IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 06, Issue 02 (February. 2016), ||V2|| PP 25-34

Examining the Performance of Hot Mix Asphalt Using Nano-Materials

Abdelzaher E. A. Mostafa
Associate Professor, Civil Engineering, Mataria School of Engineering, Helwan University, Cairo, Egypt.

Abstract: cold environments and soft in hot environments. Pavement material is characterized by number of failures modes at low and high temperature such as cracking, fatigue cracking, or permanent deformation which causes a reduction of quality and performance [1]. Any improvement in service life of road pavements will be off course of a great economical advantage and any modifications of asphalt are attempts to extend the service life and improve the performance of asphalt pavements [2].

In this study a forward investigation of s nano silica and nano carbon on the physical properties such as penetration, softening, and viscosity then studying its effect on the mechanical properties of marshall specimen. Two methods of mixing nano-materials (Mechanical and High-Shear) were examined. Results showed that nano carbon or nano silica decrease the penetration and increase softening and viscosity. Furthermore increased stability and decreased flow. Micro scanning proved that high shear mixing is better than mechanical mixer in case of nano carbon while there was no significant different in case of nano silica.

Index Terms- *Hot Asphalt Mix; Polymers; Nano-Materials.*

I. INTRODUCTION

Improve the performance of asphalt. To demonstrate many of the prospective applications, researches have conducted a series of positive and effective efforts dealing with the preparation of modified asphalt to demonstrate the mechanism of modification and the resultant improvement in performance [1].

This research studies the effect of nano-material such as nanocarbon tube and nano-silica on the Physical properties bitumen such as penetration, softening, and viscosity then Asphalt (or bitumen) is used in road pavements as the binder of aggregates in a great extent all around the world. Asphalt pavements must undergo heavy loads and unfavorable environmental conditions for an acceptable period of time.

High-temperature rutting and low temperature cracking are the most considerable limitations of unmodified and pure asphalts. Therefore, modification and reinforcement of asphalt binder is necessary [3].

Modification of base asphalt is required to improve the material's performance (e.g. adhesion, temperature sensitivity, friction properties, oxidation resistance, aging resistance and durability). There many kinds of asphalt modifiers, including various resins, rubbers, polymers, sulfer, metal complexes, fibers and chemical agents [4]. In recent years, nanotechnology has gradually been incorporated into the field of modified asphalt with various kinds of nanomaterials being used to modify asphalt [5].

Nanotechnology has been used in various fields. In pavement engineering research, nanomaterials is used as a form of new material at the molecular level. A number of researchers have used nanomaterials in Portland cement materials. Lately, some researchers have started to work on the improvement of asphalt materials with nanomaterials in asphalt cement and emulsions. There are various nanomaterials which have potential to be used in asphalt modification; such as nanoclay, nanosilica, nano-hydrated lime, nano-sized plastic powders, or polymerized powders, fibers, and nanotubes [6].

The recent practices of nanotechnologies are those using nano-sized particles in so-called nanomaterials and nanometer-size features on integrated circuits. These materials frequently show properties that are completely different from those demonstrated by the same products with larger dimensions. A reason for this can be found in the increased relative surface area of minute particles as shown in Figure (1) and [7].

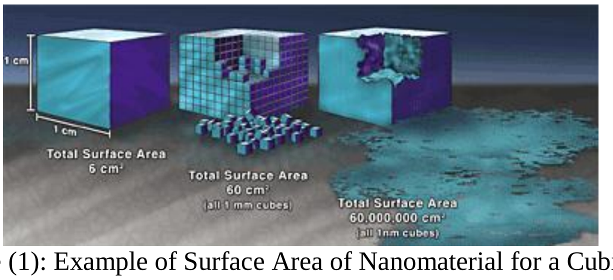

Figure (1): Example of Surface Area of Nanomaterial for a Cubic [7]

Nanotechnology has been gradually penetrated into the field of asphalt modification. Seemingly magic effects of nano-materials have now been brought to studying its effect on the mechanical properties of HAM.

