STIFFNESS PROPERTIES OF MODIFIED ASPHALT USING HIGH DENSITY POLYETHYLENE (HDPE) AS AGGREGATE ADDITIVE MATERIAL CONTAIN PORTLAND CEMENT AND FLY ASH AS A FILLER

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ABSTRACT

Nowadays, plastic are being produced in a large amount because it has become one of the necessity for users to carry good and food containers. There is a various types of plastic that are produced such as High Density Polyethylene (HDPE), Polyethylene (PET), Low Density Polyethylene (LDPE) etc. The main objective of this study is to evaluate the stiffness characteristic of the modified asphalt mixture using HDPE as additive material and Portland cement and Fly ash as mineral filler by using the Indirect Tensile Stiffness Modulus (ITSM). The modified asphalt mixtures were produced from the content of HDPE pallet form. The size of recycled HDPE pallet is passing at sieve size between 3.35mm and 2.36mm. The HDPE was added into the mixture with a difference percentage which is 2%, 4%, 6%, 8% and 10%. The temperature that was used to evaluated the stiffness characteristic of the control asphalt and modified asphalt is 20°C. The weight of the bitumen content that was used is 5% as follow hot mix asphalt 14 (ACB14) in Public Work Department (PWD) requirement. The result shows that the stiffness modulus value was increased when the content of HDPE is increased. The additional of HDPE in asphalt mixture with Portland Cement as a filler was enhanced the stiffness of the modified asphalt. The modified asphalt that was using Portland cement as mineral filler shows the positive effects on stiffness modulus until the maximum of HDPE percentage at 10%. Meanwhile, the trend of line asphalt mixture using fly ash as a filler was shows that it is decreased with the additional of HDPE amount in asphalt mixture. The result shows that the stiffness was decreased with the additional of HDPE and at certain percentage of HDPE which is at 8% and 10%, the stiffness are more less than control asphalt. The optimum stiffness modulus of modified asphalt contained Portland cement as mineral filler is at 10% HDPE content while the fly ash is 2% of HDPE content. In conclusion, the additional of recycled HDPE in modified asphalt give a positive effect to stiffness characteristic of the modified asphalt. The control and modified asphalt that was used in this research also comply with the PWD requirement. The results also shows that the data was fluctuate from 0% to 10% HDPE content. The results indicates that the additional of recycled HDPE in asphalt mixture was improved the stiffness modulus performance compared with the control asphalt mixture.

ABSTRAK

Pada masa kini, penghasilan plastik semakin berkembang kerana ia telah menjadi salah satu keperluan kepada pengguna untuk membawa barang-barang dan bekas makanan. Terdapat pelbagai jenis plastik yang dihasilkan seperti High Density Polyethylene (HDPE), Polyethylene (PET), Low Density Polyethylene (LDPE) dll. Objektif utama kajian ini adalah untuk menilai ciri kekuatan campuran asfalt diubah suai dengan menggunakan HDPE sebagai bahan tambahan dan Portland cement serta Fly ash sebagai bahan pemgisis dengan menggunakan Indirect Tensile Stiffness Modulus (ITSM). Campuran asfalt yang diubah suai dihasilkan daripada HDPE di dalam bentuk pallet. Saiz HDPE adalah yang melepasi saiz ayak 3.35mm dan tertahan pada saiz 2.36mm. Peratus kandungan HDPE yang ditambah ke dalam campuran asfalt ialah 2%, 4%, 6%, 8% dan 10%. Suhu yang dipilih untuk menguji kekuhan asfalt ialah 20°C. Kandungan bitumen yang digunakan ialah 5% seperti yang ditetapkan oleh Jabatan Kerja Raya (JKR). Daripada analisa yang telah dilakukan, nilai kekuatan asfalt semakin meningkat apabila kandungan HDPE di dalam asfalt bertambah. Penambahan HDPE di dalam campuran asfalt yang mengandungi Portland Cement sebagai bahan pengisi telah meningkatkan kekuatan asfalt yang diubahsuai. Asfalt yang diubahsuai yang mengandungi Portland cement sebagai bahan tambah telah menunjukkan kesan positif sehingga peratusan maksimum HDPE iaitu 10%. Hasilnya menunjukkan kekuatan asfalt berkurangan dengan penambahan HDPE dan pada tahap tertentu, kekuatan asfalt yang diubahsuai lebih rendah daripada asfalt yang tidak diubahsuai iaitu 8% dan 10% kandungan HDPE. Kekuatan asfalt diubahsuai yang optimum bagi asfalt mengandungi Portland cement ialah pada 10% manakala asfalt diubahsuai mengandungi Fly ash ialah 2%. Kesimpulannya, penambahan HDPE di dalam asfalt telah menunjukkan kesan positif terhadap ciri kekuatan asfalt yang diubahsuai. Asfalt yang tidak diubahsuai dan asfalt yang diubahsuai yang digunakan di dalam kajian ini juga mematuhi piawaian Jabatan Kerja Raya. Keputusan juga telah menunjukkan bahawa data telah berubah-ubah dari 0% sehingga 10% kandungan HDPE. Selain dari itu, penambahan HDPE di dalam asfalt yang diubah suai juga menunjukkan peningkatkan dalam kekukuhan asfalt berbanding dengan campuran asal.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays, plastic are being produced in a large amount because it has become one of the necessities for users to carry good and food containers. The producing of plastics is increases with the increasing of population, development and life style. Mostly, the plastics are collected from recycling household. There is a various types of plastic that are produced every day such as High Density Polyethylene (HDPE), Polyethylene (PET), Low Density Polyethylene (LDPE) etc. Commonly, the HDPE plastic are used in the production of plastic bottles such as bottles of juice, milk, water and cleaning product. It is also known as a durable, safe and good materials in packaging. Besides that, HDPE also was used as a garden furniture because it is can be resists the wheather and easy to cleaned.

