Studies on Modifying Strength Parameters of Bitumen Using Fibers

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Abstract:

Bitumen as a binder in coating and insulating materials is modified with polymers to improve its performance in service conditions. Almost all polymers are incompatible with bitumen, and at high temperatures due to relatively very low viscosity of the bitumen phase, are separated from it. These lead to a considerable limitation in the use and handling of polymer-modified bitumen. An understanding of the mechanisms of phase separation of these incompatible mixtures helps to improve methods of transportation and handling of polymer-modified bitumen.

Keywords: Bitumen binder, Polymer modified bitumen ,glass fibers ,rheological property.

1. Introduction:

Two types of polymer are generally used to modify bitumen for road construction: plastomers and elastomers. EVA (Ethene-Vinyl-Acetate) and PE (Polyethylene) are examples of commonly used plastomers. SBS (Styrene-Butadien-Styrene) is the most used elastomer. Basically, plastomers increase the viscosity and stiffness of the bitumen. Elastomers also improve the elastic behavior of the bitumen.

Applying a stiffer bitumen in asphalt mixtures generally results in improved performance with respect to rutting resistance. Both SBS, EVA and PE modified bitumen have been applied successfully in situations where rutting was a problem with penetration grade bitumen (up to a limit). However, the bitumen should not be too stiff, because that may result in brittle asphalt mixtures, which has caused severe cracking failures with some types of plastomer modified bitumen in practice, even at (air) temperatures of 40 °C and higher.

As it is known that the modification of bitumen by the use of polymers enhances its performance characteristics but at the same time significantly alters its rheological properties. The rheological study of polymer modified bitumen (PMB) was made through penetration, ring & ball softening point and viscosity test. The results were then related to the changes in the rheological properties of polymer modified bitumen. It was observed that thermoplastic polymer shows profound effect on penetration rather than softening point. The viscoelastic behavior of polymer modified bitumen depend on the concentration of polymer, mixing temperature, mixing technique, solvating power of base bitumen and molecular structure of polymer used. (Noor Zainab Habib et al., 2011)

Properties have been followed using standardized tests, of bitumen – polymer mixtures. Impact of polymers has been evaluated, on the values of the following basic bitumen joints quality parameters: Softening point; penetration; breaking point.(Daučík Pavol et al., 2009)

Polymer-modified bitumen emulsions present a safer and more environmentally friendly binder for enhancing the properties of roads.(A. FORBES et al., 2001)

2. Impact of modified bitumen:

The author had presented a part of research on the rheological properties of bitumen modified by thermoplastic namely linear low density polyethylene (LLDPE), high density polyethylene (HDPE) and polypropylene (PP) and its interaction with 80 pen base bitumen. As it is known that the modification of bitumen by the use of polymers enhances its performance characteristics but at the same time significantly alters its rheological properties. The rheological study of polymer modified bitumen (PMB) was made through penetration, ring & ball softening point and viscosity test. The results were then related to the changes in the rheological properties of polymer modified bitumen. It was observed that thermoplastic copolymer shows profound effect on penetration rather than softening point. The viscoelastic behavior of polymer modified bitumen depend on the concentration of polymer, mixing temperature, mixing technique, solvating power of base bitumen and molecular structure of polymer used. PP offer better blend in comparison to HDPE and LLDPE. The viscosity of base bitumen was also enhanced with the addition of polymer. The pseudoplastic behavior was more prominent for HDPE and LLDPE than PP. Best results were obtained when polymer concentration was kept below 3%. Tests performed on bitumen samples proved that the nanoclay modifications help increase the stiffness and aging resistances. Comparison of the rutting parameter hows that nanoclay modification. (Noor Zainab Habib et all)

