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Effect of Batu Pahat Soft Clay (BPSC) Concentrations on the Physical and Rheological Properties of Asphalt Binder

Mohd Idrus Mohd Masirin[1]*, Allam Musbah Al Allam[2] and Ahmed Suliman Bader Ali[1]

[1]*Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*
[2]*Research Centre for Soft Soils (RECESS) Malaysia, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*

ABSTRACT

The major aim of this research was to investigate the addition of BPSC on the physical and rheological properties of asphalt binder. In this study, addition of five different percentages of BPSC compositions were studied, namely (2, 4, 6 and 8%). The impact of modifier on the rheological and physical properties was determined using conventional tests, such as softening point, ductility and penetration, and measurements from a dynamic shear rheometer. Based on the results, it was observed that the addition of BPSC has a significant impact on the rheological properties of asphalt binder and would improve rutting resistance at high temperatures. Meanwhile, results related to physical properties indicated that a decrease in penetration and increase in softening points results in stiffness of BPSC. The results showed that BPSC reduced temperature susceptibility and increased stiffness and elastic behaviour in comparison to unmodified asphalt binder. This means BPSC would increase the resistance of permanent deformation (rutting). Finally, BPSC could be considered as an appropriate additive to modify the properties of asphalt binder.

Keywords: Amplitude sweep, Asphalt binder, DSR, physical properties, soft clay, superpave parameter (rutting)

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E-mail addresses:
idrus@uthm.edu.my (Mohd Idrus Mohd Masirin),
alallm84@yahoo.com (Allam Musbah Al Allam)
*Corresponding Author

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INTRODUCTION

In principle, asphalt binder plays a critical role in enhancing the quality of hot mix asphalt. Thus, pavement engineers should have a comprehensive understanding of the behaviours of asphalt binder (Zaniewski & Pumphrey, 2004). Airey (1999) found that the performance of asphalt binder has become increasingly more complicated with increased utility of PMB in the asphalt pavement industry. Traditionally, asphalt binder has been widely used as cementing materials in the construction of flexible pavements (Kamal et al., 2012). This is in order to improve the performance of pavement based on the specifications for asphalt mixtures and binders (Kennedy & Harrigan, 1990). In recent years, modified asphalt binder has been applied in the asphalt pavements (Hasham et al., 2013). A recent study (Patted et al., 2013) showed that rheological is a very strong instrument for quantifying material properties, as well as, the rheological properties of asphalt binder . Several indexes methods have been proposed to assess the low and high-temperatures performance of asphalt binders respectively (Shan et al., 2015).

Similarly, researchers have showed that rheological behaviour relies on the structure of pure and chemical composition of modified binder (de Camargo Forte et al., 2004). One of the most important challenges for researchers is proposing an effective method to improve the properties of asphalt binder to provide longer service life (Muniandy et al., 2013).

MATERIALS AND METHODS

Materials

In this research, 80/100 of penetration grade was used in order to prepare all the test samples; the specific gravity of the asphalt binder is 1.03. The physical properties of asphalt binder are shown in Table 1.

Sample Preparation

BPSC particles at various concentrations (2, 4, 6 and 8%) was added to asphalt binder (bitumen was prepared using a high shear mixer). The material was then stirred for 60 minutes at speed of 3000 rpm while maintaining a temperature of 165°C to ensure that the soft clay particles were homogeneous during the process of mixing and well dispersed inside the medium of bitumen binder.

Experimental Procedures

Physical Properties of Asphalt Binder. Before conducting physical properties tests, prior tests such as softening point, ductility and penetration are vital (see Table 1). The DSR measurements were done according to ASTM specifications in order to ensure reproduction changes of BPSC. The penetration test value is to determine the stiffness of asphalt binder while the softening point is where asphalt binder starts to become a fluid while the ductility test value is measure the distance in centimetres which is a standard briquette of asphalt binder.

