INFLUENCE OF RECYCLED HIGH DENSITY POLYETHYLENE ON THE CONVENTIONAL AND MORPHOLOGY PROPERTIES OF BITUMEN

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ABSTRACT

The aim of this research is to evaluate the effect of recycled High Density Polyethylene (HDPE) pellet in bitumen as an additive in bitumen modification. The concentration of HDPE ranges between 1 to 5% of the weight of a soft (160/220) penetration grade bitumen were used and then compare to intermediate (100/150) penetration grade bitumen. This bitumen modification was prepared by using a high speed mixer at temperatures between 140˚C to 180˚C. The conventional tests such as penetration, softening point and visocosity were conducted to determine the basic characteristics of the HDPE modified and unmodified bitumen. Furthermore, the study on the morphology characteristic of HDPE modified bitumen was evaluated by using fluorescent microscopy to examine the degree of compatibility of the recycled HDPE pellet. The finding indicates that this bitumen modification has the ability to enhance conventional and morphology properties of bitumen. In addition, the plasticity interval and Penetration Index (PI) values of bitumen were also increased. Therefore HDPE modified bitumen can resist the previously mentioned road failures. Finally it could improve the level of performance and the service life of the road. It can be concluded that the application of HDPE modified bitumen gives more advantages compared to the neat bitumen. Having considered the environmental and economical aspects, HDPE modified bitumen is found suitable to be used for road pavements.

KEYWORDS*: modified bitumen, recycled HDPE, morphology.*

1.0 INTRODUCTION

Asphalt mixtures are composite materials commonly used for construction of pavements. They consist of bitumen and aggregate mixed together then laid down in layers and compacted. The bitumen will act as a binding agent to glue aggregate particles into a dense mass and waterproof the mixture. When bonded together, the aggregate will act as a stone framework to impart strength and toughness to the asphalt mixture. The performance of an asphalt mixture depends on the properties of the individual components and their combined reaction in the asphalt mixture (Asphalt Institute, 2001).

Polymers are long chain molecules of high molecular weight made up of smaller molecules that are joined together by chemical bonds (Brent, 2006). Nowadays, polymers are often used in road pavement application as bitumen modifiers. It is proved that the addition of a very small amount of polymer into bitumen can increase the level of performance and the pavement service life (Sengoz and Isikyakar , 2008). As a result, polymer modified bitumen (PMB) increases the resistance of the pavement to pavement defects such as permanent deformation, thermal cracking, fatigue damage and stripping (Yildirim, 2007).

In addition, PMBs are used to improve the temperature susceptibility of bitumen by increasing binder stiffness at high service temperatures and at the same time, decreasing its stiffness at low service temperatures (Airey, 2002). The application areas of PMBs in road construction are airports, motorways and city roads, special surfaces such as drainage asphalt and thin layers, surface dressing for high traffic, slurry seals, bridges and tunnels, intersections and parking areas for trucks, and renovation of concrete roads (Giavarini *et.al*., 1996).

In the road construction industry, polymers can be subdivided into two main categories namely elastomers (rubber) and plastomers (plastics). Plastomers are tough, rigid, three dimensional networks which are resistant to deformation such as polyethylene, polypropylene, ethylene vinyl acetate (EVA) and so on. This polymer can be heated and cooled several times without affecting the properties. Meanwhile, elastomers resist deformation from the applied stress by stretching and recovering their shape quickly when stress is removed. The commonly used elastomers in PMBs are styrene-butadiene-styrene (SBS), styrene-butadiene-rubber (SBR), styrene-isoprene-styrene (SIS) and the like. However these materials are more expensive than plastomers (Freddy *et.al.*, 1996).

According to the Waste and Resources Action Programme (WRAP) survey in 2007, most plastics collected for recycling from the household waste stream are plastic bottles. While there are many polymer types, the majority of bottles are made from either Polyethylene Terephthalate (PET) or High-Density Polyethylene (HDPE) material. They estimated that the ratio is 55-60% PET to 40-45% HDPE (WRAP, 2007).

Some plastic products such as PET soda bottles and HDPE jugs are easy to identify. However some plastics are more difficult to distinguish, especially when they are not easily identified by original shape. In 1988, the Society for the Plastic Industry (SPI) produced is a resin identification coding system to identify the resin type or family to assist both consumers and sorters at collection facilities (Brent, 2006). A number and a recycling symbol have been assigned to each of the major resin types or families. Resin is a polymer that has not yet been formed into its final useful shape. In other word, resin is a solid or liquid that is subsequently shaped into a plastic part. The major resin types and their numbers are given in Table 1.

