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The effects of nano kaolin clay modified bitumen on the softening point and storage stability

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Abstract. Utilisation of nanomaterials in asphalt binder is widely explored to improve the performance of the bitumen. Among the potential of nanomaterials, nanoclay received much attention as a modifier in bitumen modification due to their low cost of production and abundance in nature especially in tropical country. This study focused on investigating the physical properties of bitumen containing nano kaolin clay (NKC). The NKC were added at different percentages (3%, 5%, 7%, and 9%) for the modified bitumen production. The softening point and storage stability test were carried out in order to study the physical properties of bitumen. The results show that the addition of nano kaolin clay positively impacts the physical performance of the asphalt binder. It is enhancing the stiffness in terms of softening and storage stability value.

1. Introduction

Increasing traffic volumes and rising cost of bitumen making it necessary to improve the engineering properties and performance of binder through bitumen modification. Various types of modifiers have been employed as bitumen binders in order to improve the properties of the bitumen mixture, particularly with regard to its resistance to aging, cracks due to fatigue and thermal conditions, moisture-induced damage and permanent deformation. However, fibres and polymers are common materials used in bitumen modification [1-5]. Nanomaterials have emerged as the potential solution to greatly enhance the properties of binder with the purpose of improving the performance of asphalt mixture. Nanomaterials are defined as materials with at least one dimension that falls in the length scale of 1-100 nm. Due to the small size and high surface area, the property of nanomaterials is much different from the macro-scale and micro-scale size materials [6]. Besides that, nanomaterial is also can be consider as the economically interesting material because conventional materials are usually added in percentages varying between 20% and 40%, while nanomaterial at a typical quantity may be between 2% and 5%, which shows it is a light weight material [7-9]. This is also supported by Roy et al. [10], which reported that only a small weight percentage of nanomaterial is sufficient to enhance the compressive and shear strength of the mixtures. One of the common and widely used of nanomaterials in bitumen is nanoclays. Nanoclays are nanoparticles of layered mineral silicates which the class of nanoclay is depending on chemical composition and nanoparticle morphology. Therefore, this study aims to assess the use of the nano kaolin clay as asphalt modifiers and potential binder in road construction through the softening point and storage stability test.

2. Materials and Experimental work

2.1. Bitumen and Nano Kaolin Clay

An asphalt binder with a penetration grade of 60/70 was used in this study while the kaolin clay (KC) was used as a modifier in binder as shown in Figure 1. There is no calcination process involved because the KC powder that used in this study was from pure natural clay. In addition, to produce the Nano kaolin clay (NKC), a ball mill machine was applied. The KC powder was ground into 15 hours to obtain the NKC size of 50 nm.

Figure 1. Kaolin clay used through the study

2.2. Sample Preparation

The modified binder nanocomposite was prepared using a high shear mixer with 3000 rpm as suggested by Hussein et al. [11] and Jeffry et al. [12]. This is considered as the most efficient rate to mix asphalt binder with nanocomposites. NKC levels of 3%, 5%, 7%, and 9% by weight of binder were applied; these are referred to as NKC3, NKC5, NKC7 and NKC9, respectively. At the laboratory, after the binder was heated to 160 °C to a fluid state, a mixing rate for 1 hour was used to disperse the intercalated NKC powder. Then, after homogenous modified binder blends were obtained, the binders were left to cool at room temperature prior to being used to investigate the properties of asphalt binder.

2.3. Softening Point Test

The softening point test was performed according to ASTM D36 [13]. This test was conducted in order to measure the susceptibility of blown asphalt binder to the temperature at which the material will be adequately softened to allow a standard ball to sink through it. The bitumen was heated and poured into two rings and cooled for 30 min. The two rings and two ball centering guide were placed on the ring holder in a liquid bath. Then, 3.5 g of steel balls were placed on each sample and heated. The temperature that made the bitumen touched the base plate was taken, and the mean temperature of the two samples was calculated.

2.4. Storage Stability Test

The storage stability test was conducted in accordance with the ASTM D5976 [14]. This test was performed in order to evaluate the high temperature storage stability of modified binder. An aluminium tube (25 mm in diameter and 140 mm in height) was filled with about 50 g of asphalt binder and then stored vertically in an oven at 163 °C for 48 hours. Then it was taken out and cooled in a refrigerator at -7 °C for 4 hours. The tube was cut into three equal sections. If the difference between the softening point of the top and the bottom sections of the tube was less than 2.2 °C, the sample could be regarded as storage stable blend.

3. Results and discussion

3.1. Softening Point Value
Figure 2 illustrates the relationship of the softening point value and NKC content. The result shows that the temperatures of the asphalt binder increased significantly with the increasing of NKC content. A higher softening point indicates the lower sensitivity of binder towards temperature. From the graph, the softening point for the un-aged modified binder increased from about 1 °C to 3 °C as compared to the un-aged control binder. The similar trend was also observed at softening point for agedmodified binder, where the softening point value increased from 2 °C to 3 °C as compared to the aged control binder. The high softening point value in NKC content showed the low temperature susceptibility properties, which had high resistance to temperature exposure. The high softening point performance was desirable since this characteristic can withstand high temperature effect thereby minimising the presence of permanent deformation deterioration in pavement. Approximately 5% of NKC content was identified as an optimum binder based on the highest softening point.

