UTILIZATION OF WASTE HIGH DENSITY POLYETHYLENE (HDPE) AS COARSE AGGREGATE REPLACEMENT AND KAOLIN AS FILLER IN HOT MIX ASPHALT

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ABSTRACT

Many researches and development of waste material as an alternative option to replace existing material in pavement design have been done nowadays. One of the common waste materials that used in research is High Density Polyethylene (HDPE).

This research is about the utilization of waste HDPE as coarse aggregate replacement and Kaolin as filler in hot mix asphalt (HMA).The objectives of this study is to determine the optimum bitumen content, stiffness modulus and permanent deformation behavior of asphalt mixture. Waste HDPE will be replace the coarse aggregate (by weight) in five different percentages in range 2%, 4%, 6%, 8%, and 10% in flakes form. There are 3 samples for every percentage of HDPE. This research also used penetration grade bitumen of 80/100 and Kaolin as filler. Density and Voids analysis is carried out to find the optimum bitumen content. The determination of stiffness modulus of samples is done by Indirect Tensile Stiffness Modulus Test. Meanwhile the Repeated Load Axial Test (RLAT) is conducted in determines the permanent deformation of asphalt mixture.

The results obtained from the experimental at laboratory, shows that the stiffness of asphalt is increase with 4% of HDPE usage. As for permanent deformation, it can be reduces the value of axial strain if the usage of HDPE is more than 10%. The finding also reveals that Kaolin plays important roles in increasing the stiffness and decreasing the axial strain of asphalt. This indicates that Kaolin give better performance than Portland cement as filler in asphalt mixture.

ABSTRAK

Banyak kajian dan pembangunan bahan buangan sebagai pilihan alternatif untuk menggantikan bahan sedia ada dalam reka bentuk turapan telah dilakukan pada masa kini. Salah satu daripada bahan buangan yang biasa digunakan dalam kajian adalah *High Density Polyethylene* (HDPE).

Kajian ini adalah mengenai penggunaan sisa HDPE sebagai pengganti agregat kasar dan Kaolin sebagai bahan pengisi dalam campuran asfalt panas. Objektif kajian ini adalah untuk menentukan kandungan bitumen optimum, kekukuhan dan deformasi kekal campuran asfalt.

Sisa HDPE akan menggantikan agregat kasar (mengikut berat) dalam lima peratusan yang berbeza dalam julat 2%, 4%, 6%, 8%, dan 10% dalam bentuk kepingan. Terdapat 3 sampel bagi setiap peratusan. Kajian ini juga menggunakan bitumen gred penetrasi 80/100 dan Kaolin sebagai bahan pengisi. Analisis Ketumpatan dan Lompang dijalankan untuk menentukan kandungan bitumen optimum.

Penentuan kekukuhan sampel dilakukan dengan menggunakan ujian *Indirect Tensile Stiffness Modulus (ITSM)* . Sementara itu *Repeated Load Axial Test (RLAT)* dijalankan dalam menentukan deformasi kekal campuran asfalt.

Keputusan yang diperolehi daripada eksperimen di makmal menunjukkan bahawa kekukuhan asfalt meningkat dengan penggunaan 4% HDPE. Bagi deformasi kekal, ia boleh mengurangkan nilai ketegangan paksi jika penggunaan HDPE adalah lebih daripada 10%. Kajian ini juga menunjukkan bahawa Kaolin memainkan peranan penting dalam meningkatkan kekukuhan dan mengurangkan deformasi kekal campuran asfalt. Ini menunjukkan bahawa Kaolin memberikan prestasi yang lebih baik daripada *Portland cement* sebagai bahan pengisi dalam campuran asfalt.

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LIST OF SYMBOLS

°C	Celsius
%	Percent
µm	micrometer
N	Newton
MPa	Megapascals
kPa	Kilopascals

LIST OF ABBREVIATIONS

ACV	Aggregate Crushing Value
ACW	Aggregate Course for Wearing
AIV	Aggregate Impact Value
ASTM	American Society for Testing and Materials
BS	British Standard
HDPE	High Density Polyethylene
HMA	Hot Mix Asphalt
ITSM	Indirect Tensile Stiffness Modulus
LA	Los Angeles
MS	Malaysian Standard
OBC	Optimum Bitumen Content
PC	Portland cement
RLAT	Repeated Load Axial Test
SSA	Specific Surface Area
PWD	Public Work Department
VFA	Voids Filled with Asphalt
VFB	Voids Filled with Bitumen
VMA	Voids in Mineral Aggregate
VTM	Voids in Total Mix

