ISSN 2229-5518

Using of Nano Materials and Additives to Enhance the Hot Mix Asphalt

Mohammed Elsadek Ouf[a], Ahmed Ebrahim Abu El-Maaty Behiry[b], Saddam Shahrah[c]

aAssociate professor,Highways and Airports Engineering, Engineering Faculty, Civil Department, Helwan University,Egypt
bAssociate professor,Highways and Airports Engineering, Engineering Faculty, Civil Department, Minufiya University, Shibeen El-kom City, Egypt
c Graduate Student, Demonstrator, Faculty of Engineering, Department of Civil Engineering, Ibb University, Yemen

Abstract— In recent years, the use of nano materials for improving various mechanical and performance related properties of polymer-modified asphalt binders has been growing rapidly. However, few researches investigated the effects of base binder and styrene butadiene styrene (SBS) structure on the performance of polymer nano composite modified asphalt mixtures. In this paper, two different nano materials (nano clay and nano silica) and one additive (styrene- butadiene- styrene) were used with asphalt binder 60/70 to investigate the effect of using nano materials on the properties of bitumen. The modified binder was screened and selected according to conventional performance indicators of asphalt binder, including penetration and softening point test. The results showed that the nano silica and nano clay with SBS decrease the penetration and increase the softening point.

Index Terms— Asphalt binder, HMA, Nano clay, Nano silica, Physical properties, SBS.

1 Introduction

In the recent years, highway pavement construction industry has been rapidly progressing all over the world due to a dramatic increase in traffic loads. Traditional pavement materials are hard to meet the practical demands of present and future highway pavement construction. Thus, higher quality, more safety, more reliable and more environmentally friendly pavement materials are urgently demanded (Li et al., 2017).

Pavement lifetime is one of the most important issues to be taken into account in the economy and other reasons. Asphalt pavement distresses reduce the lifetime of the pavement, and to sustain the lifespan of the pavement, there is need to address this issue. Most common pavement modes of distresses is rutting damage which commonly happen in the form of permanent deformation and fatigue cracking damage (Bala et al., 2018).

For many years, when the loads on the pavements was not severe, different pure asphalts (unmodified binders) were combined to improve their properties. However, in recent years, by increasing the traffic volume, use of heavier axle loads, new axle configurations and higher tire pressures, the demands on the highway pavements and asphaltic layers have increased, requiring the enhancement of the performance of the existing asphaltic materials. Among additives, which are mixed with bitumen, there are polymers that are used mostly. Such polymers as styrene–butadiene–styrene (SBS), ethylene–vinyl acetate (EVA), styrene–ethylene–butylene–styrene (SEBS), polyethylene (PE) and polypropylene (PP), polyvinyl chloride (PVC). All of them have been tested in bituminous hot mixtures and it affect many parameters such as stability, resistance against moisture damage, fatigue, and rutting resistance (Zhang et al., 2018).

Several nano materials have the possibility to be utilized to modify asphalt, as, for examples, nano-sized hydrated lime, Nano-sized plastic powders or polymerized powders, Nano clay, Nano silica, Nano tubes and Nano fibers (Yusoff et al., 2014).

Ezzat et al., (2016) focused on the investigation of the properties of asphalt binder modified with different percentages of the two different nanomaterials. These materials are nano clay and nano silica. Three different nanomaterial percentages were mixed with the binder (3%,5% and 7%) . Results showed that, Nano silica synthesized from silica fume tends to decrease the penetration value and increase the softening point temperature. The Nano clay on the other hand was found to increase the penetration and decrease the softening point temperature.

Taherkhani and Afroozi. (2018) investigated the creep behavior of a typical asphalt concrete containing different percentages of nano-silica. The penetration grade of 60/70 asphalt cement was modified with different percentages of nano-silica (1, 3 and 5%, by weight of binder) and was used for making the asphalt concrete specimens. The asphalt concrete specimens were subjected to dynamic creep tests. Dynamic creep tests were conducted on different stress levels and temperatures. The results showed that, the flow increased and the steady-state strain rate decreased with increasing nano silica content, indicating the increase of resistance against permanent deformation.

