International Journal of Science Academic Research
Vol. 03, Issue 09, pp.4330-4333, September, 2022
Available online at http://www.scienceijsar.com

ISSN: 2582-6425

Research Article

EFFECT OF ORGANOPHILIC NANOCLAY MODIFIED BINDER ON HIGH TEMPERATURE PERFORMANCE OF ASPHALT MIXTURE

***Ahmad Afnan Gandapur and Dr. Imran Hafeez**

Taxila Institute of Transportation Engineering, University of Engineering and Technology Taxila, Pakistan

Received 29th July 2022; **Accepted** 24th August 2022; **Published online** 20th September 2022

Abstract

Organophilic nanoclay is a mixture of organic and in-organic matter, mainly clay and organic molecules, which was made to enhance the physical and chemical properties of different material used in across multiple fields of technologies including engineering. In this study, multiple percentages of organophilic nanoclay ranging from 3.0%, 3.5%, 4.0%, 4.5% to 5.0% were used across two performance grade (PG) bitumen, i-e: N.R.L 60-70 & N.R.L 80-100. The addition of organophilic nanoclay in asphalt binder, bitumen, greatly reduced the effects of rutting at high temperatures when the specimens were subjected to cyclic loading. A total of ten modified binder specimens were prepared and in addition to these, another two bitumen specimens of virgin bitumen were prepared and subjected to cyclic loading using Wheel Tracker Test (WTT) for comparative analysis. After completion of the tests, the results were thoroughly analyzed, and remarkably it was found that organophilic nanoclay modified bitumen had a very pleasing result on rutting in asphaltic concrete layer. The results showed that rutting decreased and was reduced across all the samples of nanoclay modified bitumen, and in some cases, rutting as reduced to as low as 69.23% compared to the original virgin bitumen with the same PG bitumen. This article reflects on advancements in use of modifiers in engineering and is based upon previously updated and new research study.

Keywords: Binder modification, Organophilic nanoclay, Rutting, Wheel tracker test.

INTRODUCTION

A Pavement is characterized as a multi layered structure which rests on the Subgrade of the soil. As a Pavement is subjected to Traffic Loads and variation in temperature, Permanent deformation may arise within the pavement or on its surface such as Rutting. Rutting usually occurs in both asphalt layers as well as in the underlying unbound layers but almost 85% - 95% of rutting accumulates in the asphaltic layers. With advancements and research in field of nanotechnology, a new material comprising of layered silicate nanoparticles became an additive in asphalt, which is known as Nanoclay. Nanoclay is an agglomerate where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm – 100 nm. Nanoclay Modified bitumen composition have been successfully used to improve the physical, rheological properties as well as the performance of bitumen. According to the recent findings, by using nanoclay as a modifier to further improve the performance of Styrene–Butadiene–Styrene (SBS) polymer modified asphalt, it was found that the viscosity of the SBS-modified asphalt as well as the stiffness (complex modulus) increased while the phase angle decreased. These results confirmed that Organophilic nanoclays had a potential to reduce the permanent deformation characteristics / rutting of pavements especially in the asphaltic layers. Recent studies have shown that nanoclay modified bitumen can reduce rutting at high temperatures, reduce bitumen content, acquire desirable results with minimal additives. This will not only be useful in saving maintenance cost in the long run but can also prove to be beneficial to save human lives by reducing road accidents. In this research diverse percentages of nanoclay ranging from 3.0%, 3.5%, 4.0%, 4.5% to 5.0% of the total weight of bitumen in asphalt mix will be used to make multiple molds or cakes of asphalt to be tested upon using a wheel tracker apparatus to measure permanent deformation / rutting and to find if nanoclay modified bitumen will have desirable results of reducing rutting.

Corresponding Author:** ***Engr. Farhan
University of Engineering and Technology Taxila, Pakistan

RESEARCH AND FINDINGS

Objectives of Study

Virgin asphalt mixes has been used for a very long time but it has some varied drawbacks, such as deforming and flowing at high temperatures and higher loading. The main objectives of this research are to study and investigate the conventional and rheological properties of neat (virgin) and organophilic modified bitumen, to design and characterize neat and organophilic modified asphalt mixes, and to study and compare the rut resistance properties of different asphalt mixes.