Table 1
The physical properties of asphalt binder

Physical Properties	units	Limits	Specification
Penetration@ 25°C, 0.1mm	0.1mm	80-100	ASTM D 5
Softening Point, °C	°C	45-52	ASTM D 36
Ductility @ 25°C, cm	cm	≥ 100	ASTM D 113
Specific Gravity, g/cm^3	-	1.01-1.05	ASTM D 70

Rheological tests. It has been recently established that the rheological properties of the asphalt binder impact on the performance of asphalt binder (Shafabakhsh & Ani, 2015).

Dynamic shear rheometer. The SHRP Superpave performance grade binder specifies lowest values for G*/sin δ of 1000 Pa for original asphalt binder. After placing the sample into the DSR device, HAKE software was used in order to perform the test oscillation. Basically, the Superpave specification of rutting parameter (G*/ sin δ), provides a measure of rutting resistance of asphalt binder, as well as identify a term to be used for high and intermediate temperature performance. Procedures for the DSR are given in AASHTO 315.

Rutting performance. The resistance of asphalt binder versus rutting was determined using dynamic shear rheometer test. In order to determine the permanent deformation (rutting) resistance, DSR test was done on unaged asphalt blend. Temperatures at 46°C, 52°C, 58°C, 64°C and 72°C were used to determine the permanent deformation tests (rutting) accurately.

RESULTS AND DISCUSSIONS

Physical Properties of Asphalt Binder

The effect of different ratios of BPSC on the physical properties of asphalt binder, such as softening point, ductility and penetration test, is shown in Table 2.

Penetration

The penetration test is defined as an empirical test, used to determine the consistency of asphalt binder (Leng et al., 2014). The test was conducted at 25°C and according to ASTM D 5. As per Figure 1, the addition of soft clay constrictions to base asphalt show declared reduction in penetration for up to 4% of BPSC.

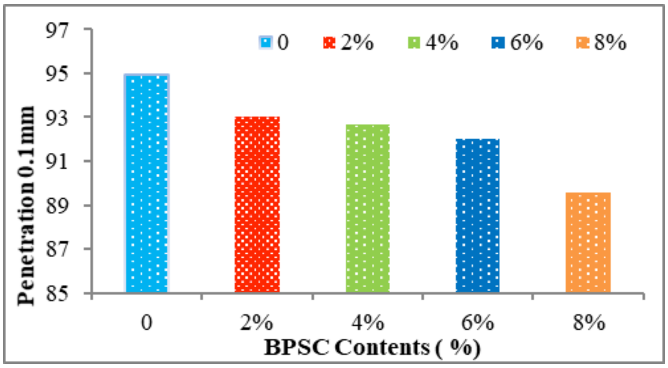

Figure 1. Penetration test at 25°C

Softening Point

This test is defined as the temperature at which an asphalt binder cannot support the weight of a steel ball and begins to soften. The test is conducted using ball and ring process in accordance with ASTM D36. Reciprocally, an increment in the softening point happens up to 4% of BPSC, followed by a decrease in other concentrations as shown in Figure 2.

