

Investigation of Using Plastic Waste in Asphalt Concrete Mixture as Binder Modifier

Abdul Aziz, M. A.¹, Shamshuddin, M. K.^{1*}

¹Faculty of Civil Engineering and Built Environment,
University Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: <https://doi.org/10.30880/rtcebe.2022.03.01.049>
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: There is a detrimental environmental effect of plastic waste products. The reuse of plastic waste will enhance the properties in engineering construction projects such as road paving bitumen and mixtures of asphalt. In order to decrease harmful of plastic waste to the environment, it have been reused in asphalt concrete mixture as binder modifier. The purpose of this study is to investigate the suitability of using plastic waste in asphalt concrete mixture and to evaluate the durability of asphalt mixture with plastic waste. The plastic waste used in this study was in the form of sheets about 3 mm length and width from PET plastic mineral bottles and the proportion used for this study about 0.2, 0.4 and 0.6% of percentage plastic waste. Method that had been used in this study was indirect tensile strength test (ITS) with Marshall procedure to conduct the study. The result from the performed test showed that plastic waste also suitable as binder modifier in certain percentage such as less than 0.2%. This is because of more percent of plastic was added, it will reduce the durability of the asphalt concrete due to lose the original characteristics of asphalt concrete mixture but it still relevant to use as binder modifier in order to create potential to reduce the pollution. Utilization of plastic waste was satisfying for asphalt concrete performance. For the recommendation, the plastic waste to be used as a modifier in asphalt concrete must not exceed 0.2 percent as it will reduce the durability of asphalt concrete mixture. Performing another more tests in detail using same percentage of 0.2% to obtain more criteria with respect to the decrease in durability of the asphalt concrete.

Keywords: Indirect Tensile Strength (ITS), Asphalt Concrete (AC), Polyethylene Terephthalate (PET)

1. Introduction

In this globalized world, technology has become a valuable asset in many field, especially in engineering field. Nowadays, the development of engineering become better when influenced by the implementation of technology because as recent advances in technology have proven that technology is leading to more faster, safer, easier and efficient work. In this age of globalization, the technology was extremely growth and changing faster day by day due to the increases of intelligent in development

of technology that realized them to the important of technology. In this regard, it is also associated with the increasing environmental pollution such as the pollution of waste plastic materials. As we all know, plastic waste cannot be disposed of, however they can be reused and used as useful materials for our daily lives. There was a significant increase in plastic waste from international to Malaysia, which has caused outsiders to have a bad view of Malaysia because it is seen by our country as a landfill. This is very worrying because it can cause many negative things to happen if plastic waste increases. Nevertheless, plastic waste is still imported into this country in large quantities [1].

The aim of this research is to investigate the suitability of using plastic waste in asphalt concrete mixture as binder modifier and to evaluate the durability of asphalt mixture with plastic waste using indirect tensile strength test. This study was conducted to create potential to reduce the rate of plastic waste and also reuse it for future good. It will be able to decrease the negative impacts of plastic disposal on the environment. Asphalt concrete is a composite material that is commonly used in the building of sidewalks, roads, airports, parking lots, and other types of pavement. This study is to achieve goals which satisfy the title of the study on investigation of using plastic waste in asphalt concrete mixture as binder modifier due to the significant increase in waste plastic materials in Malaysia.

2. Materials and Methods

Experiments were performed on asphalt concrete mixture with different percentages of Polyethylene Terephthalate (PET) type plastic waste starting with 0%, 0.2%, 0.4% and 0.6%. Sieve analysis was conducted with different sizes were prepared according to the Marshall Standard gradation type AC14. The experiment was conducted with a total of 8 specimens with different percentage of PET added. All samples had been test with the same test which indirect tensile strength test.

2.1 Materials Preparation

Asphalt mixture defines a mixture which contains aggregate and bitumen. The aggregate divided into fine and coarse aggregate. The aggregate usually makes up 90 to 95 percent of the whole mixture, while bitumen makes up 5 to 10% of the total mixture to produce asphalt concrete [2]. The aggregate in asphalt mixture work as the filler while bitumen filled the voids between aggregate and work as a binder. This study focuses primarily upon the addition of PET in asphalt concrete mixture as binder modifier. Specification of materials used in this study are as follow:

- Bitumen with penetration grade 80/100 supplied by Chevron Company.
- Aggregates with JKR specification of gradation limit for AC14 type.
- Plastic waste type of PET

