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A Review of Laboratory Studies on Use of Low Density Polyethene (LDPE) and Non-Silica as Bitumen Modifiers

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ABSTRACT- Pavements experience numerous distresses including rutting, fatigue cracking, ravelling, etc. as a result of rising axle loads, rising traffic volumes, and poor maintenance. These annoyances lengthen travel times and raise maintenance costs for automobiles while lowering the pavement's riding quality. By incorporating various additives like polymers, nanomaterials, and other compounds into bitumen, one can improve the desirable qualities of the bitumen binder and so lessen the likelihood of these distresses occurring. Although they have demonstrated beneficial benefits on bitumen, polymer additives including polyethylene, ethylene-butyl acrylate (EBA), and styrene-butadiene-styrene (SBS) have certain downsides, such as low storage stability[2]. More study is currently being done to determine how utilising nanoparticles can improve the performance of pavements. Nanomaterials are advantageous because they have a lot of surface area and good dispersion.

KEYWORDS- Nano-Materials, LDPE (Low Density Polyethylene), Softening Point, Penetration Value

I. INTRODUCTION

Roads are regarded as a nation's lifelines, and a country's road infrastructure is a key indicator of its wealth[3]. Roads are essential for everything from the transportation of products to public transportation to disaster management to national security. The condition of the driving surface is one of the most crucial aspects of the road infrastructure, and flexible pavements, which are most popular in India, are more susceptible to surface distresses than rigid pavements. It is crucial to examine the structure of flexible pavement in order to assess and alleviate these distresses[1].
A surface course, a binder course, a base course, a subbase course, and a subgrade make up the composition and structure of flexible pavement shown in Fig 1. Bitumen or asphalt layers serve as the wearing surface of flexible pavements, which support loads through bearing. Their flexural strength is modest[5].

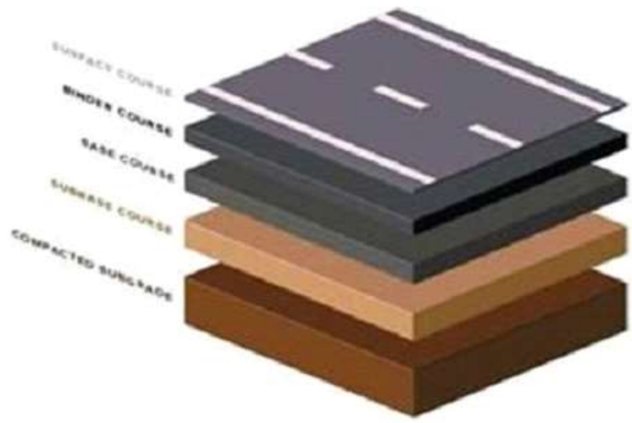

Figure 1: Layered structure of flexible pavement

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II. MATERIALS

A. Bitumen

Asphalts, also known as bituminous materials, are widely utilized to build roads, largely due to their strong binding and water-proofing qualities and affordable price. Bitumen is a solid with a dark colour or a viscous cementitious substance that is mostly made of high molecular weight hydrocarbons extracted from petroleum or natural asphalt. Bitumen has adhesive qualities and is soluble in carbon disulfide.

B. Nano Silica

The application of nanomaterials in many construction industries has received recent attention. Nanomaterials may offer solutions to a number of issues relating to the pavements because of their high strain resistance, high functional density, and high specific surface area. Asphalt modification uses a variety of nanomaterials, including nano silica, carbon nanotubes, nano clay, and nano aluminum trioxide[3].

C. Low Density Polyethylene (LPDE)

A thermoplastic produced from the monomer ethylene is called low-density polyethylene (LDPE) . "A density range of 0.917-0.930 g/cm3 defines LDPE" . Except for strong oxidising agents, it is hardly reactive at ambient temperature, and some solvents cause swelling[5]. It can endure temperatures as high as 90 °C (194 °F) briefly and 80 °C continually[6]. It is made in transparent or opaque versions and is remarkably durable and flexible.The production of various containers, dispensing bottles, wash bottles, tubing, plastic computer component parts, and various moulded laboratory equipment uses LDPE extensively. Plastic bags are its most typical application.

