PAPER • OPEN ACCESS

Performance of asphalt mixture incorporating kaolin clay at different aging

To cite this article: P J Ramadhansyah *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **220** 012004

Performance of asphalt mixture incorporating kaolin clay at different aging

P J Ramadhansyah[1], H Awang[1], M S Nur Amirah[2], M S Mohd Khairul Idham[2], Y Haryati[2], H Mohd Rosli[2], A H Norhidayah[2], M W Muhammad Naqiuddin[2], Abdul Rahim Abdul Hamid[2] and M H Mohd Rosli[3]

[1]Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia
[2]Faculty of Engineering, School of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia
[3]School of Civil Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia
Corresponding author: ramadhansyah@ump.edu.my

Abstract. In the fast-changing construction industry, the usage of natural material resources is tremendous. In order to comply with the demand of construction, waste materials have been used as a replacement of natural mineral resources. In pavement engineering, waste materials can be added into road composition. Kaolin clay is one of industrial waste materials successfully been used as a replacement of cement in concrete, but in the pavement, it has lack extensive study. In this investigation, kaolin clay partially replaced bitumen and the performance of aged asphaltic concrete AC14 were investigated. Kaolin clay replaced bitumen at 0%, 3%, 6% and 9% by weight of bitumen were used through this study. Tests conducted to measure the mixture performance were Marshall Stability, resilient modulus and dynamic creep test. Generally, it shows that the samples of unaged and long-term aging of asphalt mixture containing kaolin clay at 6% to 9% showed excellent, while 9% kaolin clay were most favorable for short term aging.

1. Introduction

As the construction industry show increasing growth rate, lack of natural material resources needs to be concerned for [1]. The tremendous usage of virgin materials in construction hence less number of resources left worrying many people. One of the construction materials is bitumen. Bitumen which is a black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation is used as the glue for aggregate to form pavement. Most of the pavement in the world needs to use bitumen in order to bind all of the road materials. Clay has been used widely in industrial activity as it shown tremendous advantages in the application [2]. Clay can be categorized into 4 types; common clay, industrial kaolins, bentonite, and palygorskite–sepiolite [3]. For industrial kaolins, the major material proportion is kaolinite and a small portion of high-quality kaolin minerals [4]. Every year, processed-kaolin had been producing about 20 million ton. A long time before, kaolin has already been used functioning as filler in plastic and rubber [5]. It also used in making ceramic products. Porcelain, bone china, vitreous sanitary ware, and earthenware are using high pure kaolin while the low-quality kaolin was used as filler to brick, pipes, and tiles [6]. Kaolin is widely known as white and soft clay which exhibits plasticity with the composition of fine-grained plate-like particles. It is formed from the alteration of anhydrous aluminate silicates in feldspar-rich rocks like granite through weathering or hydrothermal processes. The microstructure of kaolin comprises grains with a number of different morphologies such as regular and irregular hexagonal platelets, rolled sheets, co-axial sheets, and sometimes tubes [7]. When amorphous silica and specific surface both in high amounts, it contributes to the pozzolanic reaction [8]. Every natural pozzolanic material has these material properties, which clay capable to do so [9]. Kaolin has been used in research as the cement replacement partially in the construction industry [10]. It has been used to increase the durability of mortars and cement after the process of clay calcining [11]. By introducing this approach, less amount of cement will be used. In the manufacturing process of cement, it requires a huge amount of energy which at contributes to CO_2 emission at the same time [12]. Without precaution and awareness, it enhances the global warming phenomena which are bad for the environment.

2. Materials and methods

2.1. Aggregate and Binder

Aggregates that were used in this study were AC14 which means that the nominal maximum aggregate size in the asphalt mixture is 14 mm (see Figure 1). While bitumen with penetration grade 60/70 is selected as the binder for the asphalt mixture.

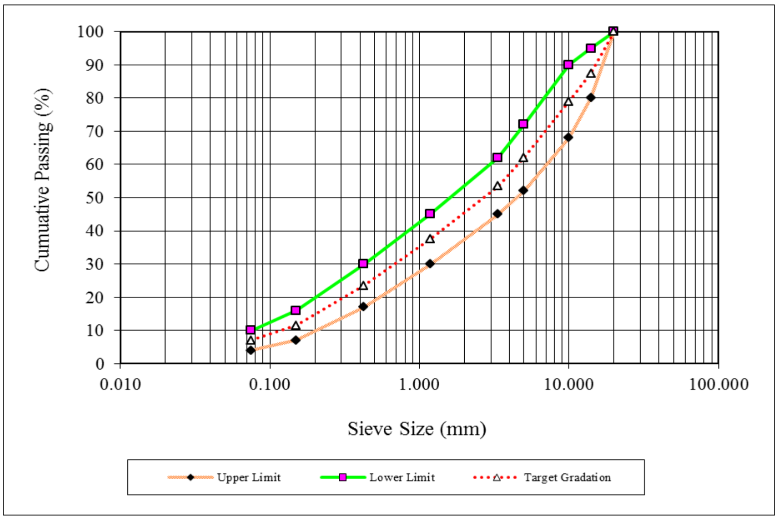

Figure 1. Aggregate gradation of asphaltic concrete AC14 [13]

