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Original Article

Moisture Susceptibility of Organophilic Nano Clay Modified Asphalt Mixtures

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Abstract - *The durability is one of the major assets of bituminous paving mixtures. One of the major factors that can interfere with the functioning of mixtures is moisture damage. Actually, Moisture damage deteriorates asphalt pavement. An asphalt mixture or pavement is susceptible to moisture when there is a weakening between the bond of aggregate and asphalt binder in some moisture. When this weakening becomes severe, it leads to the failure of HMA pavement. The existence of moisture in the HMA pavement causes two mechanisms: a) Loss of adhesion between the bitumen and aggregate surface and b) Loss of cohesion in the mixture.*

The goal of this study is, therefore, to observe the moisture susceptibility of different recipes of five different percentages of organophilic nano clay to be mixed with the asphalt mixtures with the same aggregate quarry/source and two binder types of different penetration grade and properties, and to check the performance of these sample combinations with four laboratory tests: Static Immersion Test, Total Water Immersion Test (TWIT) Test, Boiling water Test and Rolling Bottle Test. In order to collect the information necessary for loose coated bituminous paving mixtures, the tests necessary to do so have been performed at the Taxila Institute of Transportation Engineering (TITE). The results show that adding 4.5% ONC to both binder types decreases moisture damage and shows the best resistance against moisture damage. The Rolling Bottle Test is the best test to differentiate between different loose-coated Asphalt mixtures, regardless of the time taken by the test.

Keywords - *Moisture Sensitivity Tests, Organophilic Nanoclay, Moisture susceptibility, Rolling Bottle Test, Boiling water test, Static immersion test, Total immersion test.*

1. Introduction

The sensitivity of an HMA pavement to the effects of moisture is the key factor contributing to its collapse. The presence of water droplets in hot-mix asphalt mixture or hot-mix asphalt pavement, in general, weakens the bond between the asphalt binder and aggregates, which ultimately leads to adhesive failure. Additionally, moisture can sometimes lead to the failure of the cohesive bond in asphalt binders. In point of fact, adhesive failure is defined as the separation of asphalt binder from the aggregate surface. In contrast, cohesive failure is defined as the separation of the asphalt binder from the surface of the asphalt binder due to the presence of moisture. Both cohesive and adhesive failure can cause the HMA pavement to crumble prematurely, resulting in stripping, raveling, and potholes. It demonstrates that the presence of moisture constitutes a significant threat to the HMA pavements. Many different strategies have been implemented in an effort to stop the deterioration of moisture in HMA pavements. These strategies involve modifying asphalt binders and asphalt aggregates with particular modifiers to improve the properties of HMA mixtures.

The use of nanotechnology in today's research is becoming increasingly widespread among scientists and has developed into a standard practice in the community of scientists. In reality, organophilic nanoclay is an aggregate or agglomeration in which at least fifty percent of the particles have at least one exterior dimension that falls within the range of one nanometer to one hundred nanometers.

Since the 1920s, asphalt researchers have made several efforts to improve laboratory trials to differentiate between good and poor performance of bituminous mixes concerning moisture damage. They have also divided the tests used to classify the moisture damage resistance of an asphalt mixture into two main categories: those performed on loose mixtures and those performed on compacted mixtures.

2. Literature Review

The attachment system of the aggregate-binder interface is greatly impacted by moisture surroundings and determines the reaction of bituminous mixes to various sufferings. Moisture degradation of an asphalt mixture is primarily caused by three mechanisms: 1) loss of cohesion within the binder, 2) adhesion failure between the binder and the aggregate border (i.e., stripping), and 3) aggregate deterioration. The main metric in evaluating a binder's opposition to moisture damage is bond power between the asphalt and aggregate boundary.

- Mamun and Arifuzzaman (2018) found that the CNT-polymer-modified asphalt was more resistant to moisture damage than the equivalent polymer-modified asphalt when they added a certain quantity of (CNTs) to (SB) and (SBS) asphalt.

- As per Das and Singh (2018), using Nano-sized hydrated lime (NHL) filler was much more essential than the standard-size hydrated lime (RHL) filler in increasing the binding strength and moisture resistance of asphalt mastic.

- Sezavar et al.2020 discovered that Nano silica might improve the moisture constancy of asphalt mixes using (the GMDH) algorithm.

- Goh et al. (2015) discovered that incorporating nano clays into asphalt might significantly minimize the mixture's water damage potential.

- It was established by Omar et al. & Ashish et al.2016 that using Nano clays as modifiers increases asphalt's moisture resistance. Even if the vast majority of industry professionals agreed that nano clay had the potential to protect asphalt from water damage, there are still some professionals who maintain their skepticism.

- Lopez-Montero et al.2018 found that when fresh combinations were subjected to moisture damage, a Nano clay-modified mixture behaved similarly to the control mixture.

- Hossain et al. (2014) tested the binders' capacity to withstand moisture after being pretreated with varying concentrations of two nano clays. They expected that the nano clay-modified binders might exhibit poorer hydrophilicity than the basic binder, whether these binders weren't altered with an anti-stripping agent or other additives.

