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# Experimental Investigation of Nano-Silica and Crumb Rubber Modified Bitumen.

**Supriya Kosalge[#1], Aishwarya Jadhav[*2], Abhijit Temkar[#3], Mangesh Pawar[#4], Pravin Wale[#5]**

*[#1-4]UG Students, Civil Engineering Department, Savitribai Phule Pune University, Pune*
*[#5]Assistant Professor, Civil Engineering Department, Savitribai Phule Pune University, Pune*

*[1]supriyakosalge22@gmail.com*
*[2]aishwaryajadhav232@gmail.com*
*[3]abhijittemkar3@gmail.com*
*[4]pmangesh49@gmail.com*
*[5]pmwale_sits@sinhgad.edu*

***Abstract***

*Roads are an important mode of transport in India. They carry about 85% of total traffic generated in the country. So there is a need for better roads with less dam- ages and maintenance cost. Nanomaterials have been used widely in almost all fields which also penetrated into the field of bitumen modification to improve its performance. Disposing of rubber waste has become a vast problem. Every year millions of tons of rubber produce in India. Utilising these materials in highway road construction, the pollution and disposal problem can be successfully be reduced. This paper investigates the feasibility of using Nano-silica and crumb rubber to enhance the physical properties of bitumen. Softening Point, Penetration, Flash and fire, ductility, Marshall Stability test were carried to analyze performance of nanosilica and crumb rubber modified binders. In this study crumb rubber and nanosilica were added to VG 30 grade bitumen with 2% crumb rubber and 1-5% Nanosilica by weight of bitumen. This helped to understand effect of bitumen properties under various concentration of modifier. Results showed that there is increase in softening point and decrease in penetration value and ductility of bitumen due to addition of nanosilica with crumb rubber (NSWCR). Addition of nanosilica with crumb rubber in the binder the stability value of the mix increases upto 3% after that decreases. Results show that NSWCR-3% is the best performing mix in its class.*

*Keywords— Nanosilica, Crumb rubber, Bitumen, NCWCR*

## I. INTRODUCTION

Road transport is vital to India's economy. It enables the country's transportation sector to contribute 4.7 percent towards India's gross domestic product. This is in comparison to railways, which contributed 1 percent from 2009 to 2010. Road transport has grown in importance over the years despite significant barriers and inefficiencies in inter-state freight and passenger movement, compared to railways and air. The government of India considers its road network as critical to the country's development, social integration, and security needs. India's road network carries over 65 percent of its freight and about 85 percent of passenger traffic. Nanotechnology is an emerging field of science related to the understanding and control of matter at the Nano scale, i.e., at dimensions between approximately 1 and 100 nm. At the Nano scale, unique phenomena enable novel applications. Nanotechnology encompasses Nano scale science, engineering, and technology that involve imaging,



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measuring, modelling, and manipulating matter at this length scale. Just how small is "Nano"? In the serviceability index system of units, the prefix "Nano" means 1-billionth or 10–9. Therefore 1 nm is 1-billionth of a meter Nano scale particles are not new in either nature or science. Recent developments in visualization and measurement systems for characterizing and testing materials at the Nano scale have led to an explosion in nanotechnology-based materials in areas such as polymers, plastics, electronics, car manufacturing, and medicine.

For a developing nation such as India, roads and highways are preferred as primary modes of transportation. It is a fact that bituminous material, such as bitumen is mainly used on large scale and huge quantity for construction and maintenance of roads results in degradation of environment and depletion of natural resources such as raw materials etc. so it is necessary to stimulate the application of nano materials for asphalt pavements for evaluating mechanical and physical properties and as well as durability of asphalt pavement.

## II. SELECTED PREVIOUS RESEARCH WORK

Nabin Rana Magar."A detailed review of research works carried out on modified bitumen with crumb rubber", This paper presents a study of the penetration value and softening point of modified bitumen. The penetration shows lower values as rubber content increases at different mix conditions of rubberized bitumen binder, indicating that the binder becomes stiff and more viscous. The results of penetration values decreased over the aging as well as before aging by increasing the rubber content in the mix. The use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as rubber crumb content increases.

Aman Patidar, Dipankar Sarkar, Manish Pal "Studying the Behavior of Asphalt Mix and Their Properties in the Presence of Nano Materials", In this study VG30 grade bitumen modify with addition of nano-silica with 1% to 5% (increment of 1%) by weight of bitumen. Hot mix asphalt (HMA) have higher mixing, laying and rolling temperatures which leads to higher consumption of fuel. To address this issue, a nano material named Zyco Therm which is chemical warm mix asphalt (WMA) additive is added to bitumen. Nano- silica modification (NSMB) results in the increase in stability compared to unmodified bitumen (UMB). WMA modified mix shows slightly higher stability than UMB and NSMB in a lower bitumen con- tent. The Retained stability and tensile strength ratio (TSR) is more than 75% and 80% respectively for both mixes. Nano-silica with WMA has more resistant to temperature susceptibility, moisture susceptibility and short term aging than NSMB.

