EFFECTIVENESS USING RECYCLED POLYETHYLENE TEREPHTHALATE(PET) AND MINERAL FILLERS AS ADDITIVE IN ASPHALT MIXTURE FOR BINDER COURSE

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ABSTRACT

Polyethylene Terephthalate (PET) is the most popular recycle plastic in the world because it is highest polymer in numbering system for plastic recycling. In this research, recycle PET used as a material in the mix asphalt modification. The objectives of this research were to determine the aggregate in asphalt mixture for binder course and to evaluate the effect usage recycle PET as additive in modified asphalt mixture by determining the stiffness properties at temperature 20^0 Celsius. In experiment conducted, there are two type of mineral fillers used which are Portland cement and lime for control and modified samples with 5.5% was added in asphalt mixture. The modified asphalt mixture consists of recycle PET in pallet form. The recycled PET was used from 2% to 10% of weight asphalt mixture with sieve size from 2.36mm to 1.18mm. The 80/100 penetration grade of bitumen was used in this experiment and this grade is usually used in Malaysia. The 5% weight of bitumen content was used in this experiment as followed the standard specification from Public Work Department for binder course (ACB 28). The sample testing performed using Indirect Tensile Stiffness Modulus Test (ITSM) to evaluate the stiffness properties of modified asphalt mixture. The result shows that the percentage of PET content in modified asphalt is higher stiffness compared to unmodified asphalt. All PET modified asphalt are more stiff rather than unmodified. The maximum modulus stiffness occurs at 4% PET content using filler Portland cement and 2% PET content using filler lime in asphalt mixture. In binder course layer of pavement structure, the 4% PET is high modulus stiffness compare with modified asphalt. In conclusion the value of modified asphalt using fillers such as lime can increase the stiffness properties compared to using Portland cement. In term of economic value, the recycle PET is a good material to use in construction because it could be improve the life service and also reducing the cost of road construction. Furthermore the material which is bitumen is cheaper and easy to obtain. The finding indicates that, the recycled PET has ability to improve the stiffness properties in modified asphalt mixture.

ABSTRAK

Polyethylene Terephthalate (PET) adalah plastik yang paling popular di dunia kerana ia adalah polimer tertinggi dalam kerana ia adalah polimer tertinggi dalam sistem penomboran untuk plastic kitar semula. Dalam kajian ini, ia digunakan sebagai bahan dalam pengubahsuaian campuran asfalt. Objektif kajian ini adalah untuk menentukan penggredan agregat dalam campuran asfalt untuk kursus pengikat dan menilai kesan penggunaan plastik (PET)kitar semula sebagai bahan tambah dalam campuran asfalt yang diubahsuai bagi menentukan sifat-sifat kekuatan pada suhu 20^0c. Dalam eksperimen yang dijalankan, terdapat dua jenis mineral pengisi yang digunakan iaitu Portland simen dan kapur untuk sampel yang tidak diubahsuai dan sampel yang diubahsuai dengan 5.5% ditambah di dalam campuran asfalt. Campuran asfalt diubahsuai terdiri daripada PET kitar semula. PET kitar semula telah digunakan dari 2% hingga 10% daripada berat campuran aspal dengan saiz ayak 2.36mm dari 1.18mm. Gred bitumen 80/100 digunakan di dalam eksperimen ini dang red ini biasa digunakan di Malaysia. Sebanyak 5% kandungan bitumen digunakan mengikut standard dari Jabatan Kerja Raya untuk kursus pengikat (ACB 28). Ujian ke atas sampel dilakukan dengan mengunakan Indirect Tensile Stiffness Modulus Test (ITSM) untuk menilai sifat-sifat kekuatan campuran asfalt yang diubahsuai pada suhu 20^0c. Keputusan eksperimen menunjukkan bahawa peratusan kandungan PET dalam campuran aspal yang diubahsuai menjadikan ketegangan lebih tinggi berbanding dengan asfalt yang tidak diubahsuai. Semua asfalt PET yang diubahsuai lebih tinggi berbanding yang tidak diubahsuai. Kekuatan maksimum telah berlaku pada 4% kandungan PET menggunakan pengisi simen portland dan 2% kandungan PET menggunakan pengisi kapur dalam campuran asfalt. Dalam lapisan kursus pengikat, 4% kandungan PET adalah tekanan tinggi berbanding dengan aspal diubahsuai. Kesimpulannya nilai asfalt diubahsuai dengan menggunakan pengisi seperti kapur boleh meningkatkan sifat-sifat kekuatan berbanding dengan menggunakan simen Portland. Dari segi aspek ekonomi, PET kitar semula adalah bahan yang baik untuk digunakan dalam pembinaan kerana ia dapat meningkatkan jangka hayat dan juga dapat mengurangkan kos pembinaan jalan.Tambahan pula, bahan seperti bitumen murah dan senang didapati. Daripada dapatan kajian menunjukkan bahawa, PET kitar semula mempunyai keupayaan untuk memperbaiki sifat-sifat kekuatan dalam campuran asfalt yang telah diubahsuai.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