- Lu and Harvey (2013) assessed the hydrophilicity of an HMA mixture created to use an aggregate from California that is well-known for having poor interaction with asphalt binder. To assess the tolerance of combinations to water deterioration, the researchers carried out fatigue and tensile strength tests. The evaluation of the combination's tensile strength properties demonstrated that hydrated lime improves tensile values during both the unconditioned and moisture-conditioned phases. They demonstrate that the standard and fluid A-treated mixtures had far lower tensile ratios than the lime-treated combinations, which had much higher tensile ratios.

- Polymer additives such as (SBS) are utilized to increase the qualities and practical features (e.g., greater rut confrontation) of asphalt binders, which raises the inclusive budget of the asphalt binder (Gierhart 2011; ODOT 2012).

- (Anderson 1996). Unnecessary clay-like small particles in HMA can cause a deficiency of constancy (rutting or pushing), as well as moisture damage and peeling (Hauser and Colombo 1953; Ray and Okamoto 2003). Nano clays are naturally occurring multilayer silicates, making them ecologically safe, cost-effective, and long-lasting. Montmorillonite (MMT), one of the most common layered silicates, has a 2:1 multilayered assembly with two silica tetrahedron layers enclosing an alumina octahedron layer.

3. Problem Statement

Moisture damage deteriorates asphalt pavement, which may occur when binder losses its adhesion with aggregate surface and loss of cohesion of asphalt. It can cause a reduction in the strength of the mixture and can lead to early failure in the form of stripping, raveling, and potholes.

4. Aims and Objectives

The main objectives of this research work are:

- To examine the affinity between aggregate and binders (NRL 60/70&80/100) of asphalt mixtures using varying percentages of organophilic nanoclay modifier.
- To determine the optimum percentage of organophilic nanoclay content using different moisture sensitivity tests.
- To compare the performance of organophilic nanoclay modified mixes with virgin bituminous mixes.

5. Materials and Methods

The study of the moisture susceptibility of loose coated asphalt mixture, which contains different grades and different properties of asphalt binders, was carried out using a total of four tests: the static water immersion test, the total water immersion test, the boiling water test, and the rolling bottle test. The grades NRL 60/70 and NRL 80/100 are frequently employed.

Aggregates were obtained from the Khanpur crush plant and utilized. The organophilic nanoclay was utilized as the modifier, and it was applied in one of five distinct concentrations, namely 3%, 3.5%, 4%, 4.5%, or 5%. The results obtained are compared with one another to determine the optimal amount of organophilic nanoclay.

