INVESTIGATION OF RECYCLED MICRONIZED POLYETHYLENE TEREPHTHALATE (MPET) AS A FILLER IN ASPHALT PAVEMENT

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ABSTRACT

Sustainability development is one of the issues that had been a debate for many years as it consist of the responsibility of many people including engineers specifically at the highway construction industry. Nowadays, the plastic pollution such as Polyethylene Terephthalate (PET) is one of the most critical issues that need to be solved. Many alternative ways had been done including reducing the use of the plastic. They are several studies that had been done to recycle these plastics into production of highway materials including rubber, plastic bag and even plastic bottle. For this study, the plastic bottle was recycled as a source for Polyethylene Terephthalate (PET) as filler in asphalt pavement. For this research, the PET was micronized mechanically by heating and then crush until it passed the 0.075 mm sieved. The Micronized PET were added into asphalt mixture as dry mix at 0%, 4%, 8% and 12% by weight of the filler. The asphalt mixture containing the micronized PET were evaluated for its engineering properties and adhesion properties. Based on the findings, the most optimum temperature on heating the PET would be 190°C where the particles managed to passed the 0.075 mm to be used as fillers in the asphalt mixture. Other than that, the results also show the utilization of MPET affects the engineering properties where the VTM decreases while the Gmb and VFB increases by increasing the MPET content. Furthermore, the strength properties also enhanced from the fact that the values of the resilience modulus and indirect tensile strength increases. Finally, the adhesion testing through water boiling shows that the modified asphalt containing 12% of MPET had less stripped bitumen rather than the other samples where it shows that the adhesion properties of the modified asphalt increase by increasing the amount of MPET usage. It can be concluded that the most optimum percentage of MPET content would be 12% by weight of fillers where we can utilize more of the waste material without compromising the performance of the asphalt mixture. Based on the findings, micronized PET had indicated the potential to be used as a filler in asphalt pavement.

ABSTRAK

PENYIASATAN POLIETILENA TEREPHTHALATE MIKRONISASI KITAR SEMULA SEBAGAI PENGISI DALAM TURAPAN ASFALT

Pembangunan kelestarian merupakan salah satu isu yang menjadi perdebatan selama bertahun-tahun kerana ia terdiri daripada tanggungjawab ramai orang termasuk jurutera khususnya di industri pembinaan lebuh raya. Pada masa kini, pencemaran plastik seperti Polyethylene Terephthalate (PET) adalah antara isu paling kritikal yang perlu diselesaikan. Banyak cara alternatif telah dilakukan termasuk mengurangkan penggunaan plastik. Ia adalah beberapa kajian yang telah dilakukan untuk mengitar semula plastik-plastik ini kepada penghasilan bahan-bahan lebuh raya termasuk getah, beg plastik dan juga botol plastik. Untuk kajian ini, botol plastik telah dikitar semula sebagai sumber Polyethylene Terephthalate (PET) sebagai pengisi dalam turapan asfalt. Untuk penyelidikan ini, PET telah dimikronisasikan secara mekanikal dengan memanaskan dan kemudian dihancurkan sehingga melepasi ayak 0.075 mm. PET Micronized telah ditambah ke dalam campuran asfalt sebagai campuran kering pada 0%, 4%, 8% dan 12% mengikut berat pengisi. Campuran asfalt yang mengandungi PET mikronisasi telah dinilai untuk sifat kejuruteraan dan sifat lekatannya. Berdasarkan penemuan, suhu paling optimum untuk memanaskan PET ialah 190°C di mana zarah berjaya melepasi 0.075 mm untuk digunakan sebagai pengisi dalam campuran asfalt. Selain itu, keputusan juga menunjukkan penggunaan MPET mempengaruhi sifat kejuruteraan di mana VTM berkurangan manakala Gmb dan VFB meningkat dengan meningkatkan kandungan MPET. Tambahan pula, sifat kekuatan juga dipertingkatkan daripada fakta bahawa nilai modulus daya tahan dan kekuatan tegangan tidak langsung meningkat. Akhir sekali, ujian lekatan melalui pendidihan air menunjukkan bahawa asfalt diubah suai yang mengandungi 12% MPET mempunyai bitumen terlucut yang kurang berbanding sampel lain di mana ia menunjukkan sifat lekatan asfalt diubah suai meningkat dengan meningkatkan jumlah penggunaan MPET. Dapat disimpulkan bahawa peratusan paling optimum kandungan MPET ialah 12% mengikut berat pengisi di mana kita boleh menggunakan lebih banyak bahan buangan tanpa menjejaskan prestasi campuran asfalt. Berdasarkan penemuan, PET mikronisasi telah menunjukkan potensi untuk digunakan sebagai pengisi dalam turapan asfalt.

