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A Study of Plastic Waste in Bitumen as A Binder of A Wearing Layer in Flexible Pavement

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Abstract: Developments in the use of plastics have affected the increase in the amount of plastics discarded. Increased traffic has also caused damage to the pavement. This can cause damage to the pavement. For this reason, this study was conducted to review plastic bitumen of mechanical test results from past research in terms of penetration, ductility and softening point test. The last objectives is to compare plastic bitumen results with JKR Standards in penetration, ductility and softening point test. Six types of plastic bitumen mixtures are available (2.50 %, 5.00 %, 7.50 %, 10.00 %, 15.00 % and 20.00 %). The best ratio obtained is at 2.50 % on the penetration test and softening test based on the study. The data obtained for penetration tests were in the range of 60 mm - 70 mm while 45 °C – 56 °C for softening tests on PEN 60/70 and PEN 80/100. This ratio achieves the specifications set by JKR / SPJ / Rev 2008. For the ductility test, no best ratio is obtained due to not reaching the specifications set by JKR. This is because the technique used is not destroyed. Through this study, bitumen's plastic properties have been obtained, namely, durability, stability, and strength. It can be concluded that the use of bitumen plastic mixture as a binder is highly recommended as it provides an alternative to recycling plastic waste as waste material.

Keywords: Plastic, Bitumen, Penetration Test, Ductility Test, Softening Test, JKR

1. Introduction

Malaysians discarded RM 476 million worth of recyclables two years ago. They recorded the most waste production at 17 percent or RM 205 million, the second-largest source of plastic was 9 percent or RM163 million. The plastic bags that drifted into the sea also killed turtles and marine animals because they thought it was jellyfish. The production, removal and decomposition of plastic bags is not as easy as expected. It directly contributes to the formation of greenhouse gases that affect global warming [1]. Bitumen is very important to produce quality road pavement to avoid road damage in the future. However, bitumen is a thermoplastic liquid because of its properties that act like a viscous liquid

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at high temperatures and behave like an elastic solid. This proves that its unstable nature depends on the area's temperature [2].

One of the main contributing factors to this problem is that due to the repetition of loads of traffic on the road, a vehicle's weight can dramatically increase stress applied to the bitumen surface. Road crashes such as cracks, corrosion and potholes occur in high-temperature countries as we know the thermoplastic bitumen's properties cause its physical state to fluctuate and change with temperature [3].

1.1 Objectives

- To review plastic bitumen of mechanical test results from past research in terms of penetration, ductility and softening point test.
- To compare plastic bitumen results with JKR Standards in penetration, ductility and softening point test.

2. Literature Review

Flexible pavement is a structure that maintains intimate contact with and distributes load to the subgrade and depends on aggregate interlock, particle friction and cohesion for stability. Flexible pavement uses a more flexible surface course and distributes loads over a small area. It relies on a combination of layers for transmitting load to subgrade. To take maximum advantage of this property, material layers are usually arranged in order of descending load-bearing capacity with the highest load-bearing capacity material on the top and the lowest load-bearing capacity material at the bottom [4]