Experimental Studies

Testing Materials

A. ***Aggregates:*** Coarse and fine aggregates were obtained from Khanpur quarry which is amongst the top mechanically fractured aggregate producing quarry in Pakistan. The aggregate gradation used in the mix are mentioned in Table 1. Multiple tests were conducted to determine engineering properties of the specified aggregate. Los Angeles abrasion value was determined to be 21.1% and the percentage absorption value of the aggregate was 0.94%. Cubic angular shaped aggregate were used and flaky aggregates were discarded in the mix.

Table 1. Aggregate Gradation

Sieve Size	Passing (%)	Tolerance	NHA Specifications Limit
19 mm	100	±7	100
12.50 mm	76.9	±7	75-90
9.50 mm	62-76	±7	60-80
#4	43-51	±4	40-60
#8	31-39	±4	20-40
#50	7-15	±4	5-15
#200	4-6	±1	3-8

Table 2. N.R.L 60/70 Grade Rutting Bitumen

		Nano Clay Content				
Bitumen Mix Type	-	3.0%	3.5%	4.0%	4.5%	5.0%
Nano clay Modified	Rutting (mm)	1.9	1.5	1.2	0.8	0.9
Virgin		2.6	2.6	2.6	2.6	2.6

Table 3. N.R.L 80-100 Grade Rutting

			Nano Clay Content				
Bitumen Mix Type	-		3.0%	3.5%	4.0%	4.5%	5.0%
Nano clay Modified	Rutting	(mm)	2.5	2.2	1.6	1.1	1.3
Virgin			3.4	3.4	3.4	3.4	3.4