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Road is a wide way leading from one place to another, especially one with a prepared surface that vehicles can use. Road play a very important role in the socio-economic development of the country. Therefore, road pavement needs to be maintained from time to time to achieve its purpose and contributes comfort to the road users (Aziz, 2007). A major step in the improvement of the existing performance of roads starts with ensuring proper mix design and using suitable ingredients (Dr Hassan H.Jony, Mays F.Al-Rubaie, Israa Y.Jahad, 2011). Pavement is the actual travel surface especially made durable and serviceable to withstand the applied load by vehicles commuting upon it. Pavement grants friction for the vehicles thus providing comfort to the driver and transfers the traffic load from the upper surface to the natural soil. There are three major types of pavement which are flexible, rigid and composite. Flexible pavement is most common used in the most of the Malaysia roadway. This type of pavement is a construction of bituminous and granular material with hot mix asphalt (HMA) poured on top level. A flexible pavement structure is generally composed of several layers which are subgrade, sub base, base, binder and wearing course. Flexible pavements are easily, quickly constructed and repaired. It does generally require a maintenance or rehabilitation every 10 to 15 years.

1.2 PROBLEM STATEMENT

Flexible pavement is most common used in the most of the Malaysia roadway. There are three major failures of pavement such as rutting, fatigue cracking and thermal cracking. Since our country has inconsistences weather conditions, so the temperature affect the conditions of the pavement. Moreover, over load by heavy vehicles also can cause the structure of the pavement become weak and leads to the damage of the road pavement. Besides that, the creation of non-decaying waste materials such as plastic has resulted in a waste disposal crisis and effect to our environments. To solve this problem one of the solution is by recycling waste into useful products. So, by this research the waste materials will be utilized in asphalt to reduce the pollution beside to improve engineering properties of asphalt.

1.3 OBJECTIVE

The objectives of the study are:

1. To determine optimum bitumen content of asphalt mixtures by using waste HDPE as coarse aggregate and Kaolin as filler.
2. To investigate stiffness modulus of modified asphalt.
3. To determine the permanent deformation behavior of modified asphalt by using Repeated Load Axial Test.

1.4 SCOPE OF STUDY

This study is mainly about experimental in laboratory. There are two types of samples for this research which is control sample and modified sample. For both control and modified sample, the aggregate gradation of ACW 14 for wearing course in Standard Specification of Road Work in Malaysia with 80/100 penetration grade bitumen had been used. For control samples, it is following the aggregate gradation of ACW 14 in Standard Specification of Road Work in Malaysia with 4%, 4.5%, 5%,

5.5% and 6% of bitumen contents and Portland cement as filler. While for modified samples, it is divided by two types. Type 1 was used Waste High Density Polyethylene (HDPE) in flakes form in range of 2% until 10% (by weight) in replacing the coarse aggregate and using Portland cement as filler. For type 2 of modified samples, same range of HDPE (by weight) is used for replaced the coarse aggregate and Kaolin for replace the Portland cement as filler. In finding the optimum bitumen content, Density and Voids Analysis has been done using the controls sample and the results was applied for modified samples. Both control and modified samples was tested with Indirect Tensile Stiffness Modulus Test (ITSM) in order to investigate the stiffness of modified asphalt. Meanwhile the permanent deformation of modified asphalt mixture was determined by using the Repeated Load Axial Test (RLAT).

1.5 SIGNIFICANT OF STUDY

The uses of waste HDPE as coarse aggregate replacement in HMA is expected to resolve environmental problems. Since it cannot be composed, then the using of waste HDPE as alternative materials in road construction, this problem can be overcome to some extent. The cost of road construction also can be reduced since HDPE is a waste material.

Besides that, the use of Kaolin as filler in HMA is also expected to increase the viscosity of the bitumen thus increasing the strength of the bond between the bitumen and aggregate. Moreover, there is not much research on Kaolin as filler in HMA, so this study will help other researchers to get information about Kaolin in HMA mixture. In future, Kaolin may be used as a filler to replace existing mineral filler that currently used in HMA.