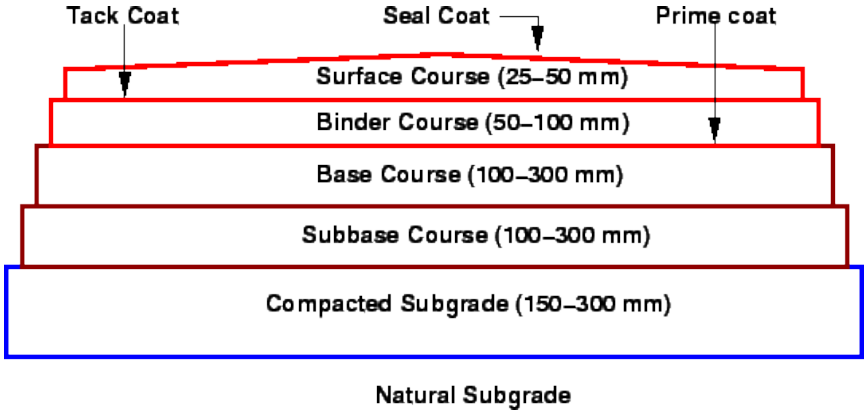

Figure 1: Layer of Flexible Pavement

Bitumen can be obtained from two main sources which are natural sources and petroleum. Natural sources is bitumen located in geological stratum and can be obtained in the hard and soft term. Petroleum bitumen is bitumen in colloidal from the refinery process of crude oil and has been widely used in road construction [4]. The penetration bitumen commonly used in flexible pavement. Penetration bitumen will form a hot mixture when melted by heating it to mix with the aggregate and when cooled, it will form a very strong pavement and afford to support the load from the vehicle [5].

Low-density polyethylene has a good balance of flexibility, strength, barrier properties, and cost and can have a wide combination of properties. Low-density polyethylene has high clarity, is chemically inert, and has good impact strength and excellent tear and stress crack resistance. LDPE has applications in sterile blister packs for drug packaging. Linear LDPE is used in films and packaging due to its flexibility and toughness [6]. High-density polyethylene is a thermoplastic polymer that the liquid can become liquid and re-mixed to a solid-state. It's tough, cheap, and it has excellent process capabilities. It is used in many applications ranging from plastic grocery bags to heavy-duty plastic containers. Moreover, HDPE is also widely used in the construction industry for piping and electrical equipment insulation [7].

3. Methodology

To facilitate the project and achieve the objectives as expected, the research process is carried out in the following order of methodology:

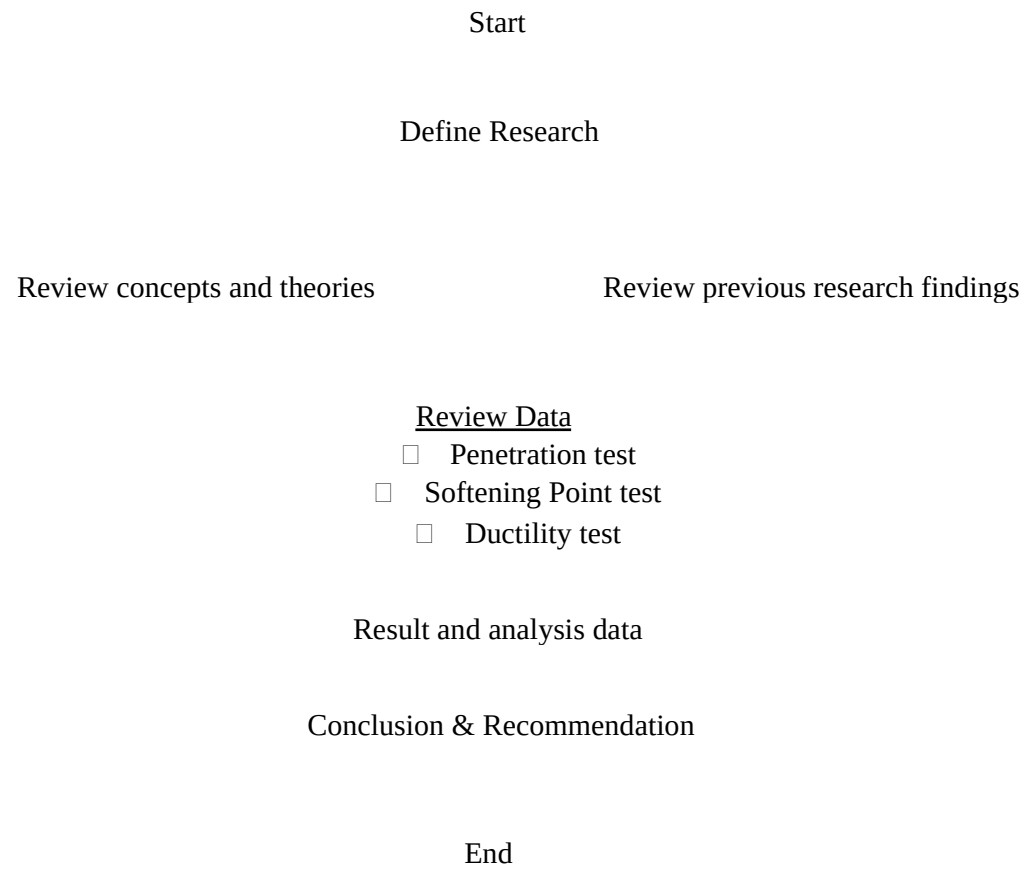

Figure 2: Research methodology

3.1 Penetration Test

The penetration of PEN 60/70 and PEN 80/100 bitumen was checked following the ASTM D5 standard test procedure and complied with the road work specifications Jabatan Kerja Raya Malaysia. The penetration test is the most common test for penetration bitumen. The central point of the penetration value range is to measure the consistency or hardness of the asphalt binder and can be interpreted as the decomposition value of the laboratory experiment

3.2 Softening Point

The binders used in this study were PEN 60/70 and PEN 80/100 following the ASTM D36. In this test, 60/70 and 80/100 bitumen were tested for a softening point. The temperature was measured at a specific asphalt viscosity at a certain point during the transition from slowly changing fragile or very thick material to a softer and less viscous liquid.

3.3 Ductility Test

Ductility is a test bitumen to measure elasticity following ASTM D113 standard test procedure. The paving asphalt's ductility is determined by the distance at which it is stretched until splitting or fracture. Two ends of the briquette specimen are forced apart at a given speed and temperature.

4. Results and Discussion

This chapter will discuss previous researchers' results, including analyzing data obtained from the study. Among the tests taken are penetration tests, softening tests and ductility tests according to the specified specifications. Six types of bitumen plastic mixtures as fasteners were taken as (2.50 %, 5.00 %, 7.50 %, 10.00 %, 15.00 % and 20.00 %).

4.1 Penetration Test

The penetration value range is to measure the consistency or hardness of asphalt binders. It can be classified based on the penetration of values taken through previous studies. The results of penetration tests with modified bitumen based on previous studies are shown. The bar graph in Figure 3 shows that plastic bitumen's penetration test decreases when the ratio of plastic increases. The result shows decrease sharply from 64.00 for 2.50 % until 18.00 for 10.00 % [10]. The highest value of penetration from Hossain (2006) was recorded 95.00 mm, and the lowest value from Kashem (2012) and Panda et Al (1997) was recorded at 18.00 mm. If the penetration test data is higher and does not follow the actual specification value, then the value will not be taken to be the best value.

Table 1: Result of Penetration Test

References	Ratio	Result (mm)
(Kashem, 2012) [8]	2.5 %	59.00
	5.0 %	39.00
	7.5 %	20.00
	10.0 %	18.00
(Islam, 2003) [9]	2.5 %	65.00
	5.0 %	55.00
	7.5 %	35.00
	10.0 %	24.00
(Panda et Al, 1997) [10]	2.5 %	64.00
	5.0 %	47.00
	7.5 %	39.00
	10 %	18.00
(Abebe Welegabir et al, 2016) [11]	5 %	68.00
	10 %	65.00
	15 %	63.20
	20 %	62.60
(Hossain, 2006) [12]	2.5 %	95.00
	5.0 %	69.00
	7.5 %	50.00
	10 %	38.00