In roadway pavement, there are three types of pavements namely flexible, rigid and composite. The road in Malaysia mostly built from flexible pavement like the road of municipal, state and federal. The typically of flexible pavement consists of asphalt concrete as top layer and supported by the compacted soil consists of granular base, sub base and subgrade layer. (Papagiannakis et al.,2008).

The structure of flexible pavement basically has four layers of subgrade, subbase, base and wearing course. Formation of subgrade level is the first stage of building asphalt mixture. Subbase layer acts to distribute the load from the site to the subgrade layer. This layer also acts as a temporary and protects the lining of the subgrade. The base layer receiving the traffic load and distribute it to the subbase layer.

The surfacing layer is top layer and it is usually made of asphalt mixture consists of binder course and wearing course. The binder layer is pre-mixed layer which acts to support the wear layer on top and cover the base path. This binder layer also flexibility, binds the aggregate together, and gives waterproofing properties to the pavement. (Lavin et al., 2003). The wearing course is top layer in flexible pavement. It functions is

to support the applied load from vehicle wheel and to distribute to the subgrade. Normally, the materials used must have the highest quality compared to other layers. This is because the wearing course directly receiving from the traffic load.

According from Elma, Rohani and Bahardin, the structural strength depends on individual material strength characteristic and thickness layer. Some form of deflection within the elastic limit is allowed. Surface readability is good but relatively less durable or susceptible to high temperature.

Nowadays, Polyethylene Terephthalate (PET) is the most popular type of plastic packaging in households is made from this recycled plastic. PET plastic is now used as a packaging material for a whole range of consumer products in addition to carbonated beverages (Hurd, 2001). Plastic PET is semi-crystalline materials with excellent chemical resistance, good fatigue and wear resistance and wide range properties. (Zahra, Abdelaziz and Mohamed Rehan, 2010). The modification of polymer for binders shows improvement in term of pavement condition such as temperature susceptibility, thermal cracking, rutting resistance, and stripping and fatigue damage.

1.2 Problem Statement

The development of Malaysia is growing rapidly, especially in road transport. Therefore, research should be done to produce a quality road network and to achieve long life span. The road in Malaysia is using the bituminous pavement which is flexible pavement. The quality of flexible pavement will provide a good performance in traffic load conditions, the environment, climate and other factors. The flexible pavement is facing three major failures such as rutting, fatigue cracking and thermal cracking (Rohaya, 2010). This failure occurs due to the traffic load and the material use for construction (Thom, 2008)

Meanwhile, road damage often occurs due to several factors, for example whether such as rain, heavy vehicle and load from traffic cause failure of the pavement structure. The failure of pavement divided into two types, which are an internal and external failure. Usually, the internal failure of pavement that caused by the lack of the pavement mixture material such as aggregate gradation, which does not use the appropriate size used and during construction implemented(Elma, Rohani and Bahardin, 2010).

1.3 Objective

The failure of asphalt pavement often occurs. In order to avoid the failure that occurred, the study on the modification of asphalt concrete using the recycled plastic PET as an additive in asphalt mixture for the binder course. The objectives of this study are below.

i. To determine the aggregate in asphalt mixture as followed the standard specification from Public Work Department for binder course ACB28.

ii. To evaluate the effect usage recycled PET in modified asphalt mixture with Portland cement and lime by determining the stiffness properties at temperature 20^0c using Indirect Testing Stiffness Modulus Test (ITSM).