Table 1 Numbering System for Plastics Recycling

Polymer Name	Recycling Number	Recycling Symbol
Polyethylene Terephthalate	1	PETE or PET
High-Density Polyethylene	2	HDPE
Vinyl or Polyvinyl Chloride	3	V or PVC
Low-Density Polyethylene	4	LDPE
Polypropylene	5	PP
Polystyrene	6	PS
Other	7	OTHER

HDPE generate under low temperature and pressure polymerization conditions. HDPE is used in household applications required greater stiffness or strength. For instance, milk, water, detergent and bleach bottles are HDPE because they are usually made with very thin walls to save material, cost and retain their shape. In addition the trash carts and chemical storage tanks are usually made of HDPE because of its superb chemical resistance. The automotive fuel tanks also are produced from HDPE because its require strength, chemical resistance and low permeability (Brent, 2006).

The influence of HDPE concentration on the rheological properties and microstructure of HDPE modified bitumen has been recorded in Journal Energy and Fuel (Perez-Lepe *et.al*., 2005). The 60/70 penetration grade bitumen was used as base bitumen while HDPE pellet was used as a bitumen modifying agent. This polymer modification concentration ranges from 1 to 5% of the weight of bitumen. The blends of bitumen and HDPE were manufactured at 180°C and rotation speed of 8200 rpm.

In Turkey, the investigation of the waste material containing powdered HDPE in the hot mix asphalt as a bitumen modifier was studied (Hinislioglu and Agar, 2004). Hinislioglu and Agar used HDPE between 4 and 8% of the weight 50/70 penetration grade bitumen and crush limestone to create 19mm continuously graded asphalt mixture. The machine blending was operated at 200rpm and at the same time, Hinisliogiu and Agar applied varies mixing temperature from 145 to 165°C and from 5 to 30 minutes of mixing time to produce HDPE modified bitumen. After obtaining the HDPE modified bitumen, aggregate and HDPE modified bitumen were heated separately between 155 and 165°C. Then all materials mixed together in a mechanical mixer. The asphalt mixture was placed in a Marshall mould and compacted by applying 75 blows on each side of the specimen at 145°C. In Marshall Stability and Flow tests, Hinisliogiu and Agar claimed this modified asphalt mixture was highly resistance to permanent deformation because it has Marshall Quotient (MQ) values higher than conventional mixture. MQ is the ratio of stability to flow and is an indication of stiffness of the mixture in Marshall Mix design method.

The aim of this research is to evaluate the effect of recycled HDPE pellet in bitumen as an additive by determining the conventional and morphology properties of the modified material the concentration of HDPE ranges between 1 to 5% of the weight of a soft (160/220) penetration grade bitumen. Then this PMB compare to a soft and intermediate (100/150) penetration grade bitumen.

2.0 EXPERIMENTAL PROGRAM

A 160/220 penetration grade bitumen provided by Shell Bitumen with penetration value and softening point are 172 and 37˚C, respectively. A palletised HDPE were obtained from LINPAC Packaging, United Kingdom with diameter of 5cm in black colour and were insoluble into water. This material also obtains softening point between 100 and 120°C and density is 0.955g/cm3. Polymer concentration in the modified bitumen was in the range from 1 to 5 percent of weight bitumen.

The recycled HDPE modified bitumen was prepared in a high shear laboratory mixer from Silverson L5M, United Kingdom. This PMB was manufactured at temperature between 140°C and 180°C for 2 hours with as high as 3000 rpm. In one session blending process, the minimum weight of bitumen to produce PMB is 2 kg.

Conventional tests such as penetration, softening point and visocosity were conducted to determine the basic characteristics of the HDPE modified and unmodified bitumen. The study on the morphology characteristic of bitumen has been done using fluorescent microscope to examine the degree of compatibility of the recycled HDPE pellet. A drop of a heated sample was placed between the microscope slides. Samples were observed using a fluorescent microscope.

3.0 RESULT AND DISCUSSION

The effect of penetration value and softening point of bitumen of HDPE modified bitumen can be seen in Figure 1. The decrease in penetration and increase in softening point indicate an increased hardness or stiffness of the HDPE modified bitumen. The penetration value and softening point of 100/150 grade bitumen almost equal to 3% recycled HDPE added in 160/220 grade bitumen. In term of economic value, it show that this recycled HDPE could reduce cost of road construction because 160/220 grade penetration is cheaper than 100/150. Moreover, it gives another alternative material to planner or engineer.

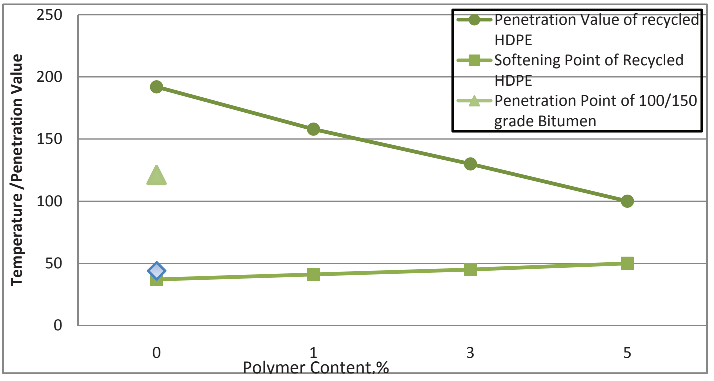

Figure 1 Relationship Between Penetration, Softening Point and Recycled HDPE Content

All bitumens display thermoplastic properties i.e, they become softer wheb heated and harden when cooled. The penetration index (PI) was developed by Preiffer and Doormall to indicate temperature susceptibility of bitumen (Pfeiffer and Doormal, 1936) . The value of PI is range from -3 for highly blown low temperature susceptible to +7 for highly temperature susceptible bitumen. Figure 2 indicates that additional recycled HDPE in 160/220 grade penetration bitumen give an improvement in temperature susceptibility. This graph also represent the PI value of 3% HDPE modified bitumen greater than 100/150 grade penetration bitumen.