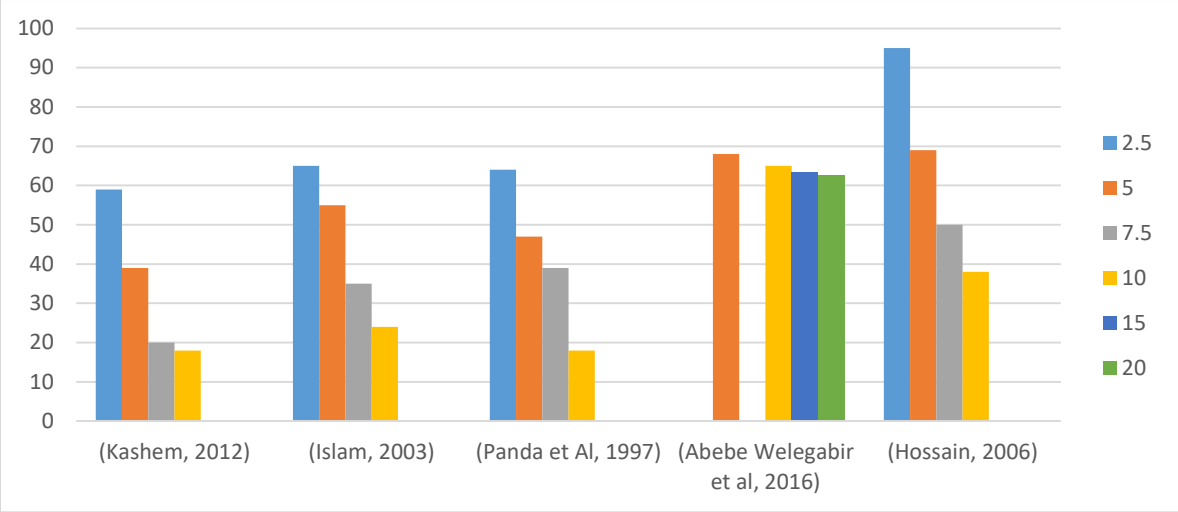

Figure 3: Result of the Penetration Test

4.3 Softening Point Test

The softening point test measures temperature at which binder changes from semi-solid to liquid state under a standard steel ball's weight. It is not a measure of melting point. From Table 2, it can be calculated by Kashem (2012), Islam (2003) and Panda et al (1997) that the addition ratio of 2.50 % of plastic content while by Abebe (2016) addition ratio is 5.00 % of plastic content. As we can see, the highest value of softening point value from Panda et al (1997) at 81 °C and the lowest value from Islam (2003) at 48 °C. Figure 3 shows that the softening point increases to 70 °C from 51 °C based on the ratio of plastic bitumen content [8]. The higher the ratio of plastic bitumen, the higher the value for the softening point test.

Table 2: Result of Softening Point Test

References	Ratio	Result (°C)
[8]	2.5	51
	5.0	60
	7.5	68
	10.0	70
[9]	2.5	48
	5.0	54
	7.5	68
	10.0	70
[10]	2.5	51
	5.0	55
	7.5	61
	10.0	81
[11]	5.0	56
	10.0	60
	15.0	63.55