Temperature susceptibility characteristics and the physical properties of asphalt bitumen at high and low field-operating temperatures can affect the final performance of the mixture. To improve the performance of bitumen and asphalt concrete mixtures, the addition of modifiers such as polymers have become popular in recent years. As a matter of fact, polymeric nanocomposites are one of the most exciting of materials discovered recently and physical properties are successfully enhanced when a polymer is modified with small amount of nanoclay on the condition that the clay is dispersed at nanoscopic level. Many studies have been conducted on nanoclay modified polymers, though relatively little published information is available about nanoclay modified bitumen. Material variables, which can be controlled and can have a profound influence on the nature and properties of the final nanocomposite include the type of clay, the choice of clay pre-treatment, the selection of polymer components and the way in which the polymer is incorporated into the nanocomposite . The structure of bitumen and polymers are different, with bitumen being a very complex polymer and not stable. Bitumen is a highly heterogeneous mixture of hydrocarbons and is composed of polymers. Bitumen is a mixture of organic liquids that are highly viscous, black, sticky, entirely soluble in carbon disulfide, and composed primarily of highly condensed polycyclic aromatic hydrocarbons. It can be divided into the chemical families of saturates, aromatics, resins, and asphaltenes. The structure of asphaltenes on bitumen depends on the temperature and chemical composition of the bitumen. The asphaltenes are highly associated to each other in gel type, but they are not associated to each other in sol type, and as such have poor network and lower asphaltenes proportions and need different approaches of clay and bitumen interaction that probably limit the successes obtained in bitumen-nanoclay modifications. Tests performed on bitumen samples proved that the nanoclay modifications help increase the stiffness and aging resistances. Comparison of the rutting parameter shows that nanoclay modification can improve the rutting resistances of bitumen, depending upon the type and amount of nanoclay. So as far as the analysis of fatigue resistance parameter is concerned, it was shown that the nanoclay modification reduces the fatigue life at the low to medium temperature ranges. However, the nano clay modification shows the same fatigue life as that of the unmodified bitumen after aged condition.(S. Ghaffarpour Jahromi,et all)

