INVESTIGATION OF ASPHALT PROPERTIES IN FLEXIBLE PAVEMENT BY USING PELLET HDPE AS ADDITIVE MIXTURE FOR BINDER COURSE

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ABSTRACT

The permanent deformation or rutting is a longitudinal surface depression in the vehicle wheel paths. It can occur on any types of pavement either high or low volume road. The aim of this study is to determine the permanent deformation properties of HDPE modified asphalt with Portland cement and Fly ash as filler by using Repeated Load Axial Test that comply with Public Work Department in Malaysia. The percentage of addictive added to asphalt mixture is up to 10%. A 80/100 penetration grade bitumen was used in this experiment and the grade is usually used in Malaysia. The 5% weight of bitumen content used to conduct this experiment. To achieve the permanent deformation on modified asphalt mixture, 20°C temperatures are selected to conduct the Repeat Load Axle Test (RLAT). The testing (RLAT) was used to determine the permanent deformation properties of asphalt mixture. The result indicates that the permanent deformation at 10% additive with Fly ash gives the optimum value performance for this research. It also shows the additive value of asphalt mixture resist rutting compared with unmodified sample. In addition, the HDPE additive would give positive affects to the permanent deformation performance of road at flexible pavement. In conclusion, the HDPE additive has capability to improve permanent deformation and also suitable to be used for road pavement.

ABSTRAK

Deformasi kekal atau aluran adalah satu kegagalan permukaan memanjang atau membujur di laluan roda kenderaan. Ia boleh berlaku pada mana-mana jenis struktur jalan sama ada jalan yang berisipadu tinggi atau muatan yang rendah. Tujuan kajian ini adalah untuk menentukan sifat-sifat ubah bentuk kekal HDPE diubahsuai dengan menggunakan asfalt simen Portland dan Fly ash sebagai bahan pengisi dan Beban berulang Paksi Ujian yang mematuhi Jabatan Kerja Raya di Malaysia. Peratusan penambahan HDPE ditambah kepada campuran asfalt adalah sehingga 10%. Bitumen gred 80/100 telah digunakan dalam eksperimen ini dan gred itu biasanya digunakan di Malaysia. Berat 5% daripada kandungan bitumen dipilih untuk digunakan bagi menjalankan eksperimen ini. Untuk mencapai ubah bentuk kekal pada campuran asfalt diubah suai, suhu 20°C adalah dipilih untuk menjalankan Repeated Load Axial Test (RLAT). Ujian (RLAT) telah digunakan untuk menentukan sifat-sifat ubah bentuk kekal campuran asfalt. Hasilnya menunjukkan bahawa ubah bentuk kekal pada 10% tambahan dengan Fly ash memberikan prestasi nilai optimum untuk kajian ini. Ia juga menunjukkan nilai tambahan campuran asfalt menentang aluran berbanding dengan sampel diubahsuai. Di samping itu, bahan tambahan HDPE itu akan memberi kesan kepada positif kepada prestasi ubah bentuk kepada struktur jalan. Kesimpulannya, bahan tambahan HDPE terbukti mempunyai keupayaan untuk meningkatkan ubah bentuk kekal dan juga sesuai digunakan untuk turapan jalan.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Pavement is a necessary part of our life. Pavement can be verified as the hard surface on the road for example road, runway, street and parking lot. According to other engineering structure in civil, pavement is ordinary to be strong and durable for their design life. It can be classified into two parts such as flexible and rigid pavement. The rigid pavement was made up from Portland cement while the flexible pavement consist an asphalt mixture such as aggregate, bitumen and soil layers. The Sub-grade, sub-base, based course and surfacing are the main layers in flexible pavement. Furthermore, surface layer was divided separately into certain layers which are wearing course and binder course. (Croney, D. and Croney, P. 1976).

Bitumen is a viscoelastic material that is depends on the temperature and load at the same time it also can form as solid or liquid. According to The American Society for Testing and Material (ASTM), bitumen made up from brown-black or dark colour substance in solid/ semisolid/viscous consist mostly of hydrocarbons. Bitumen also gives waterproofing properties to the asphalt pavement when it binds together with an aggregate. (Lavin, 2003).