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LIST OF SYMBOLS

Σ	-	Summation
%	-	Percentage
°C	-	Degree Celcius
G*	-	Complex Unit
sin	-	Sinus
δ	-	Phase Angle
Mpa	-	Mpa
cm	-	Centimetre

LIST OF ABBREVIATIONS

MSW	-	Municipal Solid waste
PET	-	Polyethylene Terephthalate
HDPE	-	High Density Polyethylene
LDPE	-	Low Density Polyethylene
PP	-	Polypropylene
MPET	-	Micronized Polyethylene Terephthalate
SSA	-	Specific Surface Area
UMS	-	University Malaysia Sabah
EVA	-	Ethylene Vinyl Acetane
ASTM	-	American Society for Testing and Materials
MW	-	Molecular weight
ITS	-	Indirect Tensile Strength
HMA	-	Hot Mix Asphalt
HL	-	Hydrated Lime
VTM	-	Voids in Total Mixture
VMA	-	Voids in Mineral Aggregate
VFB	-	Voids Filled Bitumen
FHWA	-	Federal Highway Administration
PVC	-	Polyvinyl Chloride
WCO	-	Waste Cooking Oil
PG	-	Performance Grade
OBC	-	Optimum Bitumen Content
SMA	-	Stone Mastic Asphalt

ASTM	-	American Society for Testing and Materials
AASHTO	-	American Association of State Highway and Transportation Materials

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In the recent years, the optimization of waste materials in pavement construction has gained many attentions towards consuming the waste materials without compromising the pavement qualities (Ma and Huang, 2020; Ma et al., 2020). Plastics have become a widespread commodity that involved in many aspects of human life. The production of plastics shows a rapid growth from 2 million metric tons on the year 1950 up to 322 million metric tons in 2015 timeframe (Geyer et al., 2017). According to study by Abd El-Rahman et al., (2018), the cumulative amount of plastic production reached 8.3 billion metric tons in 2017. As for that, due to the lack of awareness from recycling or reusing the, plastics waste, it had rapidly become a major concern of municipal solid waste (MSW).

The feasibility engorging waste material used in the highways construction industry is playing a leading role worldwide as a green investment movement (Ahmad et al., 2018; Zair et al., 2021). In Malaysia, approximately 0.80 kg/capita to 1.9 kg/capita of the municipal solid waste is generated daily, and this is expected to increase every year which make plastic waste as the third largest waste after putrescible waste and paper (Ecosystem et al., 2011). As for that, the study regarding the technologies of incorporating plastics in asphalt pavement is very crucial since it

was found that microplastics between 100 and 100 µm existed from leachate samples collected from landfills (He et al. 2019).

The most commonly recycled plastics are Polyethylene (PET), High-Density polyethylene (HDPE), Low-Density polyethylene (LDPE) and polypropylene (PP), which accounts for 85% of reprocessed plastic (Chin and Damen 2019). However, most of the plastic waste is drinking bottles which are made from PET. Based on the study in Malaysia, it was found that other than High Density and Polyethylene (HDPE) and Low-Density Polyethylene (LDPE), PET is made up of 13% of total plastic being produced. The high statistic of PET used have attracted many researchers to develop a guideline of studying the properties of asphalt pavement with PET as the filler. Accurate and effective characterization of pavement material is crucial to understand the behavior or response of the asphalt pavement under external stimuli of traffic loading as influenced by construction quality and environmental conditions.