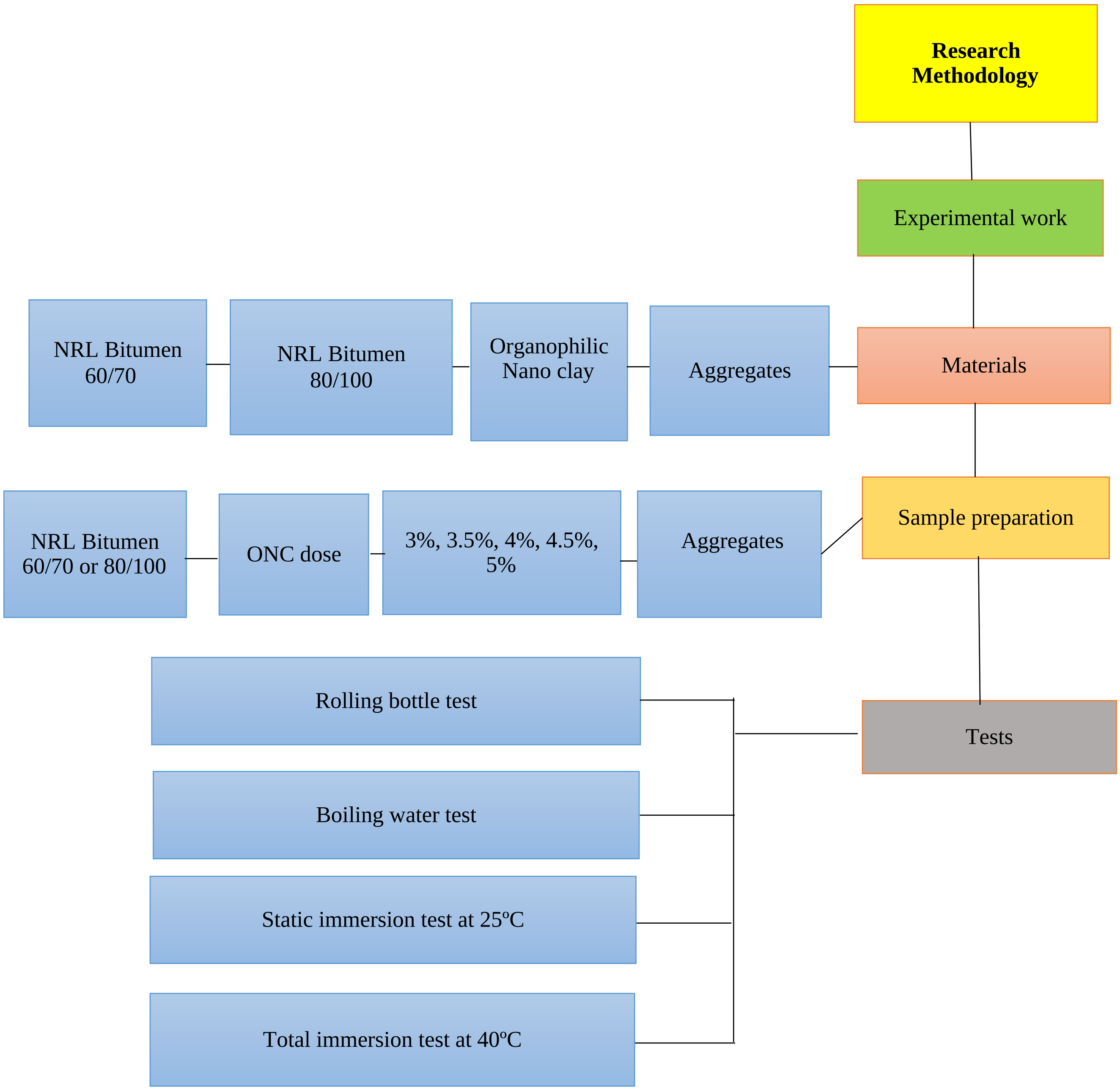

Fig. 1 Research Methodology

The modified mixes were compared with virgin bituminous mixes to determine whether or not there was an increase in the affinity of asphalt binder with the aggregates. These comparisons were carried out with the help of the four moisture sensitivity tests discussed earlier.

Table 1. Mean Penetration Values of Designated Binders

Sr. No	Binder Type	Mean Penetration Value(mm)
1	NRL60/70 pen	61
2	NRL80/100 pen	84

The methodology adopted for this work is shown in Fig. 1.

6. Results and Discussion

6.1. Static Immersion Test

The results of this experiment can only be used to estimate if more than or less than 95% of the aggregate's total visible area is coated. It was discovered that the stripping of the binder is barely perceptible, and most of the results are almost entirely preserved.

