min to 45 min. The Universal Testing Machine (UTM), computer set and Marshall samples were the apparatus needed for this test.

CHAPTER 4

RESULT AND DATA ANALYSIS

4.1 Introduction

This chapter discussed the result obtained from the experimental and laboratory works that had been conducted to test the performance of the asphalt mixture after mixing with the waste plastic. For this experiment, the conventional asphalt mixture and the mixing asphalt mixture was undergoing Marshall Test, Dynamic Creep Test and Resilient Modulus Test. The objectives of carrying all those tests was to determine the engineering properties of each percentages of waste plastic added into the asphalt mixture and being compared with the conventional asphalt mixture which is not being added with the waste plastic.

4.2 Marshall Stability

4.2.1 Volumetric Properties

Table 4.1 shows the summary of the volumetric properties for different percentage of plastic added which is the density, void in total mix (VTM), void filled with bitumen (VFB), stability, flow and stiffness. Mixture volumetric properties are being used in order to measure the long-term performance and durability of the pavement. The control volumetric properties is based on JKR/SPJ/2018.

Table 4.1 Volumetric properties of every percentage of waste plastic added

% Plastic Added	Density, mg/m^3	VTM, %	VMA,%	VFA,%	Stability, kN	Flow,mm	Stiffness, kN/mm
0	2.26	3.6	15.6	75	14.25	3.1	4.71
5	2.24	2.18	68.69	197.29	9.28	6.53	1.4
7	2.23	2.62	68.4	199.85	9.02	7.04	1.10
9	2.13	14.8	69.82	187.06	8.73	9.34	0.76

4.2.1.1 Density

Density is a mass per unit volume. For this experiment, the result of density for every percentage of waste plastic added is shown in the figure 4.1. The bar chart shows that the density of the conventional asphalt mixture was the highest which is 2.26 g/cm^3. The density value were going decrease as the more the percentage of the waste plastic added in the asphalt mixture. At 5% of plastic, the density is 2.24 g/cm^3, followed by 7% and 9% of plastic which is 2.23 g/cm^3 and 2.13 g/cm^3 respectively. The density of modified asphalt mixture at 5% and 7% of plastic has lower 1% from the conventional asphalt mixture and 6% lower when 9% of plastic was added. In conclusion, the more the percentage of plastic added in the asphalt mixture, the lower the density of the asphalt mixture.

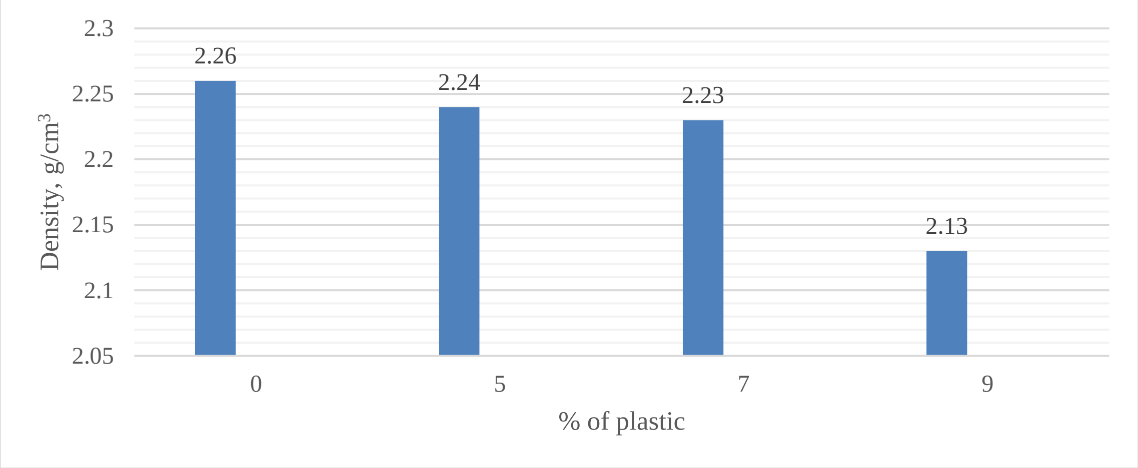

Figure 4.1 Effect of different percentage of plastic to density

4.2.1.2 Void in Total Mix

The effect of different percentage of waste plastic to void in total mix is shown in figure 4.2. The conventional asphalt mixture shows the reading of the void in total mix which was 3.6%. The trend of the bar chart went decreased at 5% of plastic and increased when more percentage of plastic was added into the mixture. For the mixture asphalt concrete, 9% of plastic shows the highest void in total mix which was 14.8%. The void in total mix for 5% of plastic is higher than the conventional asphalt mixture which was 2.18% and going increase at 7% of plastic which was 2.62%. The modified asphalt mixture at 5% and 7% of plastic has lower VTM up to 39% from the conventional asphalt mixture. But there was a huge gap for VTM between conventional asphalt mixture and modified asphalt mixture at 9% of plastic which the gap is more than 100%. Void in total mix or air voids is the total volume of the small pocket of air between the coated aggregate particle throughout a compacted paving mixture, express as percent of the compacted mixture. If the compaction process going smoothly and properly, the void will be reduced. The condition of the compactor machine must be in a good condition as it will affect the result of the void in total mix of the sample tested

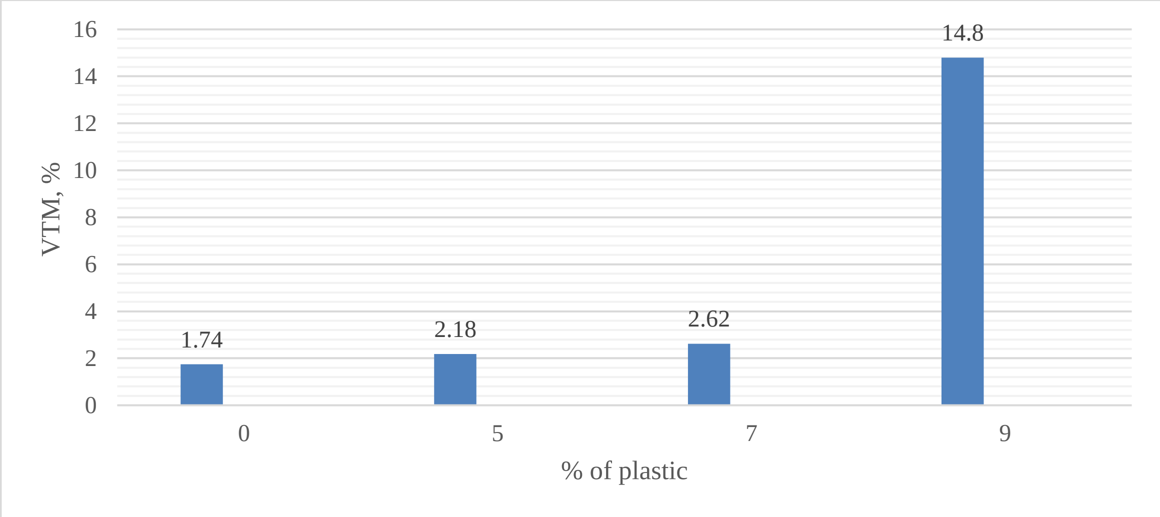

Figure 4.2 Effect different percentage of plastic to void in total mix.