II. LITERATURE REVIEW

In 2013, M. Faramarzi et al. [9] attempted to promote technical characteristics of asphalt mixture using carbon nanotubes as an additive material for bitumen. In this study, marshal test parameters of hot mix asphalt, modified with 0.1, 0.5, and 1% carbon nanotubes, are investigated and compared to conventional asphalt mix. Wet and dry process methods are most practical ways of mixing CNF in AC. It was decided that the best method to adopt for this investigation was dry process. According to the results, the more carbon nanotubes increase, the better asphalt concrete specifications will be. Thus sample containing 0.01 carbon nanotubes by weight of bitumen, has the best results. This sample regarding Marshal Stability 32.53 percent and Marshal Ratio 44.71 percent is higher than the control sample. Also Marshal flow 8.4 percent and specific gravity 0.68 percent is lower than control sample. It should be noted that despite the decrease in flow, it is still within the permitted regulation. The initial cost of both samples 0.005 and 0.01 is higher than the control sample but for total cost, the amount and type of work should be investigated. When using modified mix, due to its high stability, the lower layer thickness will be less than the control mix and then the amount of total costs will decrease. [9]

Yadykina, V.V et al. [10] made a guess based on theoretical researches that inserting CNT into bitumen will make a positive impact on its stress-strain properties. In researchers' opinion it may be possible because of aromatic compounds presence in bitumen connected with π-conjugated links system. It will cause the CNT and carbon amorphous particles dispergating improvement and forming theirs Table suspensions in organic solvents. These suspensions will consist of separated carbon amorphous particles and carbon nanotubes, this will cause forming a grid from nanotubes and carbon nanoparticles at asphalt-concrete and asphalt binder with improved stress-strain properties.

Ziari Hasan et al. [11] discussed the mixing conditions of CNT with asphalt and the effect of various mixers on the CNF mixing with asphalt cement (AC). In the first stage, multi wall carbon nanotube, which its weight proportion to asphalt is three percent, and asphalt are mixed together. This mixture is divided into three smaller mixtures (samples). Each sample is mixed by using a different mixer and in different conditions. These mixers are mechanical, high shear and ultrasonic mixers similar results were observed in almost all samples mixed by the mechanical mixer. While there was a concentration of nano materials in some parts of samples there was almost no nano materials concentration in some other samples. This indicates that the use of the mechanical mixers, to mix nano materials, leads to forming a heterogeneous mixture based on the materials dispersion in asphalt. In addition, it cannot prevent nano materials from becoming agglomerated. [11]

In contrast to the provided samples by the mechanical mixer, the dispersion of nano materials in the whole sample mixed by the high shear mixer was homogeneous. But unfortunately, this mixer, like the previous one, could not disperse nano materials in nano scale and these materials were dispersed in micro scale. Therefore, agglomeration of nano materials in the sample was observed. Consequently, they normally become agglomerated and approach micro scale. Therefore, this mixer cannot separate these nano materials from each other. [11]

For samples mixed by an ultrasonic mixer, nano materials are observed homogeneously and separately dispersed in asphalt (without agglomeration). Also, CNT particles are separated from each other and easily recognizable. [11]

Mojtaba Ghasemi et al. [12] reported the potential benefits of nano-SiO2 powder and SBS for the asphalt mixtures used on pavements. Five asphalt binder formulations were prepared using various percentages of SBS and nano-SiO2 powder. Then, Marshall samples were prepared by the modified and unmodified asphalt binders. The results of this investigation indicated that the asphalt mixture modified by 5% SBS plus 2% nano-SiO2 powder could give the best results in the tests carried out in the current study so that this modification can increases physical and mechanical properties of asphalt binder and mixtures. The modified bitumens were prepared by a high shear mixer. The physical properties of the modified bitumens (such as softening point, penetration and ductility) were measured. The obtained optimum bitumen content for the control mixtures was 6.3% which was used for preparing all other modified mixes in order to maintain consistency throughout the study. [12]

III. EXPERIMENTAL WORK

This research aims to study the improvement in properties of modified bitumen, by adding nano-materials as a percentage of weight. The effect of nano-materials (nano-silica and nano-carbon) is examined. To achieve the optimum content, five different percentages of nano-silica (1, 3, 5, 7, and 9%) and four different percentages of nano-carbon tubes (0.01, 0.1, 0.5, and 1%) are mixed with bitumen. Nano-silica and nano-carbon tubes are mixed with bitumen using two different methods: (i) using the mechanical mixer and/or (ii) using the high shear mixer as shown in Figure (2); the better method later determined through results.