Results for NRL 60/70

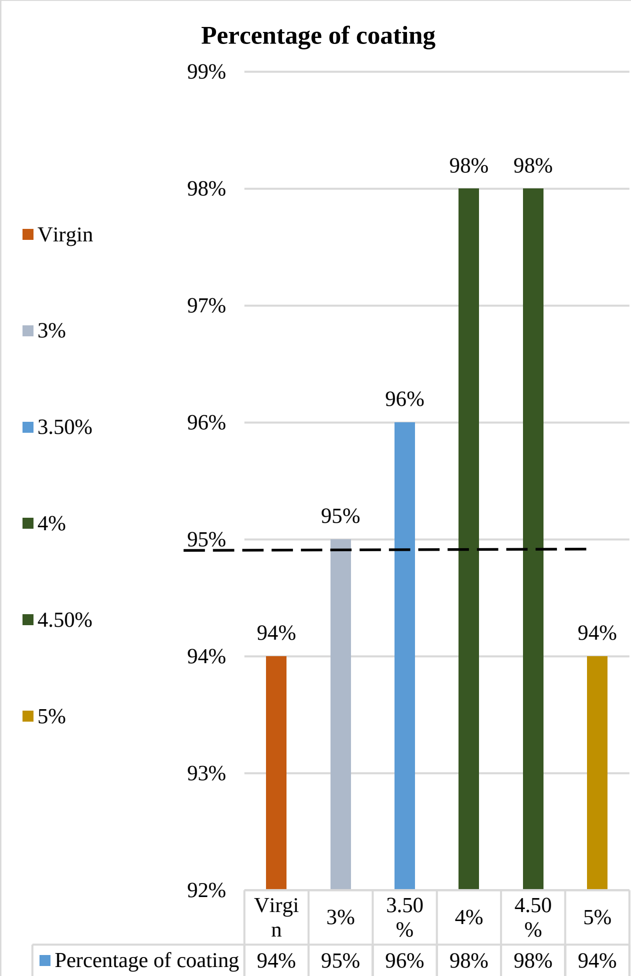

Fig. 2 Bar chart of SI Test for NRL60/70

Results for NRL 80/100

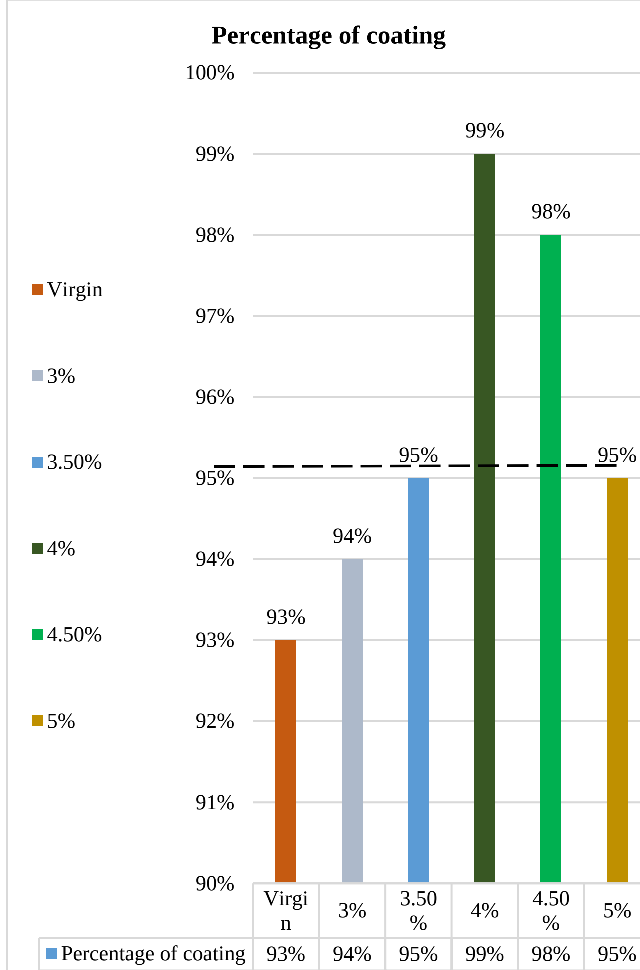

Fig. 3 Bar chart of SI Test for NRL80/100

From Fig. 2 for bitumen type NRL 60/70, we can observe that the virgin bituminous mix has less coating percentage than the rest of the modified bituminous mixes. The virgin bituminous mix has 94% coating on it. Then after modification with certain percentages of organophilic nanoclay, the coating is increased, and at 4% and 4.5% organophilic nanoclay, the coating percentage is maximum compared to the rest.

From Fig. 3 for bitumen type NRL 80/100, we can observe that the virgin bituminous mix has less coating percentage than the rest of the modified bituminous mixes. The virgin bituminous mix has 93% coating on it, and then after modification with certain percentages of organophilic nanoclay, the coating is increased, and at 4% organophilic nanoclay, the percentage of coating is maximum as compared to the rest.

6.2. Rolling Bottle Test

After six, twenty-four, forty-eight, and seventy-two hours, the degree of bitumen coating on the particles is evaluated using the Rolling Bottle Method.

It can be seen in figure 4 that there are four clusters of bars in which the first cluster is after 6 hours of examination of the mixes and 2nd one is for 24 hours, the 3rd one is for 48 hours, and the last one is for 72 hours. This chart shows a decrease in the percentage of coating with respect to time, which is obvious. The light blue colored bar is for virgin bituminous mix and has the least percentage of coating left on it compared with the rest of the modified mixes from 6 hrs up to 72 hrs. After examining them after 72 hours, it can be seen that the virgin bituminous mix has 56% coating left, while all the modified mixes have more coating on them than the virgin bituminous mix. The blue bar is of 4.5% ONC modified mix, and it shows the highest percentage of coating, which is 70%, and thus it is considered the optimum percentage of ONC in this case.