4.2.1.3 Void Filled with Asphalt

The voids filled with asphalt (VFA) was plotted against percentage of plastic add in Figure 4.3. Voids filled with asphalt binder is the perfect of voids in mineral aggregate (VMA) that is filled with cement. VFA for conventional asphalt was 219%. 5% of plastic added gave a result of 146.8% while 7% of plastic added get 110.12%. 9% of plastic added give the lowest result of the modified asphalt mixture which was 82.04%. Based on the JKR/SPJ/2008 specification, the range for the VFA is 70% to 80% and it seems all the samples were out of the range.

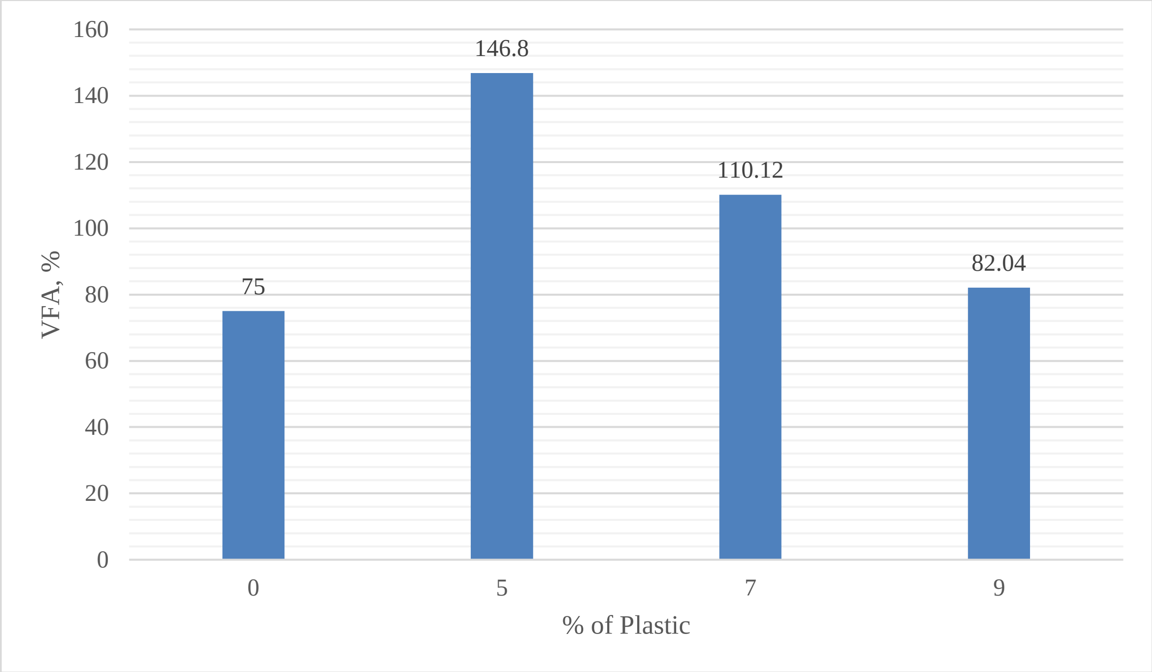

Figure 4.3 Effect of different percentage of plastic to void filled with asphalt

4.2.1.4 Stability

The relationship between stability and percentage of plastic is shown in Figure 4.4. 5% of plastic had the result of stability which was 9.28 kN it is slightly decreased when more percentage of plastic was added. The gap between 5% of plastic and the conventional asphalt mixture was 35% lower and this shows that the stability is decreased when plastic was added into the mixture. 7% and 9% of plastic added give a result of 9.02 kN and 8.73 kN. It shows a big different between the conventional asphalt mixture and when plastic was added. Conventional asphalt mixture had a stability of 14.25 kN which the highest compare to the modified asphalt mixture. From the result obtained, it is clearly show that plastic could not increase the stability of the asphalt mixture.