Road can be divided to 2 types of road which is flexible pavement and rigid pavement. Most of the roads in Malaysia especially federal, municipal and state road is a flexible types of pavement. Due to the increasing of road users, the design road pavement need to be improve in order to support the loads of vehicle and have a long life. According to Costa *et* al. (2013), the addition of materials such as polymers in bitumen or asphalt mixture will improve the strengthen of the pavements. In addition, from the previous study shown that the addition of polymers in the asphalt mixtures has

improved the performance of asphalt mixtures such as the increases of resistance in rutting and higher stiffness at high temperature.

The important thing in the design pavement is to know the stiffness properties of bound pavement layers. Stiffness can be defined as a ratio of unaxial stress and the corresponding strain. The stiffness can be divided into 2 types which is elastic stiffness and viscous stiffness. Thus, the elastic stiffness occurs under the low temperature or short loading times and the viscous stiffness occurs under the high temperature.

1.2 PROBLEMS STATEMENT

In this few last year, the producing of plastic was increasingly and it can be seen mostly at the landfills (Moghaddam et al., 2013). This is become a problem in many countries because the plastic is not a biodegradable materials. Besides that, it can be cause a environmental problems. In order to overcome this problems, it would be useful if the waste plastics can be reused as a materials in asphalt pavements. On the other hand, this solution could be improve the service life of asphalt pavement and preventing the environmental pollution.

Road is a important facilities in transportation system. The development of pavement infrastructure was rapidly increases in Malaysia for a few years (Elma *et* al., 2010). In addition, the numbers of vehicle is also increasing where every family have at least two cars. Although the pavements in Malaysia are designed for 10 to 20 years design life, the increasing of vehicles particularly heavy vehicles such as lorries, containers and car caused damaged to the pavements. According to Elma *et* al. (2010), there is a lot of factors that are caused damage to the pavement either internal or external factors. The damage was happen when the roads are not able to carry the load from the vehicles. This problems has always happen at the industrials area where the heavy vehicles always using these roads. The increasing of the number of vehicles such as lorries, trucks, van and heavy vehicles was decreases the service life of road (Moghaddam *et* al., 2013).

In order to improve the road pavement, recycled plastic was use as a additional materials in asphalt pavement. It is proven by the researcher Esmaeil *et* al. (2011), where is the additional of PET in the Stone Mastic Asphalt (SMA) was shown a positive effects on the characteristic of the asphalt. One of the solution that can be taken to improve the road pavement is increasing the thickness of road pavement and using a materials as additive such as waste plastic bottles in asphalt pavement (Moghaddam *et* al., 2013). In addition, Ravisankat *et* al. (2009) found that the surfacing modified bituminous content have a better performance and longer life under heavy traffic load and extreme climate condition. There is various types of plastic waste such as HDPE, PET and LDPE. The recycle HDPE can be used as additive in pavement mixture to enhance the strength of pavement and also solved the environmental problems.