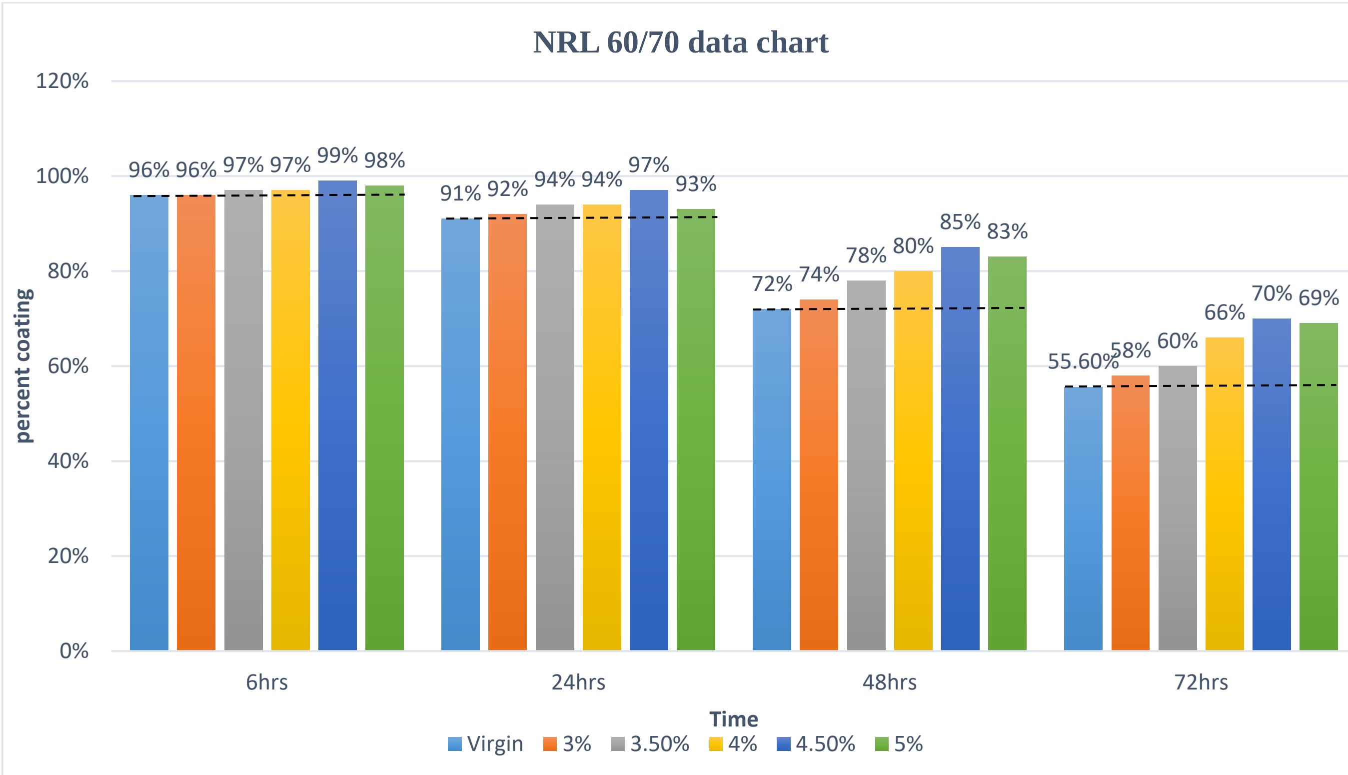

Fig. 4 Rolling Bottle Method for NRL 60/70

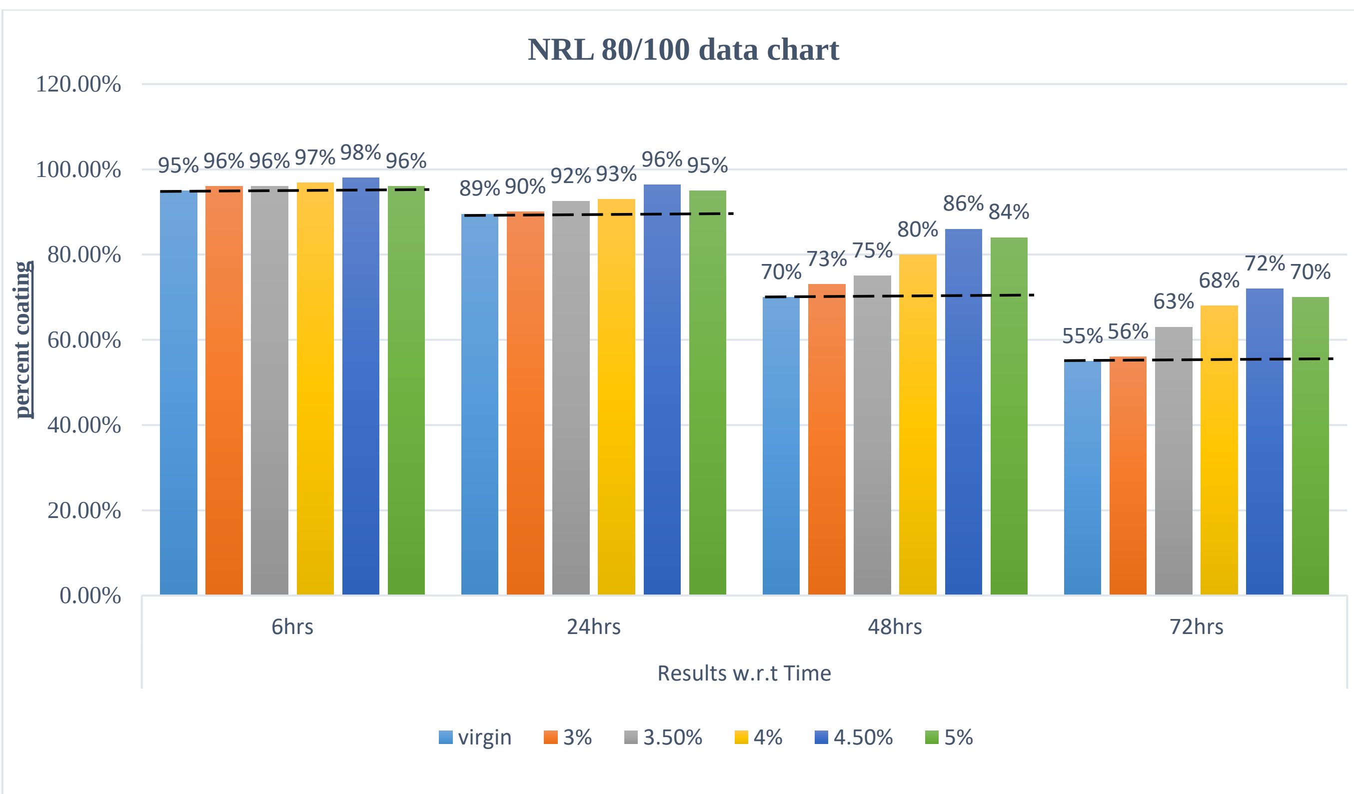

Fig. 5 Rolling Bottle Method for NRL 80/100

In this chart, the light blue colored bar is for virgin bituminous mix and has the least percentage of coating left on it as compared with the rest of the modified mixes throughout the time from 6 hrs up to 72 hrs. After examining them after 72 hours, it can be seen that the virgin bituminous mix has 55% coating left, while all the modified mixes have more coating on them than the virgin bituminous mix. The blue bar is of 4.5% ONC modified mix, and it shows the highest percentage of coating, which is 72%, and thus it is considered the optimum percentage of ONC in this case too.

6.3. Total Water Immersion Test

TWIT measures the average percentage of binder coverage after three hours of immersion in 40°C water. This test is an improvement on the Static Immersion Test. It employs 40°C water instead of room temperature (25°C) to achieve superior outcomes.