Mechanical High Shear

Figure (2): Methods of Mixing Nano-Materials with Bitumen

A variety of tests are carried out on all samples to study potential improvement. Tests conducted were the penetration test, viscosity test and softening point. The standards associated were ASTM-D5, ASTM-D4402 and ASTM-D36, respectively (See Figure (3)).

According to ASTM D5581 - 07a (2013), the Marshall test is carried out on specimen prepared by 5.5% of modified bitumen of dry aggregate weight (taken as the optimum percent from previous research studies). Figure (4) illustrates some of the experimental work steps conducted in the laboratory. Unconfined compression tests are also carried out on the optimum percent of the Marshall specimen to obtain the stress-strain curve, accordingly, as shown in Figure (5).


Penetration Test Apparatus Viscosity Test Apparatus


Softening Point Apparatus

Figure (3): Physical Properties of Bitumen

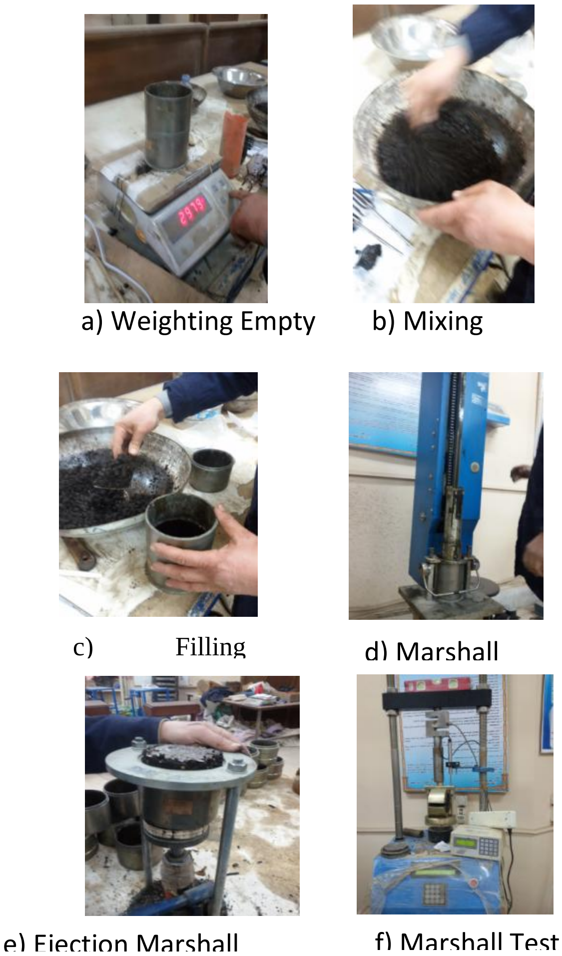

Figure (4): Experimental Work Steps

All results compared are compared to the control specimen.

Figure (5): Unconfined Compression Test

IV. RESULTS

As mentioned earlier, in this effort, the effect of nano-carbon and nano-silica – using either mechanical or high shear mixing - onto the physical properties of bitumen is emphasized upon. From the obtained results, it is evident that increasing the percentage of nano-carbon or nano-silica decreases penetration; whereas increases softening and viscosity as shown in Figure 6 to Figure 11.