1.3 OBJECTIVE

The stiffness is one of the structure failure on asphalt pavement. In order to produce a durable service life of pavement, the study of the modified asphalt mixture using HDPE was proposed to fined the stiffness properties of the modified asphalt using HDPE as additive material compared with the control mixture by using the Indirect Tensile Modulus (ITSM). The objectives of this research are :

1. To determine the properties of aggregate and bitumen as follow Public Work Department (PWD) requirement by using the Aggregate Impact Value (AIV), Ten Percent Fine, Softening Point and Penetration Test.

2. To evaluate the stiffness properties of the HDPE modified asphalt contain Portland Cement and Fly Ash as a filler at 20°C by using the Indirect Tensile Stiffness Modulus (ITSM).

1.4 SCOPE OF RESEARCH

The laboratory testing was conducted to determine the properties of aggregate and bitumen as follow Public Work Department (PWD) requirement. The laboratory testing were conducted in this studies is Aggregate Impact Value (AIV), 10% Fine, Softening Point and Penetration Test.

In addition, to evaluate the stiffness properties of the HDPE modified asphalt contain Portland Cement and Fly Ash as a filler at 20°C by using the Indirect Tensile Stiffness Modulus (ITSM). Firstly, the scope of this research is consist of two part which is control mixture and modified mixture of asphalt. The ACB14 of aggregate gradation size was used in the design pavement for control mixture and modified mixture. The modified asphalt was proposed to be use in the binder layer. Bitumen grade 80/100 of penetration was used for control asphalt and modified asphalt. The temperature that was used to evaluated the stiffness characteristic of the control asphalt and modified asphalt is 20°C. The HDPE was added into the mixture with a difference percentage which is 2%, 4%, 6%, 8% and 10%. The two types of mineral filler were used in this studies which is Portland cement and fly ash.

1.5 SIGNIFICANCE OF RESEARCH

It is important to know the stiffness characteristic of the asphalt by using the Indirect Tensile Stiffness Modulus (ITSM). The stiffness is one of the major failure and influence the pavement design in pavement. From the previous researcher, it is proven that the modification of pavement by using a polymers such as HDPE, LDPE, ethylene-vynil acetat (EVA), acrylonitrile-butadiene-styrene (ABS) and scrumb rubber has a positive effects to asphalt pavement (Costa *et* al., 2013).

From this research, it will help to evaluate the stiffness properties characteristic of the modified asphalt compare with the control asphalt. In other hand, it will help to determine the optimum effects of the HDPE as a additive in asphalt. The improving of stiffness characteristics will increase the service life of asphalt pavement. Therefore, it will help to reduce the negative impact of the waste materials to the environmental with used it in asphalt pavement as a additive materials. it is also will help to decrease the volume of waste that are transfer to the landfills.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The increasing of the traffic users has caused the damage to the asphalt pavement. In this research, the recycled plastic that was choosen as a additive in asphalt pavement is High Density Polyethylene (HDPE). In this chapter, the topics that were included is High Density Polyethylene (HDPE), asphalt pavement, flexible pavement and types of pavement failure.

The first part is describes about HDPE and the function of HDPE in asphalt mixture. It is also consists the effects of using HDPE in asphalt mixture according to the previous studies.

Second part is explained about the asphalt pavement. this part will explained about the aggregate, bitumen, mineral filler and aggregate gradation. There is several testing were conducted to evaluated the asphalt pavement such as Aggregate Impact Value (AIV), Ten Percent Fine, Softening Point and Penetration Test.

The last part in this chapter is consists of the types of pavement failure. The common pavement failure is stiffness. Besides that, this part also explained the caused of pavement failure in flexible pavement.

2.2 HIGH DENSITY POLYETHYLENE

Plastic is a polymers that will take a long time to disposed and will stay unchanged for at least 4500 years along with the increases of population and demand (Chavan, 2013). In the research paper by Korjakins and his colleagues, they stated that the production of plastic in the world is around 225 million tons/year and increasingly especially in the developing country. The types of plastic that are commonly produced is High Density Polyethylene (HDPE), Polyethylene (PET), Low Density Polyethylene (LDPE) etc.

HDPE can be defined as a thermoplastic materials that is composed from carbon and hydrogen atoms. Meanwhile, Polyethylene can be characterized as a semi-crystalline polymer. This polymer is made up from crystalline and amorphous regions. HDPE resin has a greater proportion of crystalline regions than low-density polyethylene. The size of crystalline regions can be determine by the tensile strength and environmental stress crack resistance (Lester and Gabriel, undated). HDPE have a greater proportion of crystals and it is more density and strength.