NRL 60/70

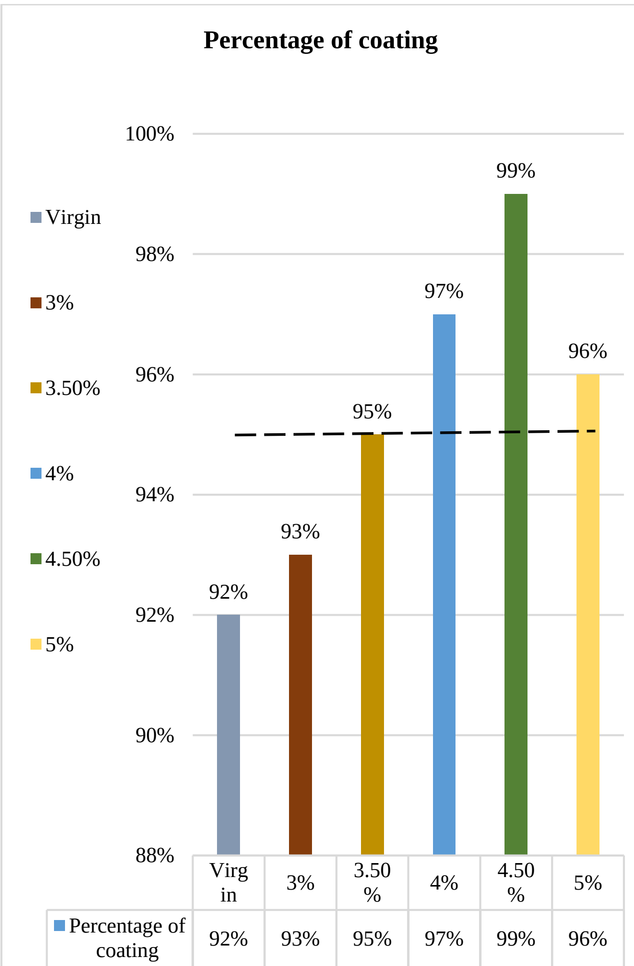

Fig. 6 TWIT method for NRL 60/70

NRL 80/100

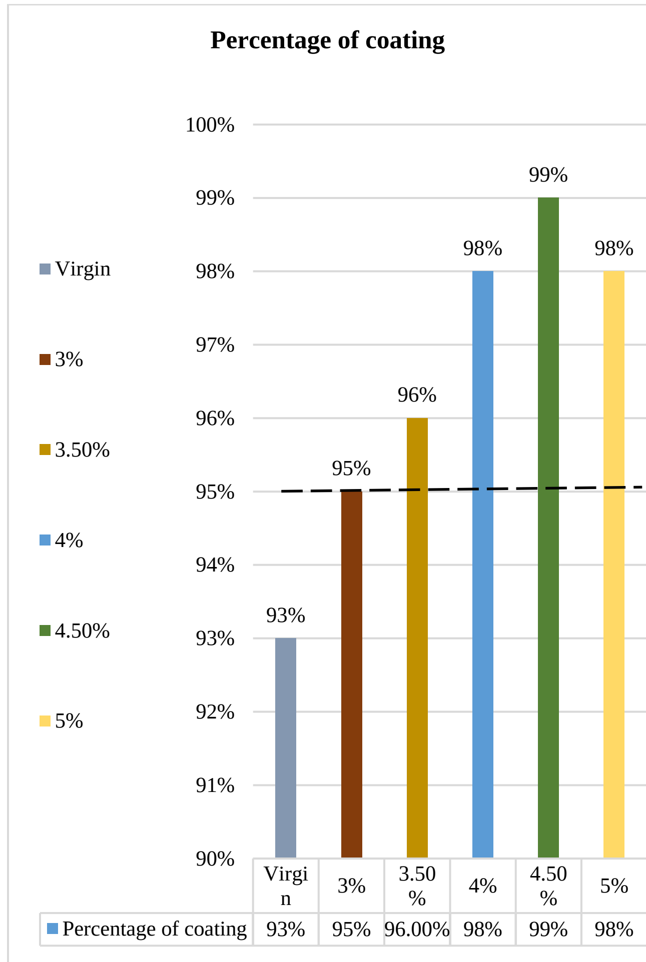

Fig. 7 TWIT method for NRL80/100

The above figure shows the improvement in the performance of asphalt mixtures when modified with organophilic nanoclay. The virgin bituminous mix shows 92% coating, less than the rest of the modified mixes. In modified mixes, the 4.5% ONC is the optimum value because it shows more coating, which is 99%.

Here we can see that the virgin bituminous mix shows 93% coating, which is less than the rest of the modified mixes. In modified mixes, the 4.5% ONC is the optimum value because it shows more coating, which is 99%.

6.4. Boiling Water Test

After boiling the sample for ten minutes, the Boiling Water Test determines what percentage of the surface is covered in bitumen. The results are