Recently the rate of using plastic in our life increased rapidly because it has strength, friendly design, long life and low cost for the users. It also used widely in packaging, industrial purposed and medical delivery systems. Plastic can be classified into two types which called thermosetting and thermoplastic.

The thermoplastic types will be soft again by the action of heat and pressure. Besides that, thermoplastic are clearly able to give a good properties on modified binder. The High Density Polyethylene (HDPE) is one of the examples in thermoplastic types. The HDPE materials are very popular in Malaysia because it is flexible, corrosion, superficial and chemical resistant. (Siddique et al., 2007).

1.2 PROBLEM STATEMENT

Over the last few years, the amount of waste plastic dramatically increased due to changes in society and lifestyle. The one of solution to solve this problem is recycled plastic into other useful product. There are many types of plastic such as Polyethylene Terephthalate (PET), High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP) and etc. A lot of recycled plastic are made from High Density Polyethylene (HDPE). The items of this plastic consist of motor oil, containers for milk, shampoos, detergents and soap bottles. (Siddique et al., 2007).

The most important function of the pavement is to withstand the load applied from vehicles such as truck, lorry and aircraft without any deformation. The major failure modes for flexible pavement are permanent deformation, fatigue, cracking and low-temperature cracking. As soon as traffic begins to run under the flexible pavement, permanent deformation will start occur in the area of wheel tracks or other commercial vehicles due to repeated loading at high temperature. All pavement layers are subjected to wheel load and also can be called as vertical compressive stress. In the engineering terms, permanent deformation is the cause of repeated loading by the action of high stress load at high temperatures near the surface of the pavement. (Croney, D. and Croney, P. 1976).

1.3 OBJECTIVE OF STUDY

Permanent deformation is the cause of pavement failure. To achieve durable and service life of an asphalt pavement, the modification of asphalt mixture is proposed to discover the permanent deformation performance. This research had two main objectives. The objectives of this research are:

i. To investigate the aggregate that complies with Public Work Department in Malaysia.

ii. To determine the permanent deformation properties of HDPE modified asphalt with Portland cement and Fly ash as filler by using Repeated Load Axial Test.

1.4 SCOPE OF STUDY

This scope of study is focused on laboratory testing. The properties of material are divided into two parts which are aggregate and bitumen. The aggregate gradation for binder course mainly divided by two such as ACB 14 and ACB 28. To conduct this experiment, aggregate gradation size ACB 14 was selected to be used in both methods for control and modified of asphalt mixture. There are many type of grade bitumen such as 60/70, 80/100 and 100/ 150. The 80/100 penetration grade of bitumen was used in this experiment because it is the most suitable substance in Malaysia. The percentage of HDPE as aggregate additive in the modified asphalt mixture is up to 10%. In addition, the Fly ash and Portland cement was prepared for mineral filler in unmodified and modified asphalt mixture.In the laboratory, the experiment carried out by using The Repeated Load Axial Testing (RLAT) to verify the permanent deformation properties of asphalt mixture. In the other hand, used RLAT is the easier way to conduct and get the result of this experiment. The 20°C temperature is selected in order to get the result of permanent deformation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this project, the High Density Polyethylene (HDPE) was used as an additive with aggregate gradation ACB 14 in PWD Standard Specification of Road. This chapter consist of discussion on previous researches have been done, which was related to this study. Furthermore, there were a lot of researches have been done about flexible pavement and wasted plastic as additives in asphalt mixture. In this chapter also explain about a flexible pavement, asphalt mixture and polymer. The first elements in this chapter elaborate about flexible pavement. Most important part in flexible pavement consists of pavement structure and pavement failure. The example of pavement deformation

The second element of this chapter is about the pavement material such as asphalt or bitumen, aggregate and soil. To determine the properties of asphalt mixture there are several test should be conducted which are Repeated Load Axial Test, Penetration Test and Softening Point. Bitumen and aggregate are part of asphalt mixture materials. Aggregate properties and aggregate gradation are the important topics in aggregate should be discussed briefly.

