

THE INFLUENCE OF AS
(POLYETHYLENE TER



3 PROPERTIES USING PET
N FLEXIBLE PAVEMENT

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ABSTRACT

Most plastic collected for recycling from the household waste stream and the majority plastic bottle come from Polyethylene Terephthalate (PET). Rutting or permanent deformation is one of the most important failure mechanisms in asphalt pavement. The objective of this study is to determine the rutting of asphalt mixture. The bitumen content used in binder course is 5%. The range of percentage additive of PET into asphalt mixture is up to 10% that were calculated and assessed with the laboratory test. There are two type of mineral filler used which Portland cement and lime for both control and modified asphalt. To evaluate the rutting of asphalt mixture, the samples were subjected to Repeated Load Axial Test (RLAT) loading for 1800 cycles and axial load applied 100kn. RLAT is common testing method in laboratory to measure the resistance to rutting of asphalt mixture. The finding indicates that rutting occurs at the highest percentage of PET addition which 10%. It means that PET was improved the rutting properties on asphalt mixture. In term of economic aspect, the PET could reduce cost of road construction because this material is cheaper than bitumen and easy to get. The outcome shows, addition of PET modified asphalt mixture can resist road failures as well as it increase the level of performance and the service life of the road. For the environmental consideration, PET modified asphalt is most suitable to be used for road pavements. It can be conclude that, the PET modified asphalt gives more advantages compared to the conventional method.

ABSTRAK

Kebanyakan plastik dikumpulkan untuk dikitar semula daripada aliran sampah rumah dan botol plastik yang majoriti datang dari Polyethylene Terephthalate (PET). Aluran atau ubah bentuk kekal adalah salah satu mekanisme kegagalan yang paling penting dalam turapan asphalt. Objektif kajian ini adalah untuk menentukan aluran campuran asphalt. Kandungan bitumen yang digunakan dalam kajian ini ialah 5%. Rangkaian peratusan PET ke dalam campuran asphalt ialah sehingga 10% yang dikira dan dinilai dengan ujian makmal. Terdapat dua jenis pengisi mineral digunakan yang simen Portland dan kapur untuk kedua-dua sampel kawalan dan asphalt yang diubahsuai. Untuk menilai aluran campuran asphalt, sampel telah tertakluk kepada Repeated Load Axial Test (RLAT) pemuatan untuk 1800 kitaran dan beban paksi digunakan 100kn. RLAT adalah kaedah ujian yang sama di dalam makmal untuk mengukur rintangan untuk aluran campuran asphalt. Hasil kajian menunjukkan bahawa aluran berlaku pada peratusan tertinggi PET tambahan yang 10%. Ini bermakna PET telah dipertingkatkan ciri-ciri aluran pada campuran asphalt. Dari segi aspek ekonomi, PET dapat mengurangkan kos pembinaan jalan raya kerana bahan ini adalah lebih murah daripada bitumen dan mudah untuk didapatkan. Hasilnya, penambahan PET yang diubahsuai dalam campuran asphalt dapat menahan kegagalan jalan dan juga kerana ia meningkatkan tahap prestasi dan hayat perkhidmatan jalan. Untuk pertimbangan alam sekitar, PET yang telah diubahsuai dalam campuran asphalt adalah yang paling sesuai digunakan untuk turapan jalan. Ia boleh membuat kesimpulan itu, PET diubahsuai asphalt memberikan lebih kebaikan berbanding dengan kaedah konvensional.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In general, there are two types of pavement structures which flexible pavements and rigid pavements. However, composite pavements (which are made of both rigid and flexible layers), continuously reinforced pavements, and post-tensioned pavements are also other types of pavement (Fred et al., 2005). Mostly, roads in Malaysia especially municipal, federal and state are built from flexible type of pavement. A flexible pavement is constructed by asphaltic cement and aggregates and consists of several layer which subgrade, subbase, base, base course and wearing course. A pavement's function is to distribute the traffic load stresses to the subgrade at a magnitude that will not shear or distort the soil. The wearing course is an upper layer in roadways and this is the layer in direct contact with traffic loads. It is meant to take the brunt of traffic wear and can be removed and replaced as it becomes worn.