Based on the statement that we have known, asphalt pavement is characterized with numerous of failures represented by the low temperature cracking, fatigue cracking and rutting (permanent deformation) at high temperature which can cause the quality of roads to decrease. As a result, any increase in the useful life of road pavements will undoubtedly have significant financial benefits. The attempts to modify asphalt are made to increase the performance of asphalt pavements while extending their useful life.

According to Wang et al., (2017), particles larger than the thickness of the asphalt film behave as mineral aggregate and hence contribute to the contact points between individual aggregate particles. As for that, this study will focus on the technique of using micronized PET (MPET) as a filler of asphalt components by analyzing its parameters related to its mechanical and chemical properties. The method of recycling the PET into micronized size particles would be assess to identify the effect to the optimum binder content and its relationship towards the performance of the asphalt and the MPET capability to blend in with the asphalt components.

1.2 Problem Statement

In Malaysia, the waste management systems are unable to handle the amount of plastic trash produced, similar to the rest of developing nations in Southeast Asia (Kaza et al., 2018). According to a study, household burning and landfill disposal are the primary methods of dealing with plastic trash in the nation (Chen et al., 2021). However, current landfills are nearly at capacity because of the population's rapid growth and its effects on consumption patterns. Land scarcity and potential environmental effects limit the ability to find places for future waste sites (Chen et al., 2021). Regarding that, it would be a huge benefit to have the alternative of utilizing this waste into construction without having to compromise its existing performance.

Despite that, they are few studies related to the use of MPET as a filler to the design of asphalt mixture. Rheological, mechanical, the physical and chemical properties of mineral fillers are also strongly involved in the determination of pavement performances of asphalt mixture, including rutting, fatigue cracking, low-temperature cracking and stripping or moisture damage. However, the main problem is that they are lack of research regarding this statement especially in Malaysia. According to recent studies, it was found that the use of micronized PET able to improve the mechanical properties due to its ability to blend in with the other compounds of the mixture. As for that, the study regarding the use of MPET as a filler in asphalt where it is responsible for the bonding of aggregates and filling voids for asphalt mixtures, which would exert great influence on the pavement performance of asphalt mixtures can be utilized in asphalt mixture. Despite that, certain of the properties are still on debating due to differences in their results which may come from different variables that need more investigation.

Other than that, they are a lot of researchers that attracted to the study to the mechanism of PET in various particle sizes. As for that, the study on the MPET as the filler regarding the interfacial interaction behavior as fillers is one of the options to utilized the plastic waste. Therefore, the investigation of the optimization of MPET as the filler properties which related to the engineering and adhesion properties are conducted.

1.3 Objectives of Study

The study aims to investigate the effects of MPET on modified asphalt which as a filler to improve performance of the asphalt. To achieve the aim, the objectives as follows are outlined:

1. To identify micronization approach of Polyethylene Terephthalate (PET).
2. To evaluate engineering properties by incorporating different percentages of Micronized Polyethylene Terephthalate (MPET) as fillers in Hot Mix Asphalt (AC14).
3. To investigate the adhesion properties of modified asphalt.

1.4 Scope of Study

In this study, the PET was obtained from plastic bottle. The bottle cap and its label were removed, then prepared and crushed into small pieces that had been specified for micronized PET in laboratory of University Malaysia Sabah (UMS). Besides that, the laboratory analysis was done in the lab to get series of data regarding the volumetric properties, mechanical properties and the adhesion properties outcome which was also to analyze their compatibility of MPET blending with the aggregate.

For the scope of study for this study, the percentage of MPET that was used was 0%, 4%, 8% and 12%. Study by Ahmed et al., (2016) shows that filler can act as fillers for voids to prevent water seepage from entering the matrix of the asphalt. This will in turn reduce the air voids content in the asphalt while also reduce the moisture damage due to water seeping into the cracks which in turn increase its adhesion properties.

1.5 Significance of Study

Due to the limit of the study regarding the effects of micronized PET regarding its volumetric properties and adhesion on asphalt pavement, this study will focus on the investigation of the optimum MPET content in regards of its performance based on