The third element of this chapter is about polymer properties. The HDPE is the polymer that was selected in this experiment. The function of HDPE material would be described briefly as bitumen modifier of asphalt mixture.

2.2 FLEXIBLE PAVEMENT

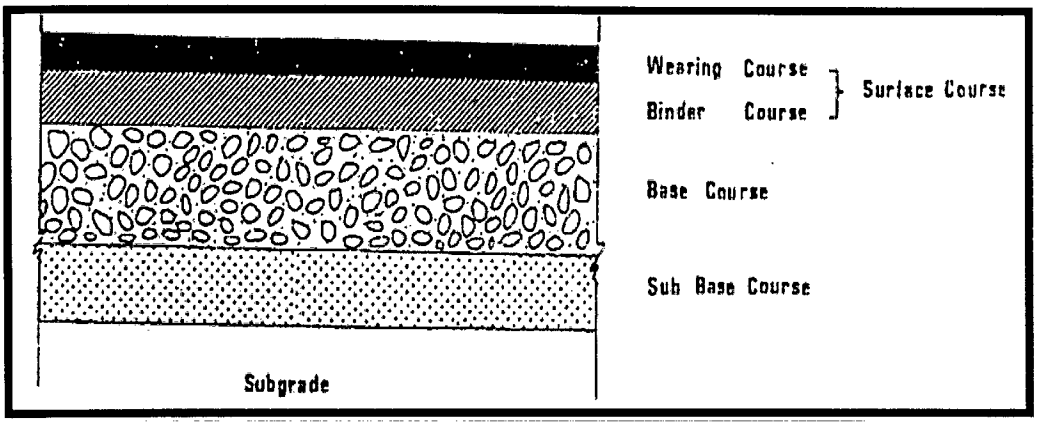

Figure 2.1: Typical cross section of Flexible pavement.

Pavements have been used for highway, airports, streets, local road, parking lots, industrial facilities and other types of infrastructure. Pavement performance is affected by the soil layers, mainly with concern to stability, bearing strength, consolidation over time, and moisture tendency. In flexible pavement, the layer directly under the pavement and divided with several layers consist surface, base course, sub-based course and sub-grade. (Delatte, 2008) Flexible, rigid and composite are the three commonly types of pavements. Most roads especially municipal, state and federal road in our Malaysia are built from flexible type. Aggregate, bitumen and soil layers are significant part of asphalt mixture in flexible pavement. The main layers in the flexible pavement are sub-grade, sub-base, based course and surface course. The surfacing is divided into two which are the wearing course and the binder course. There are difference material design for making base and sub-base. A capping layer should be used between the sub-based and the soil foundation when the soil is considered weak. The soil under the sub-based or capping layer is commonly referred to the sub-grade and the surface of the sub-grade referred to the formation level. Permanent deformation will start occur when the traffic or load begins to flow over a flexible pavement in the area of the wheel tracks. Wheel loads subject on the pavement layers are also called as vertical compressive stress. The wearing, binder and base materials will also subjected to tensile stress.

The wearing, binder and base materials will also subjected to tensile stress. The deflection of the pavement under the passage of the wheel load has been shared by pavement layers and the sub-grade. The viscosity of the bitumen used in flexible pavement increase with time over a period. In simple word the stiffness or elastic modulus of the wearing courses, binder course will increased with time, causing a decrease in the deflection under traffic. Flexible pavements that carry too much heavy traffic loads beyond their design could obtain crack as a result of the large elastic deflection. This situation can cause breakup of the surface and give increase to potholing, before permanent deformation has occurred. (Croney, 1976).