1.4 Scope of Work

The scope of study divided into two samples which is modified sample n control sample. In this study, the sample that used to proposed for binder course layer in pavement structure. For the design pavement structure, the aggregate size used AC28 in asphalt mixture is contained in the JKR Standard Specification for Road Works. In the asphalt mixture, the aggregate gradation used is AC28 in binder course layer and recycled PET used in as additive in asphalt mixture.

The different percentage of recycled PET in pallet form used which are 2%, 4%, 6%, 8% and 10% for modification asphalt mixture. Meanwhile, the bitumen is used in this test was limited to grade 80/100 penetration for used in the construction and maintenance of flexible pavement. The temperature used in stiffness testing is 20 ^{0}C. The temperature will be obtained by stiffness properties in asphalt mixture. Additional of material will be add up to 10% in asphalt mixture.There are a few experiment be conducted in order to archived the objective which is penetration testing, ITSM and softening point and aggregate impact value.

1.5 Significant of study

Damage to the road structure due to the loads imposed by vehicles is dangerous to other road users. Therefore, this study was done to solve this problem by modifying the structure of the pavement. The importance of this study is to reduce the structural failure of the pavement and to increase the service life of the road. From previous research proved that the modification of asphalt concrete pavement will increase the service life of the pavement.

The use of recycled materials from plastic polyethylene Terephthalate (PET) as an additive in asphalt can increase the capacity of the pavement. It is particularly suitable for use in asphalt mixtures as having the characteristics of mechanical and chemical. In addition, the use of recycled materials those are able to reduce the disposal of PET plastic and avoid environmental problems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Every country in the world needs a good road network in terms of road structure. This is because the road is an important role in the relationship between from area to other area. In Malaysia, there are several types of roads used in Malaysia, which is flexible pavement and rigid pavement. For this study consists by three main parts which are type of pavement flexible pavement, asphalt mixture and polymer. The first part in this study with respect to the flexible pavement, there are major components that cause failure. It consists of a flexible pavement structure and pavement failure. In pavement structure consist four layers, which are subgrade, subbase, base and surface layer. In surface layer, there are divided to two layers for binder course and wearing course. Besides that, the failures of pavement that occur are permanent deformation, fatigue cracking, thermal cracking and stiffness.

The second part of this chapter is about the asphalt mixture. The asphalt mixture is combination of aggregate and bitumen. Therefore, in asphalt mixture regarding about aggregate, there are aggregate gradation, type of aggregate gradation and describe of bituminous. In additional, to evaluate the properties of asphalt there are a several tests that have to conducted such as Indirect Testing Stiffness Modulus(ITSM),Repeated Load Axial Test and Indirect Tensile Fatigue Test (ITFT).

Final part of this study is regarding of polymer, which is one of material used in this study. The polymer will be described about polyethylene terephthalate (PET) and high density polyethylene (HDPE). Lastly, the PET functions as an asphalt modifier.

2.2 Type of Pavement

Generally, in Malaysia there are two types of rigid pavement and flexible pavement. Both of road pavements used in road network systems either on federal road, state road, municipal road others road.

2.2.1 Flexible pavement

Flexible pavement is most popular road pavement used in Malaysia. . However, the federal road is popular used flexible pavement compared to rigid pavement. This is because the flexible pavement a good strength from heavy load and it more comfortable for user.(Elma, Rohani and Bahardin, 2010). A typical flexible pavement structure as below:

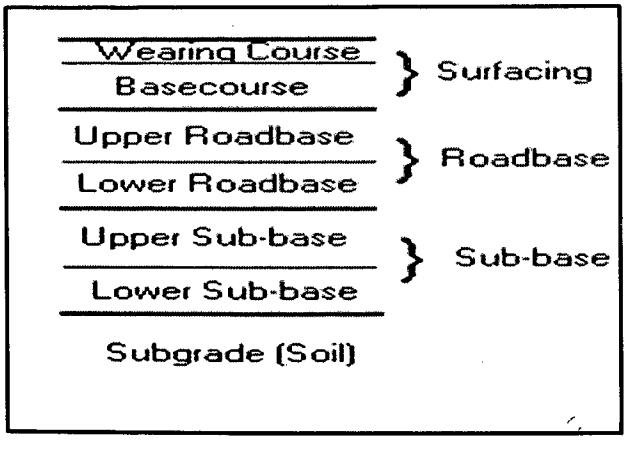

Figure 2.1: Typical flexible pavement structure

Source: Rohaya 2010

According to Ahmad Kamil(2009), a flexible pavement consists of a bituminous surfacing overlying an unbound compacted crushed stone while a rigid pavement consist of a concrete slab overlying a shallow granular bed. The component of flexible pavement consist of sub grade, sub base, base, wearing course and binder course. (Rohaya, 2010). The lowest layer of pavement structure called the subgred with natural soil. The next layer is the subbase, it consist of crushed aggregate the next layer is called road base, which can be made of crushed aggregates with a cementing material. The top layer is called surfacing layer. It is usually made of asphaltic concrete.

2.2.2 Rigid pavement

Rigid Pavement is pavement top layer of road constructed of reinforced concrete. It is consist of Portland concrete slabs resting on a base course or directly on the subgred. The modulus of the Portland concrete, which is in the order of 28000Mpa,is much higher than the modulus of the underlying layers, which typically range from 80-600Mpa. (Papagiannakis et al., 2008).

Among the advantages of pavement type is able to support of load from all types of vehicles, relatively comfortable, safe, non-dusty, a good resistance, high visibility either at night or during the day and lower maintenance costs. Besides that, the disadvantage for this type is high cost in construction and a good implementation method for achieving good pavement.

2.3 Failure of Flexible Pavement

Flexible pavement structural failure occurs when the load of the vehicle is applied to pavement. It occurs due to the deformation of the subgrade or pavement materials, components relative movement under the pavement, the expansion and contraction phases of construction of the subgrade or connection is not properly. Asphalt pavement failure occurs, usually because the pavement mixtures not follow the requirement. There are many reasons that led to the failure; the main causes are the

practice of building, factors traffic, the materials used in construction and weather factor.

Besides that, there are weaknesses in component materials and poor construction. Meanwhile, the external failures are due to overloading, diesel spillage, flooding, sink holes and other unforeseen cause such as earthquake, volcanoes and others (Elma, Rohani and Bahardin, 2010).

According to (Rohaya, 2011), nowadays the asphalt pavement has to sustain increasingly large loads. When these loads are combined with adverse environmental conditions, the distress modes in pavements lead to the rapid deterioration of road structures .Besides that, there are weaknesses in component materials and poor construction.

The failure of flexible pavements has been a risk for failure in the form of rutting (permanent deformation), fatigue cracking and thermal cracking. Therefore, there are some of testing will be carried out to evaluate the performance asphalt mixture such as static creep test, dynamic creep test, indirect tensile strength test, indirect tension test, wheel tracking test and others.

2.4 Asphalt pavement

Bitumen is a complex material consisting of hydrocarbons and it has a high viscosity is black, and is present mainly in crude petroleum and in some natural deposits. Meanwhile, asphalt is a combination of aggregate and bitumen mix in hot-mixed asphalt. The hot-mixed asphalt (HMA) used in constructing the surface layer of asphalt concrete pavement consists of asphalt binder, aggregates and in some cases chemical additive. Apart from the nature of component binder and aggregates, asphalt performance strongly depends on the mixture type (Huang, Bird, Heidrich, 2007).

The chemical additives are usually used enhance the mixture resistance to some pavement distresses such as moisture susceptibility, rutting or fatigue cracking. However, it highlights the importance of the performance distribution of the hot mix asphalt (HMA) products and therefore, indirectly, the reliability of the material performance. (Petho,2012). Asphalt material in pavement structure as follow:-

2.5 Bitumen

Bitumen is black in color and it exists both in the solid, semi-solid or viscous. This material is a viscoelastic and one of material which it has characteristics as an elastic solid at low temperatures or during rapid loading. Bitumen will act as viscous liquid at high temperatures or slow loading. When the low temperatures and plastic deformation at high temperatures, it will be improve the performance of bitumen to minimize the stress cracking that occurs. (Mehmet, 2006). It can be found in the results of the original rock and petroleum. It is a natural mixture of hydrocarbons. The use of bitumen is very important and widespread at this time is because of the various types of pavement can be produced from a mixture of bituminous materials. Although initially use only the surface layer of bitumen road only.