Rutting is caused by the accumulation of permanent deformation in all or some of the layers in the pavement structure. The accumulation of permanent

deformation in the asphalt surfacing layer is now recognized to be the major component of rutting in flexible pavements. Rutting also can be caused by wear of pavements resulting from use of studded tires (Rabbira, 2002).

One of the most familiar types of plastic packaging found in households is made from a plastic called polyethylene terephthalate PET. Introduced to consumers as the plastic soft drink bottle in the 1970s, PET quickly gained acceptance among bottlers and consumers. Because it was lightweight, economical and shatter proof, PET plastic offered unique marketing and lifestyle benefits. PET plastic is now used as a packaging material for a whole range of consumer products in addition to carbonated beverages (Hurd, 2001).

According to Esmaeil and his colleagues have review of the use of recycle solid waste materials in asphalt pavement. The addition of PET has a significant positive effect on the properties of Stone Mastic Asphalt (SMA) and it can promote the re-use of waste material in industry in an environmentally friendly and economical way (Ismaeil et al., 2011).

1.2 Problem Statement

Recently, due to the human being and development in Malaysia, the total amount of plastic waste such as High Density Polyethylene (HDPE) and Polyethylene Terephthalate (PET) was increased and majority of waste plastic comes from these two types. Most plastic collected for recycling from the household waste stream and the majority plastic bottle come from Polyethylene Terephthalate (PET). This is one of the main causes of environmental problems in Malaysia. These amounts also increase due to the population and development of a country. By using an unsystematic process of removing part of the recycling of waste items, it makes all the waste disposed of in landfill sites only.

Roads and highway play an important role to connect a place to another place. Road transportation creates a vital link in transportation networks. The ability of roads or pavements to deliver goods, people and services within acceptable costs in terms of comfort, time and safety is governed by the pavement life (Muraya, 2007). Mostly, roads in Malaysia are come from flexible type. The flexible pavements are facing several failures such as grooved or depressions (failure due to instability), disintegration, surface damage, loss of skid damage but this three major failure which fatigue cracking, thermal cracking and rutting are commonly failures happen in Malaysia. (Works, 2011) This failure occurs due to the traffic load and the materials use for the construction. The conditions of the roads are affecting the safety of road user and it will become a hazard if the roads are continuously in bad condition. This failure of the road pavement may cause the authorities or the private agencies to spend a lot of money for maintenance works.

1.3 Objective of Study

1. to determine the aggregate as follow hot mix asphalt (ACB28) that comply with PWD requirement
2. to evaluate the rutting properties of PET as additive at 20°C temperature with Portland cement and lime by using Repeated Load Axial Test (RLAT)

1.4 Scope of Study

This study is mainly based on laboratory experiment. The scope is supposedly divided into two main parts which is (i) design conventional and (ii) design modified asphalt mixture for flexible pavement. For both sample, aggregate gradation of ACB28 is use to design the pavement. The modified asphalt are proposed to use at binder course layer. 80/100 grade of bitumen penetration will be

use for control and modified asphalt. To evaluate the optimum bitumen content, the density and air void analysis will be use for the sample. The range of percentage additive of PET into asphalt mixture is up to 10%. According to Public Work Department (PWD), the bitumen content used in binder course is 5% of weight of asphalt. By conducting the experiment, the temperature used is 20°C and the samples were subjected to Repeated Load Axial Test (RLAT) loading for 1800 cycles and axial load applied 100KN at to determine rutting of modified asphalt mixture.

1.5 Research Significant

The PET product is one of most popular recyclable plastic solid waste. According to previous researcher found that in the environmental and economical aspect, PET modified asphalt mixture is suitable to be used for road pavement and also indicates that PET has ability to improves rutting properties of asphalt mixture (Wan Mohd Nazmi and Achmad, 2013 (Nazmi and Achmad, 2013). Besides, the addition of PET has a significant positive effect on the properties of asphaltic and also can promote the re-use of waste material in industry in an environmentally friendly and economical way (Ismaeil et al., 2011)

