Review Article on Self Healing, Rheological Properties and Modification Mechanism using Nano-Silica as a modifier on Hot Bitumen

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ABSTRACT

This Review article discusses the many characteristics of Nano-Silica when combined with molten asphalt. Nano-Silica has a vast array of qualities and is quite effective. Cracking and rutting may be found on the roadways in Pakistan. Due to increased traffic and expanding population, the intensity of traffic has been increasing day by day, causing a continuous load of automobiles to be imparted on the roads that exceed the road's carrying load. This evaluation also includes studies conducted in other nations. It shows how nano-silica solves the issue of the produced cracks by self healing process. Bitumen that has been treated with nano-silica initiates self-healing. Furthermore, there is discussion done on the explanation on improving rheological properties and causing of self healing due to nano-silica modified bitumen.

Keywords: Nano-Silica, Self-Healing, Rheological Properties, Rutting Resistance, Modified Bitumen.

2 INTRODUCTION:

Increased traffic volume and population growth in a country, cause pavement to be continuously loaded, resulting in pavement distress issues. The difficulty for road engineers is to create a pavement less likely to form from the asphalt mixture preventing system failure by creating new road surfaces and new techniques for building and maintaining roads. Numerous investigations on self-healing asphalt concrete have been carried out and cracking was identified as one of the primary failure causes. It reduces the service life of asphalt pavements and leads to frequent maintenance and increased maintenance cost. In addition to standard asphalt binder modifiers, the utilizationn of nanomaterials such as nanoclays, nanotubes, and nano alumina is being investigated [[10],[11]]. Nanomaterials with a high specific surface area, high functional density, and high strain resistance are potential candidates for binder modification [12].Error: Reference source not found The rheological ageing index measurement of the ageing resistance of CL-30B nanoclay modified binders revealed that the addition of CL-30B nanoclay improves the ageing resistance of asphalt binders [13]. The inclusion of nanoclay improves the storage stability of polymer-modified asphalt binders substantially [14]. The inclusion of nanosilica improved the durability of asphalt binders during ageing and storage [15]. The ageing resistance of the asphalt binder modified with SBS improved significantly after the inclusion of carbon nanotubes [16]. Asphalt binders treated with carbon nanotubes demonstrated enhanced resistance to ageing and storage stability [17]. The addition of nanosilica to the asphalt binder improved the asphalt binder's physical and rheological qualities. Literature has mostly focused on assessing the rutting resistance of nanosilica-modified asphalt binders using the Superpave (G*/sin) rutting parameter. Based on the Superpave rutting measure (G*/sin), previous studies have shown that the inclusion of nanosilica improved the rutting resistance of asphalt binders. The inclusion of nanosilica increases the asphalt binder's storage modulus and elasticity, as well as its resistance to ageing [18]. It stiffens the asphalt binder and increases its temperature resistance, as seen by a reduction in penetrability and an increase in the softening point. The inclusion of nanosilica results in an improvement in the PG grade of the asphalt binder [19]. The nanosilica enhances the self-healing potential of asphalt binders and mixes, hence enhancing the durability and longevity of asphalt pavements [20].

Asphalt's mechanical and viscoelastic qualities, as well as surface-free energy, causes fracture interface wetting. The Brownian motion of molecules from the higher to the lower density zone produced by the fracture is the cause of this self-diffusion [[21],[22]]. Bitumen and nano-silica were mixed in varied proportions. Due to their high surface energy, nano-silica particles may enter fissures and fill voids. Nano-silica will facilitate the repair of fissures [23]. The addition of nano-silica to bitumen improves its mechanical properties as well as its strength. The amounts of nano silica utilized vary from 2% to 10% [24]. The asphalt binder used as the control was modified using nano-silica. Asphalt binder and mixture tests, including the rotational viscosity (RV), dynamic shear rheometer (DSR), bending beam rheometer (BBR), and dynamic modulus (DM), are conducted to evaluate the performance, and scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FTIR) were used to examine the microstructure of the nano-modified asphalt binder.

There is several literature done on self healing of bitumen which also describes the beahvious of nano-silica.

3 LITERATURE REVIEW:

There are several research papers read so far which describe that Nano-Silica shows self-healing properties. Moreover, by using the Nano-Silica as a base modifier, it also enhances Rheological Properties as mentioned in recent research. Different technologies have evolved for the internal rectification of defects before they are observed through the naked eye, which is popularly known as self-healing technologies. These include induction heating, microwave heating, and other healing technologies that use different nanomaterials and polymers in asphalt pavements. Frequent production and application of asphalt mixes for maintenance is not only uneconomical but also generates a lot of greenhouse gases [1]. Multi-walled carbon nanotubes (MCNT) are widely employed to modify bitumen due to their excellent properties. There is limited research on using MCNT to accelerate the self-healing properties of bitumen. The compatibility and modification mechanisms were observed by a fluorescence microscope and Fourier Transform Infrared Spectroscopy. Then, the rheological properties were investigated using a DSR and BBR machine [2]. Nano-silica can be produced from rice husk and silica fumes and therefore is a cost-effective and environment-friendly binder modifier. Different percentages of nano-silica (0, 0.5%, 1%, and 3% by weight of asphalt binder) were added to VG-10 binder in a high-speed mixer. Various rheological tests like time-temperature sweeps, Superpave rutting parameter (G*/sin), Multiple Stress Creep and Recovery (MSCR) Test, creep tests, and zero shear viscosity tests were performed on bases and modified asphalt binders [3].