CHAPTER 2

LITERATURE RIVIEW

2.1 INTRODUCTION

Pavement is the actual travel surface especially made durable and serviceable to withstand the applied load by vehicles commuting upon it. Flexible pavement is most common used in the most of the Malaysia roadway. This type of pavement is a construction of bituminous and granular material with hot mix asphalt (HMA) poured on top level. A flexible pavement structure is generally composed of several layers which are subgrade, sub base, base, binder and wearing course.

The performance of pavement relies mostly on the selection of the appropriate aggregate. A major step in the improvement of the existing performance of roads starts with ensuring proper mix design and using suitable ingredients (Dr Hassan H.Jony, Mays F.Al-Rubaie, Israa Y.Jahad, 2011). It is anticipated that some failures are attributed to the poor design of the asphalt mixes and\or to the materials have been used. Thus, the use of materials according to specifications is very important to ensure a long lifespan for a pavement besides contributes comfort to road user.

Utilization of waste High Density Polyethylene (HDPE) in pavement construction as aggregate replacement is one of alternative way to reduce the waste problems by reuse or recycling since it cannot be composed.

2.2 HOT MIX ASPHALT

In simple terms, hot mix asphalt (HMA) is a mixture of graded mineral aggregate and asphalt binder, mixed at an elevated temperature and compacted to form a relatively dense pavement layer. The mixtures of these materials shall be according the specifications and with the right amount in producing high quality pavement, economy and safe to use.

2.3 MAIN COMPONENT IN HOT MIX ASPHALT

The main components of HMA consist of mineral aggregate, asphalt binder and mineral filler.

2.3.1 Aggregates

Aggregates are inert granular materials such as sand, gravel, or crushed stone that can be used in combination with cementations materials to produce concrete, bituminous materials to produce bituminous asphalt pavement or on its own as road-base.

There are two types of aggregate which is coarse aggregate and fine aggregate.

2.3.1.1 Coarse Aggregates

Coarse aggregates shall be material substantially retained on 2.4mm sieve opening and shall be crushed rock or crushed gravel and free from foreign materials. Coarse aggregate shall conform to the following requirements.

Quality	Test Methods	Requirements
LA Abrasion loss (%)	ASTM C131 -69	Not more than 60
Water absorption (%)	M.S. 30	Not more than 2
Flakiness Index (%)	M.S. 30	Not more than 30

Table 2.1: Course Aggregate for Bituminous Mix

2.3.1.2 Fine Aggregates

Fine aggregates shall be material passing a 2.4 mm sieve opening. It shall be clean, hard, durable and free from clay, mud and other foreign materials. The minus 0.425mm sieve fraction shall be non-plastic when tested in accordance with B.S. 1377:1975.

2.3.2 Asphalt Binder

Basically, asphalt is a black tar or dark brown to black cementations material in which bitumen is a predominant constituent, and is obtained from naturally or it is refined from the crude petroleum. In these processes, the cured petroleum is heated in different stage and the other different petroleum will be removed. The residue from the refining process then is known as asphalt.

According to the Malaysia Public Work Department (PWD), the bitumen shall conform to the following requirements:

Characteristics	ASTM Test Method	Penetration Grades	
		60-80	80-100
Penetration at 25 °C (1/100 cm)	D5	60-80	80-100
Loss on heating (%)	D6	Not more than 0.2	Not more than 0.5
Drop in penetration after heating (%)	D6/D5	Not more than 20	Not more than 20
Retained penetration after thin-film over test (%)	D1754/D5	Not less than 52	Not less than 47
Solubility in carbon disulphide or trichloroethylene (%)	D2024	Not less than 99	Not less than 99
Flash point (Cleveland open cup) (°C)	D92	Not less than 250	Not less than 225
Ductility at 25°C	D113	Not less than 100	Not less than 100
Softening point (°C)	D36	Not less than 48 & not more than 56	Not less than 45 & not more than 52

Table 2.2: Bitumen Properties

2.3.3 Filler

Filler is a fine powder passing the 0.075 mm sieve. The functions of mineral filler are to increase the viscosity of the bitumen and reduce its sensitivity to temperature. Besides that, filler also improves the bonding between bitumen and aggregate, fills the air voids and hardened the layer of bitumen.

2.3.3.1 Types of Mineral Filler

As explained earlier, the role of filler material is to fill air voids that found in the bituminous mixture to create a high quality paving. There is a variety of filling materials

that can be used in the pavement mixtures either using mineral filler or filler that generated from waste material.