According to Zoorob and Suparma, said that the permanent deformation or rutting of road make the structure damage and harm the road users and one way to solve this problem is by reduce the probability of the structure to fail and increase the service life of roads. The modification of asphalt mixture with modifier such polymer can improve the properties of asphalt mixture and it was proved by previous researcher (Zoorob and Suparma, 2000). By improving the properties of rutting performance of asphalt pavement, it will increase the service life of pavement. The road which is can be used for long time duration consequently gives the government or private authorities benefit because can save the cost for road maintenance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is divided by three main parts which: road and pavement asphalt mixture including its materials and polymer which Polyethylene Terephthalate (PET). First part of this chapter is the review on road and pavement. In this road and pavement part, it consists of major component of pavement structure and types of pavement which is flexible pavement and rigid pavement. But, this part is only focusing on flexible pavement that commonly used in Malaysia. The flexible pavement structures are surface course, base, sub-base, and subgrade. Meanwhile, the flexible pavement failures are including permanent deformation, fatigue cracking and thermal cracking.

The second part of this chapter is regarding to the materials of asphalt mixture. There are some materials that have been used in this study such as aggregate and bitumen. This part is focusing on the basic components in asphalt mixture which include the aggregate and bitumen. In sub-topic of aggregate, there are review on aggregate gradations, types of aggregate gradation and aggregate properties. For bitumen, it is review on production of bitumen, different forms of bitumen and requirement of bitumen.

Last part of this literature review in on polymer. The polymer part describe about polyethylene and HDPE. Lastly, there is review about PET functions as asphalt modifier.

2.2 Road and Pavement

The primary function of a pavement are to (i) provide a reasonably smooth riding surface, (ii) provide adequate surface friction (skid resistance), (iii) protect the subgrade and lastly, (iv) provide waterproofing that can prevent the underlying support layers including the subgrade from becoming saturated through moisture ingress (Gupta and Adlinge, 2003).

There are several factor that influencing the performance of a pavement which are (i) traffic, (ii) moisture(water), (iii) subgrade, (iv) construction quality and (v) maintenance (Gupta and Adlinge, 2003). Traffic is the most important factor influencing pavement performance. The performance of pavement is mostly influenced by the loading magnitude, configuration and the number of load repetitions by heavy vehicles. Moisture can significantly weaken the support strength of natural gravel materials, especially the subgrade. Moisture can enter the pavement structure through cracks and holes in the surface, laterally through the subgrade, and from the underlying water table through capillary action. The subgrade is the underlying soil that support the applied wheel loads. If the subgrade is too weak to support the wheel loads, the pavement will flex excessively which

ultimately causes the pavement to fail. If the natural variations in the composition of the subgrade are not adequately addressed by the pavement design, significant differences in pavement performance will be experienced.

Besides, failure to obtain proper compaction, improper moisture conditions during construction, quality of materials, and accurate layer thickness all directly affect the performance of a pavement. These conditions stress the need for skilled staff, and the importance of good inspection and quality control procedures during construction.

2.2.1 Flexible Pavement

The components of flexible pavement consist of surface course, base, sub-base and subgrade. The function of pavement structure is to distribute imposed wheel load over a large area of the natural soil. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives load from the above layer, spreads them out, and passes on these loads to the next layer below (Rao, 2006). Thus, the stresses will be reduced, which are maximum at the top layer and minimum on the top of subgrade. In order to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material on the top and the lowest load bearing capacity material on the bottom.

The shear strength of the soil usually not high enough to support the traffic load. If the vehicles were to travel on the natural soils itself, shear failures would occur in the wheel path in most soils and ruts would form. The structure of the flexible pavement helps the distribution of load to the lower layer and decreases the risk of pavement failure.

