



CHARACTERISATION OF RECYCLED POLYETHYLENE TEREPHTHALATE AS PARTIAL FINE AGGREGATE REPLACEMENT PROPERTIES AND BEHAVIOUR OF ASPHALT MIXTURES FOR ROAD PAVEMENTS

Wan Mohd Nazmi Wan Abdul Rahman¹ and Mohammad Affendy Omarin²

¹Faculty of Civil Engineering and Earth Resources Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang, Pahang, Malaysia

²Faculty of Engineering Technology, Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang, Kuantan, Pahang, Malaysia

E-Mail: nazmi@ump.edu.my

ABSTRACT

The primary objective of this study is to evaluate optimum bitumen content and the characteristic of recycled polyethylene terephthalate (PET) as partial fine aggregate replacement in asphalt mixtures for road pavements by determining the rutting, fatigue and stiffness properties. The percentage of recycled PET replace fine aggregate in asphalt mixture start up 25% and bitumen content start from 4 to 6% of weight of asphalt mixture. The recycled plastic substitute aggregate of sieve size aggregate between 3.36 and 1.18 mm content as follow with hot mix asphalt wearing course 14 (AC 14) in Standard Specification of Public Work Department (PWD) of Malaysia. The Indirect Tensile Stiffness Modulus Test (ITSM) was used to determine the optimum bitumen content of modified asphalt mixture and followed by the Repeated Load Axial Test (RLAT), and Indirect Tensile Fatigue Test (ITFT) both at 1800 cycles to investigate the rutting and fatigue properties of PET modified asphalt mixture consist of optimum bitumen content. The result shows the highest value stiffness modulus of 0% PET modified asphalt reach at 5.5% bitumen content. All the PET modified asphalt appears to be capable in resist rutting of road pavement. Meanwhile 5% and 15% PET modified asphalt show more fatigue resistance than unmodified asphalt at 1800 cycles. In conclusion, the 5.5% bitumen content and additional 5% replacement aggregate of recycled PET plastic on asphalt mixture would enhance all engineering properties of asphalt mixture for road pavement

Keywords: recycled polyethylene terephthalat, modified asphalt mixture, rutting, fatigue.

INTRODUCTION

Durable and long lasting pavements are most desirable to improve good riding comfort, safe and low maintenance costs. Over the years, many studies have been conducted to enhance hot-mix asphalt (HMA) mixture design for better performing pavements. In contrast, improving asphalt mixture design alone is insufficient to guarantee a good quality pavement. Accurate and effective characterisation of pavement material is crucial to understand the behaviour or response of these asphalt mixtures under external stimuli of traffic loading as influenced by construction quality and environmental conditions (Juraidah, 2010).

According to the Waste and Resources Action Programme (WRAP) survey, 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).

Meanwhile, most of those recycled plastics come from industrial and commercial sources. Recycled plastics are mainly used in the form of street furniture, insulation, ducts, pipes etc. However it is not commonly used in pavement (WRAP, 2003; Huang *et al.*, 2007). Waste recycling is especially important in dealing with certain waste materials like plastic bottles because their longer

biodegradation period i.e. very harmful to the environment and ecosystem balance (Esmail *et al.*, 2012). Thus, to decrease the negative impact of these plastics waste materials on environment and nature, it seems to be logical to propose ways to re-use waste materials of such kind in engineering and industrial construction and production projects such as road pavement (Fontes *et al.*, 2010; Ismail *et al.*, 2008). Plastic consumption in Malaysia has grown in recent years. These situation, increasing plastic consumption as well as consumption of other waste materials, have led to pressure on landfill sites to accommodate this waste.

The usage of waste PET granules pellet was conducted as a partial fine aggregate replacement in asphalt mixture. The size of this material is 3mm. The asphalt mixture was produced from 60/70 penetration grade bitumen and 12.5mm aggregate grading. The aggregate and bitumen were mixed between 140 and 180 °C and then was compacted using Marshall Hammer with 50 blows on each side. By using Marshall Stability and Flow test, the result shows that the aggregate replacement of 20% fine aggregate (2.36-4.75mm) by volume with PET granulates (5% total weight of the asphalt mixture) was the effective use to get the highest Marshall Quotient with the lowest flow and the highest of stability (Hassani *et al.*, 2005).

The experimental research on the application of waste plastic bottles PET as additive has been done in asphalt mixture. The 80/100 penetration grade bitumen,



crushed granite, Portland cement (as mineral filler) and the waste PET were used in their project. The percentage of the added PET in this research was from 0 to 10% by weight of bitumen. The result shows that the stiffness modulus of PET modified asphalts was higher than unmodified asphalt as high as 16% by using 6% PET. The wheel tracking test results illustrate that the PET modified asphalt has much higher rutting or permanent deformation resistance compare to unmodified asphalt. The lowest rut depth occurred at 4% PET modified asphalt which reduced the rut depth by 29% compared to the unmodified asphalt. The appreciate amount of PET was evaluated to be from 4% to 6% by weight of optimum bitumen content (Esmaciel *et al.*, 2012).