The filler that common used are:

a) Cement

b) Limestone

c) Coal ash

Other than these materials, there are also new discoveries to replace this natural material which physical, chemical, and mechanical property of the material is equal to or better than current materials.

a) Cement

Cement is most commonly used filler in bituminous mix design. Ordinary Portland Cement (OPC) is a type of cement that commonly used. The using of cement will affect the ductility and loss due to warming, but will lower the softening point temperature of bitumen.

b) Limestone

Limestone is added to the HMA which acts as an anti-stripping to reduce the aggregate removal. Studies on the mechanism of anti-stripping found that limestone acted with most aggregates of silica to form calcium silica crust that has a strong bond with the aggregate permeability sufficient to allow penetration into the bitumen to form a strong bond.

c) Fly Ash

Utilization of fly ash as filler in road pavement construction has been applied extensively. Between fly ash that has practiced its use in road construction are coal ash, waste oil sludge, decaying stone dust and rice husk ash.

2.3.3.2 Filler Gradation

Filler material should be graded to ensure it is in the group of filler material and shall conform to the following grading requirements:

Sieve Openings	Percentage by weight passing
600 μm	100
150 μm	90-100
75 μm	70-100

Table 2.3: Mineral Filler for Bituminous Mix

2.4 KAOLIN

Clays are among the most common mineral fillers and kaolin is the usual type of clay employed in filler uses. It is widely assumed that asphalt's bond with fine and coarse aggregates may be disrupted by the presence of the dust of clay. The situation becomes even worse with clay fines because these particles have a tendency to swell when they take on water, and this swelling can break or disrupt an existing asphalt-aggregate bond. However, it appeared that the asphalt encapsulates the kaolin particles, protecting the particles from contact with water, and promoting good binding with the larger aggregates. Further testing is needed to verify the hypotheses; however, the present results indicated that the interaction between asphalt and filler can result in desired performance for the asphalt binder and the asphalt-concrete mixture.

2.4.1 Characteristic of Kaolin

Kaolin is a hydrous aluminum silicate having a composition of Al2O3.2SiO2.2H2O. The desirable color is white and reflectance may reach 85 to 90. Generally, kaolin clay is well graded, ranged from clay to fine sand. Extremely fine grain size may be obtainable through beneficiation. Wettability and suspension in water are good. Clays are generally chemically inert but do have sorptive properties. Kaolin clay possesses very low bearing strength and it has the large surface area compared to

granite. The Specific Surface Area (SSA) property can be correlated with particle size of the filler. Smaller particles have a greater SSA than larger particles. Therefore, it appeared that kaolin particles are the smallest among granite and hydrated lime.

Table 2.4 shows the physical and chemical properties of the Kaolin performed by Eisazadeh (2010).

ENGINEERING & PHYSICAL PROPERTIES	VALUES	CHEMICAL COMPOSITION (Oxides)	VALUES (%)
CEC (meq/100g)	12.87	SiO_2	48.48
pH (L/S = 2.5)	4.34	Al_2O_3	31.10
Specific Gravity	2.66	Fe_2O_3	1.03
Surface area (m^2/g)	19.87	MgO	0.86
Liquid Limit, LL (%)	42.20	P_2O_5	9.37
Plastic Limit, PL (%)	21.30	K_2O	4.01
Plasticity Index, PI (%)	20.90	SO_3	2.07
BS Classification	CI	CO_2	1.34
ICL (%)	2.00	Soluble Phosphorus (P)	5.10 ppm
Maximum dry density (Mg/m^3)	1.64	Soluble Aluminum (Al)	5.80 ppm
Optimum moisture content (%)	18.40	Soluble Silica (SiO_2)	4.00 ppm
Unconfined compressive strength (kPa)	134.00	Soluble Calcium (Ca)	0.40 ppm