2.2. Kaolin

Kaolin clay 5M was used in this study. 5M refers to the concentration of sulphuric acid that has been refluxed towards natural kaolin. Kaolin with size passing through the 75 μm sieve was used as partially bitumen replacement in the mixture.

2.3. Mix preparation

Ordinary Portland cement and hydrated lime were used as filler in this investigation. The 60/70 PEN bitumen was used as binder for mix preparation. The aggregates were first mixed into batches according to the designated gradations and weight. These batches were then heated in an oven at the designated mixing temperature for at least 4 hours before the mixing process. The heated aggregate batches were then mixed with a specified amount of 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.

2.4. Resilient modulus test

This test identified the material stiffness under the different condition such as density, moisture and stress level. Asphalt Universal Testing Machine (UTM) was used in order to measure the indirect tensile strength of specimens in repeated loading. Testing's were done at 25°C and 40°C after 4 hours of conditioning. These tests were carried out according to ASTM D7369-11 [14].

2.5. Dynamic creep test

In order to predict specimen permanent deformation characteristics which is rutting, dynamic creep tests were performed. Samples were conditioned for 4 hours in Asphalt Universal Testing Machine (UTM) at 40 °C and tested with 300 kPa applied stress. The tests were carried out based on BS EN 12697-26:2012.

2.6. Short and long term aging test

Short-term (ST) aging method was conducted based on AASHTO R30-02 [15] description, loose mix mixtures were spread out evenly in a pan with the thickness ranging between 25 to 50 mm. Then, it was placed in a faced draft oven for 4h ± 5 min with 135 ± 3 °C temperatures. The mixtures were stirred at 60±5 min interval to avoid the uneven condition. The samples were compacted by Marshall Compactor after 4 hours inside the faced draft oven. For long-term (LT) aging, by using the same specimen that has undergone the short-term aging process, the specimens were put and left in a pre-heated forced-draft oven at 85 °C for 5 days straight. After 5 days, the oven was turned off and cooled down until room temperature by its own. Then, samples need to be taken out and tested within 24 hours after being taken out from the oven.

3. Results and discussion

3.1. Stability

Figure 2 shows the relationship of asphaltic concrete at different replacement percentage and aging condition. The modified samples had higher stability compared to un-aged (UA) samples. The stability of UA samples for each replacement percentage increased steadily by the increasing of kaolin clay. The UA 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 UA samples was at 9%. Short-term samples have lower stability compared to long-term samples and each percentage follows the same trend. The highest stability for short-term samples was at 9% while for long-term samples at 6%. Stability value increased from time to time due to the reaction of Kaolin properties such as silicon dioxide and aluminium oxide with the oxidation of bitumen.

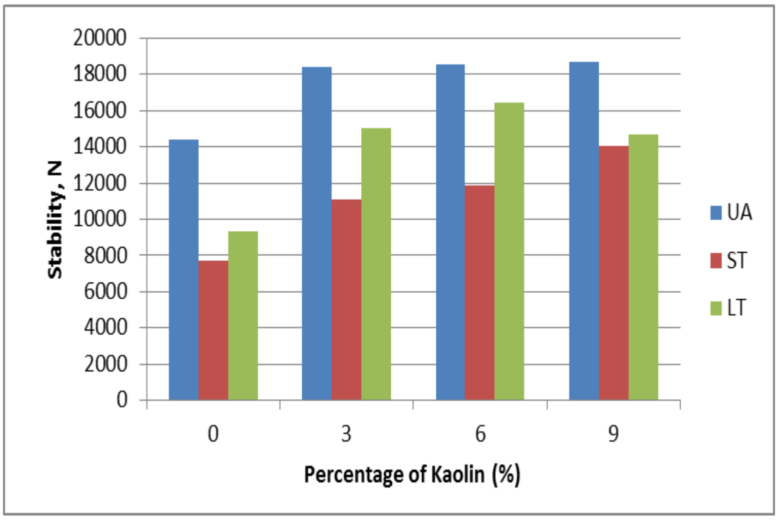

Figure 2. Stability at different aging condition

3.2. Resilient modulus

3.2.1 Conditioned at 25°C

Figure 3 illustrated the relationship between resilient modulus at 25 °C conditioning with different replacement percentage and aging condition. With the increasing amount of Kaolin replacing bitumen, the resilient modulus achieved also increasing. The resilient modulus value for unaged samples 3%, 6% and 9% increased with 23.3%, 24.7% and 39.4% higher than the controlled samples respectively. Based on un-aging results, samples at 9% Kaolin has the highest modulus of resilient. Long-term samples showed higher modulus of resilient compared to short-term aged samples. The highest resilient modulus for short term and long term samples were achieved at 9% Kaolin replacement. Resilient modulus at 25% was identifying the stiffness of the samples. Higher resilient modulus portrays stiffer and less flexibility of samples.