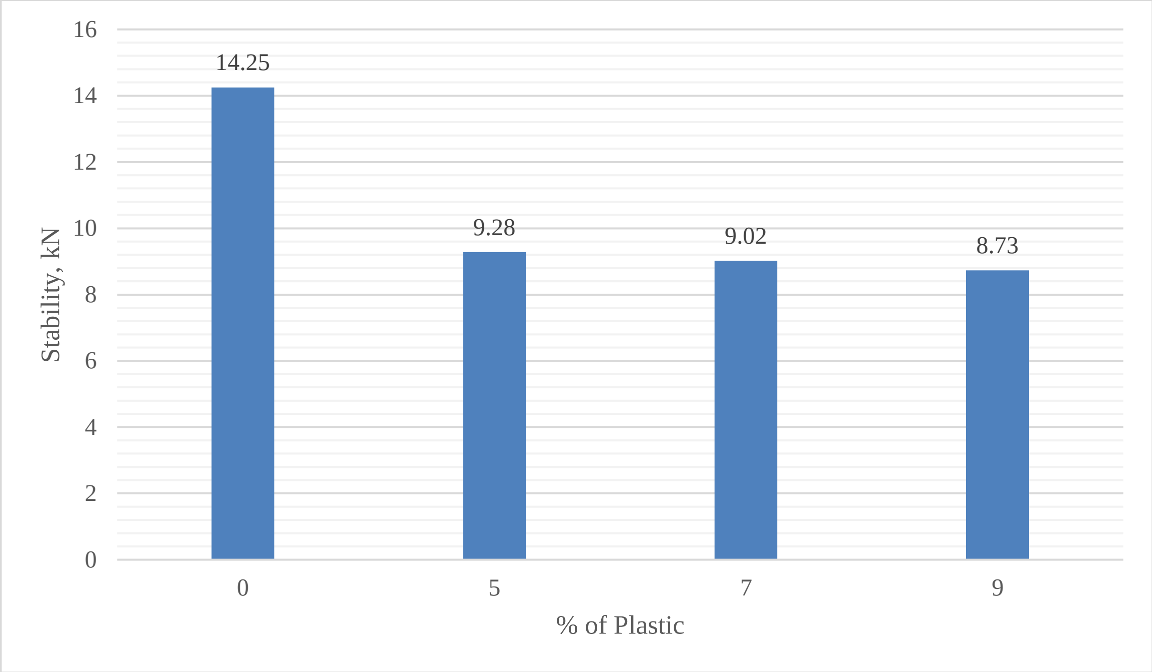

Figure 4.4 Effect of different percentage of plastic to stability

4.2.1.5 Flow

Based on the result obtained in Figure 4.5, the flow of the asphalt mixture was increased when more percentages of plastic added into the asphalt mixture. Flow is related to stability and shows the flexibility of the mix. 0% of plastic in asphalt mixture gave a result of 3.1 mm. It kept increase due to the increasing of percentages of plastic which was 5%, 7% and 9% give a result of 6.53mm, 7.04mm and 9.34mm respectively. The gap between conventional asphalt mixture and the modified asphalt mixture at 5% and 7% of plastic and 9% of plastic was added was more than 100 percent respectively.

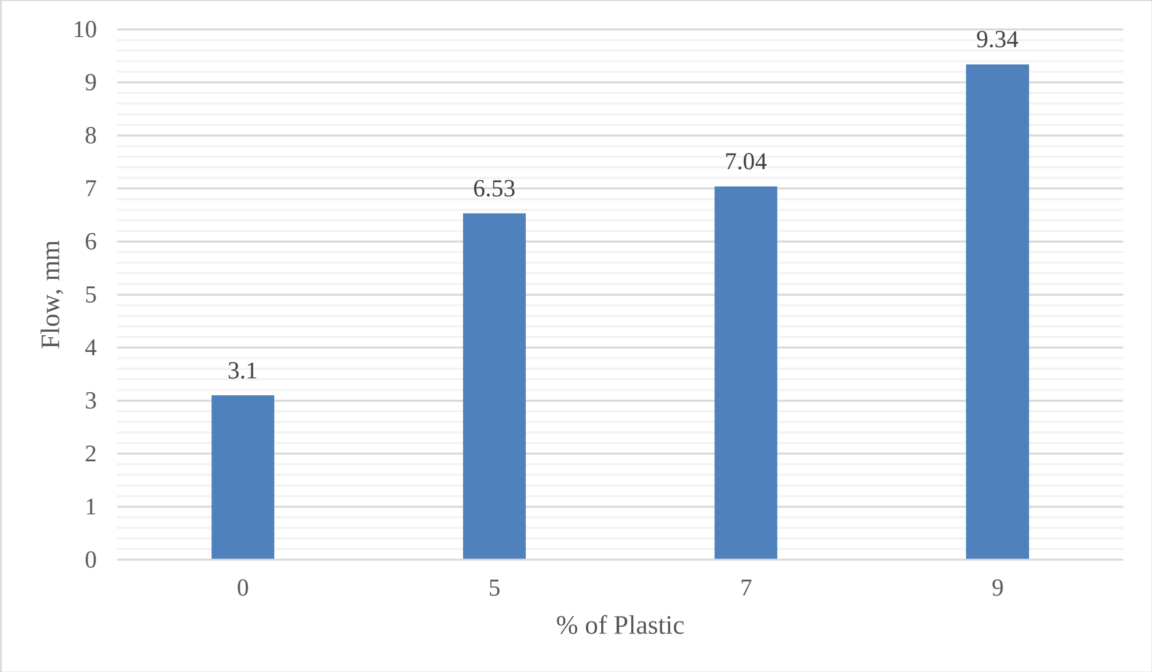

Figure 4.5 Effect of different percentage of plastic to flow

4.2.1.6 Stiffness

Figure 4.5 shows the performance of different percentages of plastic to stiffness. Based on the result, the conventional asphalt mixture gave the highest result of stiffness which was 4.71 Kn/mm. When more percentages of plastic added into the asphalt mixture, the result keep decreasing. 5%,7% and 9% give a result of 1.4 kN/mm, 1.10 kN/mm and 0.76 kN/mm. The modified asphalt mixture at 5% of plastic was lower 70% from the conventional asphalt mixture. But the gap become higher when more percent of plastic was added into the mixture which it was lower from 75% to 84%. The stiffness is important parameter to measure rutting. It is good to have a higher stiffness pavement but it can be worst if it is too high it can lead to fatigue cracking.