The HDPE is one of the recycled plastic that are produced everyday for a various of using. Usually, the HDPE is used in the production of bottles juice, cleaning product and furniture because of the large strength to density of ratio. In order to overcome the problem of recycle plastic that was increasingly every year, it was used in pavement as a additive materials.

According to Casey study, HDPE and LDPE is the most popular waste plastic that are suitable for modification of asphalt compared with PET, Polyvinyl (PVC), acrylonitrile-butadiene-styrene (ABS) and Medium Density Polyethylene (MDPE). The recycled polymers has been found can be improved the properties of binder but not all of the polymers are suitable for modification of bitumen at high temperature (Costa et al, 2013).

In a study on use of waste plastic in construction of bituminous road, Swami and his colleagues (2012) found that the polymer mixed that was coated with aggregate shown the strength of the pavement.

2.3 ASPHALT PAVEMENT

Pavement can be categorized in two types of pavement which is flexible pavement and rigid pavement. The asphalt pavement is consists of subgrade, subbase, base, binder course and wearing course. The function of the asphalt pavement is to substance load applied from surface such as cars, lorries, trucks etc. The main component in the asphalt pavement is aggregate and bitumen. This section consists of aggregate and bitumen as a two main materials in asphalt pavement.

2.3.1 Aggregate

Aggregate is a main materials and important in the asphalt pavement. The aggregate properties is most important because it will influence the performance of the asphalt pavement. Generally, aggregate can be defined as a granular, inorganic or inert materials and normally consist of stone-like solids. The aggregate can be used in road base and can be used with cementing materials such as Portland cement.

Usually, aggregate is used to form Portland cement concrete. There is various types of aggregate and it can be divided into severals of criteria depends on the different criteria. The criteria of the classification of aggregate is size, source of the aggregate and unit weight of the aggregate. The aggregate that usually used in the flexible pavement is course aggregate and fine aggregate.

The aggregate can be divided into 3 types of aggregate wich is course aggregate, fine aggregate and mineral filler. In the asphalt pavement, the aggregate size that was using asphalt mixture is called gradation. The gradation of ACB14 in PWD requirement was starting with the 0.075mm to 14mm. The course aggregate is the aggregate that

retained on the no. 4 (4.75mm) size of sieve. While, the fine aggregate is the aggregate that passes the no. 4 (4.75mm) size of sieve and retained on the no.200 (75um)sieve.

In addition, aggregate can be classified as a natural aggregate and manufactured (synthetics) aggregate. The aggregate are the important componant in the asphalt pavement and needed to be tested before it was used in the aspahlt mixture (Hunter, 2000). The aggregate are tested to find their physical properties and characterized before it is were determine their suitability to be used in asphalt pavement (Rajib and Tahar, 2009).

2.3.2 Bitumen

Bitumen is a important element in asphalt mixture and functional as a binder in asphalt mixture. For a few years, the increasing of traffic volumes and axle loads was influenced the road pavement performance. The bitumen in a asphalt mixture is a importance contribution to the performance of the road. According to Amit et al (2012), bitumen is a black, sticky, and highly viscous liquid or semi-solid in some narural deposits. Besides that, it is a viscoelastic materials depends on temperature and loading rate.

Bitumen can be form in a various forms which is cutback bitumen, bituminious bitumen and modified bitumen. Bitumen can be used in emulsified form and usually it is used as a binder in pavement (Rajib and Tahar, 2009). On the other hand, it is also functional to blend all the aggregates together.

Bitumen was functional as aggregate binder and gives waterproofing properties in the aspahlt mixture in the asphalt mixture (Lavin, 2003). According to Hunter (2000), the unmodified bitumen has been founded less capable in performance with the increasing of traffic volumes and loads. The improvements in bitumen was needed to improve the performance of asphalt.

Normally, bitumen was grouped in various of grades according to consistency. There is two types of grading systems which is viscosity grading system and penetration grading system. Usually, the penetration grading system is the most system used in malaysia. The grading is based on consistency of bitumen at 25°C because it is close to the average pavement service temperature.

2.4 FLEXIBLE PAVEMENT

Most of the road in Malaysia is a flexible type of pavement or also known as asphalt pavement. Commonly, this types of pavement are used in the world because it is more comfortable for users. Besides that, the flexible pavement can be used once the road is ready. The flexible pavement is more strong, strainth and have a good resistance. The flexible pavement also have a low flexural strength. The structural strength of the pavement was depends on the materials characteristic and the thickness of each layer.