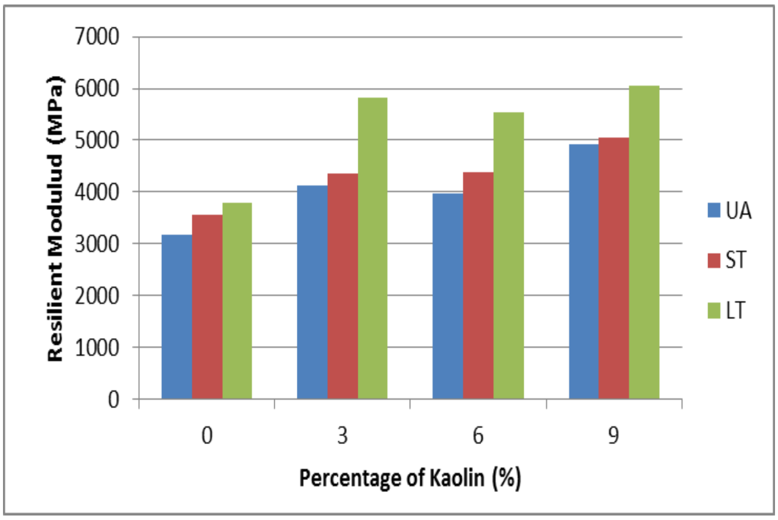

Figure 3. Resilient Modulus at different aging condition for 25 °C

3.2.2 Conditioned at 40 °C

The relationship of resilient modulus at 40 °C with a varied percentage of kaolin and aging condition is shown in Figure 4. Resilient modulus of samples tested at 40 °C was lower than those tested at 25 °C. The resilient modulus for unaged samples (3%, 6%, and 9%) showed increment compared to controlled samples with 94%, 130.12% and 112.25% higher. It is increasing steadily up to 6% and drop down to 9%. Therefore, the highest resilient modulus for un-aging is at 6% Kaolin replacement. From the figure also illustrates long-term samples had higher resilient modulus compared to unaged and short-term aged samples. For short term and long term samples, 9% replacement had achieved the highest compared to the other samples. Resilient modulus tests at 40 °C were done to identify the rutting of samples.

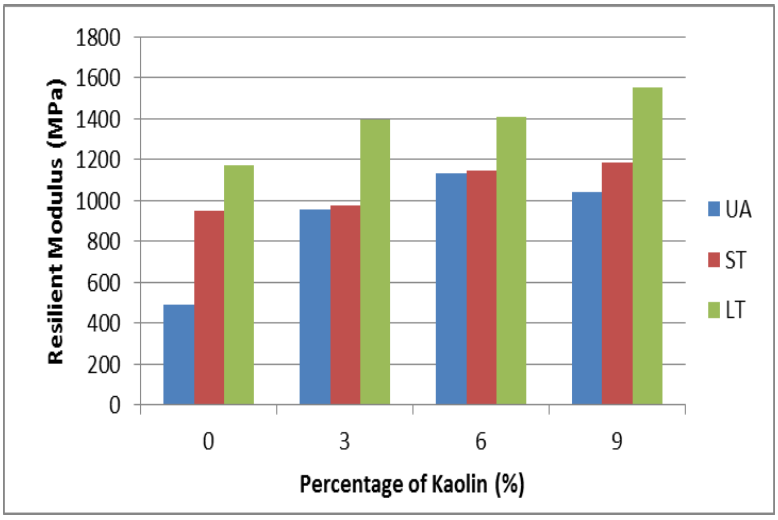

Figure 4. Resilient Modulus at different aging condition for 40 °C

3.3. Dynamic Creep

Dynamic creep modulus of each percentage at different aging condition was shown in Figure 5. With the increasing amount of Kaolin were added into the mixture, the creep modulus of un-aging samples also increased. The highest creep modulus was achieved at 9% Kaolin replacement with 89% higher than controlled samples. At 3% Kaolin replacement samples had 24% lower creep modulus compared to controlled samples while 6% Kaolin replacement is 41% higher than controlled samples. 9% samples aside, long-term samples for 0%, 3%, and 6% has higher creep modulus values compared to short-term samples. The highest creep modulus for short-term samples was achieved at 9% Kaolin replacement, while for long-term samples at 6% Kaolin replacement. The increasing of creep modulus values indicates greater difficulty for samples to deform and lessen the rutting potential.

