VOL. 11, NO. 20, OCTOBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RHEOLOGICAL PROPERTIES OF NANOCLAY AS NEW NANOTECHNOLOGY OF APSHALT CONCRETE: REVIEW

Nurulain C. M, Ramadhansyah P. J and Norhidayah A. H
Faculty of Civil Engineering and Construction Research Alliance, Universiti Teknologi Malaysia, Skudai, Malaysia
E-Mail: ann_nuri@yahoo.com

ABSTRACT

This paper aim to review literature of applies nanoclay to asphalt in order to improve asphalt concrete pavement. Nowadays, nanotechnology is one of a new creation that has been applied in most area. One of them is in asphalt concrete pavement where engineer and researcher use nanoclay for asphalt modification. The fundamental material characterization testing i.e. penetration, softening point and Dynamic Shear Rheometer was performed on conventional and modified asphalt. In addition, the Marshall Stability and ductility were examined. In previous study, asphalt type 60/70 PEN with the percentage of nanoclay were added were 2%, 4%, 6% and 8% by weight of asphalt. According to previous research they were proved that nanoclay as modified asphalt increase in softening point; kinematics viscosity and decrease in binder penetration. The overall performance of nanoclay as modified asphalt binder is improved in terms of rutting and fatigue cracking resistance. The best improvement in the modified asphalt binders were obtained with 6% nanoclay.

Keywords: polymer modified asphalt, nanotechnology, and nanoclay

INTRODUCTION

Over the years, with the increase of traffic loading and number of heavy vehicles, many pavements tends to fail prematurely either structurally or functionally even though they have designed to last longer. Repeated application of traffic loads can cause structural damage to asphalt pavement which can cause permanent deformation particularly rutting along the wheel tracks. Besides that, environment factors such as temperature and moisture also can have a significant impact on pavement material and the sub grade soil, which will affect pavement performance [1]. There are two ways that temperatures can affect the pavements. First, temperature will affects the rheology (deformation and flow characteristics) of an asphalt binder, and second, temperatures variations cause expansion and contraction in asphalt pavement [2]. Another factor to be considered is problems of exposure to sunlight which will cause a pavement's surface to age more quickly making pavement surface more brittle and prone to cracking and ravelling.

Improper design can lead to early pavement failure which can affect the riding quality [3]. In order to minimize the deterioration and increase the service life of the designed road, the bituminous layers should be improved with regard to performance properties, such as resistance to permanent deformation, fatigue, wear, stripping, aging and etc. [4]. Recently, the substitution of industrial material as a modifier to modify asphalt properties has been taken into consideration, in order to reduce life cycle costs and obtain environmental benefits. The use of nanoclay could increase the shear complex modulus and reduces the strain failure rate of base asphalt [5]. Besides that, the addition of nanoclay would decrease the moisture damage of asphalt pavement [5, 6].

Nanoclay in asphalt mixture and performance

Nanoclay is one of the nanotechnology where the clay can be modified to make a clay compatible with organic monomers and polymers. Over the year, with new research and study there are proved that nanotechnology allow the design of system with high functional density, high sensitivity, special surface effects, large surface area, high strain resistance and catalytic effects. All attributes are directly or indirectly the result of the small dimensions of nano-particles [7, 8].

Research conducted by Jahromi [9] used PEN 60/70 with two different types of nanoclay which are *cloisite-15A* and *nanofil-15*. The result shows that the nanoclay asphalt modification helps to increase the stiffness and ageing resistance. It was found that the *nanofil* particles are curly and smaller size compare to the *cloisite* particles. The existing plastic limit of nanoclay shows that it is an expansive characteristics material. Therefore, a low percent of nanoclay in bitumen leads to the changes in rheological parameter, decreasing penetration and ductility as well as increasing softening point and ageing resistance. Shahabadi [10] conducted study on two different clay which are bentonite clay (BT) and organically modified bentonite (OBT). The result proved that with addition of BT and OBT shown greater softening point, increase viscosity, higher complex shear modulus, lower phase angle and improve rutting resistance compare to unmodified asphalt.

Research conducted by El-Shafie [11] converted macroclay to nanoclay and was confirmed by X-ray diffraction (XRD) and prove that, since the high dispersion, the large surface area of nanoscopic level of clay, and the stiffening behaviour of nanoclay as they form bond chains within the binder, physical and mechanical properties of binders are significantly improved. Jahromi [12] conducted test with two different types of nanoclay which are *Nanofil-15* and *Cloisite-15A*. Test results show that nanoclay can improve properties such as stability, resilient modulus and indirect tensile strength and result in superior performance compared to that of unmodified bitumen under dynamic creep. However they found that nanoclay do not seem to have beneficial effects on fatigue behaviour at low temperatures.

EXPERIMENTAL DESIGN

Binder

The binder used by Jahromi and El-Shafie [9, 11] in their studies was a conventional penetration grade 60/70 with aggregate type AC-10. Percentages of Nanoclay were added to the mixture are 2%, 4%, 6% and 8%.

Nanoclay

There are 2 common types of nanoclay which are Cloisite and Nanofil and both nanoclay are most applicable as modified binder. In order to know the properties of nanoclay several rheological and physical test was conducted for unmodified and modified asphalt which are penetration test (ASTM D5 -86) and softening point (ASTM D36) while for fundamental rheological test is dynamic shear rheometer (DSR) (ASTM D7175).