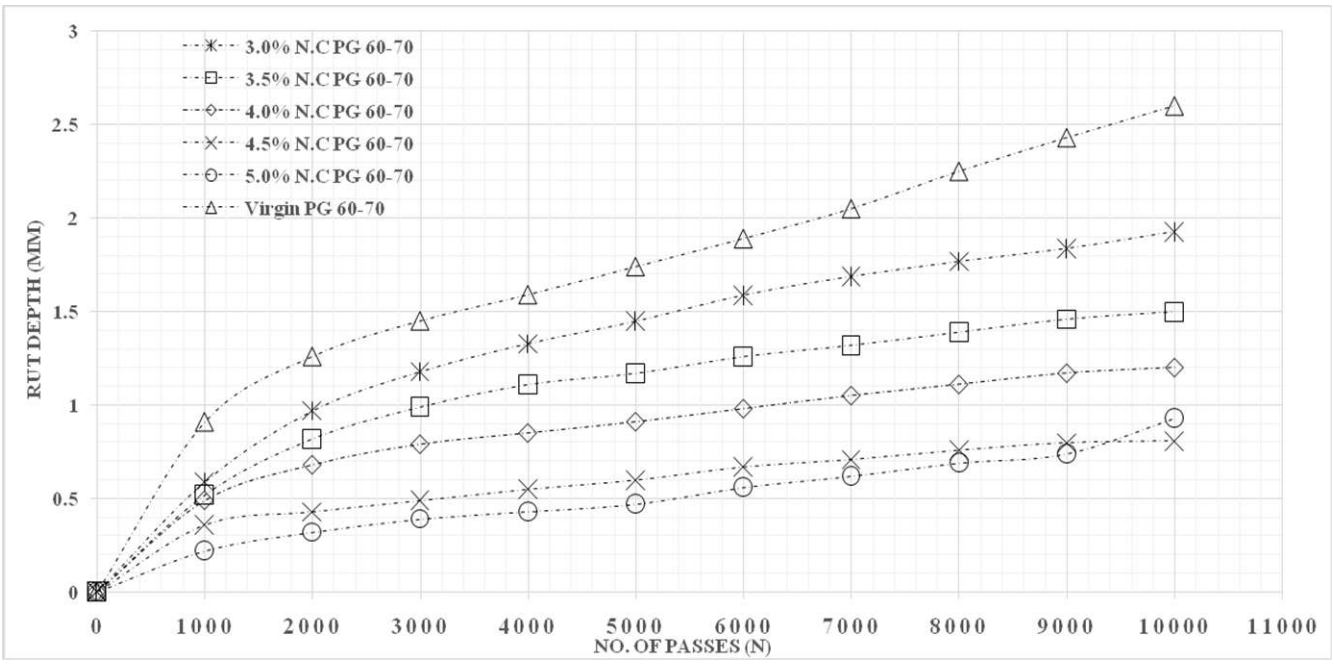

Figure 1. Scatter diagram of PG 60-70 N.C Modified Bitumen and Vırgin Bitumen

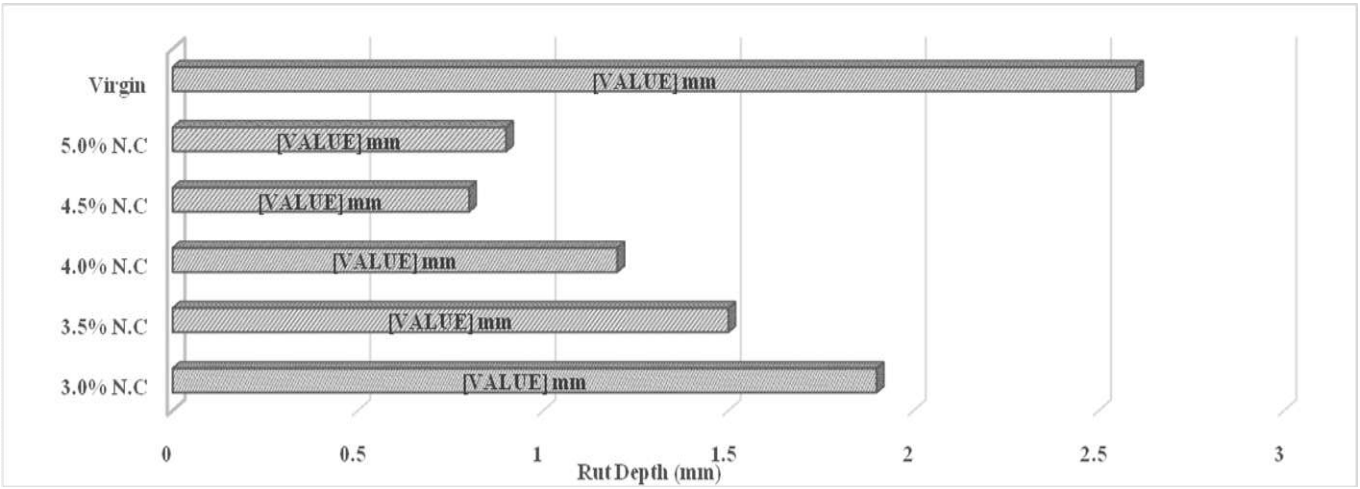

Figure 2. Bar Chart comparing rut depth in Modified Vs Virgin Bitumen

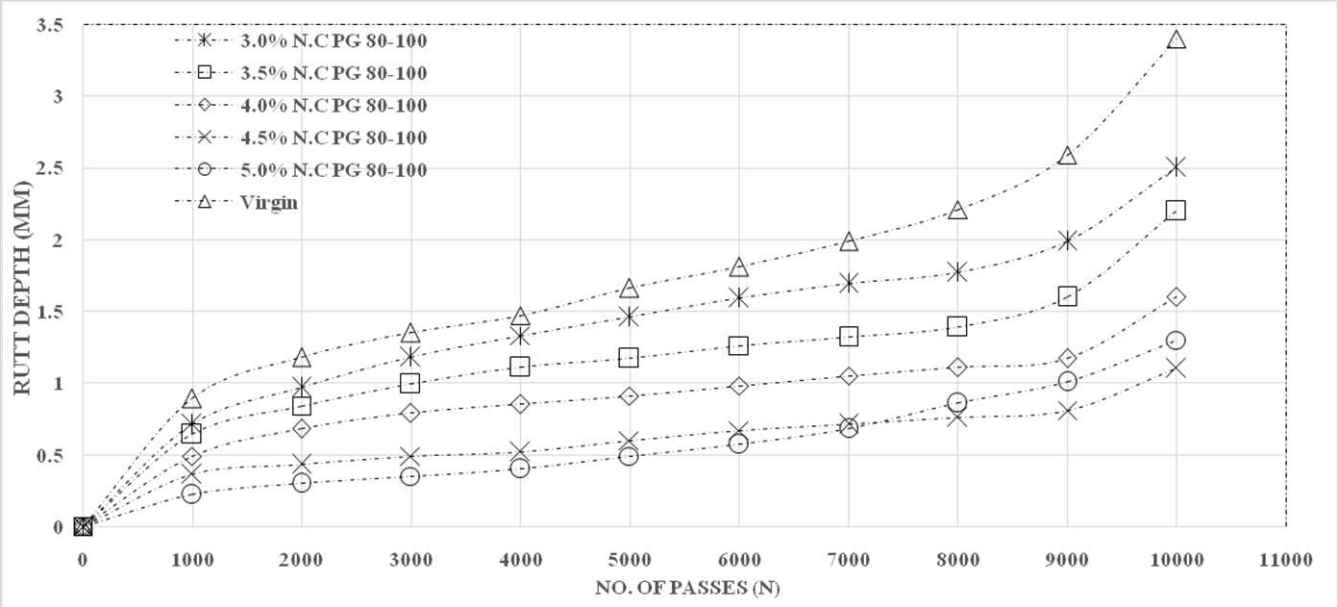

Figure 3. Scatter diagram of PG 80-100 N.C Modified Bitumen and Virgin Bitumen

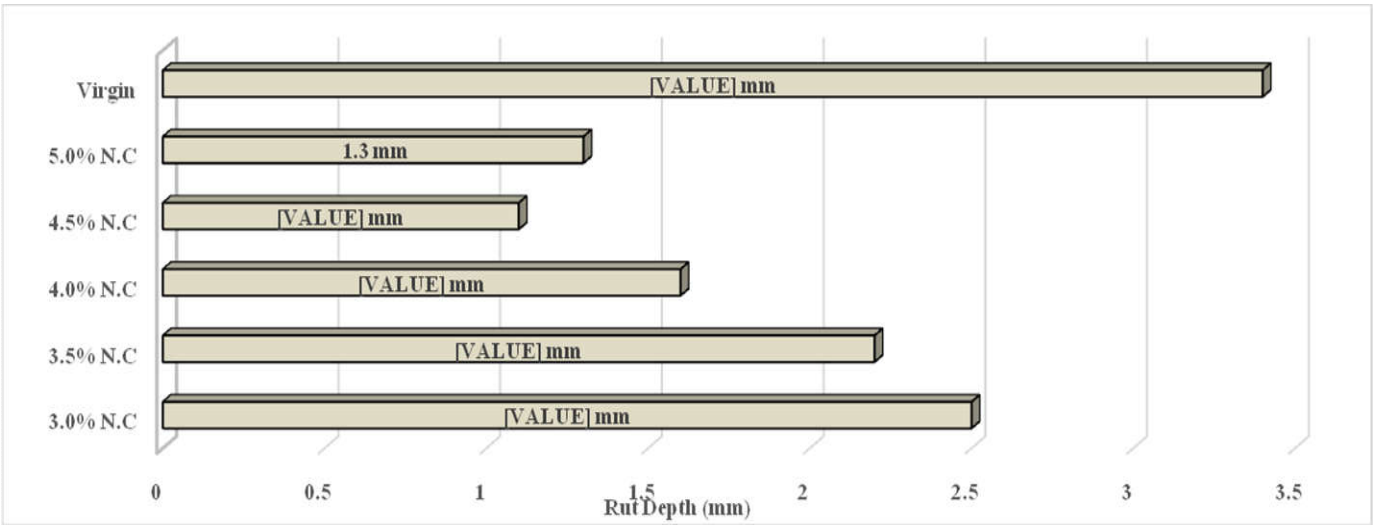

Figure 4. Bar Chart comparing rut depth in Modified Vs Virgin Bitumen

B. ***Specimen Preparation:*** Different types of samples were prepared according to NHA Class-B specifications, incorporating different percentages of nano clay (3.0%, 3.5%, 4.0%, 4.5% & 5.0%) for both PG bitumen (N.R.L 60/70 & N.R.L 80/100). Control samples of Virgin bitumen were also prepared using both PG bitumen to compare & analyze the results. The total number of specimens/ moulds prepared were 12, which comprised of 10 organophilic modified bitumen moulds and 2 control mould, which were made using same specifications but the binder used was virgin bitumen. Each mould after being compacted using the *Superpave Gyratory Compactor* was then cut using a mould grinder and the final depth of mould was 50mm or 5cm.

C. ***Testing Methodology:*** A total of 12 tests were conducted. In each test, the moulds were subjected to cyclic loading using the *Wheel tracker test* apparatus. The apparatus applied a wheel load of 700N at a temperature of 55 °C. A total of 10,000 passes were made on each mould at a rate of 26.5 cycles/ 53 passes per minute. The rut depth was recorded automatically for each mould by the apparatus.