In bitumen grading system divided into two, which is viscosity grading system and penetration grading system. In United State, this country using the viscosity system and the grades of bitumen used is designated and specified by capillary viscosity test at 60°C. However, in Malaysia normally use penetration grading system. This grading is based on consistency of bitumen at 25°C because it is close to the average pavement service temperature. The testing time is relatively short and equipment costs are relatively low. The bitumen grade shown below:

Table 2.1: Bitumen grading system

Testing	Bitumen Grade				
	40/60	50/70	70/100	100/150	160/220
Penetration , X 0.1mm	40-60	50-70	70-100	100-150	160-220
Softening Point, °C	48-56	46-54	43-51	39-47	35-43
Flash point, minimum, °C	230	230	230	230	220
Solubility, minimum, % (m/m)	99	99	99	99	99
Resistance to hardening					
-change of mass, maximum ±, %	0.5	0.5	0.8	0.8	1.0
retained penetration, minimum, %	50	50	46	43	37
-softening point after hardening, minimum, °C	49	48	45	41	37

Source: British Standard (2000)

2.6 Aggregate

Aggregate is basic materials in construction and main component in asphalt mixtures. It is include sand, gravel, crushed stone, slag and recycled concrete. Aggregates are a basic resource; necessary for any kind of modern construction. In addition, aggregates also are used in foundations and roads as base materials. It is also as known the components of a composite material used to resist compressive stresses (Aragão, 2007).

2.6.1 Aggregate gradation

Therefore, evaluation of aggregate is important for pavement structure. The effect of proper gradation will provide the pavement surface become quality and good strength, and able to incurring the load traffic

In preparation for the asphalt mixture, the gradation of aggregate can give a big impact on the pavement surface. For example, in Hot Mix Asphalt (HMA), features

such as stiffness, durability, stability, workability, permeability, fatigue resistance, skid resistance, and resistance to moisture damage that caused by improper gradation.

2.6.2 Types of aggregate

Aggregates used in highway construction are largely obtained from local supplies of natural rock. There are three main types of aggregate have been identified such as igneous rocks, sedimentary rocks and metamorphic rocks.

Igneous rocks are primarily crystalline and are formed by the cooling of molten rock magma as it moves toward or on the surface of the earth: The classification is done based of the crystal grains and on composition as either acidic or basic.

Sedimentary rocks are primarily formed either by deposition of insoluble residue the disintegration of existing rocks or from deposition of the inorganic remains of marine animals. Classification is based on the predominant mineral present as calcareous for predominance of limestone and siliceous for predominance of sandstone and argillaceous.

Metamorphic rocks are igneous or sedimentary rocks that have been subjected to heat and/or pressure sufficient to change their mineral structure so as to be different from the original rock. It generally crystalline in nature with grain sizes from fine to coarse. HMA mixture used for some materials such as lightweight aggregate produced by heating clay and slag from steel production

2.7 Polymers

There are several kinds of polymers that can be recycled in asphalt mixture. These include low and high density polyethylene such as LDPE, HDPE and also PET, widely used in packaging and plastics bottles. In this study, recycled PET in pallet form in 2% to 10 % was used as a modifier.

2.7.1 Polyethylene Terephthalate

Polyethylene Terephthalate (PET or PETE) is a polymer with the number 1 and belongs to the polyester family and it is used thermoplastic is widely used in the around the world. Usually, PET is used for beverage containers such as water of bottle, packaging materials, toys, car components, fiber, inkjets cartridges and other products.