An increase in nano-carbon decreases the penetration degree by 10.76% in case of mechanical mixing and by 11.2% in case of high shear mixing. As for nano-silica; increasing its percentage results in a penetration decrease of 8% - in case of mechanical mixing - and by 8.5%, in case of high shear mixing. On the other hand, increasing the percentage of nano-carbon increases the softening degree by 19% - in case of Mechanical Mixing - and by 21.4% in case of high shear mixing. Whereas, an increase in nano-silica increases the softening degree by 14.3% - in case of mechanical mixing - and 16.67%, in case of high shear mixing. As regards viscosity, increasing nano-carbon tubes enhances viscosity by 13.33% - in case of mechanical mixing - and by 15% in case of high shear mixing. Whereas, increasing nano-silica enhances viscosity by 10% - in case of mechanical

mixing - and 13.33% in case of High Shear Mixer.
For some results, mixing nano-materials with bitumen through high shear mixing yields better results than mixing using a mechanical mixer; however, the difference in results is insignificant. The difference in penetration for nano-carbon is constant; equal to 0.03 mm while the maximum difference for nano-silica is 0.07 mm at 7%. For softening, the change occurs at 1% by 1ºC for nano-carbon, while for nano-silica the difference does not exceed 1ºC.

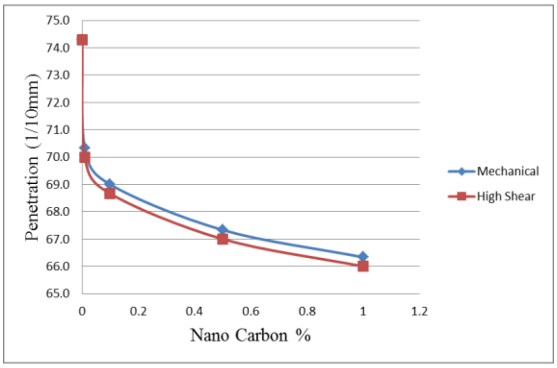

Figure 6: Effect of Nano-Carbon on Penetration

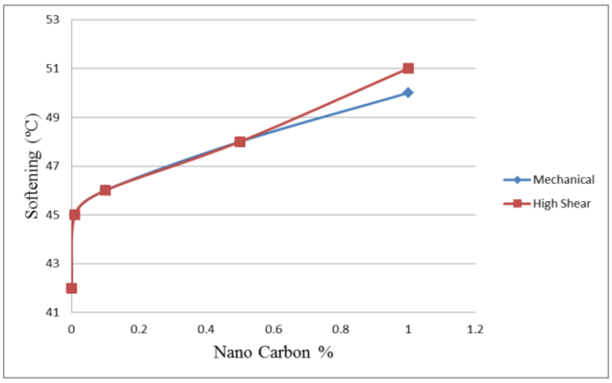

Figure 7: Effect of Nano-Carbon on Softening

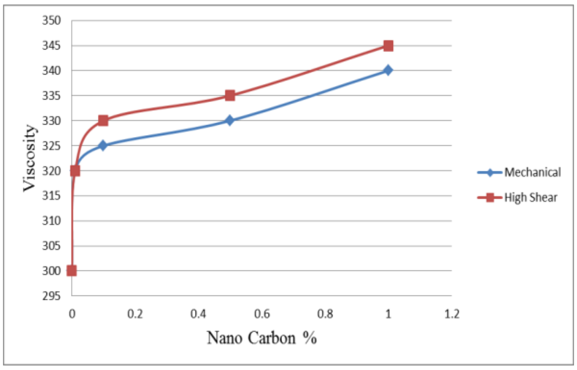