NRL 60/70

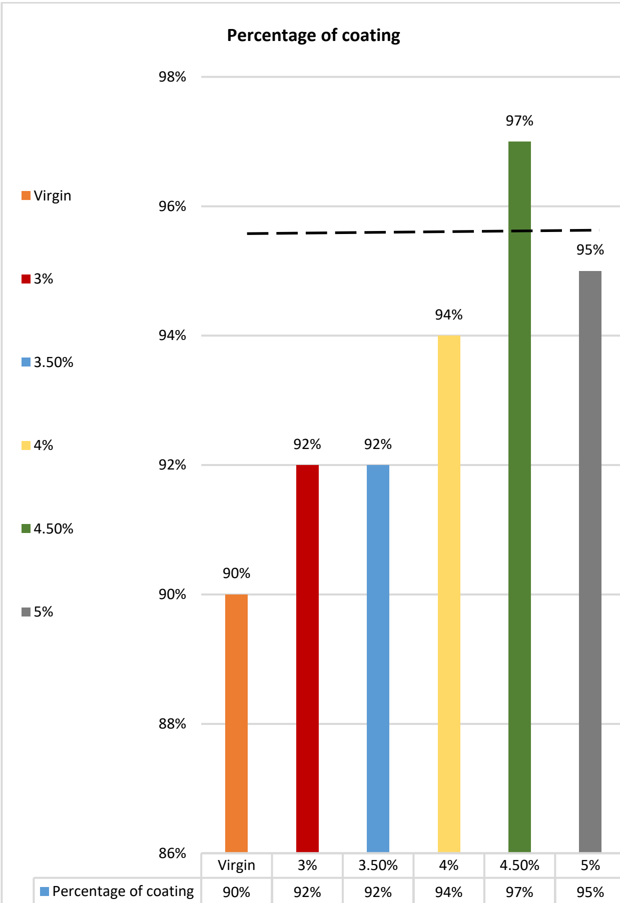

Fig. 8 BWT method for NRL 60/70

NRL 80/100

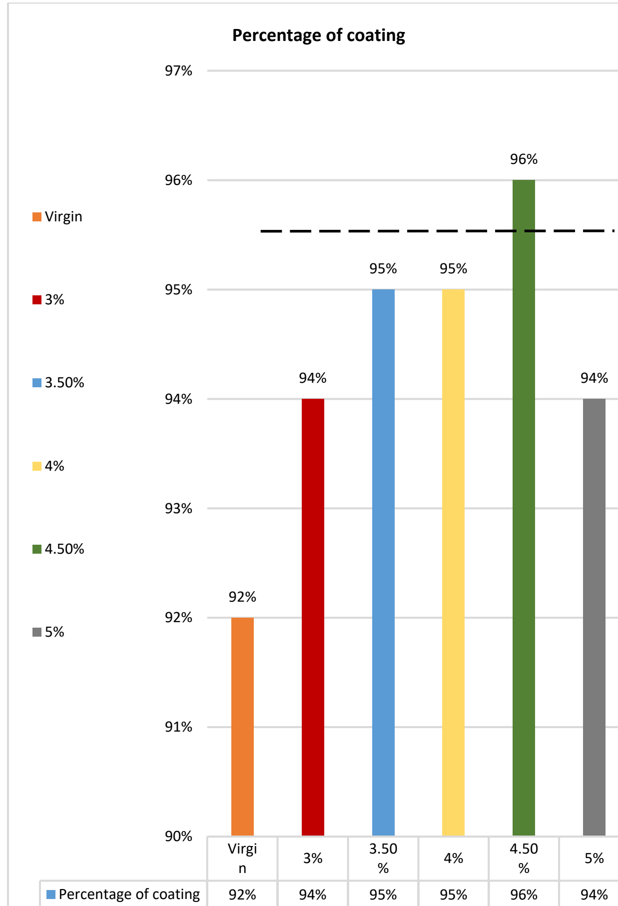

Fig. 9 BWT method for NRL80/100

In Fig. 8, we can see that the virgin bituminous mix has a lower coating value than the modified mixes and in modified mixes, the 4.5% ONC modified mix show more resistance than the rest having a coating of 97%.

In this Fig. 9 of the boiling water test, we can see the improvement in the asphalt mixes with the addition of organophilic nanoclay. The modified mixes show better results as compared with the virgin bituminous mix. Here also, the optimum percentage of ONC is 4.5%.

7. Conclusion

The Rolling Bottle Test is the most logical and satisfactory test to determine moisture sensitivity, regardless of the time spent conducting the test. Meanwhile, the Boiling Water Test is the most accurate test that takes the least amount of time to complete.

- After executing all the experiments and comparing the findings of ONC-modified asphalt mixes to those of raw virgin bituminous mixes, it can be determined that the addition of organophilic Nano clay reduces moisture damage, particularly with 4.5% and occasionally 4% ONC.
- The affinity between binder and aggregates can be improved with organophilic Nano clay.
- Compared to virgin bituminous mixtures, ONC-modified mixtures demonstrated superior resistance to moisture.
- The table below summarizes the overall performance of organophilic nanoclay in asphalt mixes, particularly at 4.5 percent and sometimes 4 percent.

Table. 2 of optimum results

Test	NRL type	Increase in affinity at optimum (4.5%) ONC
RBT	80/100	17%
	60/70	14%
BWT	80/100	4%
	60/70	7%
TWIT	80/100	6%
	60/70	7%
SWIT	80/100	6% (at 4%ONC)
	60/70	4%(at 4 and 4.5 ONC)

- In conclusion with this and existing research findings, Organophilic nanoclay is more economical, naturally abundant, and easy to use than other modifiers.

