Use of Thermoplastic Elastomers in Road Construction

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Abstract— The use of four wheeler, two wheeler vehicles etc. is increasing day by day. As a result amount of waste tyres also increasing. Waste tyres in India are categorized as solid or hazardous waste. It is estimated that about 60 per cent of waste tyres are disposed via unknown routes in the urban as well as rural areas. This leads to various environmental problems which include air pollution associated with open burning of tyres (particulates, odor, visual impacts, and other harmful contaminants such as polycyclic aromatic hydrocarbon, dioxin, furans and oxides of nitrogen) and aesthetic pollution. Therefore, it is necessary to utilize the wastes effectively with technical development in each field. One of the technical and easy way is using SBS (styrene-butadiene-styrene) in crumb rubber modified asphalt. The incorporation of SBS into crumb rubber modified asphalt is investigated to enhance binder properties and storage stability. SBS is used in crumb rubber modified asphalt to gain the high properties of road.

I. INTRODUCTION

Increased traffic factors such as heavier loads, higher traffic volume, and higher tire pressure demand higher performance pavements. A high performance pavement requires asphalt cement that is less susceptible to high temperature rutting or low temperature cracking. Asphalt exposed to a wide range of load and weather conditions, however, does not have good engineering properties, because it is soft in a hot environment and brittle in cold weather. Therefore, asphalt is usually reinforced by polymers to improve its mechanical properties. Mixing asphalt with polymers that are practically immiscible has become very important, because an inhomogeneous material can be attained to meet the performance demand. In describing the microstructure interacting between asphalt and polymer, the term ‘‘morphology’’ is often used. A limited number of polymers have been employed to mix with asphalt, including thermoplastics—ethylene-vinyl acetate (EVA), low density polyethylene (LDPE), high density polyethylene (HDPE), ethylene-propylene-diene (EPDM) and elastomers—styrene-butadiene-styrene (SBS), styrene-butadiene random copolymers (SBR), and styrene-isoprene-styrene (SIS). Among these, the most common one is poly-butadiene-base material, due to its excellent engineering properties and relatively low cost. The wide range of properties attainable with these systems were either impossible to obtain from an individual polymer or would involve costly development of new polymers. To have a new material with good performance, it is required to understand the fundamental properties of polymer-modified asphalt (PMA). For this reason, a great deal of work has been focused on PMA. PMA needs to be engineered by choosing the right binder for application and making sure any additive used is compatible with the asphalt. Thus, this study tries to analyze mechanical properties of PMA based on the morphological structure of asphalt and polymer. To improve the engineering properties of paving grade asphalt cement, SBS triblock copolymers were used in this study. The PMA generally shows enhanced properties at temperatures tested. However, no theory is available to explain why polymers are good to modify asphalt. More specifically, it is not clear how the properties of the polymer additives should be optimized to get better performances. The reinforcement mechanisms associated with the presence of polymers in asphalt are not well understood. Micromechanical models are shown to be able to predict fundamental properties of a composite based on the properties of individual constituents . The understanding of the role SBS and asphalt play in the overall behavior provides the key by which PMA can be properly selected for the optimal combination. By understanding the various reinforcement mechanisms, it is also possible to set quality control limits for polymer-modified asphalt.

II. CRUMB RUBBER MODIFIED ASPHALT(CRMA)

A. *What is Asphalt Rubber ?*

Ans. Asphalt Rubber is a mixture of 18-22% crumb rubber, Asphalt cement and in some cases extender oil reacted at elevated temperatures prior to being mixed with aggregate.
Two type of asphalt rubber are used : type 1 And Type 2.
Type 1 contains rubber only from ground lines.
Type 2 contains rubber from both ground lines and natural rubber.
Type 2 is used to improve reflection cracking resistance. The products are not be confused with asphalt rubberized asphalt products such as “terminal blends”(generally less than 10% ground tire rubber plus a polymer additive) or “dry process”(where crumb rubber is added as an aggregate and is not fully reacted with the asphalt.)

B. *How is Asphalt rubber used ?*

Ans. Asphalt rubber has been used in hot mix applications and in spray applications (e.g. chip seals ,SAM ,SAMIs) especially when reduced overly thickness is desired for controlling grade and against exiting medians. Asphalt rubber has been used in gap and open graded mixtures. It is also used in spray applications. The most common spray application is a chip seal, using a application of a heavy application of asphalt rubber follows by an same.

C. *Where should asphalt rubber products be used ?*

Ans. Asphalt rubber hot mixes can be used any place conventional mixes are used. Temperature and weather conditions can affect when the products can be placed. Asphalt rubber chip can be used where conventional chips seals are used, but offer improved performance benefits such as limited rock loss, reflection crack mitigation and longer surface lives. Also rubber chip seals can be used in combination with a rubber overlay to form a stress absorbing interlayer (SAMI) in lieu of full reconstruction.

