Global Scientific JOURNALS

GSJ: Volume 8, Issue 3, March 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Evaluation of Rutting Performance of Asphalt Modified with Nano Silica

Numan Ghani[1], Yaseen Mahmood*[1], Fawad Khan[1], Maaz Ahmad[2], Mehran Khan[3], Haidar Ali Khan[4], Muzamil Khan[5]

1. Department of Civil Engineering, Iqra National University, Hayat Abad , Peshawar KP, Pakistan
2. Department of Civil Engineering, International Islamic University, Islamabad, Pakistan
3. Department of Civil Engineering, University of Engineering and Technology Peshawar, KP, Pakistan
4. Department of Civil Engineering, Sarhad University and Information Technology, Peshawar, KP, Pakistan
5. Department of Mechanical Engineering, Sarhad University and Information Technology, Peshawar, KP, Pakistan

Correspondence*

Yaseen Mahmood

Department of Civil Engineering, Iqra National University, Hayat Abad KP, Peshawar, Pakistan
yaseen@inu.edu.pk

Abstract

Asphalt is the major parameter of pavement and there are two major types of distresses produced during its serviceability that is permanent deformation which is also known as rutting and the second one is moisture damage. It is the first priority of the Pavement Engineers to build a sustainable pavement and reduce these distresses by modifying binder which is the basic component of the asphalt. Different types of traditional additives such as rubber, clay, polymers etc are used for the modification of the binder. Currently the Nano technology has drawn the attention of the researchers and they have started using Nano particles for the modification of asphalt. The Nano particles used in this research is Nano silica (NS) 1%NS, 3%NS and 5%NS by weight of the bitumen. Basic test of bitumen, (i.e.) penetration, softening point, ductility, flash and fire point were conducted in order evaluate physical properties of bitumen. These basic tests showed that Ductility and penetration (grade) of Bitumen was reduced showing the modified bitumen had become stiffer while softening point was increased by incorporating Nano silica in bitumen. Some advance test like scanning electron microscopy (SEM) images were taken on different pixels in order to ensure the homogeneous dispersion of Nano silica in the binder. In order to know about the comparison of the rheological properties of the neat binder and the Nano silica modified binder the dynamic shear rheometer test was also conducted. The effect of Nano silica was evaluated by carried out wheel tracking test. The results of the testing revealed that Nano silica stiffened the bitumen and enhanced asphalt resistance to rutting. Thus, it was concluded that Nano silica increased its rutting resistance and enhanced performance of asphaltic mixture.

Keywords: Asphalt, Nano Silica (NS), Dynamic Shear Rheometer (DSR), Scanning Electron Microscopy (SEM).

1. Introduction

The major type of distresses in pavements are rutting, fatigue, cracking and moisture damage. It is the priority of transportation engineer to reduce these problems in pavement. As reconstruction required high budget. There are different ways to minimize these problems; one of them is to modify the binder making it more durable and stiffer. In the past researchers have used different type of traditional additives such as clay, rubber, polymer etc for the modification of the binder. But the result of these modifier shows that the characteristic of the binder does not significantly changed. Now currently the world is moving towards the Nano technology. Recently the addition of Nano materials used for the modification of binder has gained a lot of popularity. Now researchers are working on Nano composites in order to enhance the mixture properties of asphalt. Nano technology ensured a bright future for the materials industry in transportation engineering. Nano silica has been widely used in polymers concrete, and asphalt binders as inorganic filler to improve the properties of polymeric mechanical and bituminous materials. (Metwally, Hassanin, Elgendy, & Sawan, 2017) have used to modify asphalt binder.

1.1 Problem Statement

There are two types of pavements that are rigid and flexible pavements. In flexible pavements the common types of failures or distresses are fatigue, rutting and cracking. Unfortunately, Pakistan is more affected from global warming and its temperature is increases day by day so the major problem in the pavement of Pakistan is rutting. There are two types of rutting one is structural and other is nonstructural. This research work is concerned with on structural type of rutting. The main parameters which contribute in rutting are high temperature, poor compaction of sub grade. Poor martial mix design and over loading, we cannot control these factors but can improve the properties of asphalt. This can be done by modifying bitumen binder with Nano silica which can enhance the rheological properties of the asphalt and the serviceability of the pavement is increased.