2.2 Methods

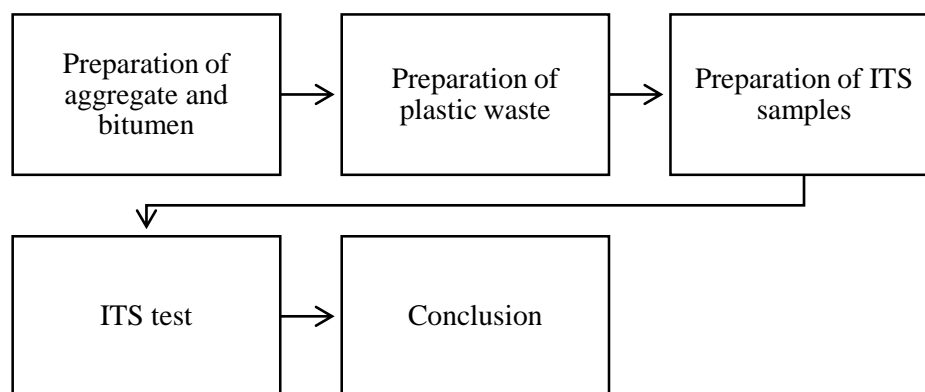


Figure 1: Flowchart of methodology

In this study, the preparation of aggregate and bitumen are important. Then, preparation of PET as binder modifier. The plastic waste used in this study was in the form of sheets about 3 mm length and width from PET plastic mineral bottles. Preparing the sample for indirect tensile test which was consist of modified samples with PET based on proportion about 0%, 0.2%, 0.4% and 0.6% and performed the ITS test. Based on the test results presented, the findings and conclusions can be drawn.

2.3 Equation

ITS value were calculated by using this formula:

$$Y = [2P/\pi\phi T]$$

Where, Y = ITS value, P = peak load, ϕ = diameter of sample, and T = thickness of sample.

2.4 Test and Specification

Tests involved in this study are referred to the standards as follow:

- Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
- Indirect Tensile Strength Test.

The aggregates gradation limit used in this study were based on Marshall design referred to the Standard of JKR [3]. The specification is provided in the Table 1. Indirect tensile strength test (ITS) have been performed as performance test of asphalt concrete mixture according to Marshall standard gradation type AC14.

Table 1: JKR specification of gradation limit [3]

B.S Sieve Size	Percentage Passing (%)
14.0 mm	90 – 100
10.0 mm	76 – 86
5.0 mm	50 – 62
3.35 mm	40 – 54
1.18 mm	18 – 34
0.425 μ	12 – 24
0.150 μ	6 – 14
0.075 μ	4 – 8
Pan	-