Roads produced with bitumen binders are subjected to many harsh environmental conditions such as trafficloading, ingress of water, chemical attack and widely fluctuating temperatures. Conventional bitumen often cannot provide the desired resistance to these conditions so modification of the bitumen properties becomes necessary. Bitumen modified with polymer is a common means of providing resistance to pavement deformation .The common pavement technique used in New Zealand is hot spray chip sealing, which requires the bitumen to be applied at a temperature of typically 180 8C and adding solvents such as kerosene, both of which lower the bitumen viscosity to allow easier application. Both of these aspects have significant safety and environmental drawbacks. However, emulsifying the bitumen with water eliminates both problems and allows greater product flexibility, because various emulsion-based products such as slurry surfacing and micro surfacing, in addition to spray chip sealing, can be used. Various polymers such as styrene butadiene rubber (SBR) latex, styrene butadiene styrene (SBS), polychloroprene latex, natural rubber latex and ethylene vinyl acetate (EVA) can be used in the preparation of polymer-modified bitumen emulsions. However, latex polymers such as SBR, polychloroprene and natural rubber, because of their liquid form, have a major advantage in an emulsion formulation. The physical form of the latex allows them to be added into a bitumen emulsion manufactured with a colloid mill by either: pre-blending latex into the bitumen before emulsification; comilling (milling the latex, bitumen and emulsifier solution in separate stream simultaneously); adding latex into the emulsifier solution; or post-adding latex to the prepared bitumen emulsion. This gives latex polymers far more processing and performance flexibility. Solid polymers such as SBS and EVA must be dispersed into the bitumen before emulsifying and this method has processing limitations .Bitumen consists of two basic chemical components ± high molecular weight asphaltenesand lower molecular weight maltenes. The addition of high molecular weight polymers to hot bitumen results in a swelling of the polymer, which in the case of SBS polymer can be up to nine times its initial volume due to the absorption of maltenes .Microscopy techniques have often been used to characterize the microstructure interactions between bitumen and polymers for modified binders and for asphalt concrete). However there had been few publications on the microstructure and curing aspects of polymer-modified bitumen emulsion binders for cold mix applications. Normally, physical testing methods are employed to characterize the degree of modification of the binder. However, visual observations can help to improve the understanding of the interaction between the emulsified bitumen and polymer after water evaporation and the means by which this interaction may result in improved aggregate retention properties and pavement deformation resistance. Oil exhibits auto fluorescence when irradiated with UV or blue light but for bitumen there is little light emission as the oil phase is mixed with an asphaltene and resin phase, which do not exhibit any fluorescence. However, the polymer has very strong fluorescence emissions. It is therefore possible to analyze the influence and compatibility of polymer in bitumen by the strength and distribution of the light emission. Fluorescence microscopy has often been used to analyse the polymer distribution in bitumen samples .The method uses mercury or xenon arc lamps to provide the light source. Although acceptable images are obtained, there are often problems experienced due to out of focus data. This situation is eliminated with the confocal laser scanning microscopy (CLSM) technique because a laser is used to optically section the sample. The CLSM technique has been used by several researchers to assess the polymer distribution, network formation and compatibility for polymer-modified bitumen but there is very little information for emulsion binder residue. This investigation examined the structural network and distributions of the polymer within dried emulsion samples prepared with different latex addition methods. They also explained how these structures improved the binder properties. They had examined the way in which the polymer helps bitumen to resist applied stress and we examine the structure of the modified binder after curing at elevated temperature. These investigations help to explain the performance improvement that polymer modification has on emulsion-based road products. This paper had compared the effects of the polymer addition mode on the microstructure and polymer distribution within the polymer-modified bitumen emulsion residue. Cationic bitumen emulsion binders containing polymer latex were investigated using co focal laser scanning microscopy, which proved to be a useful technique for this application. The emulsion binder films were studied after evaporation of the emulsion aqueous phase. They had shown how the structure and distribution of the polymer varies within the bitumen binder depending on latex addition method, and that the structure of the binder remains intact when exposed to elevated temperature. They had also shown how the polymer elongates under stress to improve the bitumen binder resistance to deformation. It was found that the polymer dispersion within a monophase emulsion binder is distinctly fine throughout the bitumen. However, the bi-phase emulsion binders resulted in a network formation of bitumen particles surrounded by a continuous polymer film. This difference in polymer dispersion and binder structure requires further investigation to determine if there is a significant effect on binder performance. The results in this study showed that emulsified binders appear to have a more homogeneous distribution of polymer compared to hot polymer-modified binders, and therefore have greater potential for consistent binder cohesion strength, stone retention and consequently improved pavement performance.(A. FORBES et all)

Use of polymers in the consumption area brings problems with their accumulation in wastes. Processes of chemical and thermic degradation enable obtaining of monomers. Polymer wastes can be recycled in this way. Ways of waste polymers recycling are being searched for, too, with lower energy demands, and simpler mechanical material use. Addition of polymers into asphalt mixtures is quite obvious today. Such use of waste polymers brings not only improvement of utility properties, but also increases of added value of the product. Therefore, the research is focused to search for the possibility of application of waste polymers in asphalt mixtures. Properties have been compared, of bitumens modified by additional polymers and rubber crumb, with those that had been modified by styrene-butadiene-styrene (SBS) and ethylene-vinylacetate (EVA) copolymers. The selected methods of evaluation of properties of polymers-modified asphalt enabled comparison of specific samples. Monitoring of the properties of the selected model polymers gives a picture of the possibilities of use of the samples that had been obtained from wastes collection and separation. (Daučík Pavol et all,2009)

3. Methodology:

3.1 Materials:

Materials used in this study include 30/40 penetration grade base bitumen. The polymer used for modification is glass fiber of length 0.3mm and 0.6mm.

3.2 Sample Preparation:

Samples were prepared using melt blending technique. The bitumen about 400gm was heated in oven till fluid condition and polymer was slowly added, while the speed of the mixer was maintained at 140 rpm and temperature was kept between 180°C and200°C. The concentration of glass fiber used, were 2%, 4%, 8%, 12% and 16% by weight of blend. Mixing was continued for 1 hr to produce homogenous mixtures. The modified bitumen was then sealed in containers covered with aluminum foil and stored for further testing. Empirical test such as penetration, softening point and viscosity were then conducted on the prepared samples.