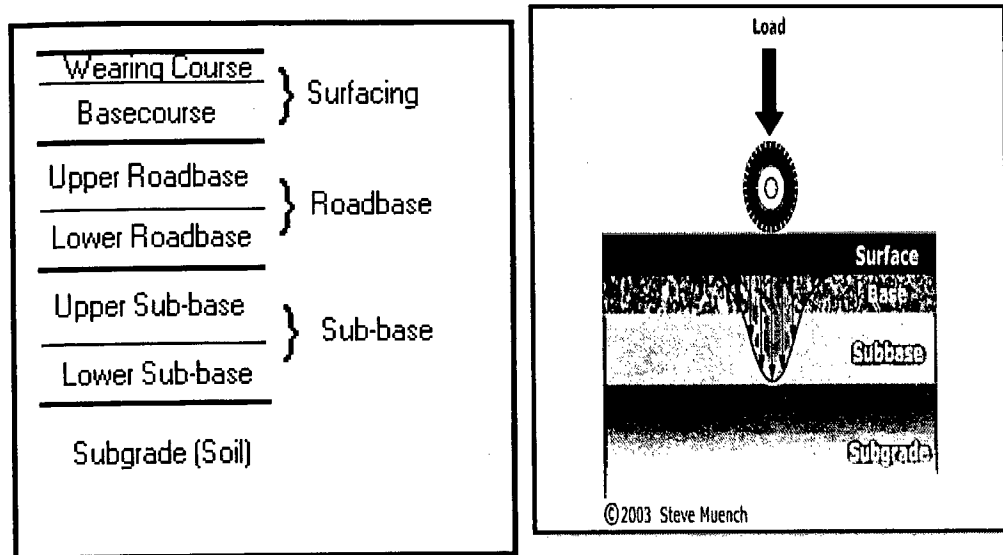


Figure 2.1: Typical cross section of flexible pavement

Surface course consist of asphalt concrete. This layer is directly in contact with traffic loads and generally contains superior quality materials and constructed with dense graded asphalt concrete (AC). The function and requirements of this layer are to provide characteristics such as friction, smoothness, noise control, rut and shoving resistance, and drainage. It also will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade. In addition, surface course must be tough to resist the distortion under traffic and provide a smooth and skid resistant riding surface (Rohaya, 2010)

Binder course provides the bulk of the asphalt concrete structure. The main purpose is to distribute load to the base course and binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-

surface drainage. It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials. The base course are usually constructed out of aggregate or hot-mix asphalt. To form a good structure, the base course must not fail in terms of shear failure and rutting (Lavin, 2003)

The sub-base course is the layer of materials beneath the base course and the primary function are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure. If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course (Lavin, 2003). The sub-base course is composed of either solely granular materials (aggregate), soils or granular materials stabilized by an additive. The granular may contains aggregate from sand, deposit from quarry, recycled concrete pavement, slag or other material. The sub-base generally consists of lower quality materials than the base course but better than subgrade soils.

2.2.2 Flexible Pavement Failure

Flexible pavement failure is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. There are several reasons for these distresses happens which is sudden increase in traffic loading especially on new roads where the design is based on lesser traffic, provisions of poor clayey subgrade results in corrugation at the surface and the temperature of bituminous mixes is not maintained properly (Kumar and Gupta, 2006). According to Rabbira Garba, said that generally there are three causes of rutting in asphalt pavement : accumulation of permanent deformation in the asphalt surfacing layer, permanent deformation of subgrade, and wear of pavement caused by studded tires (Rabbira, 2002).

The most common types of cracking are fatigue cracking which also called alligator cracking. This is a series of interconnected cracks creating small, irregular shaped pieces of pavement. It is caused by failure of the surface layer or base due to

repeated traffic loading. Eventually the cracks lead to disintegration of the surface. This type of cracking is usually associated with base or drainage problems (Gupta and Adlinge, 2003).

Permanent deformation or rutting is the result of weakness in one or more layers of the pavement that has experienced movement after construction. Rutting is usually a failure in one or more layers in the pavement. Inadequate compaction can lead to rutting. Minor surface rutting can be filled with micropaving or paver-placed surface treatments. Deeper ruts may be shimmed with a truing and levelling course, with an overlay placed over the shim. Rutting typically happens during at high temperature. There are two principal causes which are : (i) Rutting from weak subgrade and (ii) Rutting from weak mixture.