Ruikun Dong, Jinliang Li and Shifeng Wang "Laboratory Evaluation of Pre-Devulcanized Crumb Rubber–Modified As-phalt as a Binder in Hot-Mix Asphalt" This paper investigate the properties of hot-mix asphalt (HMA) prepared with devulcanized crumb rubber– modified asphalt (DCRMA), which was processed by using pre-devulcanized crumb rubber at a lower temperature (165C). HMA with different DCRMA content in weight were investigated, and it was found that the optimal binder content was 6.1grading mixture design method was applied in the design of DCRMA HMA. From the experimental results, it could be concluded that the pre-devulcanized crumb rubber can be used as one kind of good modifier for asphalt rubber to improve hot storage stability. DCRMA could also act as a cost-effective, modified binder in dense-graded asphalt mixture, and benefit the low temperature property and prolong the fatigue life cycle.

Indu Venu Sabaraya, Angelo Filonzi, Ramez Hajj, Dipesh Das, Saleh andAmit Bhasin "Ability of Nanomaterials to Effectively Disperse in Asphalt Binders for Useas a Modifier", This paper investigates the dispersion characteristics of a selected set of nanomaterials (Nanoglass, Nanoclay, Nanosilica, Nanoalumina, Tetraethyl orthosilicate, Trimeth oxymethyl silane) in surrogate solvents that represent a physicochemical environment similar to that of asphalt binders. The study also investigates



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the influence of these nanomaterials on the performance characteristics of asphalt binders. Results show that among the nanomaterials evaluated, those that tend to disperse relatively better in the surrogate environment, i.e. retain their nanoscale identity better relative to others, also tend to show a relatively better performance in terms of rheological properties. This is especially true at low temperatures.

Saeed Sadeghpour Galooyak etal. "Performance Evaluation of Nano-silica Modi- fied Bitumen", This paper presents a study of the different contents of Nano-silica, 2 wt.%, 4 wt.% and 6 wt.%, have been added to bitumen to modify the physical, mechanical and rheological properties of warm mix asphalt (WMA). WMA is containing 2 wt.% of Sasobit (mixture of long-chain hydrocarbons). Results of investigations on the asphalt mixtures demonstrated the fact that by increasing Nano-silica content, the quality of the warm mix asphalt has been improved, the resilient modulus of WMA has increased. By adding Nano-silica to the Sasobit WMA, the depth of cracking has decreased dramatically. So, fatigue life of WMA has been extended in the presence of Nano-silica. Also, the results of wheel tracking test demonstrated that the rutting depth of modified samples have been reduced. The results on WMA showed that 6 wt.% of Nano-silica is the optimum content. This result was in compliance with the rheological investigations.

## III. EXPERIMENTAL PROGRAM

A. Materials

**I.** Crumb Rubber: Crumb rubber is recycled rubber produced from automotive and truck scrap tires. During the recycling process steel and tire cord (fluff) are removed, leaving tire rubber with a granular consistency. It is compatible with bitumen and used to avoid degradation of bitumen at mixing temperature. In addition, it also produces coating viscosity at the application temperature and thus, maintains premium properties during storage application and in service. The modified bitumen is used high rain- fall areas because of the better creep resistance properties at busy junctions, bridge decks roundabouts and also, long life of surfacing in snow bound areas. It is used as stress absorbing membrane (SAM) for the purpose of sealing of cracks and preventive maintenance for delaying reflexion cracking

| **Physical Properties** | **Values** |
|---|---|
| Density | 1320 kg/m$^3$ |
| Young's Modulus (E) | 2600-2900 MPa |
| Tensile Strength ($\sigma_t$) | 40-70 MPa |
| Elongation at Break | 25-50% |
| Melting Point | 200 °C |
| Price | 20-30 per kg |

TABLE I : Properties of Crumb Rubber.

**II.** VG 30 Grade Bitumen**:** VG-30 is especially used to construct extra heavy duty Bitumen pavements that need to tolerate significant traffic loads. It can be used instead of 60/70 penetration bitumen grade.



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| Characteristics | units | VG-30 | TEST METHOD |
|---|---|---|---|
| Penetration at 25 °C | MM | 50-70 | IS 1203 |
| Softening Point | °C | 47 | IS 1205 |
| Ductility | CM | 40 | IS 1208 |
| Kinematic Viscosity, 135˚C, min | CST | 2400 | IS 1206 (Part 3) |
| Solubility in trichloroethylene, min | %Wt | 99.0 | IS 1216 |
| Viscosity ratio at 60˚C, max | - | 4.0 | IS 1206 (Part 2) |

TABLE II: PROPERTIES OF VG-30 BITUMEN.

