Review on Experimental analysis of VG-10 Bitumen for Short Term Aging Process using SBS GP-1 and Nano SiO_2

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Abstract:-**This paper reviews the application of various filler materials with bitumen to increase the pavement life. Aging of binder is the major draw-back of asphalt pavement for long service life point of view. Generally aging of binder is caused due to climatic condition which ultimately leads to cracks on pavement, rutting, fatigue cracks,which cannot withstand the changing environment and increased traffic loads, finally the pavement of failure takes place.To overcome this problem, modification in the properties of VG-10 bitumen was done by adding Elastomer Styrene-Butadiene-Styrene (SBS) of grade GP1 and Nano Silica Powder (Nano SiO_2) in suitable dosages. The short-term aging properties of bitumen were investigated using thin film oven test (TFOT) and rolling thin film oven test (RTFOT) to stimulate aging. The empirical tests including penetration and softening points were conducted to check for binder consistency.**

Keywords: **Bitumen, Aging, penetration and softening point, TFOT, RTFOT, SBS, Nano-SiO_2**

I. INTRODUCTION

1.1 BITUMEN

Bitumen is a viscous liquid, or a solid, which is soluble in trichloroethylene and is substantially non-volatile and softens gradually when heated. It is black or brown in colour & possesses waterproofing properties. It is obtained by refinery processes from petroleum, and is also found as a natural deposit or as a component of naturally occurring asphalt.Bitumen is available in different grades such as VG-10, VG-20, VG-30 and VG-40 (IS:73-2006), but its use mainly depends on the type of layer to be constructed of pavement and climatic condition of the place.

Bitumen is not only an important engineering material but also a vital material in pavement engineering whose properties changes with time. Here, the attempt is made to overcome from this problem by studying scientifically the performance related characteristics of unmodified bitumen (VG-10) with and without modifiers in the laboratory alsosimulating the effect of short term aging.

1.2 AGING OF BITUMEN

The physical properties of bitumen change with time. It may become harder or less elastic. Bitumen properties change over time on exposure to high temperature and atmosphere. This process is referred as Aging.

Based on hardening or stiffening of bitumen material, two types of aging have been derived:

1. Short term aging
2. Long term aging

Short-term aging:

This occurs when bitumen is mixed with hot aggregates i.e. during production and construction.

Long-term aging:

This occurs due to environmental exposure and loading i.e. during the life of the pavement.

1.2.1 Factors affecting aging of bitumen

- Oxidative hardening.
- Hardening due to loss of volatiles.
- Physical hardening.
- Exudative hardening.
- Hardening of bitumen during storage.
- Hardening of bitumen during mixing & transportation of mix.
- Hardening of bitumen on road.

II. MATERIALS

2.1 Nano SiO_2

Nano-silica with theproperties presented in Tables 1, 2, and 3 has beenused in this study.

2.1.1 Physical properties:

Silicon dioxide nanoparticles appear in the form of a white powder. The table below provides the physical properties of these nanoparticles.

Table 1. Physical properties of Nano SiO_2

Properties	Metric
Density	2.4/cm3
Molar mass	59.96 g/mole

2.1.2 Thermal properties:

Table 2. Thermal Properties of Nano SiO_2

Properties	Metric
Melting Point	1600°C
Boiling Point	2230°C

Table 3. Analysis of Nano SiO_2

SiO_2	Na	Fe	Ti	Ca
>99%	<50 ppm	<20 ppm	<120 ppm	<70 ppm

2.2 Styrene-Butadiene-Styrene (Grade GP-1)

Molecular Structure of SBS: Radial

Table 1 and Table 2 shows the chemical composition and thermal properties of SBS respectively.