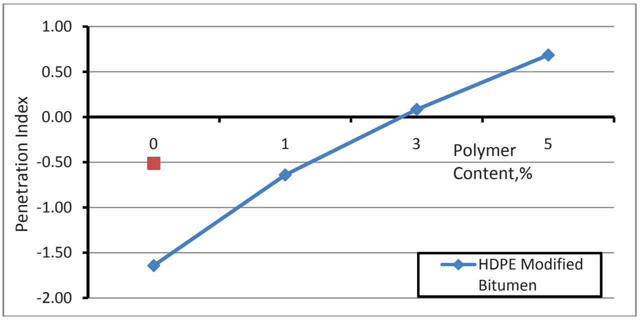

Figure 2 Penetration Index of HDPE Modified Bitumen

Rotational viscosities for 100/150, 160/220 grade bitumen and three HDPE modified bitumen from 100˚C to 180˚C are shown in Figure 3. The results show a consistent increase in viscosity with HDPE modification. Similar plots were also seen for unmodified bitumen 100/150 and 160/220 grade bitumen. As with the penetration and softening point tests the viscosities give a clear indication of the stiffening effect of HDPE modification. Moreover, the modification indices from 120˚C to 180˚C are almost linear within each HDPE modified bitumen group. This is because the EVA copolymer melts at a temperature between 100 and 120˚C and is, therefore, already in its melted state at temperatures of 120˚C and higher. Therefore, high temperature viscosity, as with penetration, only indicates the effect of recycled HDPE polymer modification hardening (stiffening) of the bitumen. Meanwhile viscosity of 100/150 grade bitumen as similar as 1% HDPE modified bitumen at 100˚C and 3% HDPE modified bitumen at 160˚C. This indicates that 1% HDPE modified bitumen more ideal for compacting and mixing process at field due to lesser viscosity at high temperature like 160˚C (Read and Whiteoak, 2003).

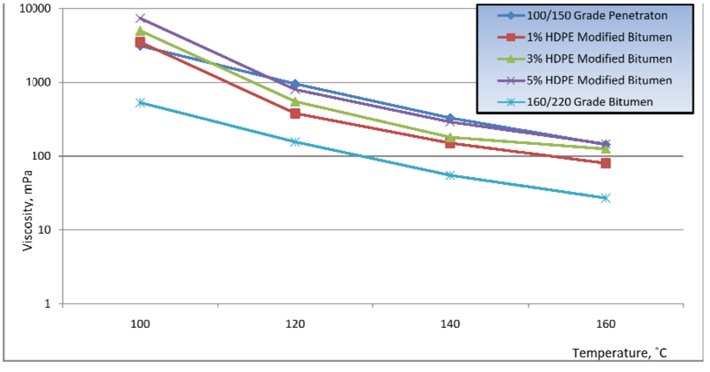

Figure 3 Viscosity of HDPE Modified Bitumen, 100/160 and 160/220 Grade Bitumen

The 100X magnification of fluorescent microscope was used to obtain fluorescent microscopy images of the HDPE modified bitumen. The fluorescent images of 1%,3% and 5% HDPE modified bitumen are shown in Figure 4. The fluorescent images illustrate a change in the morphology of the PMBs as the recycled HDPE content increases. The relative proportion of bitumen to polymer phase has been determined by means of image analysis and shows an increase in the polymer phase from 12% to 20% for 1% HDPE modified bitumen and from 60 to 80% for 5% HDPE modified bitumen.

Figure 4 Dispersion of 1, 3 and 5% Recycled HDPE in Bitumen

4.0 CONCLUSION

The addition of recycled HDPE to bitumen enhances the conventional and morphology properties of the modified binder prepared in high shear laboratory mixer. However, the extent of the effect is dependent on the polymer content. The decrease in penetration, increase in softening point and PI indicate an increased hardness or stiffness of the HDPE modified bitumen. In economic value, it shows that this recycled HDPE could reduce cost of road construction because this recycled material is cheaper than bitumen and easy to obtain this material. Therefore HDPE modified bitumen can resist the previously mentioned road failures. Also, it improves the level of performance and the service life of the road. It can be concluded that the application of recycled HDPE modified bitumen gives more advantages compared to the neat bitumen. Having considered the environmental and economical aspects, HDPE modified bitumen is found suitable to be used for road pavements.

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