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References

[1] Mamun, and Arifuzzaman, "Nanoscale Moisture Damage Evaluation of Carbon Nanotube-Modified Asphalt," *Construction and Building Materials*, vol. 193, pp. 268-275, 2018. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2018.10.155

[2] Das and Singh, "Effects of Regular and Nano-Sized Hydrated Lime Fillers on Fatigue and Bond Strength Behavior of Asphalt Mastic," *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2672, no. 28, 2018. *Crossref*, https://doi.org/10.1177/0361198118759064

[3] S. M. Mirabdolazimi, A. H. Kargari, and M. Mazhari Pakenari, "New Achievement in Moisture Sensitivity of Nano-Silica Modified Asphalt Mixture with A Combined Effect of Bitumen Type and Traffic Condition," *International Journal of Pavement Research and Technology*, vol. 14, pp. 105-115, 2021. *Crossref*, https://doi.org/10.1007/s42947-020-0043-y

[4] Zhanping You, Julian Mills-Beale, et al., "Nanoclay Modified Asphalt Materials: Preparation and Characterization," *Construction and Building Materials*, vol. 25, no. 2, pp. 1072-1078, 2011. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2010.06.070

[5] Zahid Hossain, Musharraf Zaman, et al., "Evaluation of Moisture Susceptibility of Nano Clay Modified Asphalt Binders through the Surface Science Approach," *Journal of Materials in Civil Engineering*, vol. 27, no. 10, 2015. *Crossref*, https://doi.org/10.1061/(ASCE)MT.1943-5533.0001228

[6] Lopez-Montero et al. "Evaluation of Moisture Susceptibility of Nanoclay-Modified Asphalt Binders Through the Surface Science Approach,"

[7] Chirag Jain, Gyanendra Sharma, and Govind Vaishnav, "A Review on Use of Industrial Waste in Sub-Base of Flexible Pavement," *SSRG International Journal of Civil Engineering (SSRG-IJCE)*, vol. 3, no. 5, 2016.

[8] Z. Hossain, M. Zaman, et al., "Evaluation of Moisture Susceptibility of Nanoclay-Modified Asphalt Binders Through the Surface Science Approach," *Journal of Materials in Civil Engineering*, vol. 27, no. 10, pp. 1–9, 2014.

[9] Ahmed Ebrahim Abu El-MaatyBehiry, "Laboratory Evaluation of Resistance to Moisture Damage in Asphalt Mixtures," *Ain Shams Engineering Journal*, vol. 4, no. 3, pp. 351-363, 2013. *Crossref*, https://doi.org/10.1016/j.asej.2012.10.009

[10] Zahid Hossain, Musharraf Zaman, et al., "Evaluation of Moisture Susceptibility and Healing Properties of Nanoclay-Modified Asphalt Binders," *IFCEE*, 2015. *Crossref*, https://doi.org/10.1061/9780784479087.034

[11] Han Wang, Yinchuan Guo, et al., "Effect of Nanoclays on Moisture Susceptibility of SBS-Modified Asphalt Binder," *Advances in Materials Science and Engineering*, 2020. *Crossref*, https://doi.org/10.1155/2020/2074232

[12] Panvel Sanika Kandalekar, Raju Narwade, and Karthik Nagarajan, "Feasibility of Pervious Concrete Pavement: A Case Study of Karanjade Node," *SSRG International Journal of Civil Engineering*, vol. 6, no. 3, pp. 34-39, 2019. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V6I3P105

[13] F. Moghadas Nejad, A.R. Azarhoosh, et al., "Influence of Using Nonmaterial to Reduce the Moisture Susceptibility of Hot Mix Asphalt," *Construction and Building Materials*, vol. 31, pp. 384-388, 2012. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2012.01.004

[14] Moses Gambo, Aje Tokan, et al., "Effect of Moisture Content on Nasarawu Natural Foundry Sand," *International Journal of Recent Engineering Science*, vol. 7, no. 4, pp. 1-6, 2020. *Crossref*, https://doi.org/10.14445/23497157/IJRES-V7I4P101.

[15] M.El-Shafie, I.M.Ibrahim, and A.M.M.Abd El Rahman, "The Addition Effects of Macro and Nano Clay on the Performance of Asphalt Binder," *Egyptian Journal of Petroleum*, vol. 21, no. 2, pp. 149-154, 2012. *Crossref*, https://doi.org/10.1016/j.ejpe.2012.11.008

[16] Liping Lia, Shaopeng Wu, et al., "Effect of Organo-Montmorillonite Nano Clay on VOCS Inhibition of Bitumen," *Construction and Building Materials*, vol. 146, pp. 429-435, 2017. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2017.04.040

[17] [Online]. Available: https://Web.Uettaxila.Edu.Pk/Tite/Newequipments.htm

[18] Gholam Hossein Hamedi, Fereidoon Moghadas Nejad, and Khosro Oveisi, "Estimating the Moisture Damage of Asphalt Mixture Modified with Nano Zinc Oxide," *Materials and Structures*, pp. 1165–1174, 2016. *Crossref*, http://Dx.doi.org/10.1617/S11527-015-0566-X

[19] Prakash Somani, Vikash Maharaniya, Banwarilal Kumawat and Rahul Dev Rangera, "Strengthen of Flexible Pavement By Using Waste Plastic and Rubber," *SSRG International Journal of Civil Engineering (SSRG-IJCE)*, vol. 3, no. 6, 2016.

[20] Prabin Kumar Ashish A, Dharamveer Singh, and Siva Bohmb, "Evaluation of Rutting, Fatigue and Moisture Damage Performance of Nanoclay Modified Asphalt Binder," *Construction and Building Materials*, vol. 113, pp. 341-350, 2016. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2016.03.057

[21] [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/pmc6804256/

[22] [Online].Available:https://Pavementinteractive.Org/Reference-Desk/Testing/Asphalt-Tests/Moisture-Susceptibility/#:~:Text=Moisture%20susceptibility%20is%20a%20primary,in%20the%20presence%20of%20water.
[23] Narender Singh, "Utilization of Plastic Waste to Improve the Properties of Aggregates Using Dry Process."