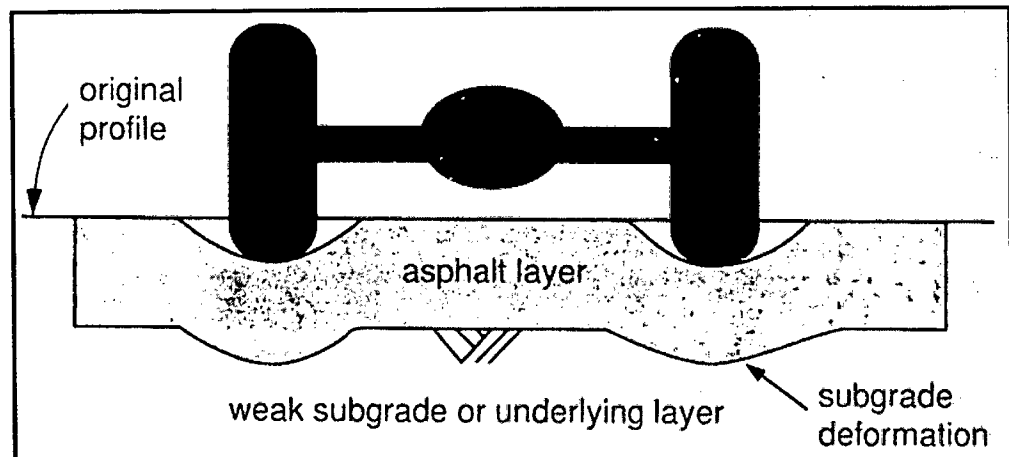


Figure 2.2: Typical cross section of rutting from weak subgrade

Figure 2.2 illustrate the typical cross section of rutting from weak subgrade. This failure occurs as too much repeated stress being applied for the subgrade (or sub-base or base) to withstand. It is considered a structural problem and happens in the underlying layer. The thickness of pavement layers not enough strength to reduce the applied stress to a tolerable level as well as it is weakened by the intrusion of moisture

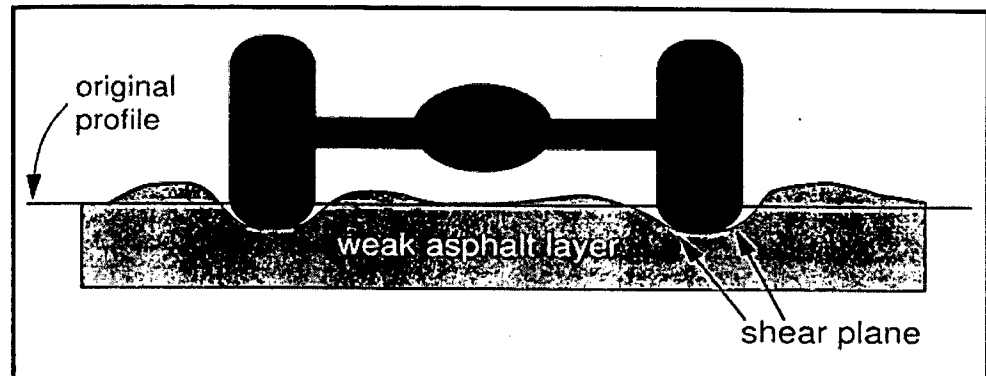


Figure 2.3: Typical cross section of rutting from weak mixture

This situation happens due to asphalt mixture without enough shear strength to resist repeated heavy loads and defect appears in asphalt surface course as shown in Figure 2.3. The weak asphalt mixture will accumulate small area (but permanent defect) and forming a rut characterised by a downward and lateral movement of the pavement.

2.3 Bitumen

Bitumen is a black, oily, viscous material that is a naturally-occurring organic byproduct of decomposed organic materials. Also known as asphalt or tar, bitumen was mixed with other materials throughout prehistory and throughout the world for use as a sealant, adhesive, building mortar, incense, and decorative application on pots, buildings, or human skin (Chavan, 2013). Bituminous materials consist of chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

2.3.1 Production of Bitumen

Bitumen is the residue or by-product when the crude petroleum is refined. A wide variety of refinery processes, such as the straight distillation process, solvent extraction process etc. may be used to produce bitumen of different consistency and other desirable properties. Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed.

2.3.2 Different Forms of Bitumen

Cutback bitumen is normal practice of heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil. There are different types of cutback bitumen like rapid curing (RC), medium curing (MC), and slow curing (SC). RC is recommended for surface dressing and patchwork. MC is recommended for premix with less quantity of fine aggregates. SC is used for premix with appreciable quantity of fine aggregates (NPTEL, 2006).

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilized by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60% and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS: 8887-1995. Three types of bituminous

emulsions are available, which are Rapid setting (RS), Medium setting (MS), and Slow setting (SC). Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

In bituminous primer the distillate is absorbed by the road surface on which it is spread. The absorption therefore depends on the porosity of the surface. Bitumen primers are useful on the stabilized surfaces and water bound macadam base courses. Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.