III. TESTING METHODS

A. Penetration Test

By measuring the depth in tenths of a millimetre to which a typical loaded needle will penetrate vertically in 5 seconds, it is possible to determine how hard or soft a bitumen is. The test methodology and equipment had been standardised by BIS. The 100g needle assembly and a mechanism for unlocking and locking the needle assembly in any position make up the penetrometer. The bitumen is heated to a pouring consistency, well mixed, and then poured into containers at a depth that is at least 15 mm deeper than the penetration that is anticipated. The test must be carried out at the designated temperature of 25°C. It should be noted that any errors in pouring temperature, needle size, weight on needle, and test temperature have a significant impact on penetration value. In hot areas, a lower penetration grade is desirable. A bitumen grade of 40/50 signifies the penetration value is in the range of 40 to 50 at typical test settings

B. Ductility Test

The ability of bitumen to undergo significant deformation or elongation is known as ductility. The distance in cm to which a standard sample or briquette of the material can be stretched without breaking is known as ductility. The briquette is precisely 1 cm square in size after being created in this manner. The bitumen sample is heated before being deposited into a plate-mounted mould assembly. These mouldy samples are cooled first in the air and then in a 27°C water bath. Using a heated knife, the extra bitumen is removed and the surface is levelled. After that, a sample-containing assembly in a mould is left in a water bath ductility apparatus for roughly 90 minutes. The sides of the mould are taken off, the clips are fastened to the apparatus, and the apparatus is run. The ductility value, which is given in cm, is the length up until the thread breaks. The pouring temperature, test temperature, pace of pulling, etc. all have an impact on the ductility value. The BIS has established a 73 cm minimum ductility value. In the figure below, bitumen-filled ductility moulds are depicted in both their stretched and un-stretched forms.

C. Flash and Fire Point Test

Depending on the bitumen grades, materials lose volatiles at high temperatures. And because it is extremely dangerous for these volatile substances to catch fire, it is crucial to specify this temperature for each bitumen grade. The temperature at which bitumen vapour under specific test conditions briefly catches fire in the form of a flash was defined as the flashpoint by BIS. The lowest temperature under specific test conditions at which bituminous material ignites and burns is known as the fire point.

D. Rheological Testing

The bitumen sample is sandwiched between two parallel plates in the illustration below, which illustrates the principles involved in dynamic shear rheometer testing. During testing, the upper plate geometry is permitted to move along its own axis while the base plate is left fixed. One smooth, continuous cycle is produced by the oscillation, which may be continually tested. DSR testing are conducted at a variety of temperatures and frequency (i.e., cycles per second)[7]. The following equation, which represents the dynamic load as a sinusoidal time function:

$\tau = \tau 0 \text{ Sin } (\omega T)$

IV. RESULTS & DISCUSSIONS

A. Softning Point

For 6% LDPE modified bitumen, the figure illustrates a consistent rise in the softening point temperature with increasing nanosilica concentration. The biggest rise in softening point temperature, by 64°C, is shown in binders with a nanosilica concentration of 3%.

B. Penetration Test

Figure demonstrates that for 6% LDPE modified bitumen binder, nanosilica causes a drop in penetration values and that this decline continues as the concentration of nanosilica increases.

C. Penetration Index

The penetration index, IP relationship was used to investigate the influence of HDPE addition on temperature susceptibility of asphalt cement using the following:

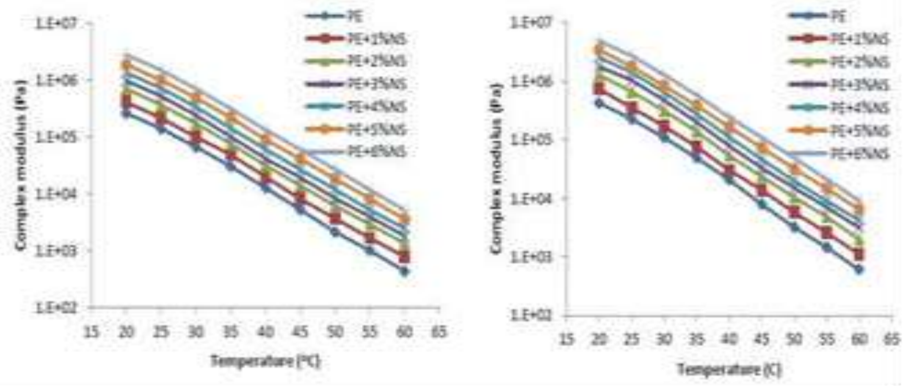

Figure 2: Temperature susceptibility of modified binders

D. Storage Stability Test

As is obvious from the table, the high temperature storage stability of LLDPE modified bitumen is the lowest and over the minimum permitted limit. The storage stability of the binder is improved and is within acceptable bounds with the addition of nanosilica.