1.2 Research Motivation

The main aim of the research was:

Evaluation of Rutting Performance of Asphalt modified with nano silica (NS)

The objectives of this research work were:

Homogeneous dispersion of Nano silica particles in bitumen.

To improve the physical properties of modified Nano Silica binder.

To determine the optimum content of Modified Nano Silica binder on the basis of rutting resistance value.

To improve the Marshall stability.

To improve the rheological characteristics of Modified Nano Silica binder.

To improve rutting resistance of Nano Silica modified binder.

2. Literature Review

As tire loads are increasing day by day due to increasing in number of cars throughout the globe, so the need to progress in pavement technology is additionally increasing. It is getting hard for the pavement materials used in the past to meet the demands of today. For this purpose, researcher used different types of additives to acquire the enhance properties of asphalt. The traditional modifiers such as crumb rubber polyethylene, styrene butadiene styrene (SBS) and clay are used to modify the asphalt binder. But the result shows that the flow values of asphalt binder are not so much decreased by these traditional modifiers, (Zhang, Yao, Yu, Liu, & Jiang, 2019) So currently researchers are centered on using Nano technology in pavement engineering due to speedy amplify in the scope of Nano technology.

Asphalt was once used as a pavement material for the first time in Babylon. The word asphalt has been derived from the Greek word “asphaltos” which means secure. It used to be with the aid of Romans for ceiling of their baths and aqueducts. Asphalt technology was once accelerated on huge scale in World War 2 due to the severe need of pavement for carrying heavy loads of aircrafts. The drive for popularity and provision of excessive best asphalt pavement has been led through the pavement industry itself. The Institution of National Asphalt Pavement Association (NAPA) took was established in 1955. NAPA carried out the initiative of Quality Improvement Program in which they are trying out of asphalt at Distinct University and testing labs was sponsored later on, then the results were shared with individuals. In the past few many years significant progress has been made to grant long lasting asphalt pavement to the users.

Various modifiers have been used for the enhancement of physical and the rheological properties of asphalt. (Adamu, Mohammed, Shafiq, & Shahir Liew, 2018) studied the effect of crumb rubber and Nano silica on the durability of asphaltic mixture and find out the addition of Nano silica of binder materials decreases the consistency of pavements (Al-Taher, Hassanin, Ibrahim & Sawan, n.d.) also modified asphalt with traditional modifiers rubber, lime and polyethylene

and observed that they decreased the flow value of asphalt binder. Zhang and Yu (2010) also modified asphalt with styrene butadiene rubber (SBR) and sulfur to investigate the property of asphalt. (Taherkhani, Afroozi, & Javanmard, 2017) also investigates the resistance of asphalt binder against low temperature and permanent deformation with addition of Nano silica.

(Leiva-Villacorta, Vargas-Nordcbeck, & Timm, 2017) also studied the effect of incorporating Nano silica into asphaltic binder and all the modified binders showed lower deformation than the neat binders. (Attaelmanan, Feng, & Al-Hadidy, 2011) found reduction in the temperature of asphalt by modifying it with high density polyethylene (HDPE). (Al-Taher et al., n.d.) Modified the asphlat binder with different percentage of nano silica and concluded that physical properties of the asphalt binder are improved.

(Yang & Tighe, 2013) has studied that the addition of crumb rubber in asphalt binder has led to accelerated performance levels of asphalt pavements due to an exceptional compatability between bitumen and the waste particles of the rubber.

These particles are generally black in colour and occured in powder form. The large surface area of these particles helps them in advancing the rheological properties of asphaltic mixture. There are different types of Nano carbon particles such as Carbon Nano Tubes (CNTs), Carbon Black (CBs), Graphite Nano Particles and Graphene Nano Platelets.

The application of Nano silica can be found in every field of life starting from medicines, agriculture and now researcher are using it for the modification of asphalt. The higher stability of Nano silica plays an important role in enhancing the rheological properties of asphalt. Nano silica is an inorganic filler and possess good qualities such as high stability large surface area, good dispersal ability, strong adsorption, high chemical clarity.

3. Methodology

Nano silica have been used for the modification of asphalt binder. The conventional test of asphalt binder has been carried out to determine rheological characteristics. With the help of marshal mix design asphalt mix has been prepared. The rut performance has been evaluated through wheel tracking machine.