Aggregate and soil layer is referred as a flexible pavement, at the same time the pavement layers deflect under a traffic load. The materials on the top layers would distribute the load that resulting stress in the bottom layers can causes deformation to the layers. The function of difference layers in the pavement is to spread out the load on the surface and also give a less pressure on the sub-grade compare with pressure on the surface. In addition, it can be compromise by the sub-grade without undergoing unnecessary deformation. The layer on the surface has to stand the maximum stress from heavy traffic. Therefore, this surface layer usually made up of the best material and most costly material. The surface layer has two major components such as aggregate and asphalt binder. The mixture of this layer needs to be design properly to give stiffness, strength and durability. Usually, for preparing this mixture need to combined hot aggregates and asphalt binder. The next layer is base course. The base course made up of a bound layer or an unbound aggregate layer. The base layer must be strong in shear same as the bearing capacity. Some additive needs to be added to the sub-grade that is made up of the existing soil or the soil mixed to improve its properties. It also known as the foundation of the pavement and it should be a good quality to resist excessive deflection under load. (Mallick and El-Korchi, 2009)

The principle types of failure modes for flexible pavement are permanent deformation, fatigue and thermal cracking. Permanent deformation occurs only on flexible pavement. Permanent deformation is defined as a longitudinal depression in the wheel path, with or without transverse displacement. It also prevents the cross drainage of water during rains. Permanent deformation is the result repeated loading which causes accumulation and can increased of permanent deformation. It also can be resulting from shear failure of the mix under traffic. In addition, permanent deformation can occur by cracks on the surface of the pavement, caused in underlying layers such as sub-grade or sub-based. Fatigue cracking is based on the horizontal tensile strain at the bottom. The failure related a number of load repetition to the tensile strain. Commonly, fatigue crack occur at the wheel path. Fatigue crack are formed due to poor underlying support at the edge of the pavement with paved shoulders. It also begins as a series of interconnected crack and develops into an alligator pattern. Repeated stress or strain at the bottom of the asphalt mix layer, caused by traffic load leads to fatigue cracking. (Mallick and El-Korchi, 2009; Huang, 2004)

2.3 PAVEMENT MATERIAL

The pavement material focuses on material that related to the design of asphalt mixture for flexible pavement. This pavement material provides explanation of the basic types of material such as asphalt, soils, aggregate and polymer to construct a flexible pavement.

2.3.1 Asphalt

The demand on the bitumen used in road construction increased over the years recently. The bitumen in the highway construction makes the important part to the performance of the road. Bitumen is also known as asphalt, it obtained from crude petroleum through a series of filtration process. In room temperature, asphalt conditions is semisolid or solid and become liquid at relatively high temperature. Thus, the properties of asphalt are affected by the temperature.

Therefore, the asphalt characteristic is required to determine the effect of temperature (Mallick and El-Korchi, 2009). Bitumen is a viscoelastic, thermoplastic material and it also easy to expose to the effect of temperature, loading stress or frequency. In a simple word, bitumen would become softer as the temperature increase, the frequency of loading decrease or the loading stress increases. (Hunter, 2000)

Bitumen is black in color and is the residues of the petroleum oils. It also has no odor, are more resistant to weathering, and less susceptible to temperature. Bitumen is a viscoelastic material and this material could be in viscous or elastic and it is depend on temperature and loading rate. On the other hand it highly resistant to the action of acid alkalises and salts. The largest use of bitumen is in the production of Hot Mix asphalt (HMA) which is primarily used in the contraction of flexible pavements throughout the world.

2.3.2 Soils

Soils can be defined as a processed soil, are present in every layers such as unbound layer or as a major bound layers. In the sub-grade the soil normally consist of unprocessed native soil, compacted to a maximum achieve density, using an optimum bitumen content and roller compaction. Some compaction necessary to improved the bearing capacity to sustain the stress and layers of the pavements. The sub-grade must have a specific depth because that it the important factor for soil. (Mallick and El-Korchi, 2009)