Flexible pavement are construct with a aggregate and asphaltic cement. It can be divided into 3 layers which is surface layer, base layer and subbase layer (David and Paul, 1998). Surface is consists of two layer which is wearing course and binder course. In addition, the base layer and subbase layer also divided into two layer which is upper base and lower base. There is 5 categories of flexible pavement design method such as mechanistic-ecpirical method, regression method based on road performance, empirical method with or without a soil strength test, limiting shear failure method and limiting deflection method (Huang, 2004).

Nowadays, the traffic volume in Malaysia and around the world has increasing and it expected to continous increased for the next decade (Costa et al, 2013). It is contributed to the failure that caused by the heavy load traffics. The quality of the asphalt pavement are depends on the composing materials of the mixture. Asphalt pavement must be withstand the long-term static and short-term dynamic load that are caused by the vehicles in a different time (Vorobjovas et al,n.d). The modification of the asphalt pavement needed to improve the performance and have a long life.

2.5 TYPES OF PAVEMENT FAILURE

Commonly, there is two types of road in Malaysia which is flexible pavement and rigid pavement. Most of the road in Malaysia are flexible pavement and some of the area used a rigid pavement. Currently, there is more 80,300km road in Malaysia (Nurul Elma Kordi et al,2010). Flexible pavement in Malaysia are design for 10 to 20 years design life as follow the Public Work Department (PWD) requirement. According to Nurul Elma Kordi et al (2010), although the road are design with a specified design life, this road are not able to support the heavy load traffics especially in industry areas.

There is two causes of pavement failure which is internal failure and external failure. Usually, the internal failure are caused by the asphalt mixture, the quality of materials that are used in asphalt mixture and the poor construction. Meanwhile, the external failure are caused by overloading of traffics, diesel spillage, flooding, sink holes and others. Eventhough there is a lot of duplicate route such as bypass, freeway or motorway, the pavement failure could be occur because it is not reduced the volume capacity of traffic. The design life of flexible pavement is important to ensure that the road could be carried out the load from vehicle and prevent any major failure (David and Paul, 1998). Besides that, the flexible pavement needed to designed to ensure the riding quality during the service life of road.

According to Rani (2007) cited by Nurul Elma Kordi et al (2010), "the flexible pavement failure can be divided into 4 types which is surface deformation, surface defects, cracking and patching and potholes". There is a lot of pavement failure but the major failures of pavement are fatigue, permenant deformation and stiffness. The fatigue failure occurs due to horizontal tensile strain at the bottom asphalt pavement.

Permenant deformation failure occurs on the flexible pavement along the wheel path and at the high temperature. It is occurs when the load that were applied on the surface of road were repeated for a long time (Rajib and Tahar, 2009). The permenant deformation also was influenced by the high temperature. In addition, the permenant deformation is caused by two causes which is permenant deformation in any layers of pavement and high strain in the subgrade.

Meanwhile, the stiffness occurs at low and high temperature. Stiffness can be defined as a ratio of unaxial stress and corresponding strain. Stiffness properties of the asphalt pavement is needed to evaluated the load-induced and thermal stress and strain distribution. Besides that, the stiffness properties are used to evaluate the damage and age-hardening in the asphalt mixture.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The first section is explained the details of materials that were used and testing involved in this study. In this research, various of testing were used to achieved the objectives of this research. The objective of this research is to determine the properties of asphalt mixture as follow hot mix asphalt 14 (ACB14) in Public Work Department (PWD) requirement and to evaluate the stiffness properties of the HDPE modified asphalt contain Portland cement and fly ash as a filler at 20°C by using the Indirect Tensile Stiffness Modulus (ITSM). The materials that were used in this study is bitumen, aggregate and recycled HDPE in a pellet form.

The second section of this chapter is about the several testing that conducted to achieved the objective which is Aggregate Impact Value (AIV), Ten Percent Fine, Softening Point, Penetration Test and Indirect Tensile Stiffness Modulus Test (ITSM). This chapter also explained the details of sample preparation for control mixture and modified mixture.

3.2 MATERIALS

The main materials in the asphalt mixture is a aggregate and bitumen. In this studies, the aggregate gradation that was used follow hot mix asphalt 14 (ACB14) in Public Work Department (PWD) requirement as showing in Figure 1. Based on the hot mix asphalt 14 (ACB14) in PWD requirement, the size of sieved from 0.075mm to 20mm. The aggregate that were used in this research was obtained from the supplier.