All the Nano particles of Nano technology present around the Globe, Nano silica was one of the suitable modifiers for this research work. The motives at the back of this choice were:

It has a vast scope of research as it is newer than other Nano particles. The research work shows that modification of asphalt with Nano silica gives us enhancing physical and rheological properties of asphalt binder.

3.1 Properties of Nano Silica

The different characteristics of nano silica were given below in the form of table 1.1 below

Table 1.1 Properties of Nano silica

Chemical formula	SiO2
Appearance	In powder form (white)
Melting point MP	>1600℃
Boiling point BP	2230℃
Diameter	25nm- 30nm
Surface area	Specific surface area 175-225 m^2/g
Molar mass	60.08 $gmol^{-1}$

Bitumen:

The type of bitumen used for this research work was 80/100 Gd bitumen, which was obtained from National Refinery Limited (NRL). The conventional test was performed on it in order to evaluate its physical properties and are mentioned in chapter 4.

Aggregate:

The type of aggregate used for this research work was obtained from Margalla hills and of NHA class A. The rock type was lime stone which has 98% carbonates, 1% of hematite and 1% of silica (Arif et al. 1999).

Mixing Method:

For the suitable mixing of nano silica there are two methods which are as follows.

Hand and Shear Mixing:

Figure-1: Shear mixing

In hand mixing method a specific amount of bitumen was taken and placed in the oven for specific time at specific temperature. Then a glass rod was used to mix the modifier in the asphalt binder. While in shear mixing method a specific amount of bitumen was heated and paced in the oven for specific at specific temperature. Then a shear mixture was used to mix the modifier in the asphalt binder at a specific speed of homogeinizer. Th mixing technique used for this research work was shear mixing in which 2000g of bitumen was heated in the oven unless it gain temperature of 160℃. Then a homogeinizer was used to mixnano silica in the asphalt binder for 10 minutes interval at a temperature of 160℃at a speed of 2000 rpm (Ahmad Kamil et al. 2017).

4. Results

The conventional tests for the asphlat binder was conducted on these samples. The results of these tests are included in Chapter 4. It is evident from the results that repeatibility was not observed in case of shear mixing samples.

4.1 Percentages of Nano Silica to be used

Different samples of Nano silica modified binder were prepared by using 3 percentages of Nano silica by weight of the binder. These percentages were 1%, 3% and 5%. After the addition of 3% and 5% nano silica the binder becomes stiffer which can be shown in the figures 3.4 and 3.5.

Figure-2: Asphalt binder after addition of 3% NS

Figure-3: Asphalt binder after addition of 5% NS

The conventional and Frequency sweep test were performed for 1%, 3% and 5% Nano silica modified asphalt binder. In order to find out the rut performance, the wheel tracking test was also performed.

4.2 Scanning Electron Microscope (SEM)

The images of Nano silica modified binder were taken by using Scanning Electron Microscope (SEM).

Figure-4: Showing SEM

A targeted beam of electrons was used in tis microscope in order to scans the material shown in Figure 3.5. Different types of Asphalt binder were poured using the stubs. Now these specimens had beam sputtered by the use of sputtering machine and then investigate under the SEM shown in figure-5

Figure-5: Sputtering Machine

5. Results and Discussions

The results of all the experimental tests carried out during this research project have been given in this chapter.

5.1 Results of Conventional Binder Testing

Table-1: Results of Conventional Tests

Test	Neat Binder	1% NS	3% NS	5%NS
Ductility (cm)	103	83	72	58
Penetration (0.1mm)	82	74	67	63
Softening point(°C)	46.5	48	50	52

It is evident from the result that by modifying bitumen with Nano silica makes it stiffer and thus the penetration grade of the binder is reduced while the softening point is increased by the addition of Nano silica.

It is evident from the below figure 4.1 that ductility of the modified binder decreases as the weight of the Nano silica increases in binder. By adding 1% Nano Silica ductility of the neat binder decreases by 19.5% and by adding of 5% Nano Silica the ductility is reduced by 43% which is more countable.