Table 2.4: Physical and Chemical Properties of Kaolin

2.4.2 Past Studies about Kaolin as a Filler

The specimens with kaolin filler showed better resistance to moisture damage compared with granite-filler specimens (Anggraini Zulkati, Wong Yiik Diew and Darren Sun Delai, 2012). Through their research, they also found that kaolin mixture had the highest deformation resistance compared with hydrated lime and granite mixtures and it had the lowest resilient modulus compared with hydrated lime and granite. Having more asphalt content transformed the mixture to behave with properties of a viscous liquid, and decreased the mixture's ability to quickly recover after deformation. The creep test was conducted at 50°C. At high temperature, it appeared that the presence of filler gave a greater effect to the elastic property of the mastic and kaolin showed better creep resistance at 50°C compared with granite and hydrated lime. Kaolin filler stiffens the asphalt to a greater extent compared with granite and hydrated

lime fillers, and affects the mixture's resistance to compaction that results in a higher VMA. It appears that particle size and surface area of filler have the best correlation with the stiffening effect of filler on the asphalt. The finer the filler, the larger surface area exposed, the more it stiffens the asphalt.

The use of kaolin as filler in road pavement is still less practiced but Kaolin can be used as mineral filler in HMA paving applications. Kaolin will typically meet mineral filler specifications for gradation, organic impurities, and plasticity. The benefits of kaolin may afford a lower cost than other mineral fillers.

2.5 WASTE IN HOT MIX ASPHALT (HMA)

A lot of waste has been produced nowadays from manufacturing operations, household, and sewage treatment plan and from industries. Waste management is now no longer an option but a necessity. Recycling has been identified as one of the best option to convert the waste materials into recycled contents. Hence, legislation has also been enacted to use or examine the feasibility of the waste. Application on industrial waste nowadays is a trend to road constructions. It is not only can reduced the volume of waste that going to landfill, but also give the better performance on the pavement.

According to Kandal (1992) waste can mainly categorize as follows:

a) Industrial waste such as cellulose waste, bottom ash and fly ash
b) Domestic waste such as waste glass and roofing shingles
c) Mining waste such as coal mine refuse

2.5.1 High Density Polyethylene (HDPE)

Today, plastic waste is considered as one of the environmental issue that facing by many countries. Since it cannot be composed, therefore one of the methods of reducing this waste is by application these materials in another industry (Taberi, 2004).

One of the research area related to waste material in pavement design is High Density Polyethylene (HDPE). It is a polyethylene thermoplastic made from petroleum.

Known for its large strength to density ratio, HDPE is commonly used in the production of plastic bottles, corrosion-resistant piping, geo-membranes, and plastic lumber. High Density Polyethylene is also somewhat harder and more opaque and it can withstand rather higher temperatures (120° Celsius for short periods, 110° Celsius continuously). High density polyethylene lends itself particularly well to blow molding.

HDPE is commonly recycled, and has the number "2" as its resin identification code (formerly known as recycling symbol). The advantage of HDPE is it can wear resistant. HDPE also flexible can have a very high elongation before breaking and generally good chemical resistance.

Hence, it seems that large volumes of HDPE can be utilized in asphalt mixtures which also offer a good opportunity in Civil Engineering field. The main purpose on utilizing the recycle HDPE in asphalt mixtures is to reduce the environmental effect.

A study about HDPE as an aggregate substitute in the HMA by Wan Rohaya (2010) indicates that 82.5% HDPE can increase the ability of asphalt mix to resist permanent if the appropriate percent of HDPE content use. Besides that, at optimum bitumen content 4.7% and optimum HDPE content 20%, the asphalt mixture produce the optimum performance in form of permanent deformation behavior with the lowest strain value. In addition, it is found that the plastiphalt also may be used cost effectively in pavement and as overlay on bridges (Hassani and Maghanaki, 2005).

For this study, waste HDPE will be used as coarse aggregate replacement.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter is discussing about the test that has been conducted in order to achieve the objectives of study. The data and result was obtained through the experimental in the laboratory. All the steps and procedures in conducting the test must be properly handled to ensure that the results obtained are accurate as required in JKR/SPJ/2008.

There are several tests that have been conducted. For aggregates, Los Angeles Abrasion Test (ASTM), Aggregate Impact Value Test, Aggregate Crushing Value (ACV), Ten Percent Fines has been done in order to get the properties of aggregate that will be used in the asphalt mixtures. Besides that, bitumen with grade of 80/100 has been test with Softening Point of Bitumen and Penetration of Bituminous Material.

In order to get the optimum bitumen content, Density and Voids Analysis has been used. Last but not least, Indirect Tensile Stiffness Modulus Test (ITSM) and Repeated Load Axial Test (RLAT) have been done in order to investigate the stiffness and permanent deformation of modified asphalt mixture.