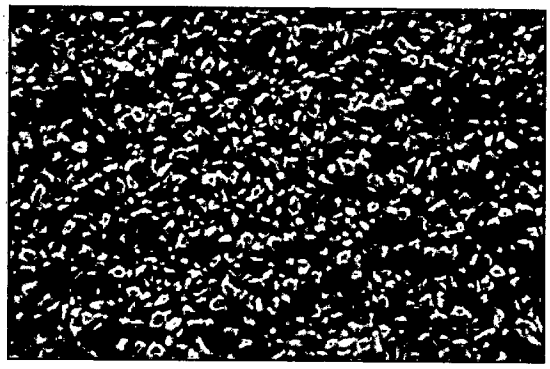

Figure 3.1 : Aggregate follow ACB14 in PWD requirement

Meanwhile the bitumen that was selected to be used in this research is the 80/100 penetration grade bitumen. It is because this type of bitumen is commonly used in Malaysia. Figure 2 shows the 80/100 penetration grade bitumen.

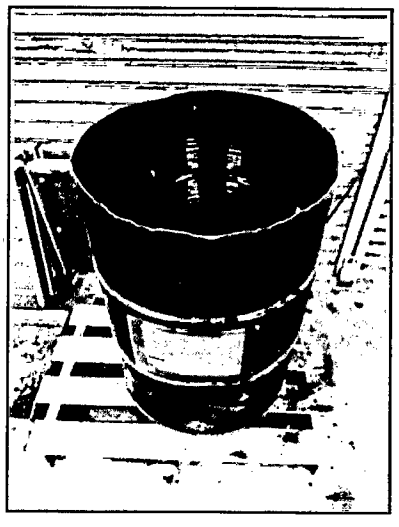

Figure 3.2 : 80/100 Penetration Grade Bitumen

The additive material that was used in this research is a recycled HDPE in a pallet form. Figure 3.3 below shows the recycled HDPE in a pallet form. It is because the pallet form is the form that are usually used in production of plastic bottles and plastic bags. The size of recycled HDPE is passing 3.35mm and retained at 2.36mm. The recycled HDPE are obtained from the supplier.

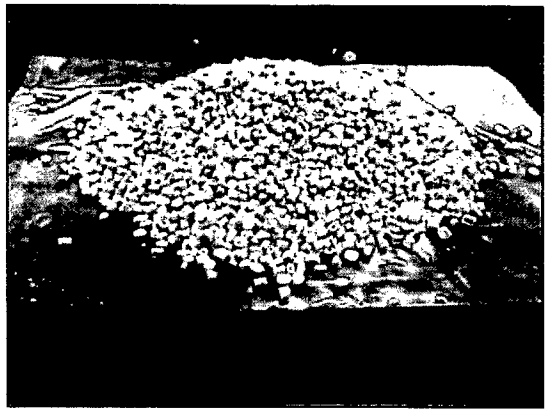

Figure 3.3 : Recycled HDPE pellet

3.3 STUDY 1 : DETERMINE THE PROPERTIES OF AGGREGATE AND BITUMEN FOLLOW PUBLIC WORK DEPARTMENT (PWD) REQUIREMENT BY USING AGGREGATE IMPACT VALUE (AIV), TEN PERCENT FINE, SOFTENING POINT AND PENETRATION TEST.

There a 2 study in this research which is to determine the properties of aggregate and bitumen as follow PWD requirement. Firstly, this study was started with preparing all of the materials. The main component in this study is aggregate and bitumen. The materials that were used in this study is aggregate, bitumen, Portland cement and fly ash.

The aggregate and bitumen should be followed the requirement of PWD. Table 3.1 shows for the PWD requirement of aggregate and bitumen. All of the testing that were used before the asphalt mixture process is Aggregate Impact Value (AIV), Ten Percent Fine Test, Softening Point and Penetration Test.

AIV is to defined the resistance of the aggregate for sudden shock or load. Meanwhile Ten Percent Fine test is to determine the relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. The penetration test and softening point is to determine the quality of the bitumen before it was used in the asphalt mixture. After the aggregate and bitumen were testing and passed the requirement of PWD, it can be used to prepare the asphalt mixture.

Table 3.1 : PWD Requirement of Aggregate and Bitumen

Testing	Requirement
Aggregate crushing value (ACV)	<30%
Aggregate impact value (AIV)	<30%
Ten Percent Fine Value	7.5%.to 12.5%
Los Angeles Abrasion Test	<30%
Softening Point	46 to 54°C
Penetration Value	80 to 100

Source : PWD (1988)