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Marshall stability properties of asphaltic concrete with kaolin clay under aging

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Abstract. The influence of kaolin clay on marshal stability properties of asphaltic concrete AC14 at different aging conditions was presented in this study. These aging conditions were named as un-aged, short-term, and long-term aging. The conventional asphalt binder of penetration grade 60/70 was used in this investigation. Four different levels of kaolin clay replacement were employed (i.e. 0%, 3%, 6%, and 9% by binder weight). Asphalt concrete mixes were prepared at selected optimum asphalt content (5%). The performance was evaluated based on Marshall Stability and voids characteristics. Results indicated the improving stability performance that the mixes modified with kaolin clay have under aging conditions. The result also showed that the use of 6% to 9% kaolin clay can produce more durable asphalt concrete mixtures with better serviceability.

1. Introduction

As the construction industry show increasing growth rate, lack of natural material resources need to be concerned for. The tremendous usage of virgin materials in construction hence less number of resources left worrying many people [1]. One of the construction materials is bitumen. Most of the pavement constructions need to use bitumen in order to bind all of the road materials [2]. The quality and performance of pavements nowadays usually not sustain for a long time. A lot of deterioration occurs on the pavement which affecting the activities of the population and costly due to maintenance and reconstruction [3]. Hence, through this study, the natural resources such as kaolin clay can be preserving, the environment can be protected and lesser materials cost with the replacement of waste materials into asphaltic concrete. In the past decades, extensive research has been carried out to investigate kaolin clay or meta-kaolin performance relative to concrete properties. However, no information is available on the study of asphaltic concrete using kaolin clay based on most existing literature. Thus, the current study focuses on the effects of kaolin clay on the Marshall properties of asphalt mixture. Aging is a natural phenomenon. Aging of binders is known to result in harder and more brittle binder [4]. Some binders are observed to age faster and hence become harder faster than others. Many researchers [5,6,7] have been evaluated the aging effects on asphalt binders since their properties can be easily measured using many conventional tests, such as rotational viscometer, dynamic shear rheometer, bending beam rheometer, and others. However, studies on asphaltic concrete containing kaolin clay at different aging condition is rather limited especially its stability, resilient modulus, air voids and others [8,9,10]. Therefore, there is a need to investigate the effects of aging on asphalt mixture properties prepared using kaolin clay.

2. Materials and methods

2.1. Bitumen and aggregate
The binder used in this study was a 60/70 PEN supplied by Chevron Malaysia. According to the manufacturer's specification, the softening point and penetration was 52 °C and 68 dmm at 25 °C, correspondingly. Crushed aggregates supplied by the Hanson Quarry in Johor were used throughout this investigation. The coarse and fine aggregates each had a specific gravity of 2.64 and water absorption of 0.48 and 0.86% respectively. The aggregate gradation of AC14 was designed based on the mean of the gradation limit according to the JKR specification [11] as presented in Table. 1.

Table 1. Aggregate gradations for AC14 used in this study [11].

Mix	**AC14 gradation**		
Sieve size (mm)	Lower Limit (%)	Upper Limit (%)	Mass Passing (%)
20	100	100	100
14	90	100	95
10	76	86	81
5.0	50	62	56
3.35	40	54	47
1.18	18	34	26
0.425	12	24	18
0.150	6	14	10
0.075	4	8	6

2.2. Mix preparation
Firstly, kaolin clay was sieved to form a size less than 75 μm. Kaolin clay was used to replace virgin bitumen at 3%, 6%, and 9% by total of weight. A 0% was represented the control sample. At the laboratory, the aggregates were first mixed into batches according to the designated gradations and weight, and then heated in an oven at the designated mixing temperature before the mixing process. The heated aggregate batches were then mixed with a specified amount of bitumen. These materials were mixed at 170 °C until the aggregate was coated well with the bitumen. The mixes were compacted with 75 blows on each side with the standard Marshall hammer. After compaction, the specimens were removed from the moulds and allowed to cool overnight.

2.3. Marshall stability test
The Marshall Stability method was used in accordance with BS EN 12697-34 [12]. Based on standard, the specimens were prepared with the specified temperature by immersing in a water bath at a temperature of 60°C±1°C for a period of 45 minutes. It was then placed in the Marshall Stability testing machine and loaded at a constant rate of deformation of 50.8 mm/minute until the maximum load was reached.