Figure 8: Effect of Nano-Carbon on Viscosity

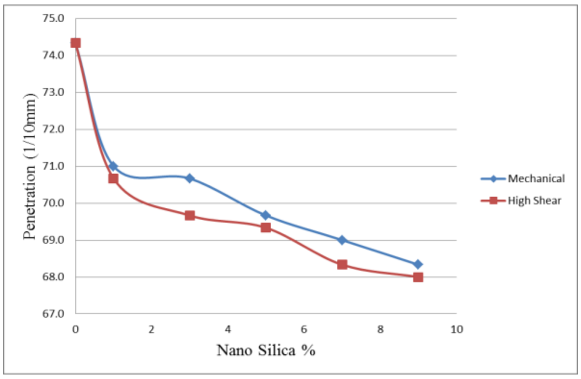

Figure 9: Effect of Nano-Silica on Penetration

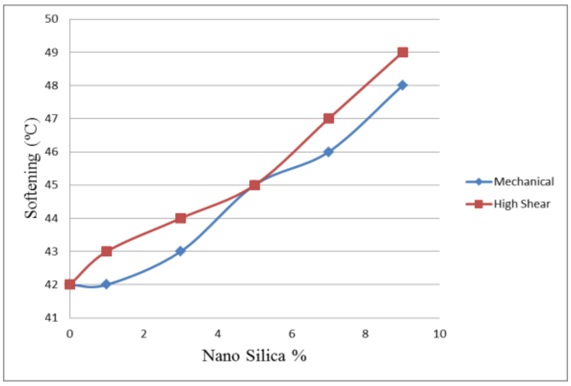

Figure 10: Effect of Nano-Silica on Softening

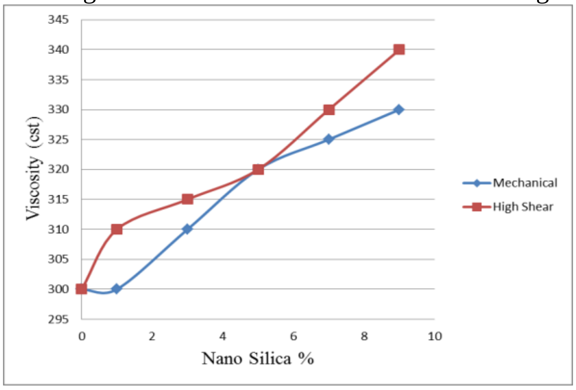

Figure 11: Effect of Nano-Silica on Viscosity

Results showed that the optimal percent for nano-carbon is 0.5%; prior to which this percentage and relationship between nano-carbon and stability is directly proportional; the relationship becomes inversely proportional after the optimal point where flow decreases on increasing nano-carbon content/percentage.

A nano-carbon addition of 0.5% increases stability by 30.3% and decrease flow by 7.35% for mechanical mixing. The latter addition also increases the stability by 58.3% and decreases flow by 8.6% for high shear mixing as shown in figures (12-13).

For nano-silica, it is observed that the optimum percent is 7%; prior to which the relationship between nano-silica and stability is directly proportional and after which the relationship is inversely proportional. Flow decreases with the increase of nano-silica as shown in Figures (14-15).

A 7% addition of nano-silica increases stability by 23.76% and decrease flow by 17.24% for mechanical mixing; whereas increases stability by 17.5% and decreases flow by 13.88% for high shear mixing.

For nano-carbon, high shear mixing increases stability by 21.5% and decreases flow by 1.33% than mechanical mixing. For nano-silica, mechanical mixing increases stability by 5.3% and decreases flow by 4% than high shear mixing.