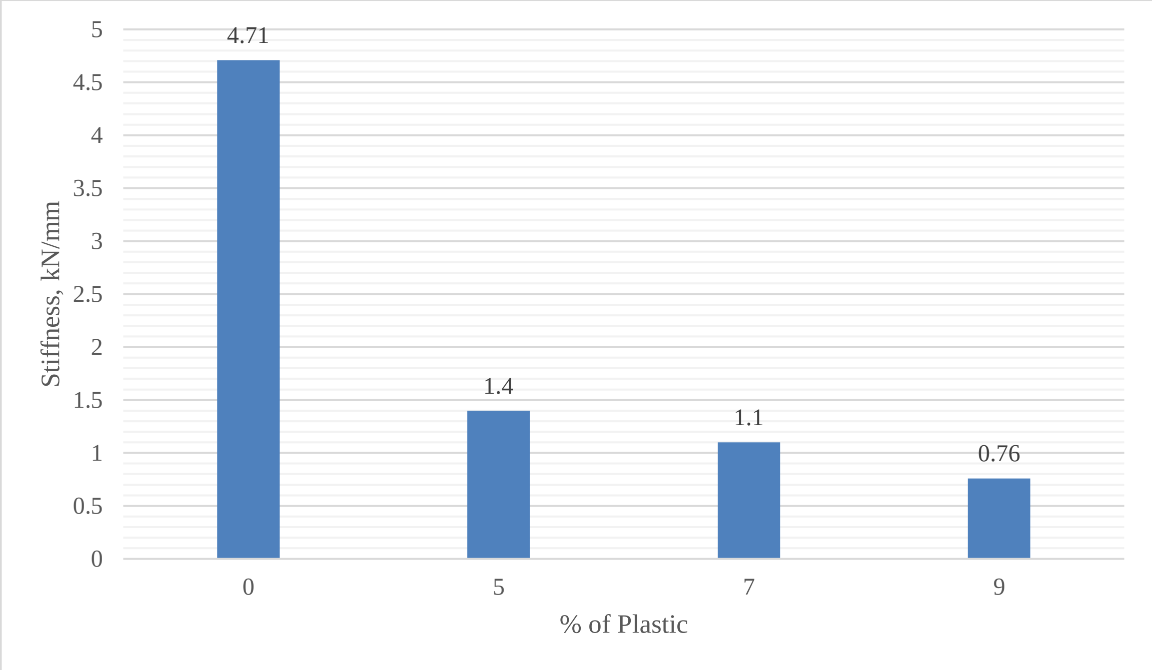

Figure 4.6 Effect of different percentage of plastic to stiffness

4.2.1.7 Void in Mineral Aggregate

Figure 4.1 shows the performance of the different percentage of plastic to void in mineral aggregate. Its shows that the conventional, 0% of plastic, gave the lowest result which was 15.6%. 5% of plastic results 68.69% while 7% of plastic have 68.4%. 9% of plastic had a highest void in mineral aggregate which is 69.82%. The gap of VFA for the modified asphalt mixture and conventional asphalt mixture is more than 100% where modified asphalt mixture shows the greater result. Based on the result, the waste plastic added in the asphalt mixture had influenced the result of VMA but quite constant and it is higher than the conventional asphalt mixture.

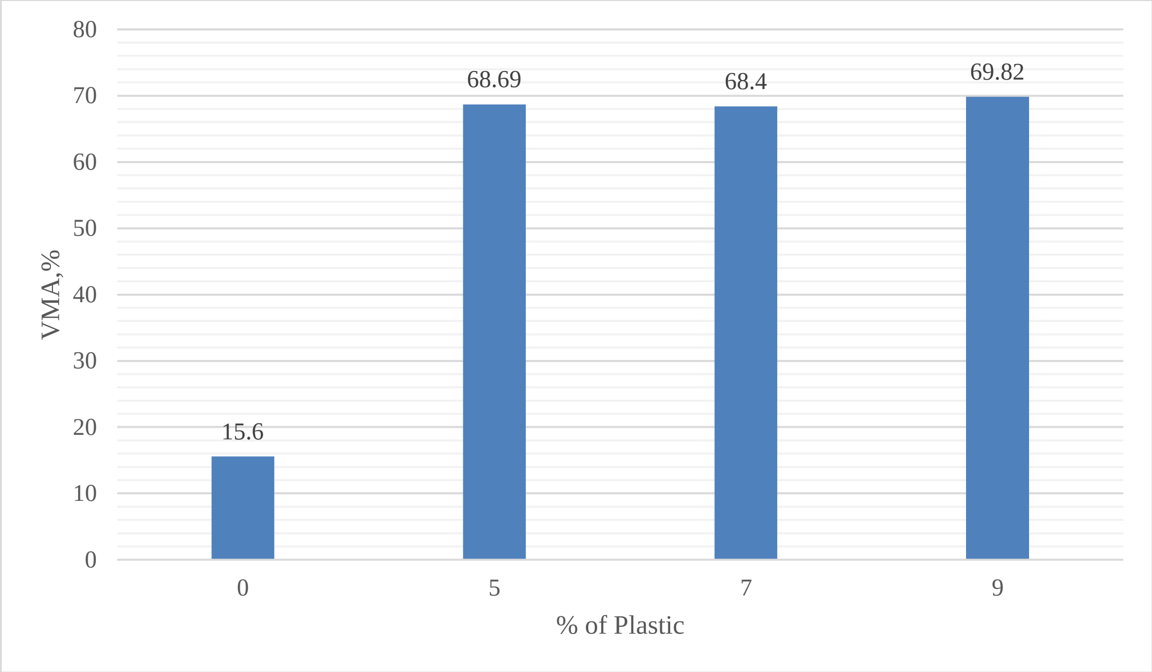

Figure 4.7 Effect of different percentage of plastic to void in mineral aggregate

4.2.1.8 Relationship Between Stability and Stiffness Against Flow

Based on the result from Marshal test, the relationship between stability against flow and stiffness against flow are shown in the Figure 4.8 and Figure 4.9. By neglecting conventional asphalt mixture, both of the graph shows that the relationship between each graph has reached its peak at 5% of plastic. The trends of graph quite constant where it went decreased from conventional asphalt to 5% of plastic added and it decrease slightly when more percent of plastic is added into the asphalt mixture.