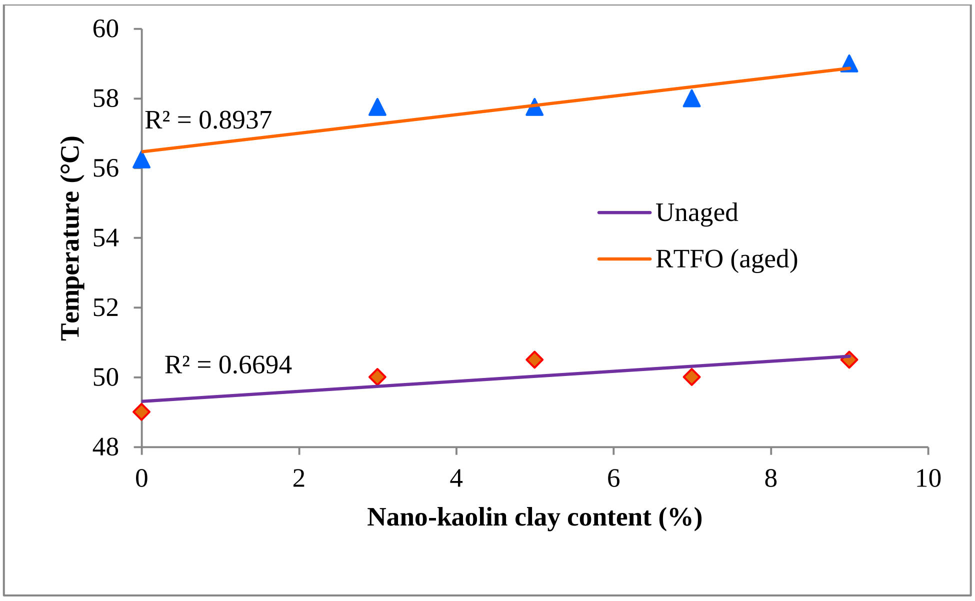

Figure 2. Relationship between softening point value and NKC content

3.2. Storage Stability of NKC Modified Asphalt
The storage stability test was conducted to ensure that the blending process was effective and the modified binders would remain stable during storage. According to Sadeghpour *et al.* [15], stability storage is a critical property for modified binders because of the differences in the solubility parameter and density between the modifier and binder, phase separation would take place during storage at elevated temperatures. Figure 3 shows a comparison between the control and modified binders in terms of their storage stability. In general, increasing the percentage of modifiers would increase the difference in the softening point values between the top and bottom sections. From the result, the difference between the top and bottom sections was less than 2.2 °C for all percentages of modified binder. Therefore, it can be said that NKC modified binder improved the storage stable blend.

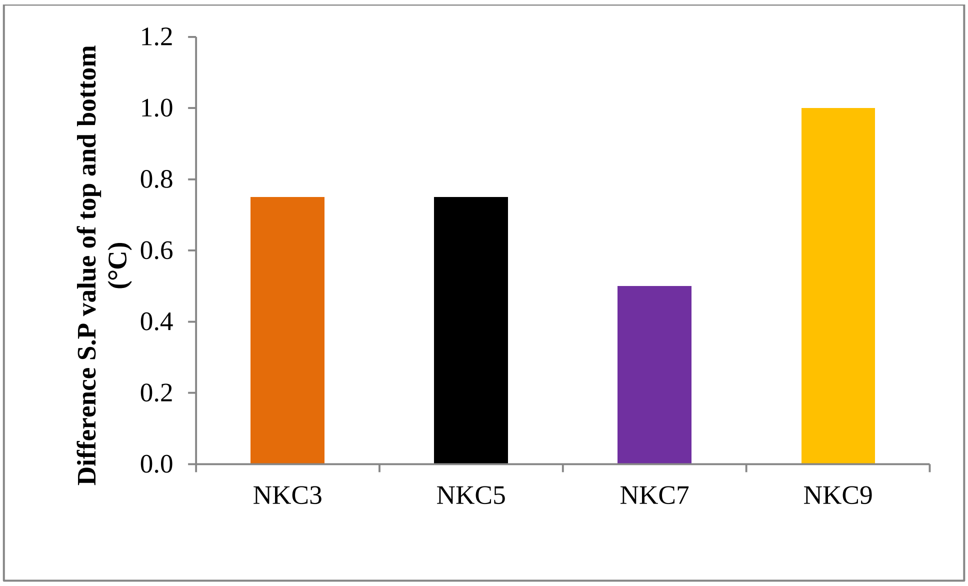

Figure 3. Storage stability test result for NKC modified binders

4. Conclusions

In this investigation, nano kaolin clay was evaluated in different levels *i.e.* 3%, 5%, 7%, and 9%, correspondingly. From the extensive laboratory work analysis, the softening point of the modified binders shows that the addition of NKC an increase in softening point. The modified binder with 5% NKC content showed the highest softening point. This indicated that lower sensitivity of bitumen towards temperature. In addition, high-temperature storage stability test proved that the NKC modified asphalt binder has good thermal storage compatibility. The temperature difference between the top and bottom section are within the allowable range, which is less than 2.2 °C for all percentages of modified binder.

5. References

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