

Evaluation of the Mechanical Properties of Asphalt Mixture Modified with RPET

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Abstract The major objective of this study is to evaluate the influence of Rynite Polyethylene terephthalate (RPET) particles on the mechanical properties of hot mix asphalt by conducting several tests such as; resilient modulus, dynamic creep and wheel tracking test. Various RPET contents namely; 3, 5 and 7% by weight of bitumen were added to asphalt mixture using wet method. From resilient modulus test, it was found that the stiffness of modified mixtures with RPET increased compared with unmodified asphalt mixture. The improvement of stiffness for intermediate and high temperatures was between 68 % for 3% of PET, while 3.88% for 7% PET respectively. The results of dynamic creep have shown a better improvement to rutting, the 3% of RPET showed the best resistance to permanent deformation compared to control sample. The results of wheel tracking test proved that the modification of asphalt mixture with RPET improved significantly the resist to permanent deformation (rutting). The addition of RPET has good performance in hot mix asphalt.

Keywords Hot Mix Asphalt, Marshall Mix Design, Rynite PET, Resilient Modulus, Wheel Tracking, Creep Test

1. Introduction

Through the past decades by growing the demand of using a large amount of vehicles on roads, it could lead to huge damages which in various situations happened even prior service life of pavement [1]. Based on past studies, improvement of using polymer to asphalt mixture is the goal of designers and road engineers [2]. As explained by [3], the road pavement is exposed to external loads by heavy traffic and thermal loading induced by thermal modifications. Recently, the demand for using waste plastic material has significantly increased because of the natural resources [4]. During the recent years, the benefit of using a waste plastic material as modifier additives with asphalt blended may have multiple environmental and economic advantages [5]. Based on the idea of Abreu, L.P [6], the recycling of waste materials are increasing and

need to be permanently enhanced. [7], pointed out that the behavior of waste plastic is a threat and became a problem globally. More importantly, the utilized of waste plastic bags in bitumen mixture showed an improvement the properties of blend with addition to resolve the disposal problems [8]. The previous results showed that adding PET to asphalt mixture could raise the resisting against permanent deformation and rutting [9]. Moghaddam, T.B [10], showed that the stiffness of asphalt mixture is a primary designing parameter of flexible pavement; also, the stiffness value is very liable to the loading and environmental situations. The quantity and sort of waste material are increasing at massive rate [11].

2. Materials

Different materials were used to prepare the hot mix asphalt mixture, including aggregate, asphalt binder and Rynite PET 530-NC10. The technical properties of these materials will be presented below. For this experiment, asphalt binder 80/100 PEN was used for the mix design. Based on the previous studies conducted in Highway and Transportation Laboratory in Malaysia, the specific gravity of bitumen is taken as 1.03.

2.1. Additive

Rynite® FR530 NC010 is a 30% glass reinforced, flame retardant, modified polyethylene terephthalate resin approved by UL as UL94V-0 @ 0.35mm. As proved by previous studies, outcomes were acquired by single size polyethylene terephthalate particles among the ranges of 0.425–1.18 mm [12]. Therefore, PET particles were used as an additive in hot mix asphalt mixture. In order to collect Rynite polyethylene terephthalate material, firstly, PET was crushed by a crushing machine, and then was sieved to obtain desirable gradation levels in 0.075µm. Table 1 shows the mechanical properties of Rynite PET 530-NC10, which was obtained from previous study. The purpose of adding PET to asphalt is to increase the stiffness of asphalt mixture, and has a good performance with the mechanical properties of asphalt mixture.

