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EFFECT OF BIO-OIL FROM EMPTY FRUIT BUNCH ON PENETRATION INDEX OF ASPHALT BINDER

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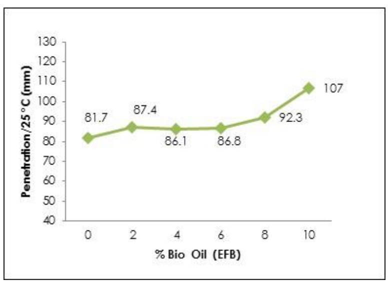
Graphical abstract



Abstract

Bio-oil which is derived from pyrolysis palm empty fruit bunch (EFB) is expected to be a potential alternative modifier for asphalt. This study focused on the effect of bio-oil on the penetration index (PI) asphalt. Bio-oil is blended between 2%-10% by weight of virgin asphalt penetration grade 80/100. Physical properties are measured and compared with virgin asphalt by the conventional physical binder test – softening point and penetration. The penetration index (PI) values is calculated to identify the typical values of asphalt type. Based on the findings, it was found that increased bio-oil content can effectively soften the asphalt at the same time maintain the temperature susceptibility. Modification asphalt is still within the grade 80/100 PEN with the addition of 10% maximum of bio oil. The stiffness of modified asphalt need to be further improved by addition polymer for better asphalt binder properties.

Keywords: Bio-oil, penetration index, asphalt, susceptibility

1.0 INTRODUCTION

Asphalt is known as a black coloured, sticky and semi solid material derived from crude petroleum and used as binder for asphalt pavement. Asphalt also is available and graded according to standardised testing methods. Nowadays, the increase of asphalt price encouraged a high demand of petroleum which subsequently has encouraged the use of alternative binder. Many researchers have explored utilising natural sources as a modification on asphalt binder. Consideration on the natural sources binder should be based on the factors and problems which are related to the sustainability of roadway constructions. Nevertheless, its natural usage should be focused on the waste such as biomass that contain similar composition with conventional asphalt binder. Biomass also is a carbon based and source of biomass from forestry crops, agricultures, animal residues, industrial residues and etc [1,2].

2.0 MATERIAL AND METHOD

Bio-oil (Figure 1) used in this study was extracted through fast pyrolysis from palm empty fruit bunch (EFB). The elemental composition of bio-oil properties are [C,H,N, S] 41.8% , 4.7%, 16.3% and 18.6%, respectively. In this study virgin binder penetration grade 80/100 was heated at 165°C in the oven to become fluid in the container. During asphalt modification, bio-oil was added 2, 4, 6, 8 and 10 percent by weight of base asphalt binder and blended using high shear mixer with the speed of 1000 rpm for 20 minutes at 145°C - 160°C. Table 1 gives the designation and binder blend composition of the tested asphalt binder.

Table 1 Binder blend composition

Designation	Binder Blend Composition
Binder A	PEN 80/100
Binder B	PEN 80/100 + 2% Bio-oil
Binder C	PEN 80/100 + 4% Bio-oil
Binder D	PEN 80/100 + 6% Bio-oil
Binder E	PEN 80/100 + 8 % Bio-oil
Binder F	PEN 80/100 + 10% Bio-oil

Figure 1 Bio-oil from palm Empty Fruit Bunch (EFB)

2.1 Penetration Test

The penetration test was used as a measure of consistency of asphalt in accordance to ASTM D5-97[9]. Higher values of penetration reading indicate softer consistency. All asphalt display thermoplastic become softer when heated and harden when cooled. The penetration of a asphalt material is expressed as the distance in tenths of a millimeter of a standard needle. Penetration needle penetrated vertically into the sample of the material under specified conditions of temperature, loading and time. Before started using the penetration apparatus, samples was heated and stirred until it became sufficiently fluid and then poured into the container. Samples were cooled at room temperature for an hour and then put into water bath which maintained the temperature at 25°C for another an hour. The tests were made with the penetrometer outside the bath and placed in the transfer dish to maintain the temperature. The test was carried out with a total applied load of 100g and duration of 5s at obtained temperature of 25°C .

2.2 Softening Point

Softening point is determined using ring and ball test according to ASTM D36 respectively[10]. The virgin binder was heated between 75 °C and 100°C and stirred to remove air bubbles and water. After the samples have become fluid, it was poured into the ring and cooled for 30 minutes. The ring then was put into the ring holder with the ball inside the centering guide. The softening point is defined as the temperature at which a asphalt sample can no longer support the weight of a 3.5g steel ball. Samples were heated in a liquid bath which supported a steel ball. The material softened and allowing the ball to pass through the ring, then the temperature at which the ball touched the bottom was recorded.