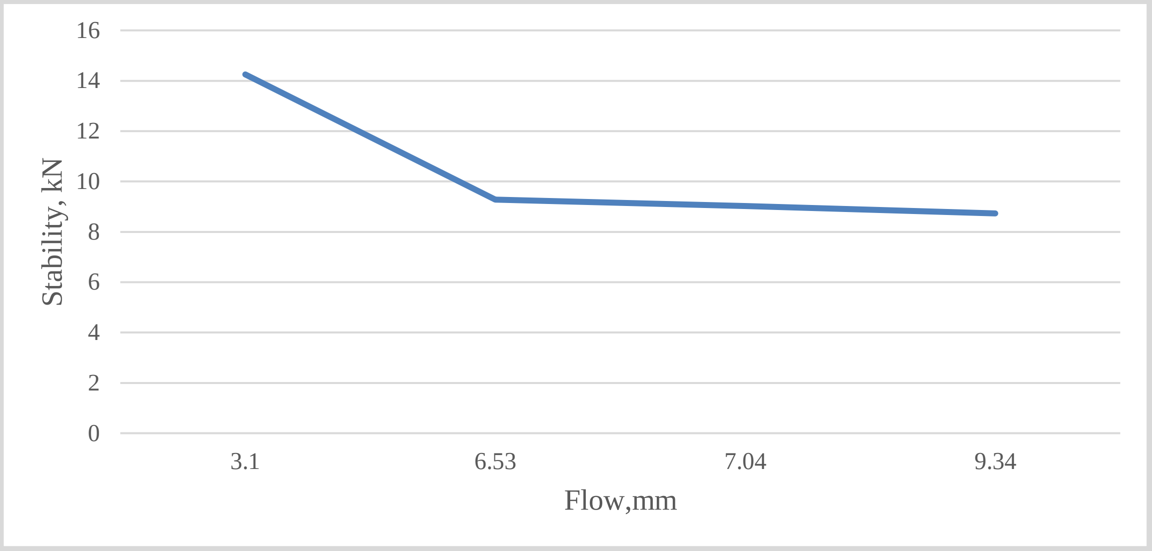

Figure 4.8 Relationship between stability against flow

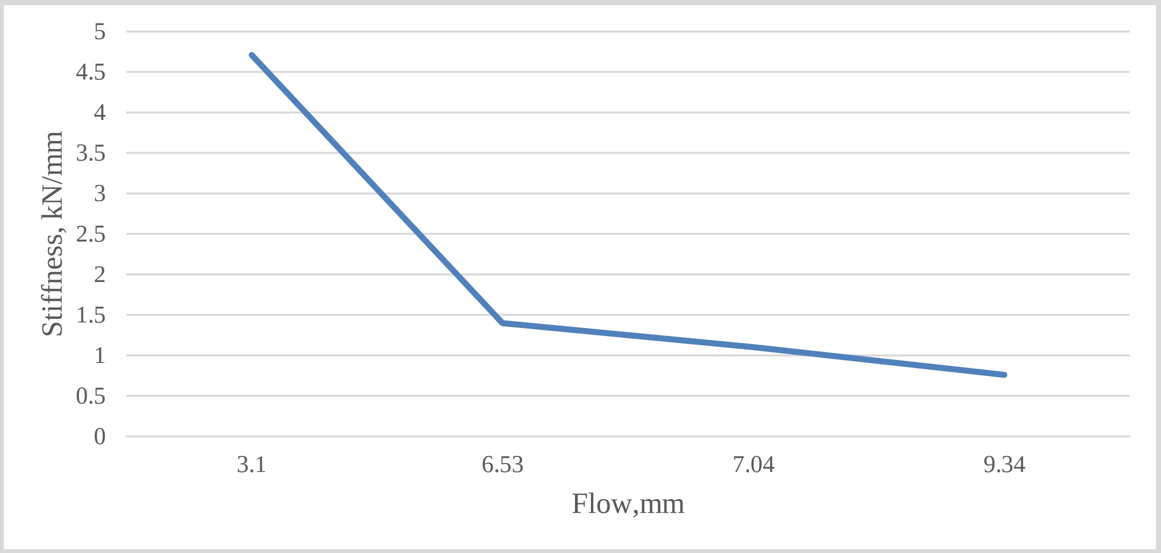

Figure 4.9 Relationship between stiffness against flow

4.2.1.9 Relationship Between Stiffness and Stability Against Density

Figure 4.10 shows the relationship between stiffness against flow while Figure 4.11 shows the relationship between stability against flow. Regarding to the experimental result, the result that take place in only at modified asphalt mixture, both graphs have a peak value at 5% of plastic compare to 7% and 9% of plastic. The both graphs have the similar trend where it kept decreased from the conventional asphalt mixture to 5% of plastic added where it was a peak value at modified asphalt mixture, then going decrease slightly when more percent of plastic added into the asphalt mixture.