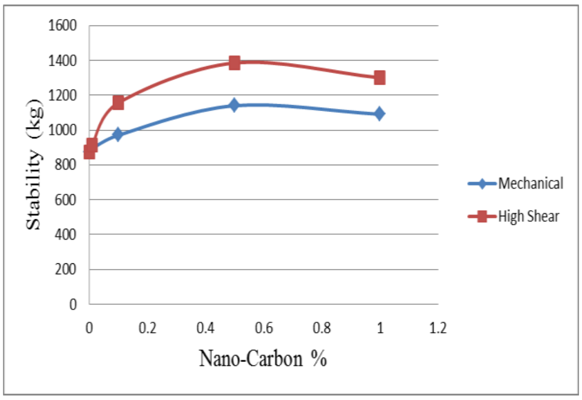

Figure 12: Effect of Nano-Carbon on Stability

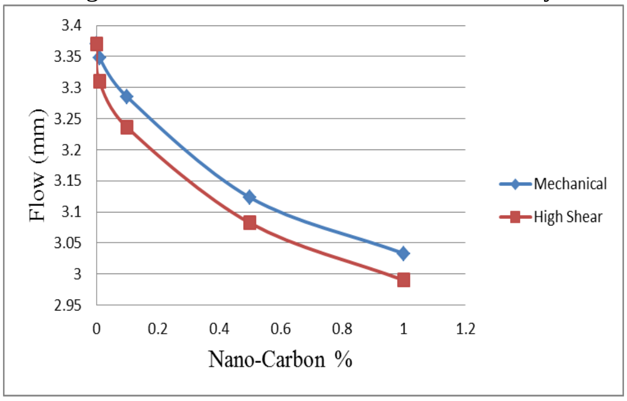

Figure 13: Effect of Nano-Carbon on Flow

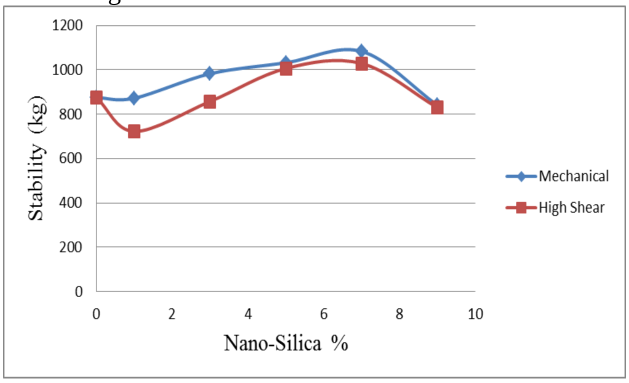

Figure 14: Effect of Nano-Silica on Stability

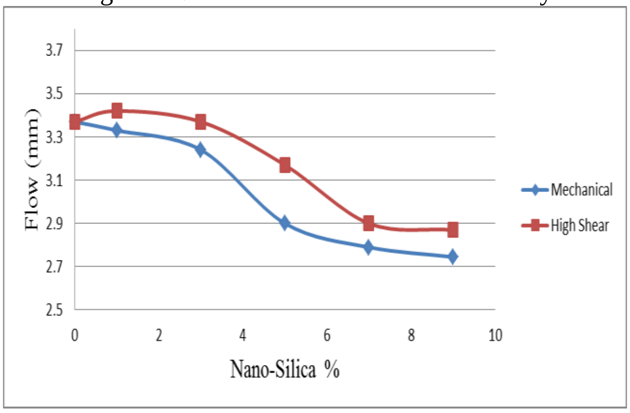

Figure 15: Effect of Nano-Silica on Flow

The comparison of the change of modulus of elasticity between pure bitumen and modified bitumen are illustrated in Figure (16)

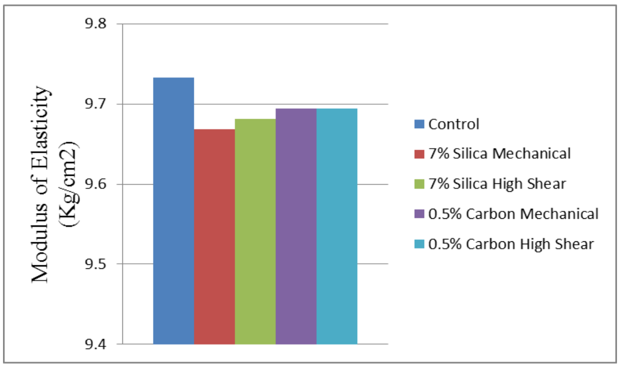

Figure 16: Modulus of Elasticity

From the obtained results, a percent of 7% nano silica mixed mechanically decreases the modulus of elasticity by 0.65%; whereas if mixed by a high shear mixer, the modulus of elasticity decreases by 0.52%. On the other hand, a 0.5% addition of nano-carbon mixed either mechanically or through high shear mixing, decreases the modulus of elasticity by 0.39%. Thus, results indicate that the effect of nano-materials on modified bitumen is insignificant in terms of modulus of elasticity.

Micro Scanning

To recognize the best method of mixing nano-materials in bitumen to get homogenous mix, microscanning tests were carried out on the optimum percent of nano-carbon (0.5%) and nano-silica (7%). Microscopic Scan equipment is shown in Figure (17). The photo is illustrated in Figures (18 to 21).

