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Imprint of Nano-silica particles on Ageing of Bitumen

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Abstract: ***Nanotechnology has been gradually penetrated into the field of asphalt modification. Seemingly magic effects of nanomaterial have been brought to improve the performance of asphalt. Pavement failure is characterized by many factors of failures. 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 This paper investigates the feasibility of using Nano silica particles to enhance the physical properties of asphalt binder. Properties of bitumen mixes change with time of ageing which starts from bitumen manufacturing temperature which leads to distress of the pavement with ever changing climate. This study aims to improve the understanding effect of bitumen on short term ageing on its properties. In order to resist the ageing process, the modifier Nano-silica the particles are added in suitable doses and the engineering properties are scientifically evaluated in the laboratory checked for its effectiveness.***
Keywords: Bitumen, Nano-silica, aging, pavement, failures

I. INTRODUCTION

Bitumen is made up of complex composition of chemical that displays viscous and elastic properties equally which rely comprehensively on time and temperature.

Visco-elastic means it behaves partly like an elastic solid (deformation due to loading is recoverable) and partly like a viscous liquid (deformation due to loading is not recoverable) and its behaviour depends on the temperature and rate of loading. At the construction stage due to rapid oxidation the bitumen become stiffer but gradually the process slow down when the pavement is in service.

This phenomenon is known as ageing or oxidative aging.

The deterioration of the flexible pavements is also due to extreme climatic conditions prevailing in the country in addition to the heavy traffic. Bitumen oxidative aging is one of the prevalent causes of pavement distresses which increase pavement susceptibility to fatigue and low temperature cracking.

This phenomenon is mainly studied through different tests which are softening point, ductility, penetration, viscosity, specific gravity and loss on heat. Several researchers have performed chemical and mechanical aging tests but still aging is a poorly understood phenomenon.

A common practice in bitumen technology is that there is a continuous effort on modifying bitumen binders for improved properties by the researchers for improving the performance of bitumen pavement.

By considering the above issue, here the endeavour is made to overcome from this issue by concentrate deductively the execution related attributes of unmodified bitumen (VG-40) with and without modifiers (rates of Nano silica) in the research facility additionally recreating the impact of here and now maturing along these lines changes in physical properties are resolved.

II. FACTORS AFFECTING AGEING

Different factors which may affect the chemical, rheological and adhesion characteristics of bitumen finally leading to failure of roads in early stage which is further increased due to water ingress causing effect serviceability comfort condition and increase in huge maintenance cost. Table 1 shows the factors affecting ageing and influence of time, heat, oxygen etc and ideal location of occurring.

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Table 1: Factors affecting ageing

Factors	Influenced by					Occurring	
	Time	Heat	Oxygen	Sun-Light	Beta & gamma rays	At the surface	In mass
Oxidation (in dark)	√	√	√			√	
Photo-oxidation (direct light)	√	√	√	√		√	
Volatilisation	√	√				√	
Photo-oxidation (reflect light)	√	√	√	√		√	
Photo-chemical (direct light)	√	√		√		√	
Photo-chemical (reflected light)	√	√		√		√	√
Polymerization	√	√				√	√
Steric or physical	√					√	√
Exudation of oils	√	√				√	
Changes by nuclear energy	√	√			√	√	√
Action by water	√	√	√	√		√	
Absorption by solid	√	√				√	√
Absorption of components at a solid surface	√	√				√	
Chemical reactions	√	√				√	√
Microbiological deterioration	√	√	√			√	√

III.SELECTED PREVIOUS RESEARCH WORK

Farhad Zafari, Mohammad Rahi , Nazanin Moshtagh, Hossein Nazockdast (2014) in their study on "The Improvement of Bitumen Properties by Adding Nano-Silica" reveals that introduction of nano-silica to asphalt binder can improve the anti-aging property, rutting performance and rheological properties of asphalt binder also FTIR spectrums showed that introduction of nano-silica can delay the oxidative aging process.

Singh, L. P., Karade, S. R., Bhattacharyya, S. K., Yousuf, M. M., and Ahalawat, S. (2013). "Beneficial role of nanosilica in cement-based materials – A review" conveyed that nano-silica has served as a promising material for designing and preparing new functional materials because of its high surface area and stability.