2.3.3 Aggregate

Aggregates used in highway construction are obtained from local supplies of natural rock. Natural rocks are classified by geologists into 3 groups depending on their origin-igneous, sedimentary, and metamorphic. Aggregate is a soil or rock with differences range of sizes used in pavement. Aggregate is a particle whose major portion of size greater than 0.075mm. In order to determine their suitability, these particles are tested for their physical properties and characteristic. The aggregate used in bound actually are the result combination of difference ratio and difference sized particles. This combination is one part of mix design process. The characterization of aggregate important because it for determination of size and shape to the action of moisture with difference condition. (Mallick & El-Korchi, 2009)

Aggregate from natural rock types are consider as igneous, sedimentary, metamorphic or sand and gravel. Several characteristics of igneous rocks can be determined as a very wide range of composition, grain size and coarse grain. Sedimentary rocks are the result of the weathering and erosion by water or wind to the rock. It also can be formed due to the chemical rainfall of minerals known as limestone. It may also consist of organic material such as coal. The change result of existing igneous or sedimentary by pressure, heat and chemical activity called as metamorphic rocks. The sand and gravel are typically dependent on the rocks deposition (Hunter, 2000)

2.4 Polymer

Plastic used in product has grown substantially in recent years. This has forced the plastic industry into developing new actions. It has force the plastic engineers, designers and scientist to develop more about plastics, their capabilities, limitation and properties. Plastic generally refer to a manmade material called polymer. To be specific the word plastic is a term referring to a substance that is capable of being shaped, reshaped, formed and drawn without losing its basic functionality. In the world of plastics, a polymer is a chemical substance product by combining many small molecules together to make a large molecule. Chemical structure is also used to give the material its generic name such as Polyethylene Terephthalate (PETE), High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE) and Polypropylene (PP) .The several properties of High Density Polyethylene (HDPE) was known as flexible, soft, chemical resistant, crystalline and high density. (Hylton, 2004)

A polymer is a very large molecule made up of many smaller units join together to create a long chain. Polymers are divided into three groups which are thermoplastic, thermosetting and elastomeric polymers. High Density Polyethylene (HDPE) is categorized as a thermoplastic polymer. The general characteristic of HDPE is strong softening with temperature, medium strength and large deformation capacity. (Farshad, 2006)

The application of plastics had a wide variety of modern society. The increased of application shows that the used of plastics will continue to growth in the world. Three type of Polyethylene (PE) consist of low density polyethylene (LDPE), high density polyethylene (HDPE) and linear low density polyethylene (LLDPE). HDPE is stronger, harder and more resistant than LDPE. It also gives stiffness and strength to the material. Therefore, toys, trash cart, barrels and chemical storage tank are made up from HDPE because it has chemical resistant and low permeability. (Strong, 2006)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology is an important part in the study and can be defined clearly as a systematic sequence of actions to solve a problem. This chapter will discuss in detail works and procedures to reach the objective of this study. There is a selection of test to be carrying out in this project. The preparation of material divided into two part which are aggregate and bitumen. There are several testing in aggregate such as Specific Gravity, Los Angeles Abrasion Test, Aggregate Impact Value and Aggregate Crush Value. The bitumen testing consist a Penetration Test, Softening Point and Density & Void Analysis

The aggregate gradations follow hot mix asphalt binder course 14 (ACB14) in Standard Specification of public Work Department will affect result of the testing. In addition, fly ash is used for mineral filler and the weight of bitumen content is 5% of asphalt mixture was selected. The percentage of HDPE in the modified asphalt mixture is up to 10%. It also used 80/100 penetration grade bitumen for the testing. To obtain the result of permanent deformation, the 20°c temperature had been used by using Repeated Load Axial Test (RLAT).