Table 1 Chemical composition of SBS

Element	Content (%)
Styrene	30
Butadiene	70

Table 2 Thermal Properties of SBS

Properties	Metric
Melting Point	160°C - 200°C

Elementary Analysis of Bitumen

The elementary analysis of the bitumen binder is presented below in Table 4

Table 4. Analysis of bitumen binder

Component	Percentage %
Carbon	82-88
Hydrogen	8-11
Sulphur	0-6
Oxygen	0-1.5
Nitrogen	0-1

III. OBJECTIVES

- To evaluate scientifically physical properties of the bitumen VG – 10 and VG – 30 with and without modifier styrene-butadiene-styrene (SBS GP-1) and Nano Silica (Nano-SiO_2) in suitable dosages before and after short term aging using Thin Film Oven Test (TFOT) and Rolling Thin Film Oven Test (RTFOT).
- Analysing High-Temperature performance by using Nano-SiO_2 and SBS GP-1 polymer in bitumen modification and improving polymer defects, thus increasing flow number by performing Dynamic Creep Test.
- The above objectives are as per the below standards:
  1. (ASTM D1754) TFOT
  2. (ASTM D2872) RTFOT

IV. LITERATURE REVIEW

Suleiman Arafat Yeroand Mohd Rosli Hainin (2012) investigated "the short term aging properties of bitumen". Used RTFOT to stimulate aging during mixing, compaction and laying of asphalt mixtures. In 2012, Mohd. Rosli Hasan carried out RTFOT for bitumen 80/100 penetration grade which resulted in oxidation of bitumen with increase in stiffness of binder.

Ms. Chinkal Patel, Prof. Rupande Desai and Dr.P.J.Gundaliya (2017) did work on "Bitumen Modified with Styrene-Butadiene-Styrene Thermoplastic for roofing applications". Also, various empirical tests like Penetration test, softening point test etc where performed by adding SBS in various dosages in bitumen and performance was checked for flat roofs.

Ashutosh Patekar and Dr. M.S. Ranadive (2014) presented a paper on "Quality assurance and control of bitumen viscosity graded approach". Information about new included tests like viscosity at 60ºC, Kinematic viscosity at 135ºC, solubility in trichloroethylene and tests on RTFOT was given.

Sajad Rezaei et al. (2017), Department of Civil Engineering, Tehran, Iran, investigated for "The effect of nano-SiO2 and the styrene butadienestyrene polymer on the high-temperature performance of hot mix asphalt". The impact of Nano-SiO_2 on high temperature performance of asphalt mixture modified with SBS polymer was studied. Marshall stability test for flow value was performed. Also, interaction of Nano-SiO_2 with aggregate surfaces was checked for increasing the resistance of asphalt against stress.

Xiaohu Lu et al.(2016) presented a paper on "Long term durability of PMB on bridge deck pavements". RTFOT was performed along with conventional tests of bitumen limiting rutting using SBS polymer modified bitumen for tough environmental conditions.

Farhad Zafari (2014) presented a paper on "Improvement of bitumen properties by adding Nano Silica". Used 60/70 penetration grade bitumen blended with 2%, 4% and 6% Nano Silica. Carried out DSR method for properties of aged and

unaged binder. Also, FTIR test was performed for aging resistance of bitumen with help of Nano Silica.

Ahmed Shalaby (2002), presented a paper on "Modelling short term aging of asphalt binders using rolling thin film oven test". Two laboratory tests for evaluating short term aging of asphalt binders were carried out: (a)TFOT (b)RTFOT. Also, DSR method was carried out for six binder types and two PG grades.

Shao-peng Wu et al. (2008), did work on "Influence of aging on the evolution of structure, morphology and rheology of base and SBS modified bitumen". FTIR, AFM and DSR tests were mainly carried out. Two laboratory simulation aging methods, named standard RTFO test and PAV test were applied in this study.

V. CONCLUSION

- *Before Aging:*

After adding SBS and Nano-SiO_2 modifiers with different proportions in VG-10 bitumen, immediate physical change was seen in binder. Also, as concentration of modifier increases, softening point increases and penetration decreases.

-*After Aging:*

Noticeable and a major change in physical state was observed in modified bitumen after conducting TFOT for short term aging, thus oxidation had taken place.

By adding Nano-SiO_2 and SBS with specific dosages 3.5% and 4% weight of bitumen respectively, it showed better performance at high temperature by dynamic shear test. Thus, aging increased binder hardness, ultimately increasing stiffness of binder after RTFOT.

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