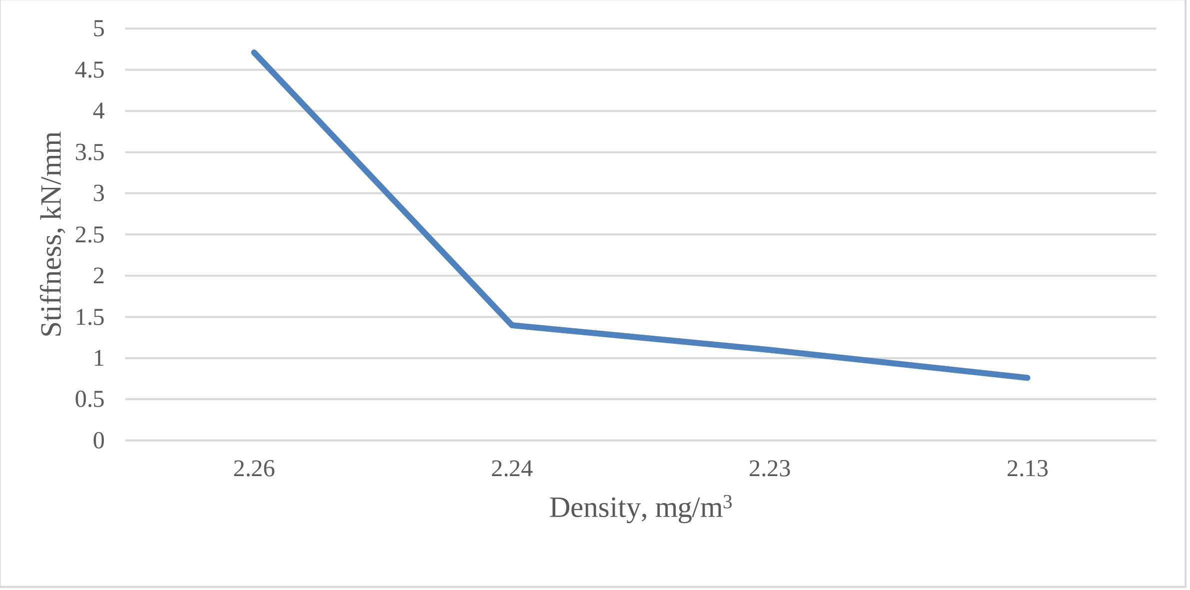

Figure 4.10 Relationship between stiffness against density

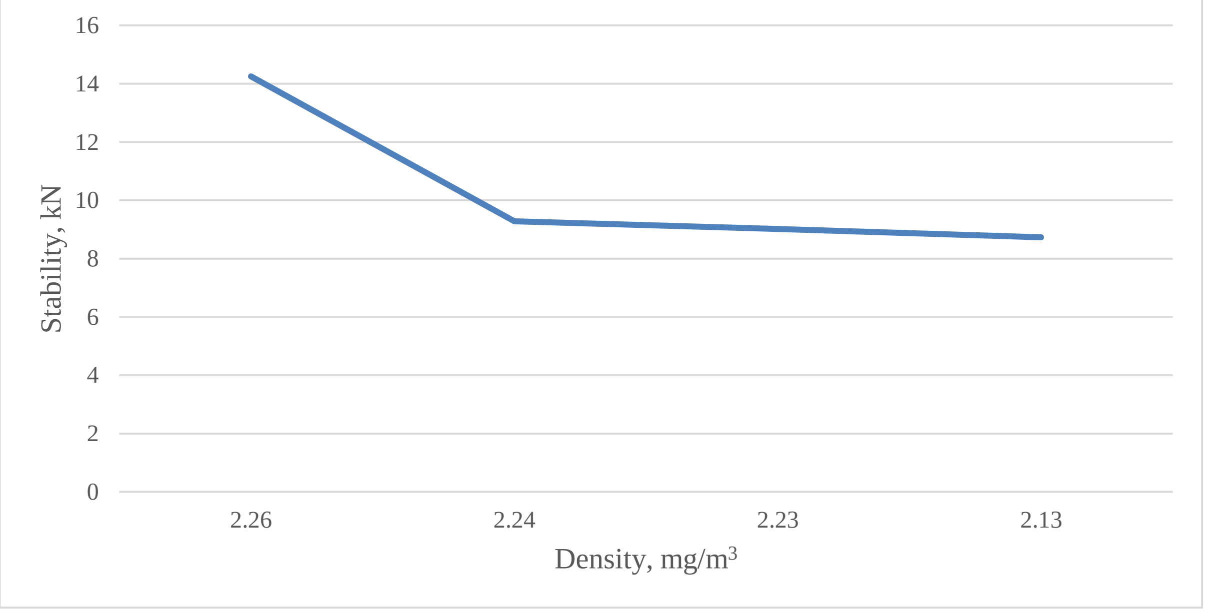

Figure 4.11 Relationship between stability against density

4.3 Resilient Modulus

Figure 4.6 shows the performance of the different percentage of plastic to resilient modulus at 25°C and 40°C. Resilient modulus test was followed the standard from ASTM D4123–82. Both bar charts give a different trend but conventional asphalt mixture at 25°C and 40°C had the highest result of resilient modulus which was 3344 MPa and 1808 MPa respectively. At 25°C, the result was decreased when 5% of plastic added to 2566MPa and increased at 7% to 2588 MPa. The value quite constant between 5% of plastic and 7% of plastic. It started to decrease at 9% where it goes to 1989 MPa. At 40°C, the result of resilient modulus goes to the lowest at 5% of plastic where the value was 1177 MPa. The result was likely to increase when more percent of plastic was added into the asphalt mixture. The result for 7% of plastic and 9% of plastic is 1630 MPa and 1767 MPa but still lower than the conventional asphalt mixture.

The resilient modulus at 25°C shows that the conventional asphalt mixture was varies 21% to 23% higher that the modified asphalt mixture at 5% and 7% of plastic. But there are a big different of resilient modulus when 9% of plastic was added which it lower almost 96% from the conventional asphalt mixture. For resilient modulus at 40°C, the trend of bar chart was same with the 25°C where conventional asphalt mixture shows the highest resilient modulus. But become lower when more percent of plastic were added which was from 35% to 4% compare to the conventional asphalt mixture.

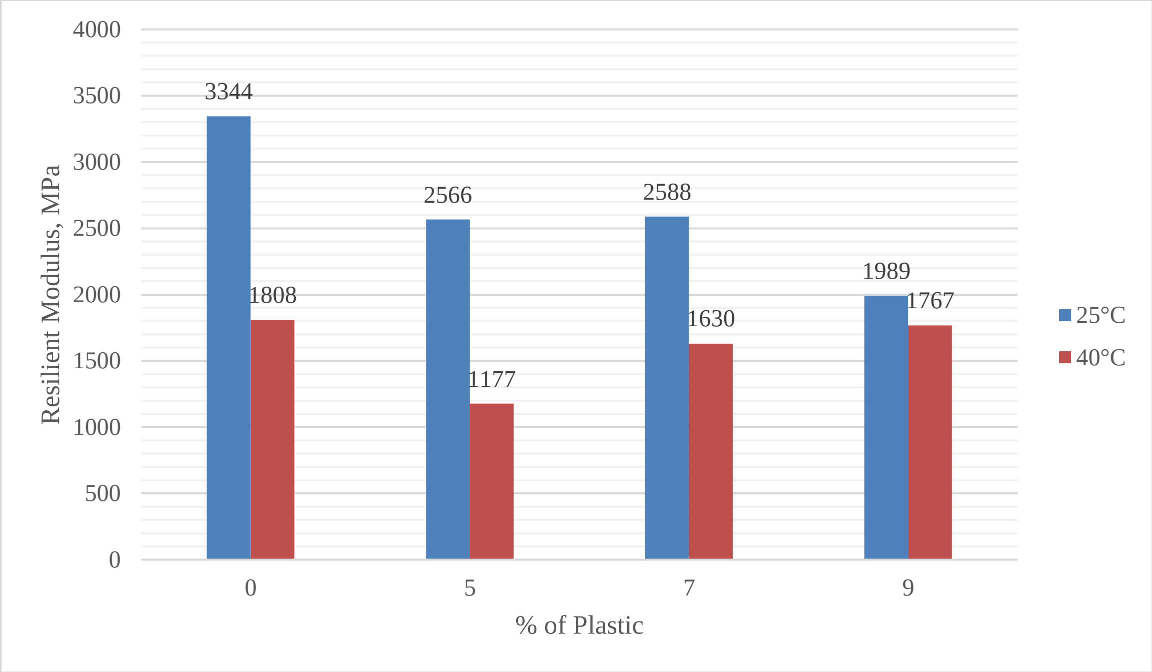

Figure 4.12 Effect of different percentage of plastic to resilient modulus

4.3.1 Relationship Between Resilient Modulus Against Density

The resilient modulus result was compared to the density of the asphalt mixture. The graphs of the relationship shown in Figure 4.13 and Figure 4.14. For resilient modulus at 25°C, the line of graph was peak at the conventional asphalt mixture and declined slightly when more percent of plastic added into the asphalt mixture. But for resilient modulus at 40°C against density, the trend of graph quite different where it 5% of plastic has the lowest value of resilient modulus and it increased when more percent of plastic is added into the mixture.