3. Results and Discussions

3.1 Sieve Analysis

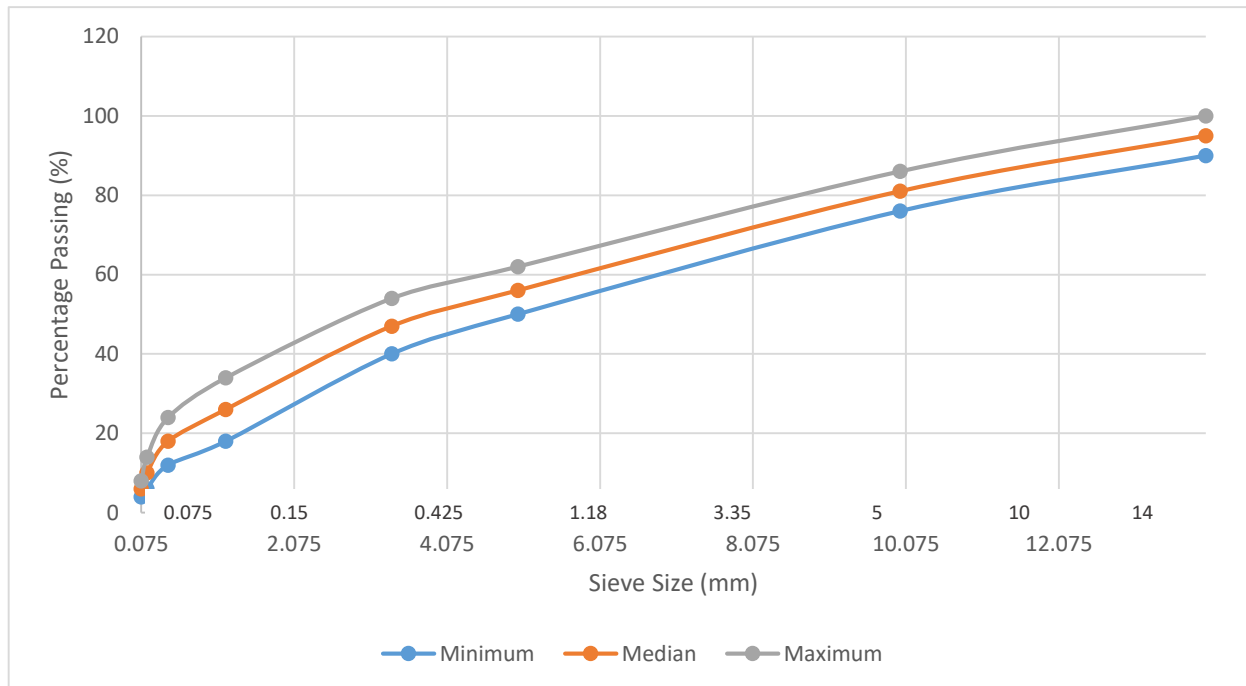


Figure 2: Percentage passing of aggregate against sieve size

From Figure 2, the size of aggregate that had been used in this study was taken by calculating the median between minimum and maximum of percentage passing according to the JKR specification for AC14 type. The mass for each size of aggregates was calculated by using the median value. The results are provided in Table 2.

Table 2: Mass of aggregates for each size

Size (mm)	Percentage Passing (%)	Mass (g)
14.0	95	60
10.0	81	169
5.0	56	200
3.35	47	108
1.18	26	252
0.425 μ	18	96
0.150 μ	10	96
0.075 μ	6	48
Pan	-	72
Total		1200

3.2 Optimum Bitumen Content (OBC)

For this study, OBC value have been used from previous studies that have been done by other students. The OBC value that we have used in this study was 5.82% [4]. It was appropriate with the standard from Marshall Mix design criteria in a range between 4 to 6 percent.

3.3 Indirect Tensile Strength Test

The strength and resistance of the compacted asphalt mixture was tested by indirect tensile strength test. This method is to test accurately and consistently a feature or parameter of the mixture response that is strongly correlated with the occurrence of pavement distress, cracking and rutting over a variety of traffic and climatic conditions [5]. The total number of samples tested was 8 and it consisted of 0, 0.2, 0.4 and 0.6% asphalt concrete samples that had been modified with PET type plastic waste. Table 3 shows the test result obtained from the indirect tensile strength test [6].

Table 3: Test results obtained from indirect tensile strength test

Percent of PET (%)	Peak load (kN)	ITS value $\times (10^{-3})$ (kN/mm^2)
0	9.098	0.84
0.2	8.382	0.78
0.4	7.543	0.68
0.6	5.971	0.53

According to the indirect tensile strength results, the standard value for asphalt concrete showed the highest ITS value with a reading of $0.84 \text{ kN}/\text{mm}^2$. Subsequently, at 0.2% percentage decreased by 7% with a reading of $0.78 \text{ kN}/\text{mm}^2$ compared to the standard value for ITS. However, these values are still relevant compared to the percentages of 0.4 and 0.6 which respectively shows a greater of ITS value decline with percentages of 19% and 37%. The devaluation of ITS value occurs when the percentage of PET added can affect the bitumen and cause it unable to bind the aggregate well due to the factor of addition of plastic material in the bond. The weakness between the plastic surface and the binder will be evident in certain temperature variations that occur naturally. This is because of mismatched thermal expansion produces tension in the binder system that results in the disappearance of the interface [7].