Sinha Ray, S., and Okamoto, M. (2003) "Polymer/layered silicate nanocomposites: a review from preparation to processing", in their research area of work concludes that the shape and dimension of the silica particles are very desirable for application in asphalt binder mainly because the surface area of interaction is much higher than that of conventional fillers. By dispersing nano-silica into asphalt matrix one can create polymeric nano-composites with enhanced mechanical behavior.

Liu, C.-H., and Pan, C.-Y. (2007). "Grafting polystyrene onto silica nanoparticles via RAFT polymerization. " Polymer, has projected after careful examination that introduction of certain Nanomaterials into asphalt binder could offer a significant improvement in asphalt physical and rheological properties leading to development of Nano modified asphalt with superior performance. As such nanotechnology has been gradually incorporated into the field of modified asphalt with various kinds of Nano- materials being used to modify asphalt in recent years. Nano- silica has been widely used in polymers and asphalt binder as inorganic filler to improve the properties of polymeric and bituminous materials.

Yang, Jun, and Susan Tighe. "A Review of Advances of Nanotechnology in Asphalt Mixtures." noted that Silica is a rich international compound that is largely used in industries producing silica gels, colloidal silica, and fumed silica, etc. Nano silica composites have fascinated several scientific interests too. The benefit of these nano-materials existing in low cost production and the high-performance features. He says that nano silica is a material with a vast surface area, robust adsorption, good dispersion, high chemical purity and excellent stability. Yusoff, Nur Izzi Md, Aeyman Abozed Saleh Breem, Hani NM Alattug, Asmah Hamim, and Juraidah Ahmad. "The effects of moisture susceptibility and ageing conditions on nano-silica/polymer-modified asphalt mixtures" has revealed that the use of nanomaterial in asphalt pavement started rather late. Nano-technology is utilized as a new

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material, device and system at the molecular stage. Several nano-materials which have been or have the possibility to be utilized to modify bitumen, such as nano-clay, nano-silica, nano-hydrated lime, nano-sized plastic powders, or polymerised powders, nano-fibres and nano-tubes.

IV. EXPERIMENTAL PROGRAM

A. Materials

The materials which are used in this work are as follows

VG 40 grade Bitumen: Bitumen VG-40 detailed to oppose both bitumen rutting at higher temperatures and thermal shrinkage cracking at bring down temperatures. In view of higher consistency, stiffer Bitumen blends can be created to revise protection from showing and different issues identified with higher temperature and substantial movement loads. Bitumen VG-40 is reasonable for overwhelming activity road, air terminal runway and taxiway, container terminals, crossing point, close toll lots and truck parking areas. For this examination VG40 is provided by Tiki-tar Industry Ltd., Halol, Vadodara and the properties are shown in table 2.

TABLE 2: PROPERTIES OF VG40 BITUMEN

Property	Units	VG – 40	Test Methods
Penetration at 25°C, 100g, 5sec, Min	0.1 MM	35	IS 1203
Absolute viscosity at 60°C	P	3200-3800	IS 1206 (Part 2)
Kinematic viscosity at 135°C, Min	cST	400	IS 1206 (Part 3)
Flash point (Cleveland open cup), Min	°C	220	IS 1448
Solubility in trichloroethylene, Min	%Wt	99	IS 1216
Softening point (R&B), Min	°C	50	IS 1205
Viscosity ratio at 60°C, Max		4	IS 1206 (Part 2)
Ductility at 25°C, Min	CM	25	IS 1208

B. NANO SILICA

The inorganic nano-silica material is generally utilized due to its high beneficial properties which include large surface area, excellent dispersion ability, high absorption, excellent stability and high chemical purity. Nano-silica composites recently attracted scientific research interest due to its greatest benefit of reduction in the cost of production and excellent performance features. Now days, due to high surface area and stability of nano-polymers and bitumen binder. Nano-silica becomes very attractive for application in bitumen modification, because the surface of nano-silica is more chemically active with high polarity unlike other nano-materials. Nano-silica has strong surface free energy and its interface atoms are arranged in a disordered manner which allows for these atoms to be bonded strongly to other outside atoms by external forces. For this study nano silica is supplied by Micro Filler, Ahmedabad. The salient properties of nano silica are shown in table.