Experimental Results and Discussion

N.R.L 60/70 Bitumen

A total of 5 tests were conducted on Organophilic nanoclay modified Bitumen (PG 60/70) with Nanoclay percentages ranging from 3.0% - 5.0% and 1 test was conducted on raw virgin bitumen (PG 60/70). The tests were conducted using similar conditions and specifications. The results yielded that Organophilic nanoclay modified bitumen had greater rut resistance as compared to raw virgin bitumen, and the maximum decrease in rut resistance was noted at 4.5% nanoclay content, which was 0.8 mm as compared to the virgin's 2.6 mm. This was a decrease of 69.23% in rutting. Table 2 represents depth of rutting with respect to different percentages of organophilic nanoclay used. While figure 1 represents rutting with respect to number of passes by the Wheel Tracker apparatus.

N.R.L 80/100 Bitumen

A total of 5 tests were conducted on Organophilic nanoclay modified Bitumen (PG 80/100) with Nanoclay percentages

ranging from 3.0% - 5.0% and 1 test was conducted on raw virgin bitumen (PG 80/100). The tests were conducted using similar conditions and specifications. The results yielded that Organophilic nanoclay modified bitumen had greater rut resistance as compared to raw virgin bitumen, and the maximum decrease in rut resistance was noted at 4.5% nanoclay, which was 1.1 mm as compared to the virgin's 3.4 mm. This was a decrease of 67.64% in rutting. Table 3 represents depth of rutting with respect to different percentages of organophilic nanoclay used. While figure 3 represents rutting with respect to number of passes by the Wheel Tracker apparatus.