Polyethylene Terephthalate (PET) commonly is made by the polymerization of ethylene glycol and terephthalic acid (Mehmet.D,2006). According to (Harold.C,2003), plastic material is also known as polymers, it is produced through the polymerization process. The polymerization process consists of one or more monomers (chemical compound) to produce by chains of polymer. PET is produced by consideration polymerization. Consideration polymerization is combining two manometers to produce the needed polymer and small molecule, which is the produced product. PET monometer is Dimethyl Terephthalate (DMA) and Ethylene Glycol and the reaction by product is Methanol. Figure shows the PET polymerization consideration reaction.

$$C_{10}H_{10}O_{10}+C_2H_2O_2 \longrightarrow C_{10}H_4O_4 +2CH_4\ O$$

DMA+Ethylene Glycol $\longrightarrow$ Polyester+Methanol

Figure 2.2: PET Consideration Polymerization Reaction

Source: Harold 2003

2.7.2 PET Modified Bitumen

Admixtures are used as the main material for producing a quality pavement. This is because the additives can improve the nature of the bitumen to be better quality. There are a lot of additives that can be used in the asphalt mix and one of them is a plastic or namely is Polyethylene Terephthalate (PET) .The use of plastic as a polymer to modify the asphalt mixture .Plastic is not easy waste for disposal and more than 8% of the total waste consists of plastic. Plastic is used to improve the ability of resistance.

It can improve the quality of adhesion, cohesion, and also the nature of its flexibility at low ambient temperatures. Bitumen modified plastic materials exhibit properties of bitumen containing additives to the rubber as an agent. Based on (Zahra, Abdelaziz and Mohamed Rehan,2011) Polymer modification of asphalt binder is increasingly becoming the norm in the design optimally performing of pavement

2.8 Mineral Filler

Mineral filler is organic additives used in bituminous mixtures. It will retain its original size and does not assume colloidal properties with bitumen when mixed in the filler - bitumen mix. There are a lot of fillers have been used in bitumen composites such as silica, limestone, basalt, green stone, granite, fly ash, mica, oyster shells and asbestos. Filler can be improved the heat resistance by adding inorganic such clay, silica, ground limestone and asbestos (Achmad Fauzi and Liza Evianti, 2011).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the detail of material and testing used in this study. The whole of this study was conducted to achieve the entire objective and scope in this study which are to determine the aggregate in asphalt mixture as followed the standard specification from Public Work Department for binder course ACB28 and to evaluate the effect usage recycled PET in modified asphalt mixture with Portland cement and lime by determining the stiffness properties at temperature 20^0c using Indirect Testing Stiffness Modulus Test (ITSM). The materials were use in this study is bitumen, aggregate and recycled plastic pallet (PET).

In this chapter also describes the detail of sample preparation for modified and unmodified sample and also testing methodology. All method conducted in this study to evaluate the aggregate, bitumen and asphalt mixture as follow the American Society for Testing and material (ATSM) and British Standard (BS). The experimental design in this study is shown in figure 3.1.