3.3 Laboratory testing:

Test on the prepared samples were conducted according to ASTM method to characterize the properties of PMBs. The different percentage of glass fiber concentration provides a wider range of results which helps in analysing each type of the glass fiber blend at particular concentration. The rheological test includes penetration at 25ºC, softening point and Marshall Stability. The test results of base bitumen are presented in tables.

3.4 Conventional properties of base bitumen:

1. Grade 30/40 pen
2. Specific gravity 1.16
3. Penetration 34 dmm
4. Softening point 83°C
5. Flash point 242 ºC
6. Fire point 163°C

3.5 Penetration (ASTM D-5):

The standard 100g, 25°C and 5sec penetration test was performed both on base bitumen and PMB with the concentration of polymer varying between 2%, 4%. 8%, 12%, 16% by weight of the bitumen. The results of the test are shown in Table 2.

3.6 Softening Point (ASTM D-36):

Ring and ball is the standard test to determine the consistency of the bitumen, which represent the temperature at which a change of phase from solid to liquid occurs. It is the temperature at which standard 3/8 inch steel ball weighing 3.55gm fall and touches the base plate which is 2.5mm away.

3.7 Marshall Stability Test:

Stability is an important property of the bitumen mixture in the wearing course design. It shows the ability to resist shoving and rutting under traffic . Marshall Stability test of PMB was performed in a Marshall testing machine at a constant rate of 51 mm/min. five specimens were immersed into a water bath at 60ºC and were tested after 1 hr and the average compressive load required to break the sample was determined and corrected by multiplying with a stability correction factor to get the initial stability to get the final stability.

4. Result & Discussion:

4.1 Marshall Stability Test:

The results of Marshall Stability are presented in Table 1. Five samples were used to obtain the average stability and the corresponding standard deviations were reported. It is observed that the stability value increases with the increase in fiber length. When the length goes on decreasing the stability value goes on decreasing gradually but the penetration values goes increasing.

4.2 Penetration Results:

The sharp decrease in the penetration value of 34 dmm for base bitumen to 25dmm for PMB of 0.65mm and 29dmm for 0.33mm length shows that increase in hardness is due to high molecular weight PMB. It is obvious from the observation that thermoplastics influence is more on the penetration with the increase in the viscosity of the bitumen as can be observed by the decrease in the value of penetration with the increase in concentration of polymer. Thus it increases the viscosity by the end of mixing process, and by the time it cools harden mixture was formed. The hardening of the bitumen can be beneficial as it increases the stiffness of the material, thus the load spreading capabilities of the structure but also can lead to fretting or cracking. This can be evaluated at later stage of this study by performance tests. The results obtained by the penetration are highly controversial although being widely used by paving industry as penetration needle displaces a relatively small volume of fluid.

Table 1: Marshall stability result

Percentage of glass fibre	Stability of specimen (KN) 0.6mm	Stability of specimen (KN) 0.3mm
2	1.55	1.7
4	1.69	1.95
8	2.63	2.65
12	2.27	2.89
16	2.18	2.57