The primary objective of this study is to evaluate optimum bitumen content and the characteristic of recycled polyethylene terephthalate (PET) as partial fine aggregate replacement in asphalt mixtures for road pavements by determining the rutting, fatigue and stiffness properties.

METHODOLOGY

A 80/100 penetration grade bitumen was used in this study due to this grade that is the most commonly used in road pavement in Malaysia. The palletised recycled PET was obtained from supplier with diameter around 2cm, density between 1300 kgm^{-3} and 1500 kgm^{-3} as well as melting point from 200°C to 248°C . The percentage of recycled PET replace fine aggregate in asphalt mixture start up with 25% and bitumen content starts from 4 to 6% of weight of asphalt mixture. The recycled plastic substitute aggregate of sieve size aggregate between 3.36 and 1.18 mm content as follow with hot mix asphalt wearing course 14 (AC 14) in Standard Specification of Public Work Department (PWD) of Malaysia.

The PET modified asphalt mixture consists of recycled PET plastic, bitumen, aggregate and mineral filler. All these ingredients were mixed and compacted at temperature 140°C and 90°C , respectively. The PET modified asphalt mixture was compacted 75 blows each surface because the application of this sample would be complies with high volume traffic.

The Indirect Tensile Stiffness Modulus Test (ITS) was used to determine the optimum bitumen content of modified asphalt mixture and followed by the Repeated Load Axial Test (RLAT), and Indirect Tensile Fatigue Test (ITFT) both at 1800 cycles to investigate the rutting and fatigue properties of PET modified asphalt mixture consist of optimum bitumen content.

RESULT AND DISCUSSIONS

The PET modified asphalts were developed by using the AC 14 aggregate recipe with bitumen content from 4% to 6% as follow PWD requirement (PWD, 2008). Figure-1 shows the comparison between stiffness modulus of unmodified and PET modified asphalt with bitumen

content from 4% to 6%. As far as the data was concerned, the additional replacement of recycled PET as fine aggregate in asphalt mixture could decrease the value of stiffness modulus of asphalt mixture. For example, the stiffness modulus value of bitumen content 4.5% for 0% and 25% PET modified asphalt mixture were 2600MPa and 1600MPa, respectively. In bitumen content aspect, all PET modified asphalt mixture obtain more stiffness modulus at 5.5% bitumen content of weight of asphalt mixture. The result also shows the highest value stiffness modulus of 0% PET modified asphalt mixture reached at 5.5% bitumen content. This graph shows the additional replacement recycled PET as partial fine aggregate in asphalt mixture could not help improve the stiffness of modified asphalt mixture. However this result is same with another study that have been done about the stiffness of recycled plastic like low density polyethylene (LDPE) and high density polyethylene (HDPE) as aggregate replacement on asphalt mixture (Nazmi *et al.*, 2014 and Zoorob *et al.*, 2000).

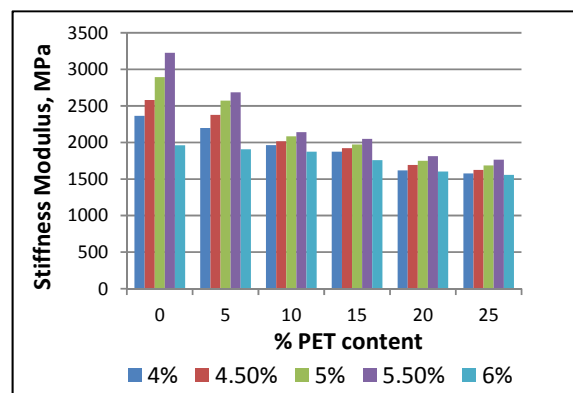


Figure-1. Stiffness modulus of PET modified asphalt mixture.

Figure-2 reveals the comparison rutting between unmodified and PET modified asphalt mixture in RLAT at temperature of 30°C . The result indicates the same trend curve with dramatically growth in the first 100 load application cycle and then slowly steady increase rutting from 100 to 1800 load application cycle tests sample. The rutting of unmodified asphalt mixture at 1800 cycle was 0.48mm. At the 1800 cycle, all PET modified asphalt indicate lower rutting than unmodified asphalt mixture. Thus all PET modified asphalt appears to be capable in resist rutting of road pavement. The permanent deformation via axial strain of PET modified asphalt mixture has been experimented at UMP (Nazmi and Fauzi, 2012). They found all PET modified asphalt could resist permanent deformation especially on 20% PET modified asphalt mixture.