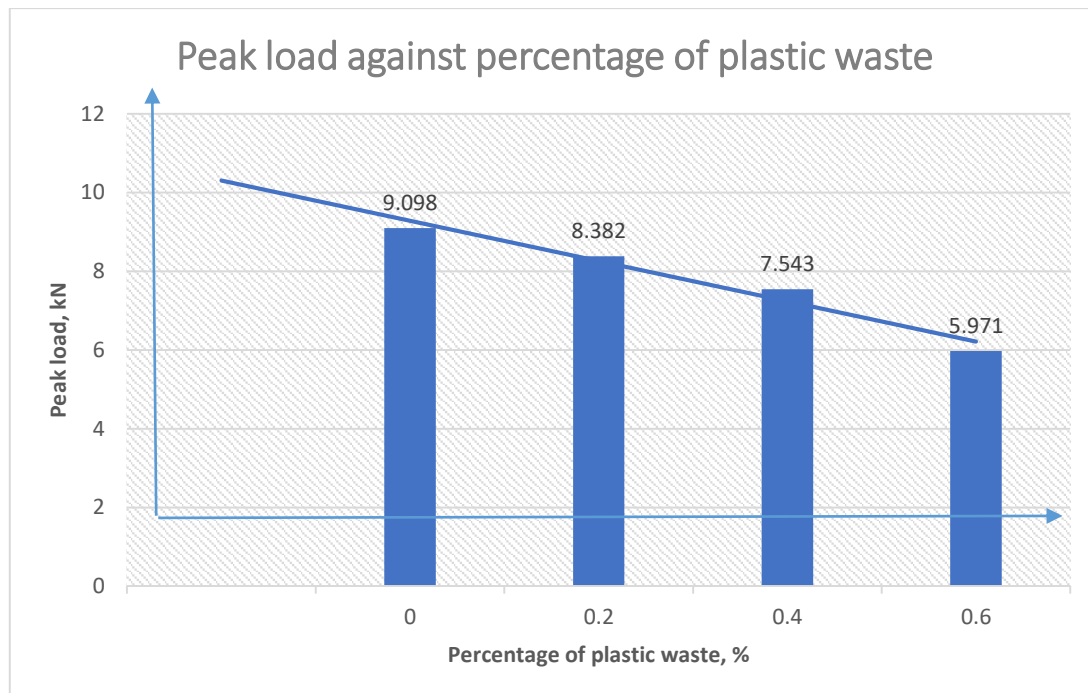


Figure 3: Peak load against percentage of plastic waste

Based on the graph above, it shows that the peak load decreasing directly proportional to the percentage of plastic waste PET type that was added into the mixture. It shows that the more plastic waste used, the less the strength of asphalt concrete mixture. This is because the asphalt concrete material has been mixed with a lot of impurities and causes it to lose the original characteristics of a mixed asphalt. However, peak load at the percentage of 0.2% of plastic waste is still relevant due to still shows higher peak load value compared to the others percent. This proves that asphalt concrete is still relevant and suitable to be mixed with plastic waste as it still shows high load resistance. In addition, with the use of plastic waste in asphalt concrete mixture will create the potential to reduce plastic disposal and be able to reduce the pollution. Therefore, it can conclude that the percentage of plastic waste added must not exceed 0.2%. It is because from the test results performed at the percentage of 0.4 and 0.6% have shown a decreased in the peak load of the asphalt concrete.

4. Conclusion

In conclusion, the percentage of PET added must not exceed 0.2%. It is because from the test results performed at the percentage of 0.4 and 0.6% have shown a decreased in the peak load of the asphalt concrete. It shows that the more PET used, the less the strength of asphalt concrete mixture. This is because the asphalt concrete material has been mixed with a lot of impurities and causes it to lose the original characteristics of a mixed asphalt. The devaluation of ITS value occurs when the percentage of PET added can affect the bitumen and cause it unable to bind the aggregate well due to the factor of addition of plastic material in the bond. However, peak load at the percentage of 0.2% of PET is still relevant due to still shows higher peak load value compared to the others percent. This proves that asphalt concrete is still relevant and suitable to be mixed with PET as it still shows high load resistance and in order to create the potential to reduce of plastic disposal and pollutant.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

- [1] Kalanatarifard, A., & Yang, G. S. (2012). Identification of the municipal solid waste characteristics and potential of plastic recovery at Bakri Landfill, Muar, Malaysia. *Journal of Sustainable Development*, 5(7), 11-17
- [2] Pasandín, A. R., & Pérez, I. (2017). Fatigue performance of bituminous mixtures made with recycled concrete aggregates and waste tire rubber. *Construction and Building Materials*, 157, 26-33
- [3] Jabatan Kerja Raya (JKR) 2008 Standard Specification for Road Works – Section 4: *Flexible Pavement* Public Works Department, Ministry of Works Malaysia (Kuala Lumpur)
- [4] Shukri, S. N. B. M. (2020). Investigation of rutting performance of hot mix asphalt containing nano zinc oxide modifier in asphalt mixture. Universiti Tun Hussein Onn Malaysia: Tesis Sarjana Muda
- [5] Wen, H. (2001). Fatigue performance evaluation of WesTrack asphalt mixtures based on viscoelastic analysis of indirect tensile test. North Carolina State University: Tesis Ph.D.
- [6] ASTM D6931 2012 *Standard test method for indirect tensile (IDT) strength of bituminous mixtures* (Philadelphia: ASTM International)
- [7] Grady, B. P. (2021). Waste plastics in asphalt concrete: A review. *SPE Polymers*, 2(1), 4-18
- [8] A. R., & Pérez, I. (2017). Fatigue performance of bituminous mixtures made with recycled concrete aggregates and waste tire rubber. *Construction and Building Materials*, 157, 26-33.