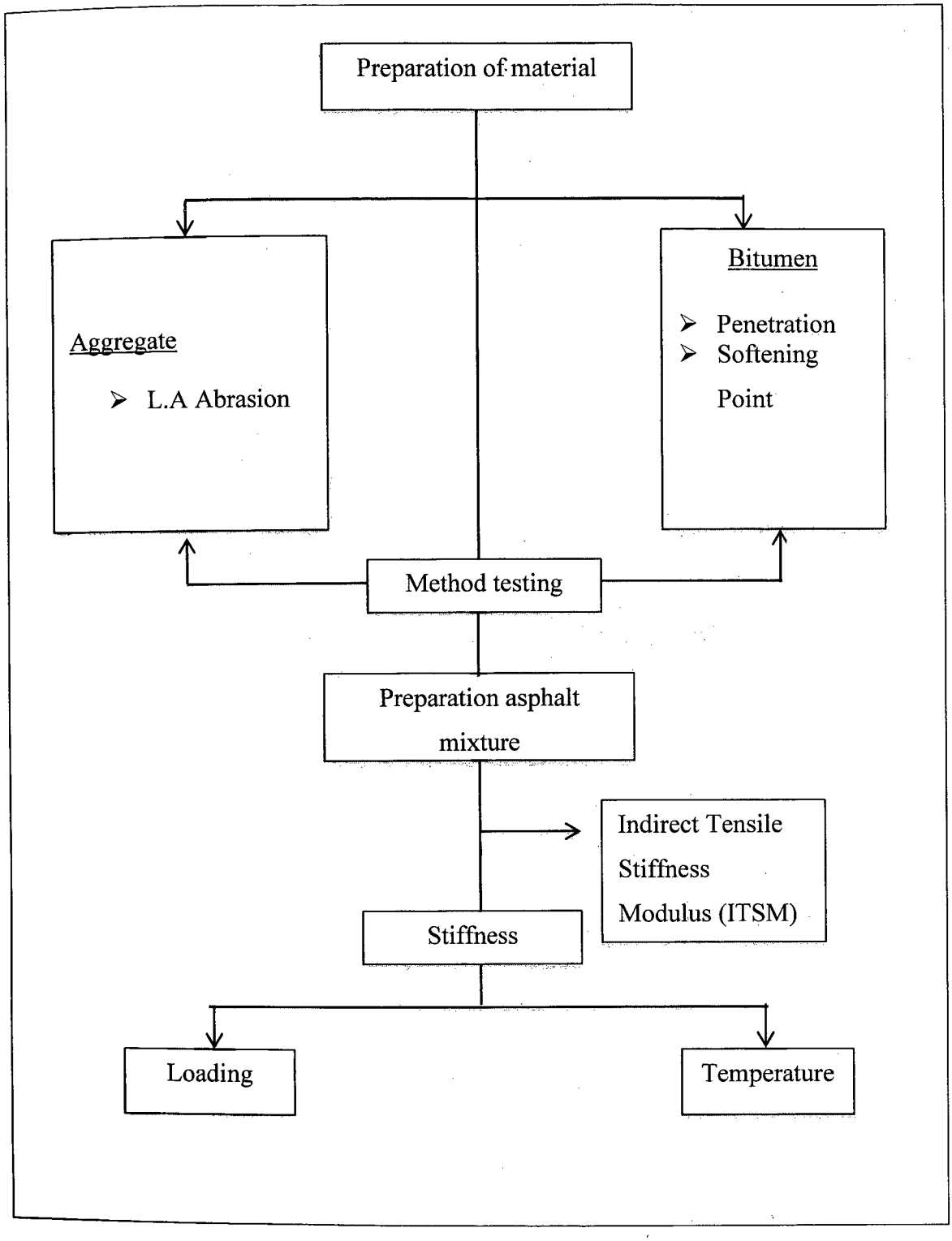

Figure 3.1: Flow chart of study

The Figure 3.1 shown the flow process in this study to obtain the information that the proposed study to achieve the objectives from the early final stage of this study. In this study, there are several methods, instruments and experiments need to be used to achieve the objective.

In order to ensure that this study will be conducted smoothly, process will be done stage by stage. First stage is preparation of material for sample. The material divided into two which is aggregate and bitumen. The next stage is method of testing, which is all testing for aggregate and bitumen will be conducted to achieve the objective. For aggregate, the testing will be conducted is Los Angeles Abrasion (LA) test while for the bitumen, the testing will be conducted is penetration, and softening point. After that, the preparation for asphalt mixture will be carried out through the Indirect Tensile Stiffness Modulus (ITSM) to obtain the result the stiffness properties. From the testing, the result for loading and temperature will be obtained from stiffness testing.

3.2 Material and Equipment

The materials are used in this study are aggregate and bitumen, mineral filler and recycled plastic pallet (PET). All materials were conducted in accordance with method testing established American society for testing and materials (ASTM) and British Standard (BS). The mineral filler like a lime and Portland cement as mineral filler and PET used additive in asphalt mixture. All materials were shown in Appendices 3.

3.2.1 Aggregate

Aggregate gradation should be done carefully because it greatly influences the performance of the pavement layer. Aggregate gradation is the percentage distribution of the different aggregate size of the total weight. The aggregate grading is intended to determine the percentage of aggregate passing sieve until the bottom sizes.

The aggregate gradation is a weigh the mass of aggregate retained on each sieve for preparing of asphalt mixture sample. However, the ACB 28 of aggregate gradation