Taherkhani and Afroozi. (2017) discussed the effects of nano-silica modification on some properties of a penetration

- *Mohammed Elsadek Ouf is currently pursuing associate professor in Highways and Airports Engineering, Engineering Faculty, Civil Department, Helwan University,Egyp. E-mail: drmohamedouf@hotmail.com*
- *Ahmed Ebrahim Abu El-Maaty Behiry is currently pursuing associate professor,Highways and Airports Engineering, Engineering Faculty, Civil Department, Minufiya University, Shibeen El-kom City, Egypt. E-mail: maaty5000@yahoo.com*
- *Saddam Shahrahis currently pursuing Graduate Student, Demonstrator, Faculty of Engineering, Department of Civil Engineering, Ibb University, Yemen. E- mail: saddamamin22@gmail.com*

grade asphalt cement and a typical asphalt concrete. 60/70 penetration grade bitumen was modified with different percentages of nano-silica (1, 3 and 5%, by weight) and was used for making the asphalt concrete specimens. After evaluated the basic properties of the modified binder, the asphalt concrete specimens were evaluated based on the stiffness and resistance against fatigue cracking, moisture damage and permanent deformation.

Bayekolaei et al., (2018) investigated the effects of base binder and styrene– butadiene–styrene (SBS) structure on rutting resistance of polymer-Nano composite modified asphalt mixtures and investigated the effect of polymer–nanocomposite modification, using two different penetration grade asphalt binders(85/100 and 120/150). The results indicated that both base binder type and SBS structure had significant effect on rutting resistance of polymer-nanocomposite-modified asphalt mixtures.

Bala et al., (2018) investigated the effect of nano silica particles on the performance characteristics of polymer modified asphalt binders. Used control 80/100 binder modified with polypropylene polymer and Nano silica particles at concentration of 0%– 4%. Both nano silica particles and polypropylene polymer were added by weight of total bitumen content. The asphalt performance tests flexural four point beam, fatigue test, indirect tensile strength, and indirect tensile stiffness modulus tests are conducted to evaluate the effect of nano silica particles. The results showed that nano silica particles improved fatigue properties of polypropylene polymer modified binder. This indicated that nano silica particles had significant effect on improving the performance properties of polymer-modified binders.

In this paper, nano clay and nano silica blended with Styrene-Butadiene Styrene (SBS) to asphalt binder will be studied.

2 Experimental

2.1 Materials

Two nano materials (nano clay (NC) and nano silica (NS) were used while, one additive styrene butadiene styrene (SBS) was added on asphalt binder 60/70. Table (1) and Table (2) presente properties of (NC) and (NS) respectively. Figure (1) and Figure (2) show the (NC) and (NS) used in this paper.

Table 1: (NC) Properties.

Property	Specification
Organic modifier	2M2HT
Density	0.5–0.7 g/cm3
X-ray result (d001)	31.5 A
Moisture content	1–2%
Specific surface area	220–270 m2/g
Weight loss on ignition	43%

Table 2: Nano Silica Properties.

Particle Name	Purity	Bulk density	Specific Surface Area	Particle Absorption Index	Concentration
Silica (RI 1.45, AI 0.01)	+ 99%	0.2 g/cm^3	140.3 m^2/g	0.010	0.2066 %

The main characteristics of (SBS) are explained in the Table (3). Figure (3) shows the particles of SBS.

Fig. 1. Nano Clay.

Fig. 2. Nano Silica.

Table 3: Explains the Main Characteristics of (SBS).

Properties	Test Method	Unit	Typical value
Specific gravity	ASTM-D792	g/cc	0.94
Tensile strength	ASTM-D412	Mpa	18
Elongation at break	ASTM-D412	%	700
300% Modulus	ASTM-D412	Mpa	2.5
Hardness	ASTM-D2240	Sh A	82
Melt flow Index	ASTM-D1238	g/10 min	1 (190°C,5kg)<
Brook field viscosity	ASTM-D1084	Pa .S	20(Toluene sol.25%wt.)

Fig. 3. SBS Particles.

The main characteristics of asphalt binder are explained in the Table (4).

Table 4: Physical Properties of Asphalt Binder 60/70.