Figure 17: Microscopic Scan

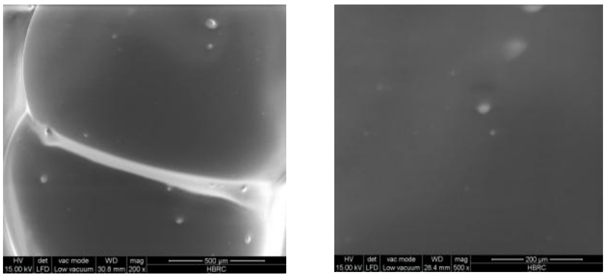

Figure 18: Micro Scan for 0.5% Carbon Mechanical Mixing

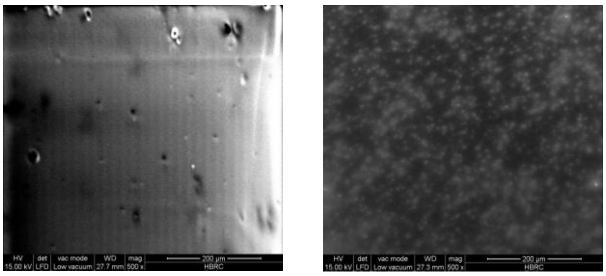

Figure 19: Micro Scan for 0.5% Carbon High Shear Mixing

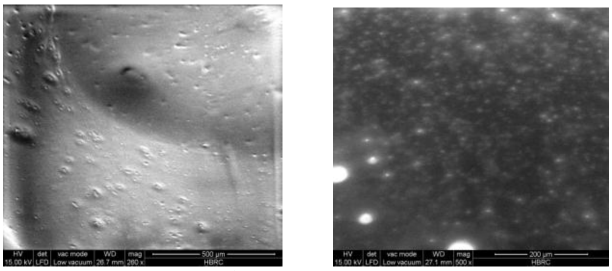

Figure 20: Micro Scan for 7% Silica Mechanical Mixing

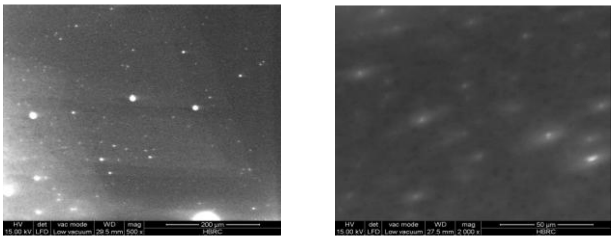

Figure 21: Micro Scan for 7% Silica High Shear Mixing

The use of the mechanical mixers, to mix nano-carbon, leads to forming a heterogeneous mixture based on the material dispersion in asphalt. In addition, this cannot prevent nano materials from becoming agglomerated. While regarding nano-carbon mixing using the high shear mixer, the dispersion of nano materials in the whole sample was homogeneous. A drawback however for this mixer is its inability to disperse nano-materials in nano-scale; these materials were dispersed in micro scale. Therefore, agglomeration of nano materials in the sample was observed as shown in Figure (19-20).

The use of the mechanical mixers or high shear mixers gave nearly the same results to mix nano-silica. The dispersion of nano materials in the whole sample was homogeneous and the mixer could disperse nano materials in nano scale. Therefore, agglomeration of nano materials in the sample was not observed as shown in Figure (21-22).

V. CONCLUSION

Based on the results obtained from this research, the following conclusions can be drawn:

1) The optimal percentages for nano-silica and nano-carbon used in the asphalt mix are 7% and 0.5% respectively.
2) A 0.5% nano-carbon content decreases the penetration degree by 9.4% in the case of mechanical mixing and by 9.8% in case of high shear mixing, whereas 7% nano-silica content decreases the penetration degree by 7.13% in case of mechanical mixing and by 8.1% in case of high shear mixing.
3) A 0.5% nano-carbon content increases softening by 14.3% in both mechanical mixing and high shear mixing, while 7% nano-silica increases softening by 9.52% in case of mechanical mixing and by 11.9% in case of high shear mixing
4) A 0.5% nano-carbon content increases viscosity by 10% in case of mechanical mixing and by 11.67% in case of high shear mixing; whereas 7% nano-silica increases viscosity by 8.33% in case of mechanical mixing and by 10% in case of high shear mixing.
5) A 0.5% nano-carbon content increases the viscosity by 10% in case of mechanical mixing and by 11.67% in case of high shear mixing, while 7% nano-silica increases viscosity by 8.33% in case of mechanical mixing and by 10% in case of high shear mixing.
6) High shear mixer - in case of nano-carbon is better than mechanical mixing – whereas vice-versa in case of nano silica.
7) Mixing nano-carbon using a mechanical mixer yields a heterogeneous mixture; nano-carbon agglomerates on mixing through high shear giving a homogenous mixture with agglomeration nano-silica.
8) Mixing nano-silica and nano-carbon using a mechanical mixer or high shear mixer gives the same results a homogenous mixture with no agglomeration of nano.