Table 3: Properties of VG40 Nano Silica

Physical Property	Value
Appearance	High dispersive white powder
Hydrophobicity	Strong hydrophobicity
SiO2 content (%) (950oC, 2h)	99.8
Purity (%)	>99.9
Loss of ignition (%)	≤ 6
Surface density (g/ml)	0.15
Average Particle size (nm)	10-25
PH value	6.5-7.5
Specific surface area (m2/g)	± 25

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V. EXPERIMENTAL INVESTIGATION

A. Brookfield Viscometer (ASTM D4402) is utilized for deciding the kinematic viscosities of the specimens at 135°C for 5 min. The rotational consistency was controlled by measuring the torque required to keep up a consistent rotational pace of 20 rpm of a cylindrical spindle submerged in bitumen kept up at the test temperature through thermosel.

B. Short term aging test: The Thin Film Oven Test (EN 12607-2, ASTM D 1754) of material is set in a pan (Samples of VG40 with and without nano-silica in dosages of 2%, 4% & 6% by weight of bitumen are placed on a revolving disc for 5 hr at 163ºC), which is held in a convection oven at 163°C for 5 hours. Impact of hardening is resolved on the premise of the adjustment in mass in the bituminous binder's attributes of penetration, softening point or dynamic viscosity prior and then afterward oven aging.

VI. TEST RESULTS AND DISCUSSION

Table 4 : Physical properties of before and after aging

Binder type	softening point (°c) (Min.50)	penetration (mm) (Min.35)	viscosity (135°c) (Min.400)	Ductility (cm) (Min.25)	Flash & Fire point (Min.220)	Specific Gravity (> 1)	Loss on Heating (%) (< 1)
Codal Provision	IS: 1205-1978	IS: 1203-1978	IS: 1206-1978	IS: 13920-1993	IS: 1209-1978	IS: 1202-1978	IS: 1205-1978
Before aging							
VG 40	56.00	40.00	654.00	94	328	1.032	0.12
VG 40 + NS 2.0 %	57	39.50	590.50	96	332	1.027	0.06
VG 40 + NS 4.0 %	59.00	38.5	587.00	97	335	1.02	0.05
VG 40 + NS 6.0 %	57.50	38.00	580.00	100	337	1.003	0.07
After aging							
VG 40	54	38	633.00	92	310	1.032	0.1
VG 40 + NS 2.0 %	54.5	37	575	94	317	1.027	0.05
VG 40 + NS 4.0 %	55	36.5	560.5	96	325	1.02	0.45
VG 40 + NS 6.0 %	56	36	550	97	331	1.003	0.04

VII. DISCUSSION

Looking to the above results tabulated in the table it is seen that there is a decrease in penetration and an increase in the softening point when nano silica was introduced to the asphalt binder. It was observed that all nano modified asphalt samples if properly diffused in bitumen phase takes place it results in bitumen stiffness. Consequently, the modified bitumen need time to change to liquid phase, so the penetration is low. The smaller the bitumen penetration, the more load capacity of produces asphalt mixture is and the more bitumen softening point, the more efficient the bitumen had lower penetration and higher softening point than control asphalt. This in turn can lead to improvement in the asphalt binder stiffness and flexibility. The higher ductility value was VG 40 with 6% nano silica compared to unstable behaviour at value of VG 40 with 2% & 4% nano silica. Further it is view that when nano silica is added in VG 40, viscosity decreases. As result, nano silica contents increase and decrease the viscosity values. Additionally, VG 40 with silica contents binder mixing process recommends that those chemical reactions and physical dispersion are prone to happening, and a new network structure might be formed due to the nano silica being temperature resistant. Moreover, Nano-silica has the ability to strengthen binder and better the recovery's ability during stress application and this is especially seen as NS at concentration 6% by weight of bituminous binder. Also, higher increase in flash and fire point test with the addition of nano silica is encouraging regarding safety issue. The properties of VG 40 grade bitumen and nano silica is almost same; hence change is specific gravity is very low. Loss on heating test also indicates that VG 40 + NS 6.0 % have the lowest loss on heating. As result, the nano silica particles are a good modifier in inhibiting oxidizing reactions in the bitumen binder.