2.3.3 Requirement of Bitumen

The desirable properties of bitumen depend on the mix type and construction. In general, bitumen should possess following desirable properties.

- i The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather the mix should not become too brittle causing cracks.
- ii The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.
- iii There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

2.4 Aggregate

Aggregates used in asphalt mixes are hard, inert materials such as crushed gravel and stone. Properly selected and graded aggregates are mixes with the

asphalts cement to form asphalt mixes. Aggregates form the principal load carrying component of the mix and total 90 to 95 of the mixture by weight (75 to 85% by volume) (AL-Shrafi, 2005). Aggregates are specified according to their grain size, shape, texture and gradation (Rao, 2006). Based on strength properties of aggregates, it may be classified into two parts which hard aggregates and soft aggregates. Hard aggregates are used to resist crushing effects and adverse weather effects. Soft aggregates are usable in low cost roads. They can be used in lower layers of good type of roads.

2.4.1 Aggregate Gradation

Gradation refers to the particle size distribution of aggregates. Gradation is usually described in terms of particle size distribution curve (also known as gradation chart), which is determined from sieve analysis. However, it is difficult to find a single parameter that quantitatively characterize all aspects of the particle size distribution curve. The shear strength and hence the resistance to permanent deformation of asphalt mixtures depends on the mechanical interlock of the aggregate skeleton especially the stone structure of course aggregates. Loss of stability, which can lead to rutting, can in general occur when gradations containing excesses of certain size fractions are used. It is believed that, strength or resistance to shear failure, in pavement and other aggregate layers that carry loads is increased greatly if the mixture is dense graded.

Several researchers have considered the effect of aggregate gradation on resistance to permanent deformation. They found that both the aggregate gradation and aggregate nominal size affected the rutting depth for pavement section as estimated by the VESYS-3AM software. Mixtures prepared using aggregate gradation passing below the restricted zone (on the Superpave gradation chart) had better resistance to rutting as compared to those made from aggregate with gradation passing through or above the restricted zone. This means that course

gradations are expected to perform better the fine finer gradation, (EL-Basyouny and Mamlouk, 1999). However, as the comparisons were made based on rutting depth predicted by model rather than measured rutting depth, the study is subject to limitations of the model.

Cross et al (1999) concluded that the finer gradation had better resistance to permanent deformation, which apparently was in contradiction with conclusion of EL-Basyouny and Mamlouk in the previous paragraph. They was evaluated two mixtures made from aggregates with different gradations and for the first mixture, they had an S-shaped gradation that stay below the maximum density line and passes below the restricted zone.the second mixture was made from aggregate with finer gradation that stayed above the maximum density line and above the restricted zone.

Thus researchers have come to different conclusions with regard to the effect of aggregate gradation on resistance to rutting of asphalt mixtures. However, most of them seem to agree that aggregate gradation has an influence on the rutting resistance of asphalt mixtures.

2.4.2 Type of Aggregate Gradation Properties

Generally, aggregate size distributions are classified as uniformly graded, well-graded and gap-graded aggregate. Aggregate gradation is typically presented in a graphical form in which the percent of aggregate passing a sieve size is plotted in an arithmetic scale.


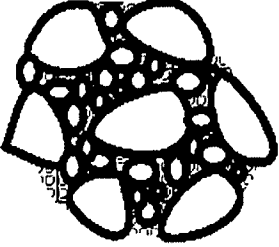
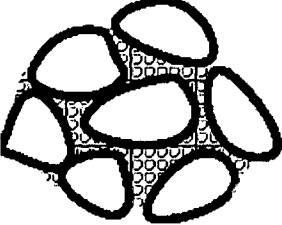
<p>Uniformly Graded Aggregate</p> 	<ul style="list-style-type: none"> • Few points of contact • Poor interlock (shape dependent) • High permeability • Low stability • Difficult to compact
<p>Well Graded Aggregate</p> 	<ul style="list-style-type: none"> • Good interlock • High permeability • High stability • High void content • Difficult to compact
<p>Gap Graded Aggregate</p> 	<ul style="list-style-type: none"> • Only limited sizes • Good interlock • Low permeability • Low stability • Moderate void content • Easy to compact

Figure 2.4: Type of aggregate gradation

2.5 Polyethylene Terephthalate (PET).

Plastic is referring to a substance that is capable to 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