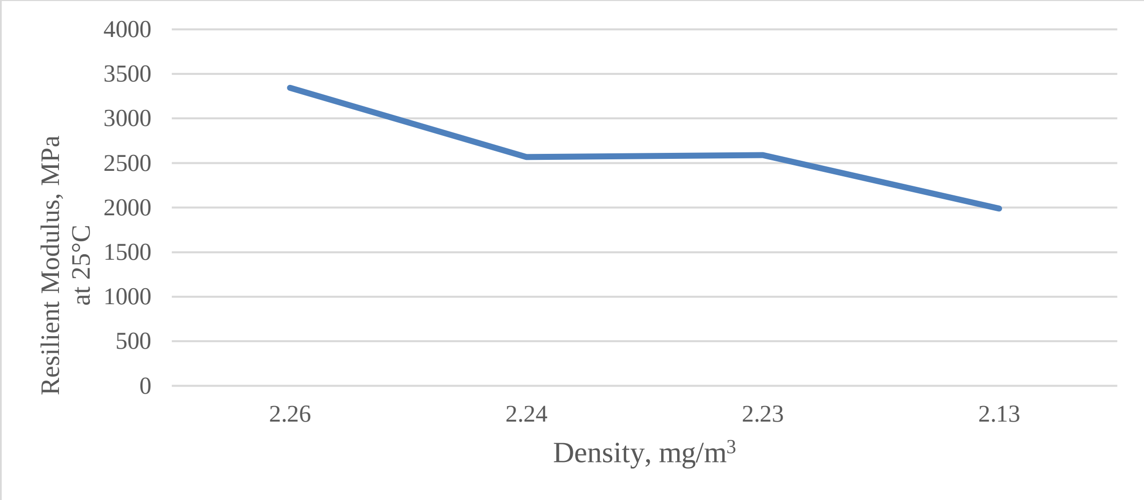

Figure 4.13 Relationship between resilient modulus at 25°C against density

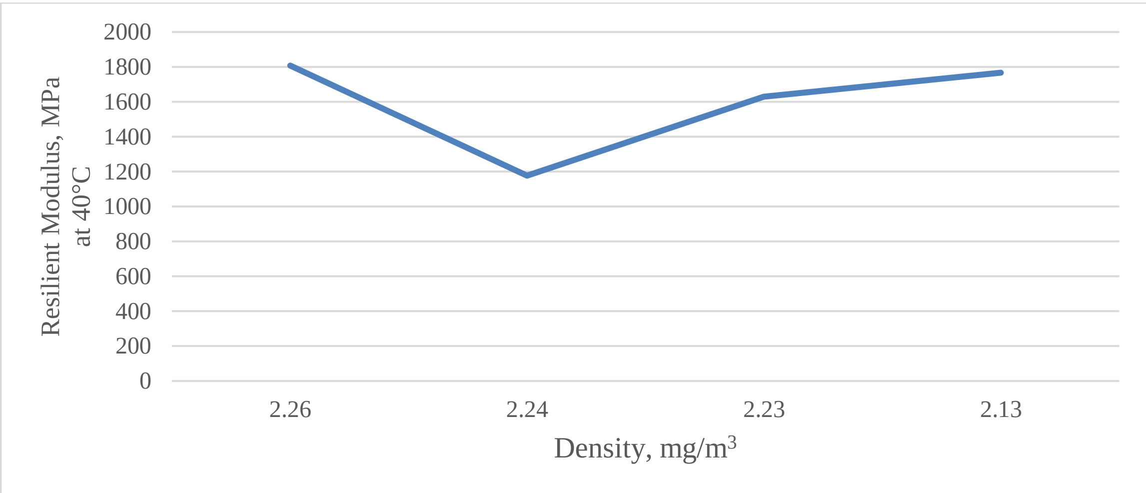

Figure 4.14 Relationship between resilient modulus at 40°C against density

4.4 Dynamic Creep

Figure 4.15 shows the effect of different percentage of plastic to creep modulus. Dynamic creep test is a process where the repeated test load application to the asphaltic concrete and cause the development of rutting. This test was accordance to BS EN 12697-25. The bar chart shows that the conventional asphalt mixture has the lowest creep modulus value which is 14.33 MPa. The result was went increased when more percent of plastic added into the asphalt mixture. For 5% of plastic and 7% of plastic, the result was 16.5 MPa and 21.75 MPa respectively. The highest value of creep modulus was at 9% of plastic which is 55 MPa. The creep modulus at 9% of plastic is more than 100% higher than the conventional asphalt mixture. But the percentage between the conventional asphalt mixture and modified asphalt mixture at 5% and 7% is 15 percent and 51 percent higher respectively. This shows that the waste plastic is useful in order to reduce permanent deformation in the form of rutting and reduce low temperature cracking of pavement surfacing.