Table 1: storage stability test results

Binder	Softening point temperature (°C) Top Bottom Difference (Top-Bottom)		
PE	69.3	62.5	6.8
PE + 1% NS	53.9	51.6	2.3
PE + 2% NS	56.6	54.5	2.1
PE + 3% NS	59.9	57.9	2.0
PE + 4% NS	61.3	59.4	1.9
PE + 5% NS	65.9	64.1	1.8
PE + 6% NS	63.4	61.3	2.1

E. Rheological Test Results

Plotted for various temperatures before and after RTFOT ageing are the complex modulus and phase angle values for binder modified with various concentrations of Nanosilica and 6% LLDP in Fig no. 3. Figure show that the addition of nanosilica increases the values of the complex modulus.Furthermore, it is clear from the figures that old samples have a larger complex modulus than fresh samples, showing a significant resistance of the binder to age hardening.

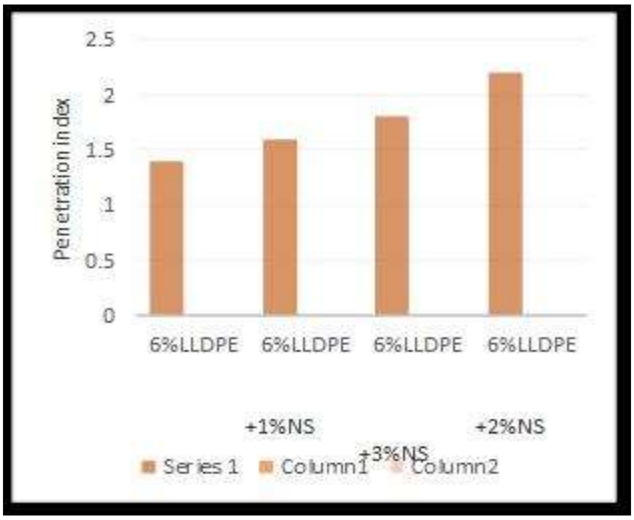

Figure 3: Complex modulus vs temperature variation for aged and unaged binders respectively

V. CONCLUSION

- Bitumen, a hydrocarbon-based substance, gives asphalt concrete its flexibility, stickiness, and heat properties. However, as a result of the increased traffic, pavement distresses such thermal cracking, fatigue cracking, and rutting occur.
- A revolutionary technique to improve asphalt qualities and prevent distresses is to employ additives to adjust properties of bitumen. Modifiers that are most frequently used are polymers like SBS, PE, and EVA. Although they somewhat enhance bitumen properties, there are still certain downsides, such as poor storage stability.
- More study is being done currently to determine how utilising nanomaterials can improve the performance of pavements. Nanomaterials are advantageous because they have a lot of surface area, a great dispersion ability, a lot of absorption, high quality, and chemical purity.
- In this work, low density polyethylene (LDPE) and nanosilica were used to modify bitumen with the intention of combining their advantageous effects on bitumen.
- In order to prepare the modified binder, bitumen must first be melted at an appropriate temperature. Then, varied concentrations of powdered nanosilica and LDPE are added to it.
- A high shear mixer is used to mix the mixture at the appropriate revolutions per minute (rpm) rate until a homogeneous mix is achieved.
- To compare the outcomes, both changed and unmodified binders are subjected to common testing like penetration and softening point tests.
- Similarly, rheological tests are performed.
- Results show that adding Nano silica and linear low-density polyethylene to bitumen causes an increase in softening point temperature and a decrease in penetration values (LLDPE).
- A lower penetration value denotes increased stiffness of the binder. For hot climate areas with significant temperature differences between day and night, a rise in softening point results in a decrease in temperature sensitivity.
- Further penetration index, a metric of temperature sensitivity, increased, reflecting a decrease in the susceptibility of the binder to temperature.
- A storage stability test revealed that the modified binder was stable within the bare minimum of allowable bounds.
- The inclusion of Nanosilica improved the storage stability of the LLDPE modified binder.
- The complex modulus G*, which represents the sample's overall resistance to deformation, and the phase angle, which illustrates the viscoelastic properties of bitumen, were measured using a dynamic shear rheometer (DSR).
- The composite additions caused an increase in G* values and a decrease in phase angle values. An increase in G* indicates an increase in deformation resistance. This is advantageous from a rutting perspective.
- Decrease in phase angle values means that when the load is removed, bitumen will recover to original shape better than before modification. Hence an improved elastic response. This is beneficial from fatigue cracking point of view.
- Due to the additives, the rusting measure G*/Sin rose in both aged and unaged samples. It suggests improved rutting resistance and extension at the pavement's maximum operating temperature.
- Thus, the laboratory analysis showed that modified bitumen performed better overall in both traditional and rheological tests.
- However, some flaws continue to exist. Virgin polymers and nanoparticles are more expensive than other ingredients in asphalt mixes.
- When kept at high temperatures for a long time, these additives have a propensity to split from the binder.
- The pavement's improvement in moisture susceptibility and low temperature performance is negligible.

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