2.4. Aging test
The aging method used in this study was based on the Strategic Highway Research Program (SHRP) procedures as described in AASHTO R30-02 [13]. In the first step, laboratory prepared loose mix asphalt was placed in a tray and conditioned in a forced draft oven for 4 hours at the mix compaction temperature. Then mixes were compacted. In the second step, the compacted specimens were placed

in a forced-draft oven, pre-heated to 85 °C, and left for five days. Long-term oven aging at 85 °C is recommended for aging test. After the aging period, the oven was turned off and left to cool to room temperature. The specimens were then removed from the oven and tested no less than 24 hours later. Different aging process was identified with labels composed of three characters i.e. UA, STA and LTA were used to represent un-aging, short term aging and long term aging, respectively.

3. Results and discussion

3.1. Stability

Figure 1 shows the results of stability asphalt mixture at different percentage kaolin clay and aging condition. It can be seen that the stability of un-aging samples for each replacement percentage increased steadily by increasing kaolin clay. Un-aging samples at 3%, 6%, 9% replacement had higher stability compared to controlled samples with an increment of 27.8%. 28.8% and 29.79%. The highest stability of un-aging samples was found at 9% kaolin clay. From Figure 1, short-term aging samples have lower stability when compared to long-term aging and each percentage follows the same trend. Generally, the highest stability for short-term aging was at 9% while for long-term aging at 6%. It can be said that stability value increased from time to time due to the reaction of kaolin clay properties such as silicon dioxide and aluminium oxide with the oxidation of bitumen [14].

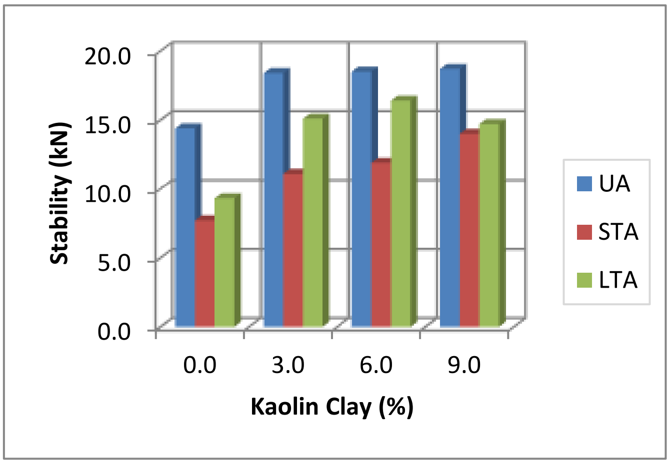

Figure 1. Stability of asphalt mixture with kaolin clay at different aging.

3.2. Voids in total mix

Figure 2 represents the VTM of each percentage of kaolin clay replacement at the different aging condition. VTM shows drop in value when a replacement of kaolin clay used, but increased steadily when the percentage of kaolin clay being replaced is high volume. The VTM of modified samples are 6 to 23% lower than controlled samples but achieved 17% higher than controlled samples at 9% replacement. Thus, the lowest VTM is recorded 3% replacement. In term of aging comparison, short-term aging samples have higher VTM when compared to long-term samples. However, 3% kaolin clay for short-term samples has the lowest VTM while for long-term aging was achieved the lowest (6% kaolin clay).

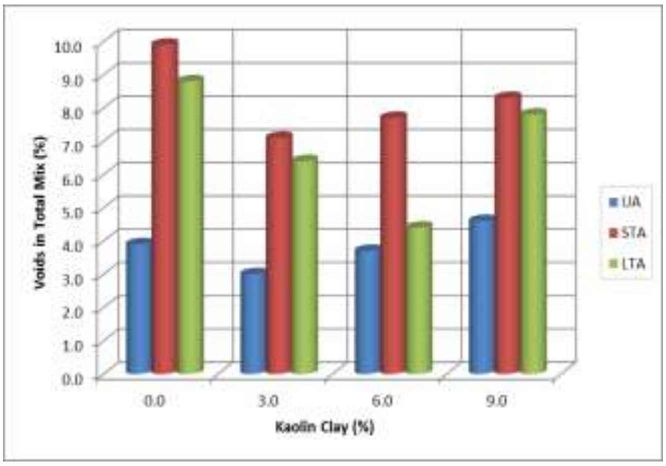

Figure 2. VTM of asphalt mixture with kaolin clay at different aging.