Table 1. Mechanical properties of Rynite® FR530 NC010 of PET

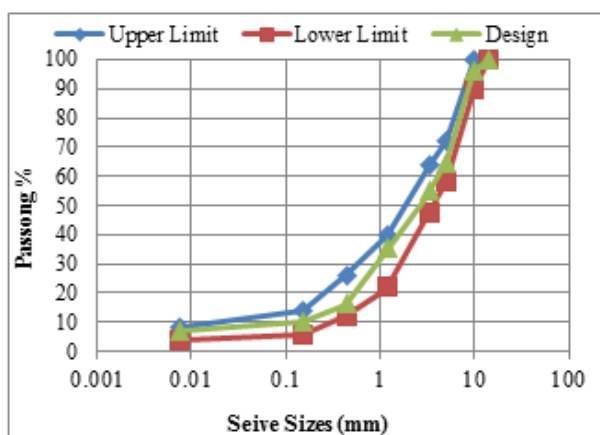
Property	Test Method	Units	Value
Stress at Break	ISO 527	MPa (kpsi)	135 (19.6)
Tensile Strength	ASTM D 638	MPa (kpsi)	-40°C (-40°F)
Strain at Break	ISO 527	%	2
Tensile Modulus	ISO 527	MPa (kpsi)	11500 (1670)
Flexural Modulus	ASTM D 790	MPa (kpsi)	11000 (1600)

Table 2. The aggregate gradation used to prepare hot mix asphalt mixes.

Sieve Size	Percent Passing (%)			Specifications (%)
	Upper Limit	Lower Limit	Design Gradation (%)	
25mm	100	100	100	100
19 mm	85	97	90	90-100
9.5mm	62	75	68	56-80
4.75 mm	42	62	53	35-65
2.36 mm	28	45	37	23-49
0.3 mm	8	16.7	12	5-19
0.075 mm	4	7	5	2-8

2.2. Aggregate

Aggregates used in this present research were obtained from the Batu Pahat Quarry. The gradation of mix design for aggregates is shown in Table 2. Moreover, Fig 1 shows the gradation curve of aggregate mix design.

**Figure 1.** Gradation of Marshall Mix Design.

2.3. Sample Preparation

According to this study, the wet method was applied as one of two process methods of asphalt mixture. In this method, the wet process was blended with the asphalt binder. Thus, bitumen was prepared using a high shear mixer, and the asphalt binder was modified with Rynite PET chips in various percentages, namely (0%, 3%, 5% and 7%) by weight of bitumen. During the process of blending, the Rynite PET was sparse and homogeneous during the process of mixture design; binder was mixed

with speed of the shear rate 3000 rpm for an hour with desirable temperature at 150°C. Then the accumulative weight of aggregate was heated to 165°C for 2 h. The accumulative weight of aggregate for each specimen was 1200 g, after that, the sample was compacted with 50 blows from the upper and lower sides of the samples. Therefore, in order to conduct the optimum binder content, three specimens were prepared for each bitumen contents which ranged between 5-7% by total of weight at 0.5% increase, with additive in different ratios of PET. After finishing the sample preparation, the volumetric properties of the samples were obtained. The value of optimum bitumen content was computed at this stage, it was calculating by volumetric properties, such as, Voids Aggregate (VA), Voids Mineral Aggregate (VMA) and Voids Filled Aggregate (VFA).

3. Experimental Designs

According to the tests of this research, the performance mechanical tests of HMA mixture, such as, indirect tensile resilient modulus, dynamic creep and wheel tracking tests, the experiments were achieved on the OBC viable to all sorts of asphalt mixture.

3.1. Resilient Tensile Modulus Test (MR)

Resilient modulus test is considered as an important input for computation of flexible pavement responses under traffic loading [13]. Moreover, the resilient modulus has not been used much to present the hot mix asphalt stiffness [14]. As explained by ASTM D 4123, the test was executed at different temperatures namely, 25°C and 40°C.

This test was applied to assess the tensile characteristics of asphalt. All the specimens of the indirect tensile resilient modulus test were determined by placing the samples in a temperature of 25 °C and get them to the specified test temperatures at least 24 h. The pulse repetitions used in this study were at 1000ms. The test was carrying out with Universal Testing Machine.

For an applied dynamic load of P in which the resulting horizontal dynamic deformations have been measured, the total Mr value is calculated from equation [15]

$$M_r = \frac{p(\mu + 0.27)}{t\pi h}$$

Where P: maximum dynamic load, N; m: Poisson's ratio (assumed 0.35); t: sample length, mm; TH: total horizontal recoverable deformation, mm.