REFERENCES

[1] J.-Y. Yu, P.-L. Cong, and S.-P. Wu, "Laboratory Investigation on the Properties of Asphalt Modified with Epoxy Resin," Journal of Applied Polymer Science, vol. 113, pp. 3557–3563, 2009.
[2] M. Sienkiewicz, J. K. Lipka, H. Janik, and A. Balas, Waste Management, vol. 32, 2012.
[3] L.H. Lewandowski,. Polymer Modification of Paving Asphalt Binders. Rubber Chemistry and Technology, 67(3): 447, July-August, 1994.
[4] J.A. Shen, Pavement Performance of Asphalt and Asphalt Concrete, China Communication Press, Beijing, 2011 (in Chinese).
[5] J.S. Zhang, Z. Li, M.T. Li, J. Xu, W.J. Yin, L. Liu, Highway 8 (2005) 142-146 (in Chinese).
[6] Zhanping You. "Nanomaterials in Asphalt Pavements." Technological University, Department of Civil and Environmental Engineering, Michigan Houghton, Michigan, 49931-1295, USA, DOI:10.6135/Ijprt.Org.Tw/2013.6(3). Iv, ISSN 1997-1400 Int. J. Pavement Res. Technol. 6(3)
[7] Erik Bakker. "Nanotechnology and Human Health in The Construction Industry." The Short Internship in Industry Performed at IVAM BV Amsterdam as Part of The Larger Curriculum for The Degree of Msc. Nanoscience, April 2008
[8] Changing Fang, Ruien Yu, Shaolong Liu, and Yan Li, "Nanomaterials Applied in Asphalt Modification: A Review" Xi'an University of Technology, Xi'an 710048, China, Sciverse Sciencedirect' J. Mater. Sci. Technol., 2013, 29(7), 589-594
[9] M. Faramarzi, M. Arabani, A. K. Haghi, and V. Motaghitalab "A Study on The Effects of CNT's on Hot Mix Asphalt Marshal- Parameters" University of Guilan, 7thSASTtech 2013, Iran, Bandar-Abbas. 7-8 March, 2013. Organized by Khavaran Institute of Higher Education.
[10] Yadykina, V.V., Akimov, A.E., Spitsyna, N.G., and Lobach, A.S. "Prospects for The Application of Nano-Carbon Tubes to Improve The Quality of Bitumen and Asphalt": Innovative Materials and Technologies: Fri. Reports. Intern. Scientific and Practical. / Belgor. State. Tehnol. Univ. ¬ Belgorod State Technological University Publishing House, 2011. - Part 4. – P.P. 306-309.
[11] Ziari Hasan, Rahim-of Kamran, Fazilati Mohammad, Goli Ahmad, and Farahani Hosein, " Evaluation of Different Conditions on The Mixing Bitumen And Carbon Nano-Tubes", Iran University of Science And Technology, International Journal of Civil & Environmental Engineering IJCEE-IJENS Vol:12 No:06
[12] Mojtaba Ghasemia, Seyed Morteza Marandia,B, Majid Tahmooresib, Reza Jalal Kamalia, and Reza Taherzadec, "Modification of Stone Matrix Asphalt with Nano-Sio2" Acivil Engineering Department, Shahid Bahonar University, Kerman, Iran Binternational Center For Science, ISSN 2090-4304 Journal of Basic And Applied Scientific Research, J. Basic. Appl. Sci. Res., 2(2)1338-1344, 2012