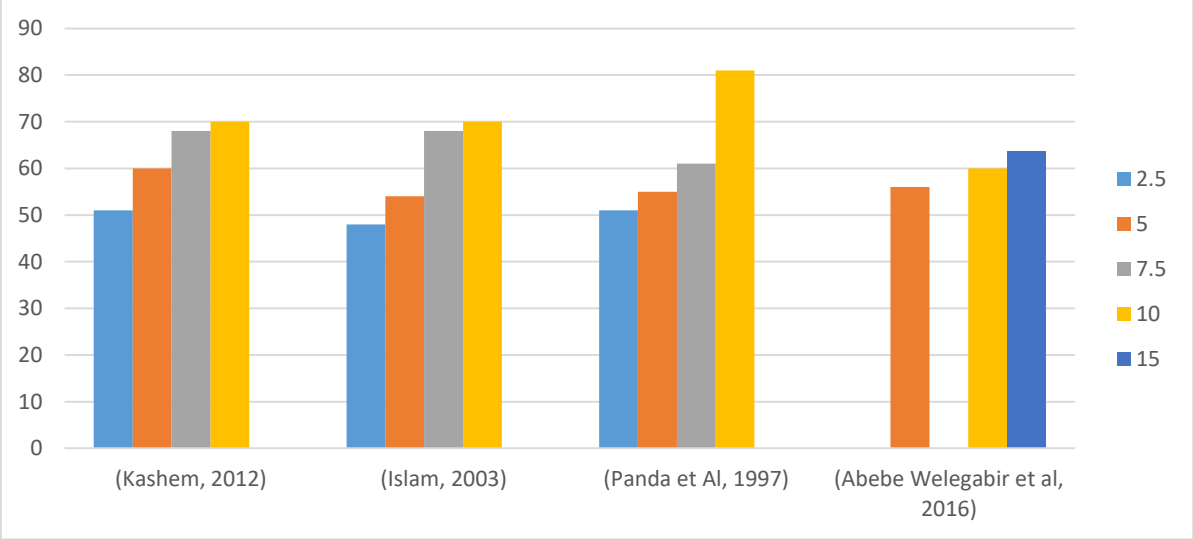

Figure 3: Result of the Softening Point Test

4.4 Ductility Test

The ductility test is a measure of cohesion on the binder's interior, where it will provide cementing properties in the bitumen mixture. Bitumen material with a high ductility value is commonly thought to be a strong binding property. From Figure 4 shows the result of the ductility test from Islam (2003) for ratio of 2.50 % at 94 decreases sharply until the ratio 10.00 % is 19. The highest value of ductility test from Hossain (2006) at 95 cm at ratio 5.00 % and the lowest value from Panda et Al (1997) for ratio 10.00 % was recorded 6 cm.

Table 3: Result of Ductility Test

References	Ratio (%)	Result (cm)
[8]	2.5	30.0
	5.0	27.0
	7.5	17.0
	10	14.0
[9]	2.5	94.0
	5.0	70.0
	7.5	45.0
	10	19.0
[10]	2.5	73.0
	5.0	60.0
	7.5	51.0
	10	6.00
[11]	5	94.6
	10	84.7
	15	76.8
	20	44.2
[12]	2.5	95.0
	5.0	70.0
	7.5	38.0
	10.0	19.0