3.2. Dynamic Creep Test

The test was performed to assess the permanent deformation of mixtures. The test was carried out by applying a static load to an asphalt mix sample, and the result of rutting was observed during the time [16]. In this study, the sample diameter was 100 mm, while loading stress of 100 kPa was applied on the specimens, and the loading cycles applied were 3600 cycles (for approximately 1 h), with temperature of 40°C. When a load is utilized to the surface of asphalt pavement, it deforms though a plurality of recovers of deformation after the load is removed [17].

3.3. Wheel Tracking Test

Wheel tracking was used to evaluate the resist of asphalt mixtures against rutting at high temperatures and under loading. Wheel tracking was conducted on the Cylindrical kernels taken from the asphalt road [18]. Moreover, rutting test with the exchanging movement of loaded wheel on asphalt samples measure the possibility of asphalt pavement rutting. The performance of this test was evaluated the rut depth formed in the specimen with the moving of device's wheel at specified time. Desired rut-gauges should have enough precision at least 0.1mm. The higher value of rut depth determines by wheel track apparatus is 20 mm and thereafter the machine turns off. Wheel tracking test was carried out accordance to British Standard BS 598: Part 110 [19]. The test was processed at temperatures of 45°C.

4. Results and Discussion

4.1. Indirect Tensile Modulus

Resilient modulus is the most general test used to measure stress–strain to assess and evaluate the elasticity

properties of the asphalt mixture representing an applied stress ratio to the recoverable strain [20].

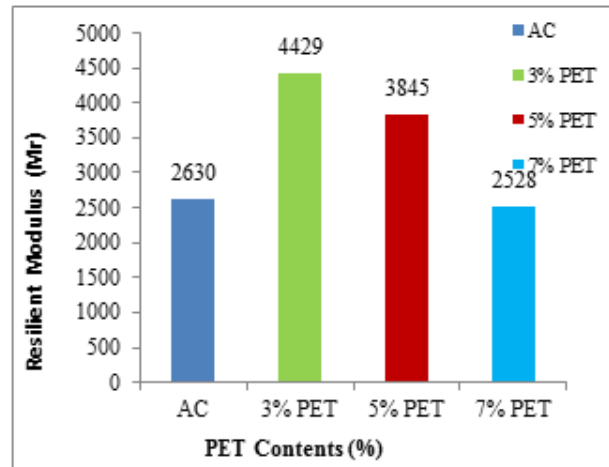


Figure 2. Resilient Modulus Test at 25°C

As presented in Fig. 2, the resilient modulus values indicated that, MR increased slightly with 1000ms of pulse repetition. All the MR values of mixtures containing Rynite PET were generally greater than the conventional mix especially at 3%, which given less susceptibility to fatigue, with value of 4429MPa. This finding showed that PET would enhance resist to fatigue deformation at intermediate temperatures. On the other hand, Fig 3 outlines the result for MR at temperature 40°C. Therefore, it could be concluded that the addition of 3% Rynite PET gave higher resilient modulus value with 1323MPa compared with the control mixture.

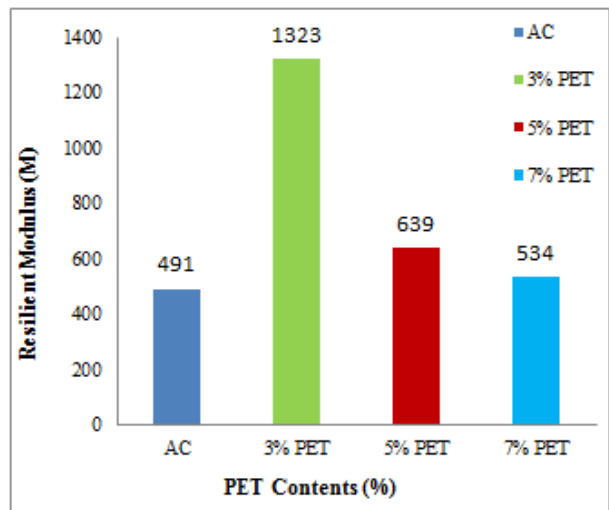


Figure 3. Resilient Modulus Test 40°C

4.2. Dynamic Creep

Rutting is one of the most distress pavements, and it caused a permanent problem in asphalt mixtures, mainly in countries with high temperatures [21]. In this test, a