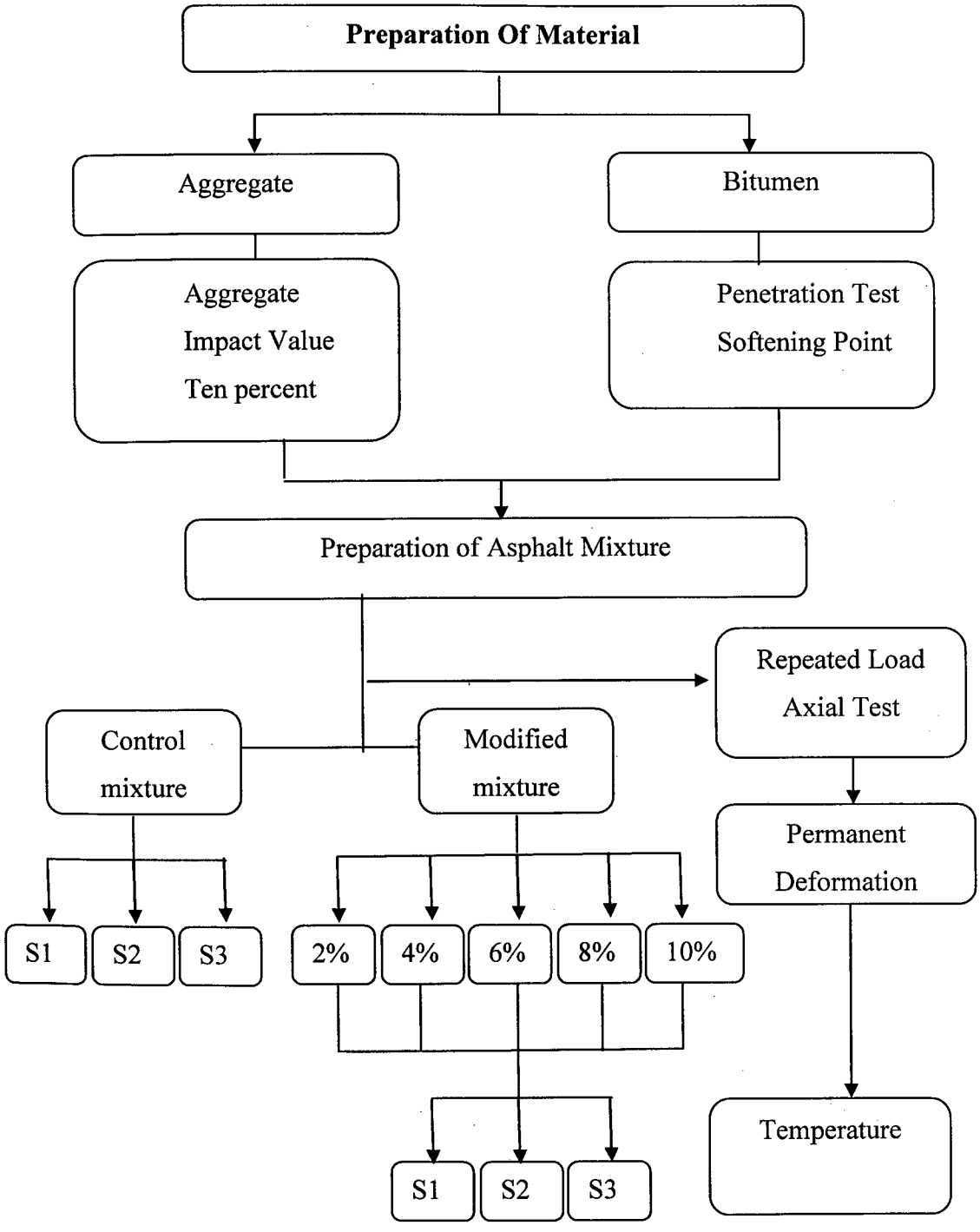

Figure 3.1: Preparation of Materials

3.2 Preparation of material (Aggregate)

3.2.1 Aggregate Impact Value

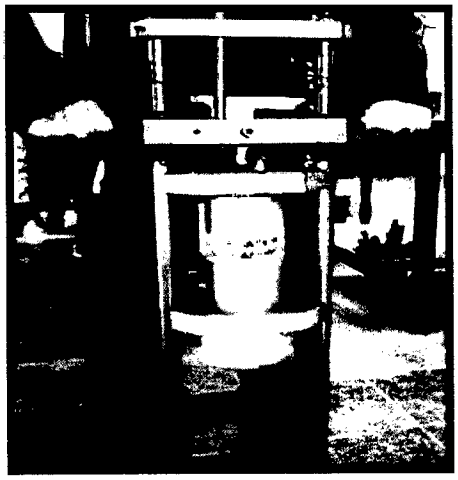

Figure 3.2: AIV Apparatus

The Aggregate Impact Value gives a measure of the resistance of an aggregate to sudden shock or impact. The aggregate size of sample is from 14mm to 10mm. These types of testing are according to BS 812: Part 112. Firstly, the sample put in into an oven at 105 ± 5°C of temperature for a time not more than 4 hours. The sample must cools at room temperature before testing. Secondly, fill the aggregate in open steel container and tamp the aggregate with 25 blows. The tamping rod blows dropped from a standard height above of the sample. Then, the sample resistance get from sieving using a 2.36mm test sieve and the mass of material passing as a percentage of the original sample weight. The accepted value of the test is less than 25 for aggregate in asphalts to measure the mass of sample (M1), the calculation of AIV are following this equation:

AIV $= M_1 / M_2 \times 100$

M_2 = the mass of the test sample (in gram)

M_1 = the mass of the material passing the 2.36mm test sieve (in gram)

3.2.2 Ten Percent Fines

Ten Percent Fines test is used to investigate the relative measure resistant of an aggregate crushing under gradually applied load. The size of aggregate that used for this test is passing 2.36mm sieve. The result obtained from ten percent fine should in the range 7.5% to 12% according to BS 812. The aggregate material is placed in the test cylinder in three layers, each layer tamped with 25 times using road steel. Then, the sample sieved over a 2.36mm sieve. The aggregate passing 2.36mm was calculated follow this equation below:

$M = M_2 M_1 \times 100$

M_2 = the mass of the sample in gram

M_1 = the mass of the aggregate passing 2.36mm in gram

3.3 Preparation of material (Bitumen)

3.3.1 Penetration Test

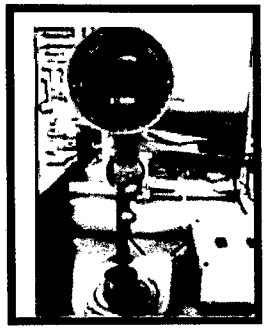

Figure 3.3: Penetration Apparatus

The penetration test is carried out according to BS EN 1426. The penetration test involves subjected a sample of bitumen to needle penetration under specified conditions of time, temperature and load. In most cases, the test is carried out at 25°c with a load of 100g for duration of 5 second. The average penetration value is taken from 3 reading per sample. The depth of penetration of the needle into the surface of the bitumen is measured in tenth of a millimetre.

3.3.2 Softening Point

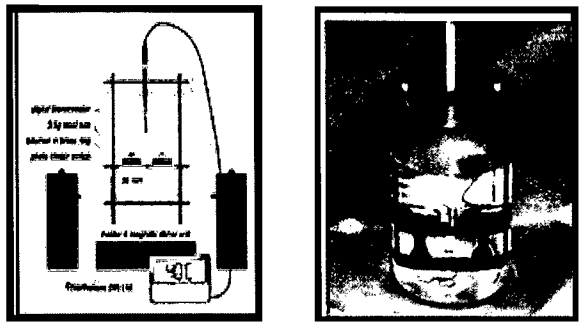

Figure 3.4: Softening Point Apparatus

The softening point test for bitumen is determined according to the BS EN 1427. In this test, two horizontal disks of bitumen are direct into shouldered brass rings and then the bitumen disks was heated at a controlled rate in a water bath while each support a steel ball. The softening point is reported as the mean of the temperatures at which the 2 bitumen disks soften to allow ball to drop downwards. Water was used if softening points of bitumen range between 28°C and 80°C. The initial bath temperature is 5°C and use thermometer with subdivisions of 0.2°C to conduct this test. The difference between the two bitumen disks could not exceed 2°C and the nearest 0.5°C is reported.