Properties	Value	Standard
Penetration (100 g, 5 s, 25 °C), 0.1 mm	61	AASHTO - T49
Flash point, (°C)	250	AASHTO – T48
Softening point (°C)	49	AASHTO – T53
Viscosity at 135 (°C)	449	AASHTO - T201

2.2 Sample Preparation

Nano materials and SBS were prepared in a small container, by the addition of 5% SBS with (1%, 2% and 3%) of nano silica and nano clay particles by weight of the base bitumen binder. Nano particles were first dissolved on to 600g weight of base binder (60/70 Pen) prior to the addition of SBS polymer. When nano particles dissolves completely on the base binder, SBS was slowly added to the modified binder and sheared using a high shear mixer at a high shearing rate. A shearing rate of 1500 rpm was utilized for the mixing.

Throughout the mixing time, the temperature was maintained at 145 ± 5 °C for about 60 min to ensure thorough dispersion. Sixth modified asphalt binders beside the control binder were prepared and divided into three groups as shown in Table (5).

Table 5: Types of the Prepared Asphalt Binders.

Binder groups	Binder type	Sample code	Description
Group 1	Unmodified binder (Base asphalt)	Control	Asphalt binder 60/70 penetration grade (Control binder).
Group 2	(Modified binders) with Nano Clay.	NC3	Control asphalt +3%NC
Group 3	(Modified binders) with Nano Silica.	NS3	Control asphalt +3%NS
Group 4	(Modified binders) with Nano Clay and 5% of (SBS).	NC1SBS	Control asphalt +(1%NC+5%SBS)
		NC2SBS	Control asphalt +(2%NC+5%SBS)
		NC3SBS	Control asphalt +(3%NC+5%SBS)
Group 5	(Modified binders) with Nano Silica and 5% of (SBS).	NS1SBS	Control asphalt +(1%NS+5%SBS)
		NS2SBS	Control asphalt +(2%NS+5%SBS)
		NS3SBS	Control asphalt +(3%NS+5%SBS)

3 Results And Discussion

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

3.1 Effect of Nano Materials and SBS on the Softening Point

The effects of the addition of (nano clay+SBS), (nano silica +SBS) and nano materials only on the softening point of asphalt binder are presented in Figure (4). At first, all the modified asphalt binders show increaese the softening temperature than the control binder by approximately from 6 to 41 °C. It can be illustrated that the addition of nano materials improves the softening point compared with control sample. Moreover, it can be showed that the addition of SBS on (NC or NS) increases the softening point compared with nano only by about 6.6% and 16.5% respectively. It can be observed that the softening point value achieved the lowest increase by about 13.9% at NS3SBS binder. Moreover, it can be noticed that the softening point value achieved the highest increase by about 83.7% at NS2SBS binder. Whereas, the highest increases at NC2SBS binder by about 69.4%, thus at a content of (2%NC+5%SBS) and (2%NS+5%SBS), the best physical properties is achieved. This proves the increased hardness of the binder with the addition of (nano clay+SBS) and (nano silica+SBS) to some extent. Finally, the softening point is an indication of a decrease of temperature sensitivity, which in turn, increases the resistance against cracking at low temperatures and permanent deformation.

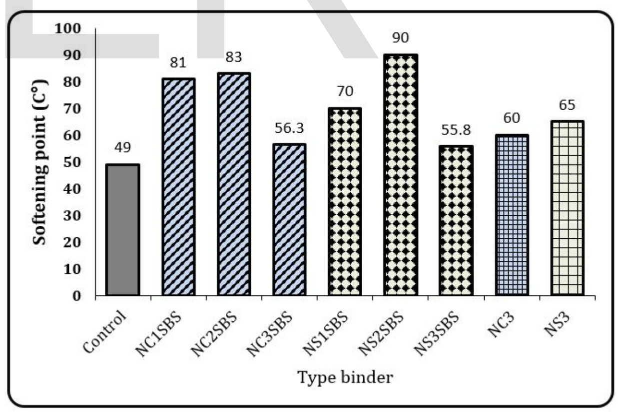

Fig. 4. Effect of Nano Materials and SBS on the Softening Point.