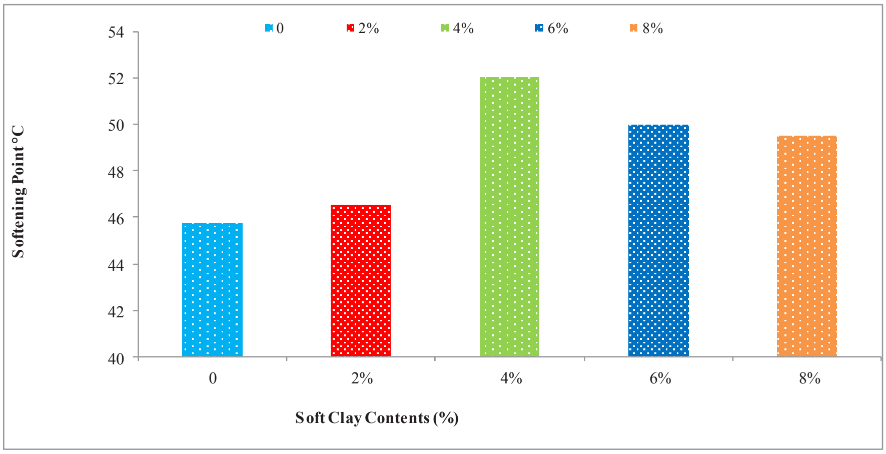

Figure 2. Softening test

Ductility

The Ductility test, run in accordance with ASTM D113, is shown in Figure 3. The ductility of asphalt binder is observed to progressively reduce g BPSC percentages that lead to increase in the stiffness of BPSC.

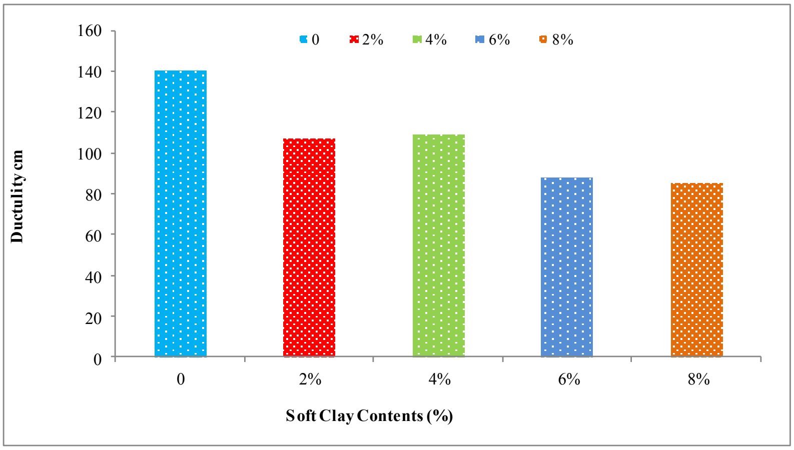

Figure 3. The ductility test

Table 2
The physical properties of asphalt binder

Asphalt Binder Contents	Ductility @ 25°C, cm	Softening Point, °C	Penetration@ 25°C, 0.1mm
0	140	45.75	94.93
2%	107	50	93.03
4%	109	52	92.67
6%	88	46.5	92.02
8%	85	49.5	89.54

DSR

The DSR is used to measure rheological prosperities of asphalt binders at intermediate and high temperatures. Moreover, dynamic shear rheometer evaluates the complex shear modulus (G*) value and phase angle (δ) of the binder at the desired temperature and loading frequency (Cao et al., 2009). Moreover, the higher value of G* means higher resistance to rutting of asphalt binder, while lower value of δ shows means increased elasticity and makes the asphalt binder more resistant to permanent deformation.

Rutting Performance

The G*/sin δ describes the rutting resistance of an asphalt binder at high temperature. According to Superpave requirement for conducting the rutting of an unaged specimen, the parameter of G*/sin δ = 1kPa (Amirkhanian et al., 2014). It uses 25 mm diameter spindle with a gap of 1000-lm' with high and intermediate temperatures ranging from 46, 52, 58, 64 and 72°C. Furthermore, the test was conducted at fixed frequency sweep and applied 1rad/sec which is equivalent (nearly 0.1592 Hz) in accordance to Superpave specification. Figure 4 shows that the lowest value of G*/sin δ was gained via use of e unmodified binder and that the 4% BPSC has the highest value of G*/sin δ. A greater value of G*/sin δ indicates that the pavement has good rutting resistance.