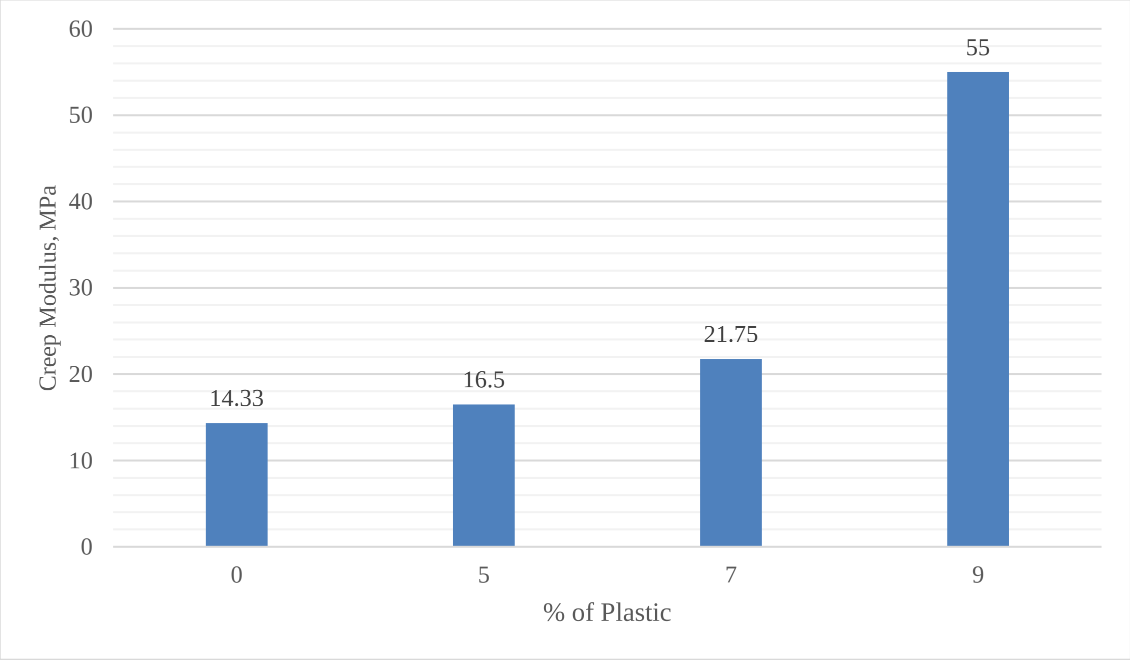

Figure 4.15 Effect of different percentage of plastic to creep modulus

4.4.1 Relationship Between Dynamic Creep Modulus Against Density

The relationship between creep modulus against density is shown in Figure 4.16. The graph shows that the line from the lowest which was the conventional asphalt mixture and increase when more percent of plastic added into the asphalt mixture. The line increased slightly from 0% to 7% of plastic and reaches its peak at 9% of plastic.

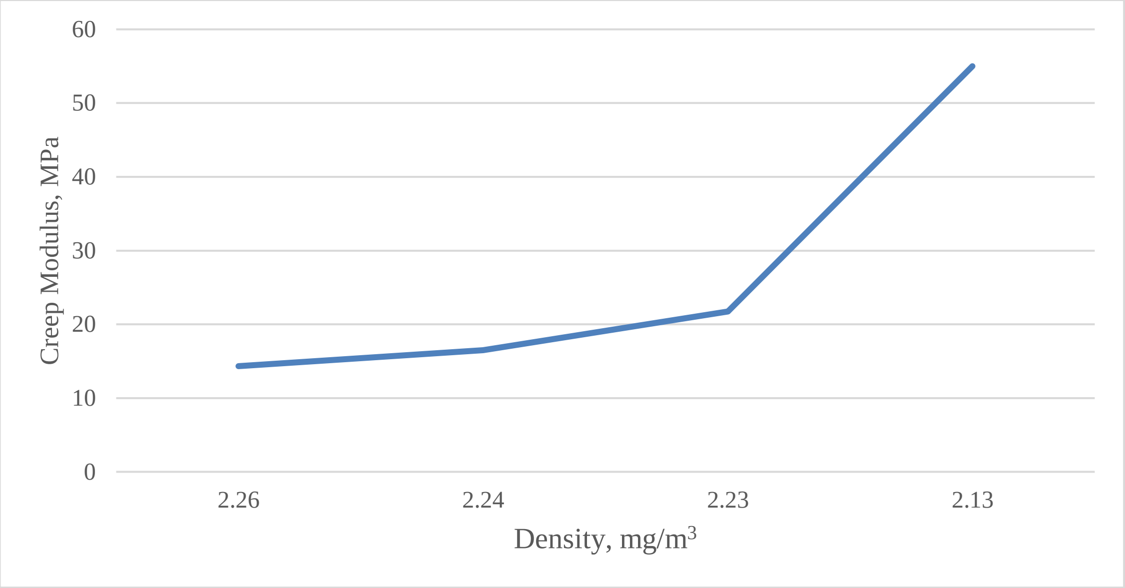

Figure 4.16 Relationship between creep modulus against density

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

The result and analysis for this study had been discuss in detail the previous chapter. The experimental and laboratory test is based on the specification from ASTM, AASHTO and JKR/SPS/2008.

5.2 Conclusion

Based on this study of the performance of plastic waste in asphalt mixture, it shows that every percentage of plastic added will influence the result of the test. Most of the test in the Marshall mixed design shows that the performance of the waste plastic in asphalt mixture is better that the conventional asphalt mixture.

I. To investigate the performance between the asphalt mixture and conventional asphalt mixture.

Based on the result from the experimental and laboratory test, it shows that the addition of plastic had affected the performance of the asphalt mixture. It can be proved from every test conducted where the modified asphalt mixture shows a different result either higher or lower compare to the conventional asphalt mixture. During Marshall test, the modified asphalt mixture shows a different performance when more percent of plastic was added into the mixture. For density and VFA, the conventional asphalt mixture have better performance than modified asphalt mixture. But for VMA, VTM, stability, flow and stiffness, the modified asphalt mixture give a higher result compare to the conventional asphalt mixture. The performance of modified asphalt mixture seems to be lower than the conventional asphalt mixture in the Resilient Modulus Test. When more percent of plastic were added into the mixture, the result were went decreased.

For Dynamic Creep Test, the performance of the modified asphalt mixture was better than conventional asphalt mixture. When more percent of plastic into the mixture, the creep modulus were increased and the up to more than 100 percent compare to the conventional asphalt mixture.

II. To study the optimum percentage of plastic waste added in asphalt mixture.

The optimum percentage of plastic waste added in asphalt mixture were different based on the tests conducted. The optimum percentage of plastic for density, stiffness, VFA and stability was when 5% of plastic added into the asphalt mixture. For VMA and flow, 9% is the optimum percentage of plastic.

For the resilient modulus test at 25°C, the optimum percentage of plastic was at 7% which is 2588 MPa while at 40°C, the optimum it at 9% of plastic which is 1767 MPa. Both 7% and 9% give the highest result compare to the other percent of plastic in the asphalt mixture when being test at that two different temperature. The highest creep modulus was at 9% of plastic which is 55 MPa and this shows that 9% is the optimum percentage of plastic waste added in the asphalt mixture.

5.3 Recommendation

This experiment had brought to some ideas on how to dispose the waste plastic in an effective way and yet can improve the performance of the asphalt mixture. The laboratory test had proved that addition of plastic can improve the performance of the asphalt mixture. For the future study ahead, there are some recommendation that need to be considered in order to get a better result.

I. This study used waste plastic as an additive without any replacement. For future study, use of waste plastic as a replacement such as fine aggregate or the bitumen.

II. Use different percentage of plastic in order to get the optimum percentage either more or less of plastic.

Use different type of plastic and differentiate every type of plastic based on their properties before mixing into the asphalt mixture

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