Conclusion

The objectives of this research study were to study the conventional and rheological properties of neat and organophilic modified bitumen at high temperatures and to design and characterize neat and organophilic modified asphalt mixes, then studying and comparing the rut resistance properties of different asphalt mixes. The following conclusions can be made by the above evaluation and analysis of results:

- By conducting multiple tests, all according to ASTM specifications and similar conditions, it was found that using nanoclay greatly enhanced the rut resistance properties of virgin asphalt mixes.
- Both PG bitumen yielded pleasing results, as not only overall bitumen content in both the mixes was reduced but the primary failure mode of an asphalt pavement was reduced by more than 60% at 4.5% nanoclay usage in both PG bitumen.
- It is safe to say that using 4.5% organophilic nanoclay for both PG bitumen to modify asphalt mix can reduce rutting, reduce maintenance and rehabilitation cost, prevent aquaplaning and can largely contribute to safety of road users by reducing accidents due to undulation in roads because of rutting.

REFERENCES

Abdullah Abdel AleemAbou Khadrah, Mohamed Mostafa Elshrief, Marwa Mohamed Sabry, 2016. "Application of Nanotechnology to improve the performance of asphalt materials"

Amir Amini, Hassan Ziari, Seyed Amir Saadatjoo, Negar Sadat Hashemifar, Ahmad Goli. "Rutting resistance, fatigue properties and temperature susceptibility of nano clay modified asphalt rubber binder".