Figure 2 Penetration test

Figure 3 Softening point test

3.0 RESULTS AND DISCUSSION

Penetration can indicate the degree of softness and consistency of asphalt. Figure 4 illustrates the penetration at 25 °C for virgin binders with five additives of bio-oil from empty fruit bunch (EFB). It is clearly observed in figure 4 that the penetration values of different asphalt binders was high as the percentage of bio-oil content was increased, which implies that the addition of bio oil can soften virgin binder by reducing its consistency. Using 80/100 grade asphalt requires having a needle depth between 8mm to 10mm. However, modification which used < 10% of bio-oil on virgin binder showed there are still in target binder range in penetration grade 80/100.

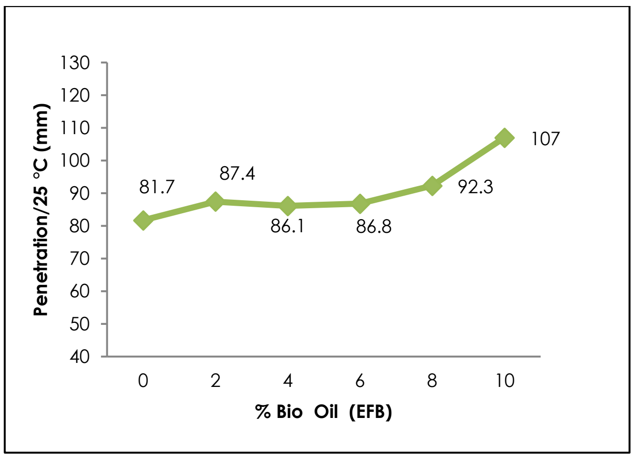


Figure 4 Penetration plots for Modified Asphalt

Figure 5 shows an experimental results of the softening point which showed that the influence of bio-oil on the modified asphalt was at low temperature from the control unaged asphalt. The main reason was because the asphalt became softer after the modification and affected the melting point. It also showed no significant change in the temperature after replacing the bio-oil as modification asphalt but there was a significant change with the control unaged asphalt. There were also some significant differences between the control unaged asphalt for softening point temperature when compared with the specification of penetration grade asphalt 80/100. Control unaged should be in the range of 45-52°C but the reading was low at the softening point temperature in the target binder range of the penetration grade 80/100.

Based on the results of penetration at 25 °C and softening point temperature, Penetration Index was calculated using nomograph for penetration index (SP/pen)[11]. PI values can be used to determine the stiffness of asphalt at any temperature and loading time. Interception from line between the softening point and penetration has given values of penetration index as in Table 2. The values of penetration index was smaller than -2 and categorised into temperature susceptible of asphalt type respectively. Hard binder have PI values less than +2 and are less susceptible to ageing[12-18].

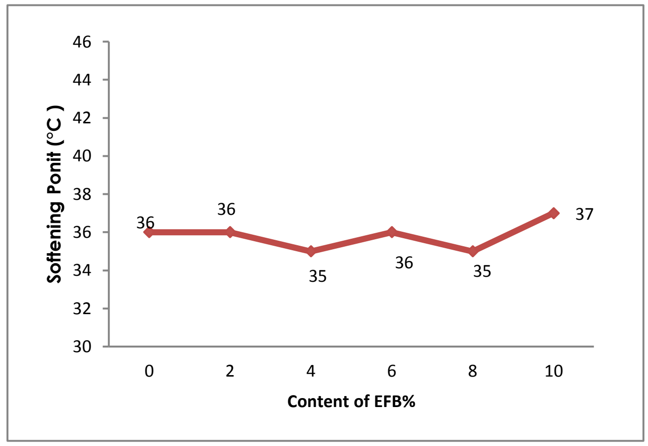


Figure 5 Penetration plots for Modified Asphalt

Table 2 Penetration Values for modification asphalt

% Bio-oil + pen 80/100	Penetration Index (PI)	Asphalt type
0	-2.4	Temperature Susceptible Asphalt
2	-4.0	Temperature Susceptible Asphalt
4	-4.1	Temperature Susceptible Asphalt
6	-4.1	Temperature Susceptible Asphalt
8	-4.1	Temperature Susceptible Asphalt

4.0 CONCLUSION

The consistency of asphalt binder containing bio-oil empty fruit bunch (EFB) has been compared to the conventional asphalt binder. The results show that modified asphalt behaviour is softer than control asphalt. Although the binder slightly become softer it still can obtain the penetration grade of 80/100 which adding below 10% less than the weight of asphalt. Penetration values of modified asphalt are less than -2 and categorised as temperature susceptible which related to stiffness of asphalt. It also identified that the addition of small percent of bio-oil can affect the typical values on the asphalt grade. Further study is recommended to evaluate the viscosity and long term performance of rheological testing using dynamic shear rheometer (DSR) for better understanding on the behaviour of asphalt binder properties.

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