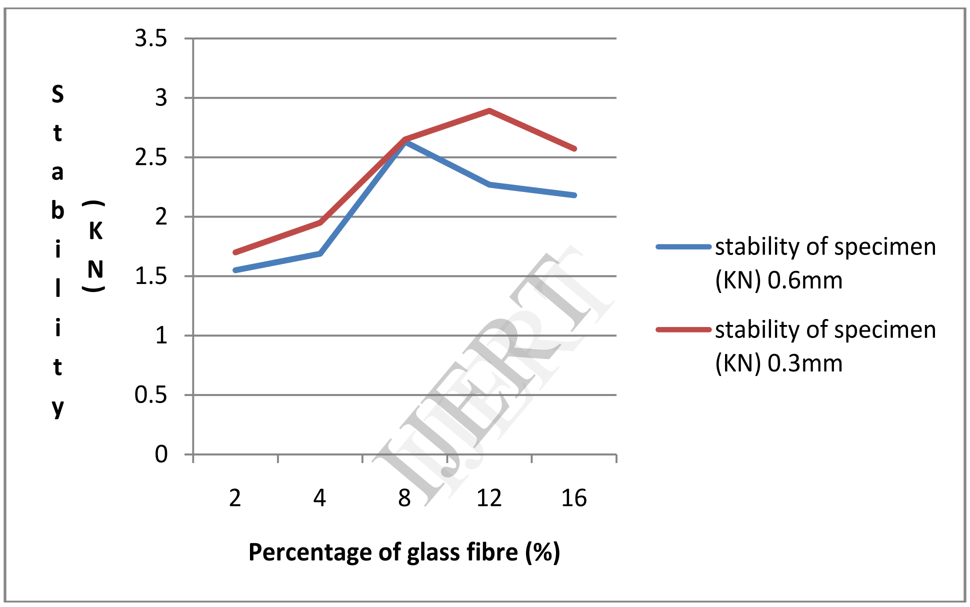

Figure 1: Comparison of stability test for different sizes of glass fibre

Table 2: Penetration test result

Penetration of glass fibre	Penetration for 0.6mm length(mm)	Penetration for 0.3mm length(mm)
2	29	33
4	27	36.75
8	25	29
12	28.25	29
16	28	29

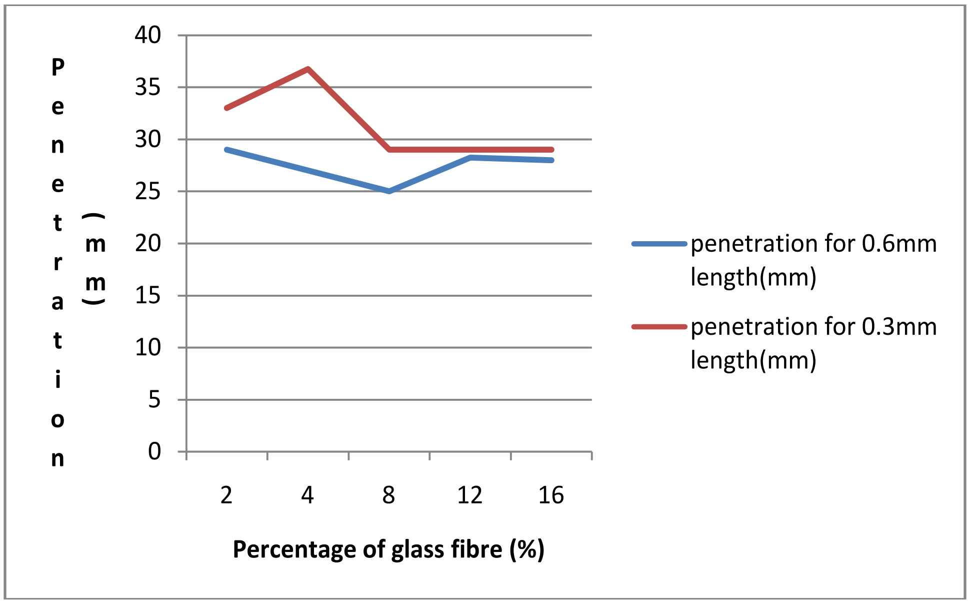

Figure 2: Comparison of penetration test for different sizes of glass fibre

5. Conclusion:

In this study polymers of different sizes were used to compare the strength of bitumen. The following conclusions were derived with various results obtained from various tests:

1. PMB showed increase in stability when compared to the base bitumen. In PMB of different lengths the results were noticed as 0.3 mm length fiber shows more stability than 0.6 mm length.
2. Penetration result generally decreases when polymers are added. In different sizes of fiber, 0.3mm length fiber has high penetration compared to 0.6mm length.

The study indicated physical hardness of the binder after adding glass fibers of different size reduces binder penetration and increases softening points. This indicates that aging depends on time and binder source.

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