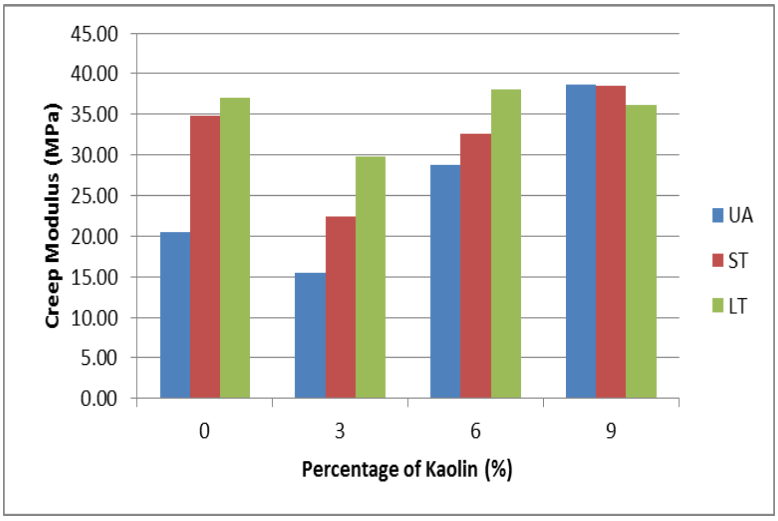

Figure 5. Creep Modulus at different aging condition

4. Conclusions

Based on the stability, resilient modulus and dynamic creep tests, the performance of asphaltic concrete were recommended at 9% of Kaolin clay replacement. Aging process definitely affected the performance of asphaltic concrete due to the oxidation of bitumen and reaction of Kaolin properties. The long-term aging samples had higher stability compared to short-term samples. Aged samples exhibit stiffer state as the values of resilient modulus were higher. It also possesses greater resistance towards deformation due to higher creep modulus.

5. References

[1] Karlsson R and Isacsson U 2006 *J. Mater. Civil. Eng.* **18** pp. 81-92.
[2] Ouyang C, Wang S, Zhang Y and Zhang Y 2005 *Polym Degrad Stab.* **87** pp. 309-317.
[3] Barata M and Angélica R 2011 *Matéria.* **16** pp. 797-810.
[4] Metin A, Konstantin S, Tomris E, Asim Y and Pelin T 2009 *Constr. Build. Mater.* **23** pp. 62-70.
[5] Samet B, Mnif T and Chaabouni M 2007 *Cem. Concr. Compos.* **29** pp. 741-749.
[6] Gonçalves J P, Tavares L M, Toledo Filho R D and Fairbairn E M R 2009 *Constr. Build. Mater*. **23** pp. 1971-1979.
[7] El-Shafie M, Ibrahim I M and Abd El Rahman A M M 2012 *Egypt. J. petrol*. **21** pp. 149-154.
[8] Dewi S J, Ramadhansyah P J, Norhidayah A H, Hainin M R and Mohd Haziman W I 2014 *Appl. Mech. Mater.* **554** pp. 203-207.
[9] Motahareh M, Akram T, Mir Karim R A and Mohammad R 2016 *Constr. Build. Mater.* **116** pp. 245-251.
[10] Hainin M R, Jaya R P, Akbar N A A, Jayanti D S and Yusoff N I M 2014 *J. Eng. Res.* **2** pp. 34-46.
[11] Luísa G A T F, Janaina L L, Bruno de C A, Juceline B S B, Jorge B S, Sandra de A S and Hosiberto B de S 2016 *Constr. Build. Mater*. **125** pp. 873-883.
[12] Ramadhansyah P J, Abu Bakar B H, Megat Azmi M J and Wan Ibrahim M H 2011 *Int. J. Technol*. **2** pp. 10-19.
[13] JKR/SPJ/2008-S4 2008 *Standard Specification for Road Works Section 4: Flexible Pavement*. Malaysia
[14] ASTM D7369 2011 *Standard Test Method for Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension Test*. ASTM International, West Conshohocken, PA, USA.
[15] AASHTO R30-02 2005 *Standard Practice for Mixture Conditioning of Hot-Mix Asphalt (HMA)*. American Association of State Highway and Transportation Officials, Washington, USA.

Acknowledgments

The support provided by Malaysian Ministry of Higher Education and Universiti Malaysia Pahang in the form of a research grant (RDU/UMP) vote number RDU1803160 for this study are highly appreciated.