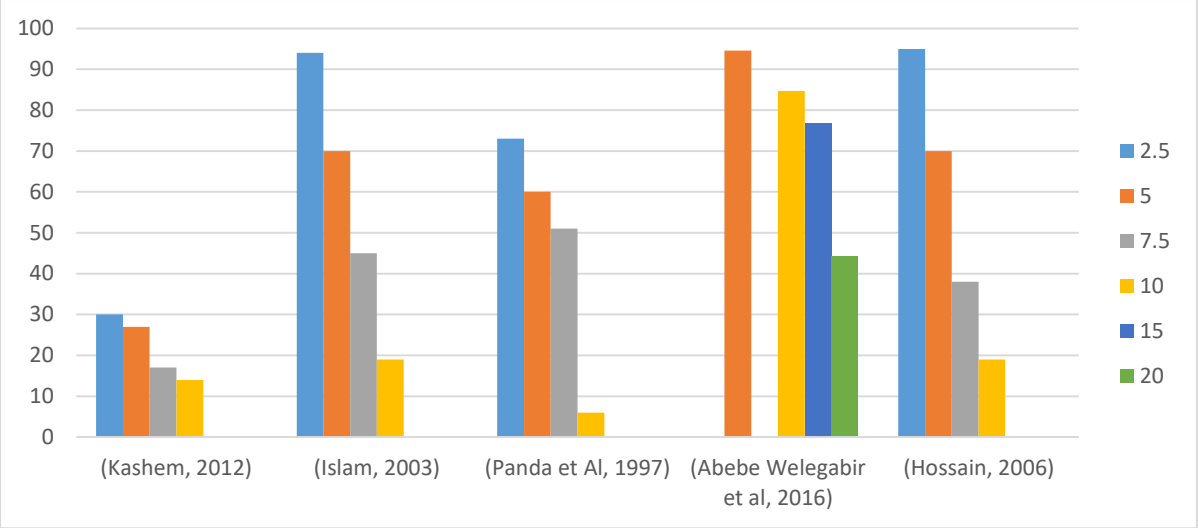

Figure 4: Result of Ductility Test

4.5 Summary of Result

Based on the data in Table 4, the bitumen PEN 60/70 was used for 2.50 % by Kashem (2012) recorded at 59.00 millimeters (mm) value of penetration was failed. According to the Islam (2003), the penetration value was recorded 65.00 mm and the usage of 2.50 % using the PEN 80/100 was recorded a penetration value at 64.00 mm was failed (Panda et Al, 2003). If results are failed based on Jabatan Kerja Raya (JKR) standard, the low penetration test value may cause an increased road strength, thus reducing water damage. Meanwhile, Abebe Welegabir (2016) penetration test for 5.00 % plastic usage achieved a JKR standard and was recorded 68.00 mm, and the penetration value for 2.50 % at 70.00 mm was achieved (Hossain, 2006).

Table 4: Best Result in Penetration Test

References	Pen Grade	Ratio (%)	JKR Standard	Result (mm)
[8]	60/70	2.5	60-70	59.00 (fail)
[9]	60/70	2.5	60-70	65.00 (pass)
[10]	80/100	2.5	80-100	64.00 (fail)
[11]	60/70	5.0	60-70	68.00 (pass)
[12]	60/70	2.5	60-70	70.00 (pass)

Based on Table 5, the value of 51 °C and 48 °C was recorded by having 2.50 % of plastic bitumen for PEN 60/70 by Kashem (2012) and Islam (2003). The bitumen grade 80/100 by Panda et Al (1997) was recorded 51 °C for ratio 2.50 %. From Abebe Welegabir (2016), the highest number where ratio of 5.00 % was recorded 56 °C for a grade of bitumen 60/70. This improved binding properties will reduce the problem of sidewalk bleeding and isolation in the summer, which is one of the important methods of sidewalk pressure in tropical countries such as Malaysia. All of the above values have been following the standard specification by JKR.

Table 5: Best Result of Softening Point Test

References	Pen Grade	Ratio (%)	JKR Standard	Results (°C)
[8]	60/70	2.5	48-56	51 (pass)
[9]	60/70	2.5	48-56	48 (pass)
[10]	80/100	2.5	45-52	51 (Pass)
[11]	60/70	5.0	48-56	56 (Pass)

Based on data obtained, the bitumen PEN 60/70 was used for 2.50 % plastic bitumen recorded 30 cm value of ductility [8]. While Islam (1997) uses PEN 60/70 for a 2.50 % ratio, the values show 94 cm. By Panda et Al (1997), the usage of a ratio of 2.50 % using the difference grade 80/100 recorded 73 cm. Albebe Welegabir (2016) stated the PEN 60/70 indicates the value of 94.6 cm by ratio 5.00 % where the highest value of ductility test. From Hossain (2006), the ductility test value was recorded at 95 cm at 2.50 %. All the results are failed based on JKR standard. This is because bitumen ductility decreases over time and the rate of decline is not the same for all types of binders. Using plastic waste with bitumen can slow down the ductility value rate even though plastic waste initially reduces natural bitumen's ductility. If the ductility is excessive, it may result in the binder not functioning as a pavement material.

Table 6: Best Result of Ductility Test

References	Pen Grade	Ratio (%)	JKR Standard	Result (cm)
[8]	60/70	2.5	≤ 100	30.0 (fail)
[9]	60/70	2.5	≤ 100	94.0 (fail)
[10]	80/100	2.5	≤ 100	73.0 (fail)
[11]	60/70	5.0	≤ 100	94.6 (fail)
[12]	60/70	2.5	≤ 100	95.0 (fail)

5. Conclusion

From this study, it can be concluded that the main objective which is to review plastic bitumen of mechanical test results from past research in terms of penetration, ductility and softening point test. Among the properties of bitumen plastics found through this study are durability for penetration, stability for softening and strength for ductility. For the second objective is to compare plastic bitumen results with JKR Standards in penetration, ductility and softening point test. This can be proved that the best ratio is 2.50 % for penetration test and softening point test follow the standard specification by JKR. No best ratios were obtained for ductility tests, although some data were close to the specified standard specifications. This may be due to the ductility of bitumen decreasing over time and the rate of decline is not the same for all types of binders.

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