**III.** 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. The salient properties of nano silica are shown in table

| Physical Properties | Values |
|---|---|
| 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 |

TABLE III: PROPERTIES OF NANO SILICA.



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## IV. EXPERIMENTAL INVESTIGATION

A. Physical Properties: Penetration test according to ASTM D5-5147, Softening point (Ring and Ball) according to ASTM D36-95, Ductility test according to IS:1208-1978.

B. Marshall Stability Test: The Marshall test is performed to evaluate the optimum bitumen content (OBC) of the bituminous mix. The test is conducted according to the ASTM: D 6927-15 [9]. In the Marshall mix design three samples are prepared at each bitumen content. The Marshall samples are prepared on three different bitumen contents each starting form 4.0% with constant increment of 0.5% up to 5.0% at mixing. The OBC is determined from plotting the graphs for each trial blend. Then calculate the average bitumen content corresponding to maximum stability.

## V. TEST RESULTS AND DISCUSSION

In this study, penetration test, softening point test, ductility test, Marshall Stability test were carried out on Nano-silica modified bitumen. The results of the test are presented in Tables IV.

| **Tests** | **Softening Point (°C)** | **Penetration (mm)** | **Ductility (cm)** | **Marshall's Stability (kN)** |
|---|---|---|---|---|
| Codal Provision | IS:1205-1978 | IS:1203-1978 | IS:1208-1978 | ASTM D6927-15 |
| VG-30 | 53.00 | 46.00 | >100 | 14.00 |
| VG- 30+CR-2%+ NS- 1% | 55.42 | 41.48 | 94.60 | 15.18 |
| VG-30+CR2%+ NS- 3% | 57.74 | 37.50 | 97.26 | 17.78 |
| VG-30+CR2%+ NS- 5% | 59.87 | 34.56 | 71.47 | 14.46 |

TABLE IV: PHYSICAL PROPERTIES AND STABILITY TEST RESULTS.

From Table IV it is observed that an increase in softening point and decrease in penetration value and ductility of bitumen due to addition of nanosilica with crumb rubber (NSWCR). This means that the nanosilica with crumb rubber reduce aging of bitumen and also reduce temperature susceptibility of bitumen. The stiffness is increased at lower and higher temperature due to nanosilica with crumb rubber.

Marshall Test Results: The mechanical and volumetric parameters of mix are evaluated from the Marshall test. After that optimum bitumen content of mix is calculated then all the parameters are determined at their optimum bitumen content. From the analysis of the TABLE IV, it is observed that nanosilica with crumb rubber mix have performed better than unmodified bitumen. From the different trail of NSWCR-3% have maximum stability value and it has also optimized the bitumen better than other NSWCR mixes. All the other parameters of NSWCR-3% are within the range as mentioned in MoRT&H specification.



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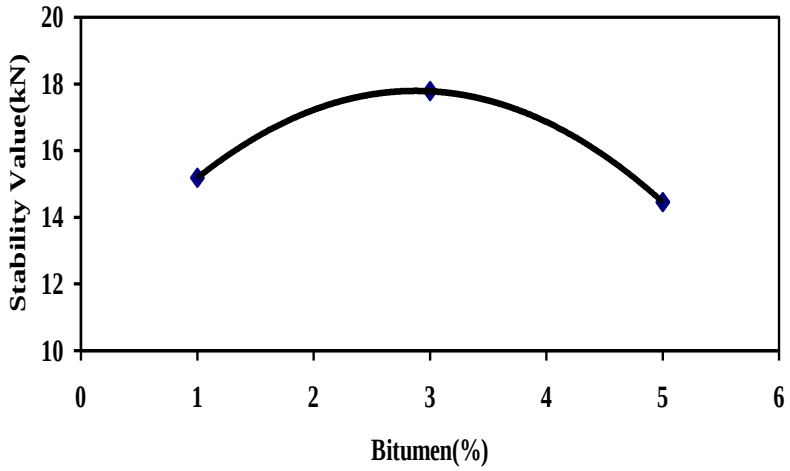


Fig.1 Marshall Stability Curve

## VI. CONCLUSIONS

The results obtained from the present work indicate that the behavior and performance of bituminous mix can be improved by nanosilica with crumb rubber. The following conclusions are drawn from the present investigation.

- From the trend of softening point, penetration value shows that nanosilica with crumb rubber modified bitumen results in improved the stiffness at lower and higher temperature. Due to the nanosilica modified bitumen also reduces the susceptibility to temperature.
- Due to addition of nanosilica with crumb rubber in the binder the stability value of the mix increases upto 3% after that decreases. Results show that NSWCR-3% is best performing mix in its class.

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