The graph of fatigue life of PET modified asphalt mixture is shown in Figure-3. The graph result is plotted as initial strain against number of cycle to failure (N_f) on a log-log graph (Read, 1996). This graph produces the trend



line relationship between initial tensile strain (ϵ_{ini}) and N_f in order to generate the fatigue life of PET asphalt mixture. For example, in unmodified asphalt case, the equation of the fatigue life trend line is $y=3766x^{-0.359}$ and R^2 is 0.869. The slope of the fatigue trend line is -0.359. The negative value shows that the ϵ_{ini} decrease as N_f increase. The greater slope or steeper fatigue trend line reveals that the sample of asphalt performance is more sensitive to the strain (Sunarjono, 2008).

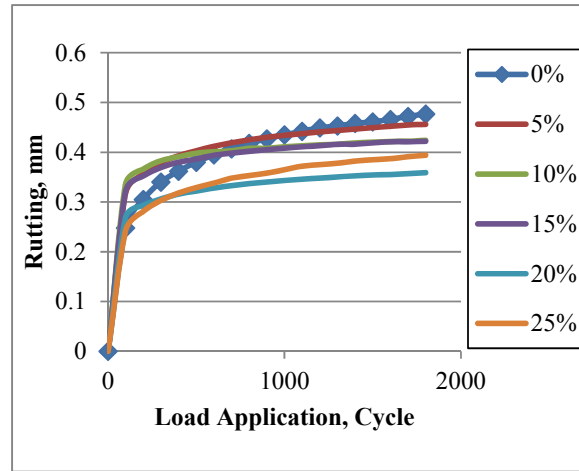


Figure-2. Rutting of PET modified asphalt mixture.

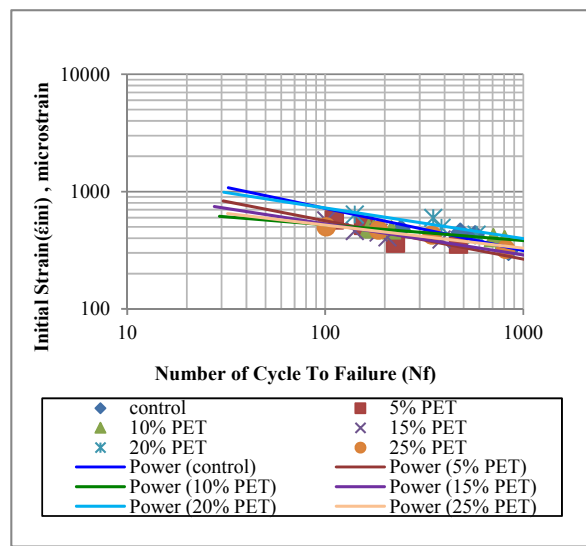


Figure-3. Fatigue life of PET modified asphalt mixture.

The summary and comparison fatigue life of PET modified asphalt mixture is shown in Table-1. This Table also shows that the prediction of strain of unmodified and PET modified asphalt mixture at 1800 cycle. The strain of unmodified asphalt mixture at 1800 cycle is 273 microstrain. The 5% and 15% PET modified asphalt mixture implicit more resistant to fatigue than unmodified

asphalt at 1800 cycle as the strain were 219 and 246 microstrain, respectively. In contrast, the strain of 10% and 20% PET modified asphalt mixture were above than 300 microstrain. Therefore 5% and 15% PET modified asphalt show more fatigue resistance than unmodified asphalt.

Table-1. Fatigue life of PET modified asphalt mixture.

Asphalt type	Equation	Strain at 1800 cycle($\mu\epsilon$)
Unmodified	$\epsilon_{ini} = 3766.(N_f)^{-0.35}$	273.234
5% PET	$\epsilon_{ini} = 2545.8(N_f)^{-0.327}$	219.457
10% PET	$\epsilon_{ini} = 970.53(N_f)^{-0.135}$	352.815
15% PET	$\epsilon_{ini} = 1797.5(N_f)^{-0.265}$	246.616
20% PET	$\epsilon_{ini} = 2412.6(N_f)^{-0.261}$	341.082
25% PET	$\epsilon_{ini} = 1284.1(N_f)^{-0.197}$	293.299

CONCLUSIONS

The optimum bitumen content for PET modified asphalt mixture is 5.5% of weight of asphalt mixture and the maximum stiffness modulus is 3300MPa at unmodified asphalt mixture. All PET modified asphalt mixture resist to rutting at 1800 cycle especially 20% PET modified asphalt mixture. In addition, 5% and 15% PET modified asphalt mixture are resist to fatigue as the strain at 1800 cycle are lower than unmodified asphalt mixture. In conclusion, the 5.5% bitumen content and additional 5% replacement aggregate of recycled PET plastic on asphalt mixture would enhance all engineering properties asphalt mixture for road pavement

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