Domingos, M. D. I. and A. L. Faxina, 2015. "Susceptibility of Asphalt Binders to Rutting:Literature Review".

Du Yinfei, Chen Jiaqi, Han Zheng, Liu Weizheng, 2018. "A review on solutions for improving rutting resistance of asphalt pavement and test methods".

El-Shafie, M. I.M. Ibrahim, A.M.M. Abd El Rahman. "The addition effects of macro and nano clay on the performance of asphalt binder".

Gang Liu; Shaopeng Wu; Martin van de Ven; Andre Molenaar; and Jeroen Besamusca. "Characterization of Organic Surfactant on Montmorillonite Nanoclay to Be Used in Bitumen".

Hassan Ziari, Ali Moniri & Navid Norouzi, 2019. "The effect of nanoclay as bitumen modifier on rutting performance of asphalt mixtures containing high content of rejuvenated reclaimed asphalt pavement".

Helal Ezzat, Sherif El-Badawy, Alaa Gabr, El-Saaid Ibrahim Zaki, Tamer Breakah, 2016. Evaluation of Asphalt Binders Modified with Nanoclay and Nanosilica".

Irfan M., Y. Ali · S. Iqbal · S. Ahmed · I. Hafeez. 2017. "Rutting Evaluation of Asphalt Mixtures Using Static, Dynamic, and Repeated Creep Load Tests".

Johan Blom, Bram De Kinder, JannesMeeusen and Wim Van den bergh, 2020. "The influence of nanoclay on the durability properties of asphalt mixtures for top and base layers".

Luísa Gardênia A.T. Farias a, Janaina L. Leitinho c, Bruno de C. Amoni b, Juceline B.S. Bastos c, Jorge B. Soares, 2016. "Effects of nanoclay and nanocomposites on bitumen rheological properties".

Polacco, G., Filippi, S., Merusi, F. & Stastna, G. 2015. "A review of the fundamentals of polymer modified asphalts: Asphalt/polymer interactions and principles of compatibility".

Prabin Kumar Ashish, Dharamveer Singh, Siva Bohm, 2016. "Evaluation of rutting, fatigue and moisture damage performance of nanoclay modified asphalt binder".

Sabahat Hussan, Mumtaz Ahmed Kamal, Imran Hafeez, Naveed Ahmad, Shahab Khanzada&Shafeeq Ahmed. (2018) "Modelling asphalt pavement analyzer rut depth using different statistical techniques".

Saeed Ghaffarpour Jahromi, Nabi Allah Ahmadi, Shahram Vossugh, Mohammadreza Mortazavi, 2015. "Effects of nanoclay on rutting and fatigue resistance of bitumen binder".

Sandra de A. Soares b, Hosiberto B. de Sant'Ana a,Pei, J., Wen, Y., Li, Y., Zhang, Z., Shi, X., Zhang, J. 2015. "Organic montmorillonite modified asphalt materials: Preparation and characterization. Journal of Testing and Evaluation".

Seyed Alireza Ghanoon, Javad Tanzadeh, Mehrnaz Mirsepahi, 2019. "Laboratory evaluation of the composition of nano-clay, nano-lime and SBS modifiers on rutting resistance of asphalt binder".

Thomas W. Johnson, Leila Hashemian, Sidharth Patra, 2019. "Application of Nanoclay Materials in Asphalt Pavements".

You, Z., Mills-Beale, J., Foley, J., Roy, S., Odegard, G., Dai, Q. & Goh, S. 2011. "Nanoclay-modified asphalt materials: Preparation and characterization. Construction and Building Materials".

Zhanping You, Julian Mills-Beale, Justin M. Foley, Samit Roy, Gregory M. Odegard, Qingli Dai, Shu Wei Goha, 2011. "Nanoclay-modified asphalt materials: Preparation and characterization".

Ziari, H., Babagoli, R. & Akbari, A. 2015. "Investigation of fatigue and rutting performance of hot mix asphalt mixtures prepared by bentonite-modified bitumen. Road Materials and Pavement Design".

****