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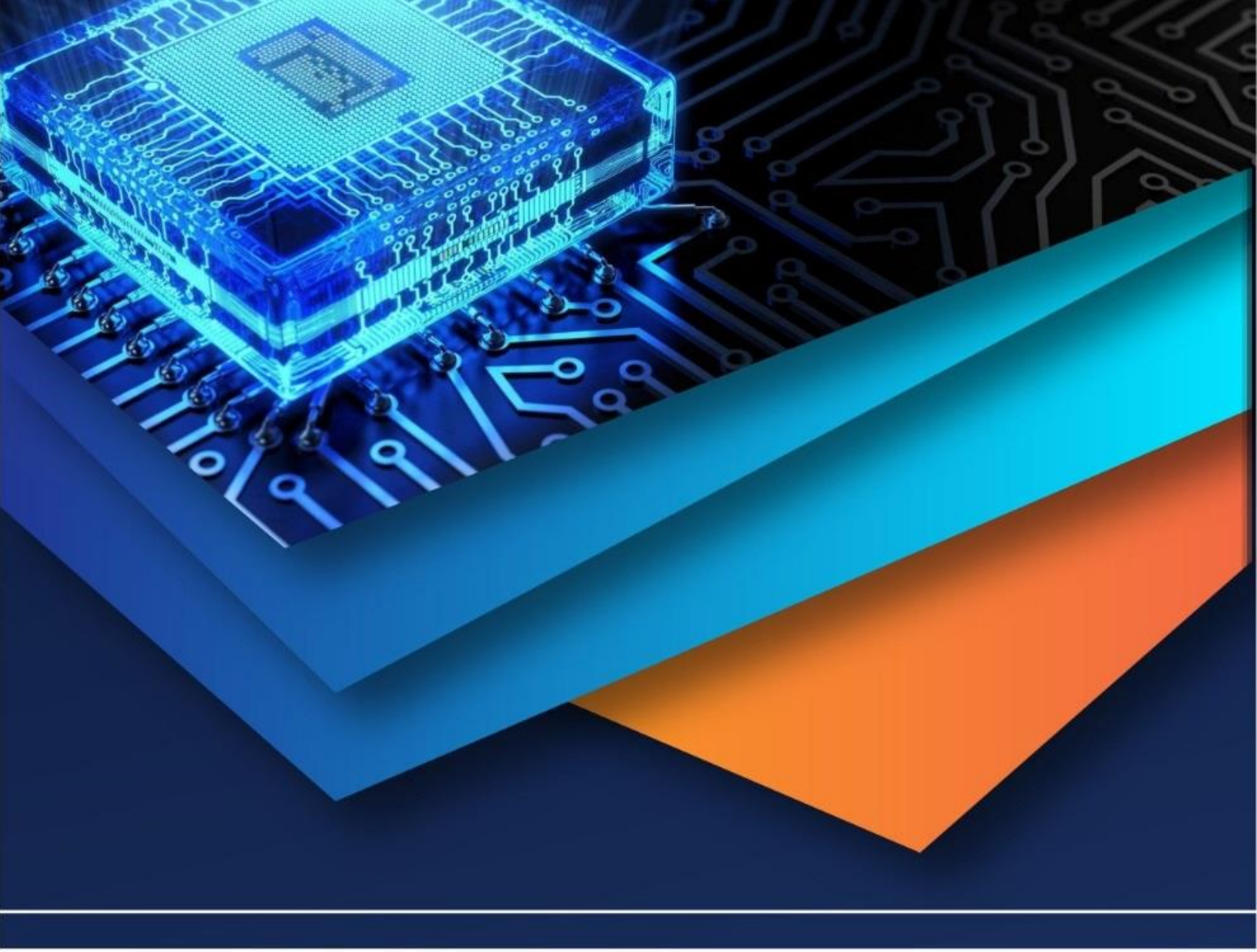
VIII. CONCLUSIONS

In this study the scope of nano silica particle in asphalt binder as an anti-aging modifier at a suitable dosage by weight of bitumen is scientifically investigated in the laboratory. The changes in properties are seen and are reflected in conventional bitumen test. The outcome of investigation indicates that Softening point, penetration and viscosity values, loss on heating and specific gravity for VG40 + 6% NS is most favorable and can be suggested to highway contractors, government policy makers, researchers too.

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