3.3. Stiffness

The stiffness of asphaltic concrete containing kaolin clay at different level replacement and aging was illustrated in Figure 3. The results show that the stiffness of samples dropped when kaolin clay being replaced up to 3%. There are 29% lower than controlled samples. The value increased was about 15% (3% kaolin clay) and dropped 3% when kaolin clay level increased up to 9%. So, kaolin clay at 6% replacement has the highest stiffness compared to 3% and 6%, respectively. In term of aging conditions, long-term samples have higher stiffness compared to short-term samples. Generally, the highest stiffness value for short-term and long term aging samples was achieved at 6% kaolin clay. Previously, Jeffry et al. [15] reported that the higher the stiffness, the higher the strength of samples but until it reaches optimum point.

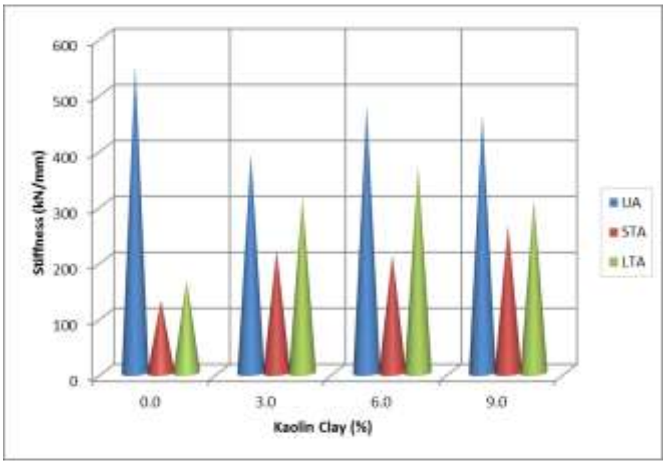

Figure 3. Stiffness of asphalt mixture with kaolin clay at different aging.

3.4. Flow

Figure 4 represents the flow of asphalt mix with kaolin clay at varying percentage and aging condition. The results indicate that 0% kaolin clay replacement shows the lowest flow when compared to other percent of replacement. At 6% kaolin clay in asphalt mix have the second lowest of flow with a difference of 49% higher than the controlled samples. Flow for short-term samples for each percentage was higher than the long-term aging. However, at 6% kaolin clay replacement has the highest flow for short-term aging, while at 3% kaolin clay has achieved the highest flow for long-term aging. It can be said that lowest flow value encourages higher deformation resistance, thus 6% of kaolin clay replacement is the best value in term of flow.

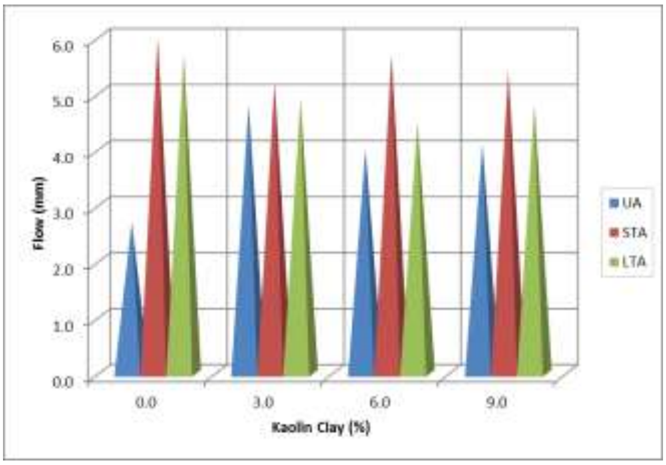

Figure 4. Stiffness of asphalt mixture with kaolin clay at different aging.

4. Conclusions

The effect of kaolin clay on the marshal stability properties of asphalt mixture under different aging was investigated. It can be seen that the addition of kaolin clay as binder replacement materials was show good improvement to the performance of asphaltic concrete. Generally, the results show that when compared among substitutes level, the use of 6% to 9% kaolin clay resulted in good stability of mixtures. In term of aging conditions, long-term aging have higher performance compared to short-term aging.

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Acknowledgments
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