Jahromi [9] mention in their study that the modification of asphalt with nanoclay was performed at nanoscale level with thermodynamic driving force. The melt intercalation process was applied to make nanoclay-asphalt nanocomposite. Thus, nanoclay is directly mixed with the asphalt matrix in the molten state and then separated their force. In order to mix this material, asphalt must be heated first up to 150 ^{o}C and subsequently with nanoclay added, shear force are applied by special cog-disk blade with mechanical stirrer at speed 550 rpm for 30 minutes.

RESULT AND DISCUSSION

Penetration

The penetration value decreases as the content of Nanoclay increases. El. Shafiq [11] studies on comparison between unmodified clay (macro-scale) and modified clay (nano-scale). The results show that the bitumen becomes more viscous and harder, which would be useful to obtain stiffer asphaltic concrete. This is an indication of an enhanced resistance against permanent deformation of the asphaltic concrete using Nanoclay modified bitumen during the service life of pavement. There are also other research conducted by Saeed [9] where they compare the penetration between *Cloisite* and *Nanofil*. *Cloisite* seem to be more viscous and harder come to *Nanofil*. However, Nanofil still more viscous compare to unmodified mixture.

Softening point

Polymer modified asphalt gives a higher softening point temperature compare with unmodified asphalt. While, asphalt modified nanoclay composite gives a higher softening point temperature respectively compared with unmodified binder. The effect of nanoclay modified asphalt are less sensitive to high temperature changes and may also be more resistant to plastic deformation (rutting) compared to unmodified asphalt. There are some improvements in the resistance to ageing in the long term due to the *Nanofil-15* modification and therefore probably suffer less when contact with hot air or hot oxygen [11].

Dynamic shear rheometer (DSR)

Zhanping [4] found that as the frequency increases to 100 Hz (or traffic loading time decreases), the nanoclay molecules play less role in bearing the shearing load compared to low frequency or increased traffic loading where the action of the nanoclay molecules starts to become prominent. Therefore, it could be stated that at low frequency, both the action of the asphalt binder and nanoclay are significant, and at high frequency, the asphalt binder tends to become more significant than the nanoclay.

CONCLUSIONS

Nanoclay modified asphalt proved that it help to increase the stiffness and ageing resistances trough tests performed. Adding nanoclay in asphalts normally increases the viscosity of asphalt binders and improves the rutting and fatigue resistance of asphalt mixtures. Besides that, it is an expectation that study at nano-scale level will provide sufficient information regarding to the behaviour and reaction among pavement materials in which will affect the later performance at macro-scale level. However they found that nanoclay do not seem to have beneficial effects on fatigue behaviour at low temperatures. Different types of nanoclay and variation on percentage of nanoclay added into binder also will affect the final result. The ongoing research will focus on porous asphalt mixture in term of resistance to thermal cracking performance and rutting resistance of the nanoclay-modified asphalt.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the Universiti Teknologi Malaysia and special thanks go to the numerous laboratory personnel from the Transportation Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia who assisted in conducting this study.

REFERENCES

[1] Information on http://www.hawiiasphalt.com.htm

[2] Hunter N. R. 2000. Asphalt in road construction London. Thomas Telford Ltd. London. pp. 77.

[3] Johnston J. and Gayle K. 2009. Polymer modified asphalt emulsion: composition uses and specifications for surface treatment. FHWA Publication.

[4] Zhanping Y. Beale M. J., Foley J. M., Roy S., Odegard G. M., Dai Q. and Goh S. W. 2011. Nanoclay modified asphalt materials: preparation and characterization. Journal of Construction and Building Materials. 25(2): 1072-1078.

[5] Goh S. W., Akin M., Zhanping Y. and Shi X. 2011. Effect of deicing solutions on the tensile strength of micro- or nano-modified asphalt mixture. Journal of Construction and Building Materials. 25(1): 195-200.

[6] Polacco G., Kriz P., Filippi S., Stastna J., Biondi D. and Zanzotto L. 2008. Rheological properties of asphalt/SBS/clay blends. Journal of European Polymer Journal. 44(11): 3512-3521.

[7] Teizer J., Venugopal M., Teizer W. and Felkl J. 2012. Nanotechnology and its impact on construction: bridging the gap between researchers and industry professionals. Journal of Construction Engineering and Management. 138(5): 594-604.

[8] Yasmin A., Abot J. L. and Daniel I. M. 2003. Processing of clay/epoxy nanocomposites by shear mixing. Journal of Scripta Materialia. 49(1): 81-86.

[9] Jahromi S. G. and Khodaii A. 2009. Effects of nanoclay on rheological properties of bitumen binder. Journal of Construction and Building Materials. 23(8): 2894-2904.

[10] Shahabadi A. Z., Shokuhfar A. and Nejad S. E. 2010. Preparation and rheological characterization of asphalt binders reinforced with layered silicate nanoparticles. Journal of Construction and Building Materials. 24(7): 1239-1244.

[11] El-Shafie M., Ibrahim I. M. and Abd El Rahman A. M. M. 2012. The addition effects of macro and nano clay on the performance of asphalt binder. Journal of Egyptian Journal of Petroleum. 21(2): 149-154.

[12] Jahromi S. G. and Rajaee S. 2013. Nanoclay-modified asphalt mixtures for eco-efficient construction. Woodhead Publishing Series in Civil and Structure. pp. 108-126.