repeated pulsed axial stress is applied to specimen mixture while the ensuing axial deformation is recorded using Linear Variable Displacement Transducers (LVDTs). The relationship between load cycles and permanent deformation was obtained by plotting data of the dynamic creep test as displayed in figure 4. According to the results, as presented in Fig 4, the addition of 3% Rynite PET showed the lowest value compared to control sample, this led to good and improvement results in terms of dynamic creep behavior.

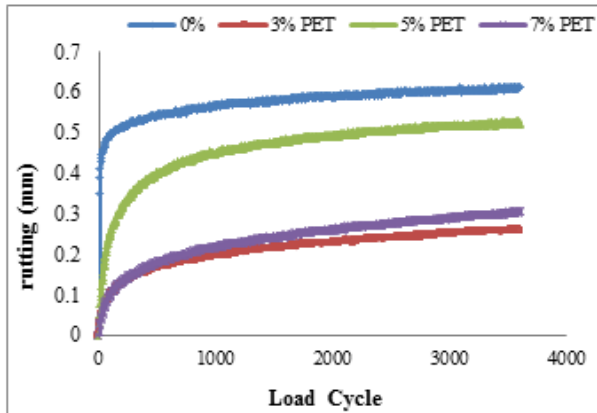


Figure 4. Relationships between Dynamic Creep Test and Load Cycles

4.3. Wheel-Tracking

In order to check the rutting of asphalt mixtures, test was conducted by wheel tracking, which includes immediate connect between the loaded wheel and the rectangular test samples [22]. The test was conducted at temperature of 45°C. The influence of using Rynite PET on rutting resistance for mixtures is displayed in Fig. 5. The results revealed that mixes containing Rynite PET have good rutting resist compared to the conventional mixture. Moreover, the rut depth for asphalt mixtures with 0%, 3%, 5% and 7% Rynite PET content was 1.76 mm, 1.44 mm, 1.54 mm and 1.65mm, respectively, which indicate that the minimum rut depth obtained for the mix with 3% Rynite PET.

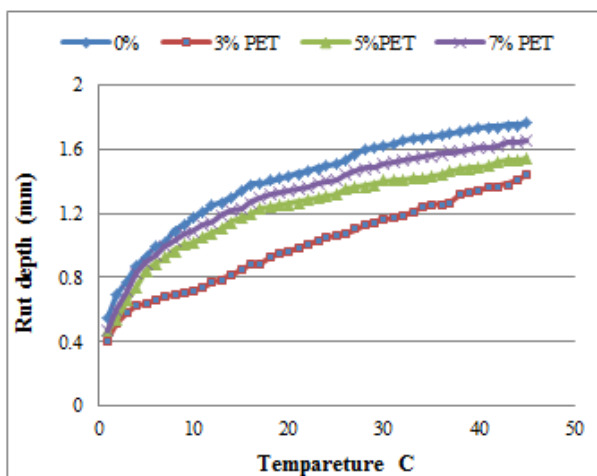


Figure 5. Wheel Tracking Test at 45°C

5. Conclusions

Based on the limited laboratory work of this study, the following conclusion could be drawn below:

The resilient modulus of the mixtures prepared using the modified Rynite PET bitumen was higher than that of the control mixture. Stiffness significantly increased at 25 °C but decreased at 40 °C. This research demonstrated that Rynite PET can decrease the susceptibility to permanent deformation (rutting).

The dynamic creep test was also performed at 40 °C and at different stress levels. The rutting properties of the Rynite PET -modified asphalt were evidently improved compared to control mixture; among the mixtures, 3% Rynite PET showed the most efficient performance in terms of good resistance against permanent deformation.

The results of wheel tracking test showed that 3% Rynite PET of asphalt mixture has better performance and reduce for permanent deformation compared to the control specimens.

Acknowledgements

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