3.2 Effect of Nano Materials and SBS on the Penetration of Asphalt Binders

Figure (5) illustrate the effects of the addition of (nano clay+SBS), (nano silica+SBS) and nano materials only on the penetration of asphalt binders. It can be observed that the penetration values for all modified binders decrease comparing with the control binder by approximately from (16 to 24) mm. It can be obtained that the addition of nano materials only improves the penetration compared with control by about 16.4 % and 14.8% for NC and NS respectively. It can be illustrated that the lowest penetration value (37) was recorded at NS2SBS binder. While, it was (44) at NC2SBS binder. It can be showed that the addition of nano materials and SBS decreases the penetration compared with control binder. Moreover, it can be showed that the samples binder (NS2SBS and NC2SBS) achieve highest decrease in penetration values by about 39.3% and 27.9% respectively, thus at a content of (2%NC+5%SBS) and (2%NS+5%SBS), the best physical properties are achieved.

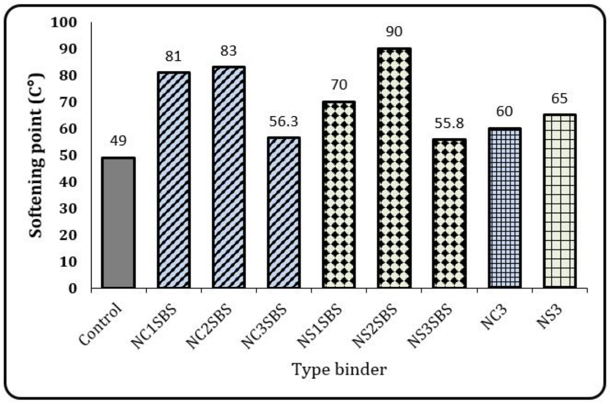

Fig. 5. Effect of Nano Materials and SBS on the Penetration.

4 Conclusion

The main objective of this paper work was to investigate the effect of using nano materials such as nano clay (NC) and nano silica (NS) blended with styrene butadiene styrene (SBS) as polymer additive on physical properties asphalt binders.
Based on the results obtained from this paper, the following conclusions can be drawn:

•The addition of nano materials only improved the physical properties, where, it increased the softening point and decreased the penetration value compared with control samples especially at 3% of (NC or NS).
•The addition of SBS on nano materials improved the softening point compared with the nano materials only specially at 3% of (NC or NS).
•The addition of SBS on nano materials improved the penetration value compared with the nano materials only specially at 3% of (NC or NS).
•At a content of (2%NC+5%SBS) and (2%NS+5%SBS), the best physical properties of the binder were achieved.
•It can be showed the addition of (2% nano silica+SBS) achieved better physical properties of binder than (2% nano clay + SBS).

References

[1] Bala, N., Napiah, M., & Kamaruddin, I. (2018). "Effect of nano silica particles on polypropylene polymer modified asphalt mixture performance". Case studies in construction materials, 8, 447-454.
[2] Bayekolaei, M. D., Naderi, K., & Nejad, F. M. (2018). "The effects of base binder and styrene–butadiene–styrene structure on rutting resistance of polymer–nanocomposite asphalt mixture". Journal of Elastomers & Plastics, 50(3), 256-275.
[3] Ezzat, H. (2016). "Evaluation of asphalt enhanced with locally made nanomaterials". Nanotechnologies v Stroitel'stve, 8(4), 42-67.
[4] Li, R., F. Xiao, S. Amirkhanian, Z. You and J. Huang (2017). "Developments of Nano materials and technologies on asphalt materials – A review." Construction and Building Materials 143: 633-648.
[5] Taherkhani, H., & Afroozi, S. (2017). "Investigating the Performance Characteristics of Asphaltic Concrete Containing Nano-Silica". Civil Engineering Infrastructures Journal, 50(1), 75-93.
[6] Taherkhani, H., & Afroozi, S. (2018). "Investigating the creep properties of asphaltic concrete containing Nano-silica". Sādhanā, 43(2), 24.
[7] Yusoff, N. I. M., Breem, A. A. S., Alattug, H. N., Hamim, A., & Ahmad, J. (2014). "The effects of moisture susceptibility and ageing conditions on nano-silica/polymer-modified asphalt mixtures". Construction and Building Materials, 72, 139-147.
[8] Zhang, H., Gao, Y., Guo, G., Zhao, B., & Yu, J. (2018). "Effects of ZnO particle size on properties of asphalt and asphalt mixture". Construction and Building Materials, 159, 578-586.