5.2 Results of conventional tests

It is evident from the results that by adding 1% NS the penetration value decreased by 9.7%. Furthermore, by adding 5% NS penetration value is decreases by 23%. This reduction of penetration values shows that the binder gets thicker by adding Nano silica.

Also, the result shows that the softening point is increases as we add NS to the neat binder. By adding 1 % NS to the bitumen the softening point were increase by 3.2% and by adding 5% Nano silica the softening point were increased by 11.8%.

6. Conclusions:

Ductility and penetration of Bitumen was reduced showing the modified bitumen had become stiffer while softening point was increased by incorporating Nano silica in bitumen.The SEM images show that Nano silica is homogeneously dispersed in the bitumen.The study of the rheology of the binder shows the significant increase in the stiffness with the addition of Nano silica.Optimum content of bitumen also increases with the increase in addition percentage of Nano Silica.The optimum content of modified NS bitumen noted was 3%.The Rutting depth was decreased by 30% as compared with Neat bitumen**.**

6.1 Recommendations

The asphalt binder modified with Nano silica should be checked for rut depth under 12000 passes in Wheel Tracking Machine.The bitumen of Grade 80/100 should be modified with even percentages of Nano Silica and studied their rut depth.Rut depth values should be checked at 60℃ on wheel tracking machine.

7. References

Adamu, M., Mohammed, B. S., Shafiq, N., & Shahir Liew, M. (2018). Effect of crumb rubber and nano silica on the fatigue performance of roller compacted concrete pavement. *Cogent Engineering*, *5*(1), 1–10. https://doi.org/10.1080/23311916.2018.1436027

Al-Taher, M. G., Hassanin, H. D., Ibrahim, M. F., & Sawan, A. M. (n.d.). *Comparative Study ofPerformance of Modified Asphalt Mixtures Using Different Traditional and Nano Additives*.

Artamendi, I., & Khalid, H. (2005). Characterization of fatigue damage for paving asphaltic materials.

Fatigue & Fracture of Engineering Materials & Structures, *28*(12), 1113–1118.

Attaelmanan, M., Feng, C. P., & Al-Hadidy, A. I. (2011). Laboratory evaluation of HMA with high density polyethylene as a modifier. *Construction and Building Materials*, *25*(5), 2764–2770.

Fernández-Gómez, W. D., Rondón Quintana, H., & Reyes Lizcano, F. (2013). A review of asphalt and asphalt mixture aging: Una revisión. *Ingenieria e Investigacion*, *33*(1), 5–12.

Heiligtag, F. J., & Niederberger, M. (2013). The fascinating world of nanoparticle research. *MaterialsToday*, *16*(7–8), 262–271.

Leiva-Villacorta, F., Vargas-Nordcbeck, A., & Timm, D. H. (2017). Non-destructive evaluation of sustainable pavement technologies using artificial neural networks. *International Journal ofPavement Research and Technology*, *10*(2), 139–147.

Metwally, G. A.-T., Hassanin, H. D., Elgendy, M. F., & Sawan, A. M. (2017). Improving the Performance of Asphalt Mixtures Using Nano Silica. *World Applied Sciences Journal, 35 (12)*(December 2017), 2614–2621. https://doi.org/10.5829/idosi.wasj.2017.2614.2621

Singh, R. K., Sharma, A. K., Dixit, A. R., Tiwari, A. K., Pramanik, A., & Mandal, A. (2017). Performance evaluation of alumina-graphene hybrid nano-cutting fluid in hard turning. *Journal of CleanerProduction*, *162*, 830–845.

Taherkhani, H., Afroozi, S., & Javanmard, S. (2017). Comparative study of the effects of nanosilica and zyco-soil nanomaterials on the properties of asphalt concrete. *Journal of Materials in CivilEngineering*, *29*(8), 4017054.

Yang, J., & Tighe, S. (2013). A Review of Advances of Nanotechnology in Asphalt Mixtures. *Procedia -Social and Behavioral Sciences*, *96*(Cictp), 1269–1276.https://doi.org/10.1016/j.sbspro.2013.08.144

Zhang, J., Yao, Z., Yu, T., Liu, S., & Jiang, H. (2019). Experimental evaluation of crumb rubber and polyethylene integrated modified asphalt mixture upon related properties. *Road Materials andPavement Design*, *20*(6), 1413–1428.