The effect of graphene oxide (GO) on the physical performance-related properties of an asphalt binder was investigated in terms of penetration, softening point, viscosity (110–185°C), and ductility as well as temperature performance indices. Subsequently, response surface methodology (RSM) was used to examine the influence of GO and asphalt content on the volumetric and strength properties of the asphalt mixture. The results showed that the tensile strength, stability, and plastic flow were highly influenced by variations in the preparations [4].

The objective of this study is to evaluate the rheological properties and chemical bonding of nano-modified asphalt binders with nano silica. Nano-modified asphalt binder and mixture were subjected to a variety of tests, including rotational viscosity, dynamic shear rheometer, bending beam rheometer, and scanning electron microscopy. The results of this study show that these binders are better at not getting old and resisting rutting and fatigue cracking [5].

Self-healing has become a hot topic in the realm of bituminous materials research. The goal is to construct the pavement in such a way that the fractures mend themselves. Exhaustion and healing have been shown to be persistent issues throughout the life of a pavement. This technique will make the street self-healing and increase its lifespan and serviceability [6].

Hot mix asphalt (HMA) self-healing may have the potential to improve. It is called nano-silica due to its spherical shape, tiny size, and higher density compared to bitumen. Scanning electron microscopy was used to investigate the size, morphology, and dispersion of nano-silica particles. A Dynamic indirect tensile test (IDT) was used to evaluate the HMA self-healing index. SEM results indicated that bitumen mortar flowing into micro-cracks may be one of the most important mechanisms for self-healing [7].

Table 1: Initial Literature Review

Ref	Author	Title	Finding
1	B.R. Anupam	A methodological review on self-healing asphalt pavements	Asphalt pavements need regular maintenance to manage traffic. Pavements can be fixed with healing chemicals, induction heating, microwave heating, and other ways that use nanoparticles and polymers as asphalt additives.
2	Fan Zhang	Mechanism, rheology and self healing properties of CNT Modified Asphalt	This study tests MCNT-modified asphalt's rheological and self-healing properties. Base bitumen was evaluated for enetration, softening point, viscosity, etc. FM tested self-healing. 1.5% MCNT is very healing.
3	Faheem Sadiq Bhat	Rheological investigation of asphalt binder modified with nanosilica	Nanosilica binds. Nanosilica. High-speed mixers combined nanosilica with VG-10 binder. Temperature, strain rate, and frequency impact viscosity. Basic and nanosilica-augmented asphalt binder underwent time-temperature

			sweeps, Superpave rutting parameter (G*/sin), MSCR, creep, and ZSV tests. Nanosilica-enhanced asphalt binder rutting. Amplitude Nanosilica decreased sweep fatigue asphalt binder and microfractures. Nanosilica shields asphalt binder polymers. Nanosilica-modified binder self-heals.
4	Abbas Mukhtar Adnan	Physical properties of graphene-oxide modified asphalt and performance analysis of its mixtures using response surface methodology	Graphene oxide (GO) was tested for asphalt binder penetration, softening point, viscosity (110–185°C), ductility, and temperature. Response surface techniques examined how GO and asphalt concentrations influenced asphalt mixture volume and strength (RSM).
5	Hui Yao	Rheological investigation of asphalt binder modified with nanosilica	Nano-modified asphalt binders study nanosilica's rheology and chemical bonding. Nano-modified asphalt binder and mixture underwent rotational viscosity, dynamic shear, bending beam, and scanning electron microscopy. Modified asphaltbinders enhanced antiaging, rutting, and fatigue cracking.

4 DISCUSSION:

4.1 Potential for self-healing of nanosilica-modified binder

Ductility and self-healing properties of basic asphalt binder and nanosilica modified asphalt binder After 4 hours, the basic binder regained 64.41% of its ductility. Nanosilica particles improve asphalt binder recovery. 82.48% recovery with 3% nanosilica. Thus, nanosilica improves asphalt binder self-healing and service life [3].

4.2 Influence of nanosilica on anti-aging:

Asphalt, being a polymer, is susceptible to aging, which is initiated by thermal-carbon bonds associated with the transfer of hydrocarbons. Adding nanosilica to the asphalt binder decreases the rutting aging index (ARPI) of the binder. With an increase in the nanoparticle content, the oxidative process was found to slow down, leading to a decrease in the aging resistance [25].

4.3 Rheological properties of nano-silica modified bitumen:

Different sizes and types of nano-Silica would significantly improve the stiffness properties by increasing the complex shear modulus. This allows for better stability and high resistance to deformation. Modifying and advancing the properties of bitumen and asphalt mixes by using certain additives is one way of boosting the service life of road surfaces [[26],[27]].

5 CONCLUSIONS:

As we are aware, there has been little study on self-healing nanosilica and this concept has neither been launched nor applied in Pakistan. Due to its expense, nano-silica has been favoured over carbon nanotubes, which were the subject of the majority of the global studies conducted on this topic. Our review paper expresses worry about verifying the results by studying the rheological characteristics of asphalt treated with nano-silica. Asphalt's rheological qualities are being evaluated by testing its resistance to rust and abrasion and by determining its complex modulus. To analyse the first healing temperature of nano-silica-modified asphalt with varying amounts of the modifier, In addition, to assess the uniformity of asphalt's self-healing characteristics at various temperatures. In other nations, little has been accomplished so far, and additional change is required.

6 3. REFERENCES

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