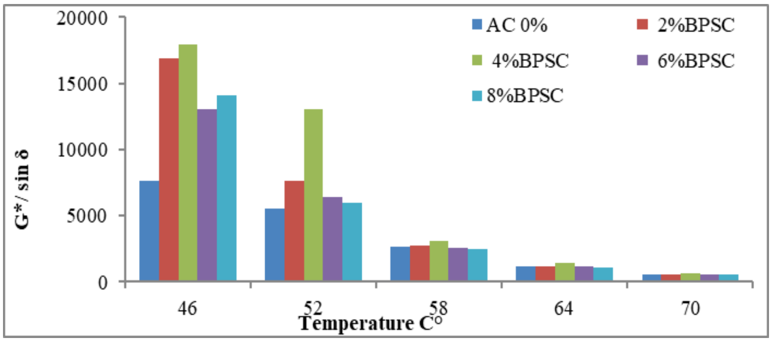

Figure 4. Influence of temperatures on the permanent deformation (rutting) of modified and unmodified binder

Complex Modulus (G*)

G* could be considered as the overall resistance of the asphalt binder to permanent deformation when frequently clipped. As shown in Figure 5, base binder has a lower complex modulus G* than other percentages of BPSC at the tested temperatures, thus exhibiting high elastic properties compared with the original binders.

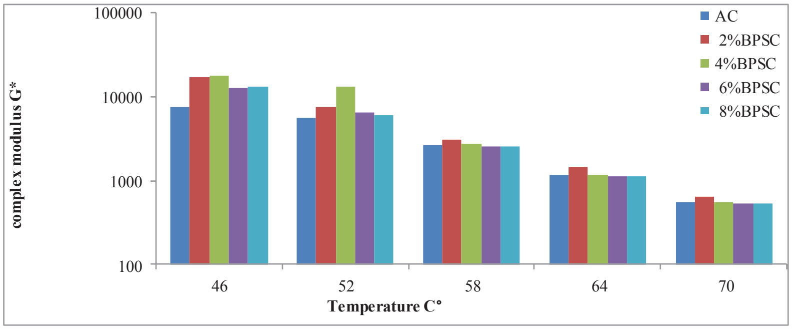

Figure 5. Complex Modulus (G*) against Temperature

Phase Angle (Δ)

Phase angel (δ) is defined as the time lag among stress and strain under the traffic loading and also is extremely dependent on the temperature and frequency of loading. Also, it could be applied as an index of elasticity and viscosity of asphalt binders (Punith et al., 2013). Figure 6 shows the performance and grade type of the asphalt binder, unmodified binder has higher phase angle compared with other percentages which display lower viscous and elastic properties.

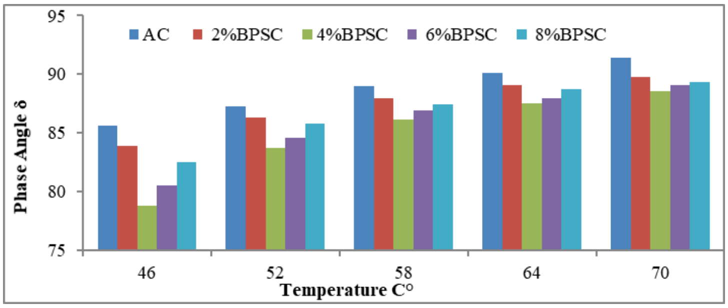

Figure 6. Phase angel (δ) against temperature

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CONCLUSION

Based on the test outcomes of this study, the following findings and conclusions can be drawn with respect to applications.

According to conventional tests for physical properties, such as softening point, penetration and ductility, it was confirmed that the hardness of asphalt binder was enhanced. The results of the permanent deformation (rutting) parameter show it could be complemented that the usage of BPSC as asphalt binder modifier could enhance the resistance versus rutting at high temperatures. An excellent result was reported for 4% BPSC. Hence, this ratio can be considered as the optimum BPSC-modifier content. Mostly, the asphalt binder influences the (G*) and (δ) values when it has decreased shear stress. Therefore, the elastic properties are also influenced by a shear stress for different concentrations of BPSC particles.

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