D. What are the benefits of asphalt rubber products ?

Ans. Several benefits are following :-

- Improved resistance to surface initiated cracking due to higher binder contents.
- Improved aging and oxidation resistance due to higher binder contents.
- Improved resistance to fatigue and reflection cracking due to higher binder contents.
- Improved resistance to rutting due to higher viscosity and softening points.
- Increased night time visibility due to contrast in pavement and striping.
- Reduced tire noise due to increased binder film thickness and open textures.
- Reduced splash and spray during rain storms due to open texture.
- Lower pavement maintenance costs due to improved pavement performance.
- Better chip retention due to thick films of asphalt.
- Lower life cycle cost due to improved performance.
- Savings in energy and natural resources by using waste products.

E. What are limitations of asphalt rubber products ?

Ans. These are following :-

- Viscosity :- The concentration of rubber must be more than 20% to ensure the satisfying performance, which results in the increase of CRMA viscosity. In order to process convenient, viscosity of CRMA must be dropped down. One of methods is to increase the processing temperature (199^o c-200^o c). At this temperature CRMA easily ages.
- Higher units costs, which are offset by using reduced thickness, resulting in lower life cycle cost as such they are primerly used for surface courses only.
- More challenging construction due to more restricted temp requirement.
- Potential odor and air quality problem.
- Difficult to hand work.

III. Asphalt Modified by Styrene- Butadiene-Styrene Block Copolymers

A. What is SBS ?

Ans. Styrenic Block Copolymers (SBCs) are the largest-volume category of thermoplastic elastomers. Annual consumption is about 1.200.000 metric ton. Being thermoplastic elastomers, SBCs possess the mechanical properties of rubbers, and the processing characteristics of thermoplasts. This is related to their molecular structure. SBCs consist of at least three blocks, namely two hard polystyrene end blocks and one soft, elastomeric (polybutadiene, polyisoprene, either or not hydrogenated) midblock. It is essential that the hard and soft blocks are immiscible, so that, on a microscopic scale, the polystyrene blocks form separate domains in the rubber matrix, thereby providing physical cross links to the rubber.

B. Why is SBS used ?

Ans. Polymer modified asphalt is increasingly used in road surfacing. Unmodified asphalt is sensitive to extremes in temperature, it becomes brittle and cracks in cold conditions and softens at higher temperatures, causing rutting and surface deformation.
Modification of asphalt by addition of polymer results in a more elastic and durable product with greater temperature stability.
One of the most common polymer modifiers is Styrene-butadiene-styrene (SBS).

C. What is the importance of SBS in CRMA ?

Ans. The concentration of rubber must be more than 20% to ensure the satisfying performance, which results in the increase of CRMA viscosity. In order to process convenient, viscosity of CRMA must be dropped down. One of methods is to increase the processing temperature (199^o c-200^o c). At this temperature CRMA easily ages. Another method is to reduce the content of rubber, which would can be called SBS/CRUMB rubber composite modified asphalt, the degraded performance could be improved; meanwhile the viscosity would be suitable.

In addition, the network structure of SBS is beneficial to improve storage stability of CRMA.

IV. Methods of Process

A. Dry process vs. Wet process

Rubberized asphalt mixtures, produced by the dry process, include the addition of tire rubber particles as substitutes for the natural aggregates of similar gradation. This technique permits the utilization of a solid waste material that is produced worldwide annually in very large amounts. According to former experience, tire rubber can modify the rheological properties of the bituminous binder-wet process-, leading this way to mixtures, which are characterized by increased elasticity, improved bonding between binder and aggregates, increased fatigue life and resistance to rutting as well as reduced thermal and reflecting cracking of the mixtures. However, by the use of the dry method, mixtures perform inferior characteristics compared to the ones of the wet method. This is attributed to the poor interaction between tire rubber particles and the bitumen, which resulted in lower resistance to moisture, the detachment of the aggregates and the reduction in the bearing capacity of the pavement. Moreover, dry process, compared to the wet process has been far less popular method because of the increased costs of having to use special graded aggregate to incorporate the reclaimed tire rubber in addition to constructions difficulties and of course due to higher cost compared to the one of natural aggregates. However, this method has the potential to consume larger quantities of rubber from worn mobile tires while it is environmentally beneficial compared to the wet process since it consumes less energy-there is no need for increased mixing time, higher mixing temperatures and as a result less negative environmental effects during production procedure. Furthermore, inclusion of tire rubber particles is much easier, since tire rubber is added simply with the natural aggregates. In this process, the interaction between rubber particles and bitumen starts as soon as aggregates are mixed with bitumen, so there is no time for chemical interactions and modification of the binder.

V. PROCESS OF MAKING CRUMB RUBBER MODIFIED ASPHALT

A. Process ingredients:

– Crumb Rubber:

Properties- 30 mesh size,Specific gravity= 1.10-1.25, Gives swelling after mixing into bitumen,Mix into hot mix bitumen in closed vessel.

– Bitumen:

Properties- 99% pure,More compatible with ingredients which to be added.

– Extender oil:

Properties-Polycyclicaeromatic natured oil,Flash point >180^{o}c, % of aeromatic unsaturated hydrocarbon content>55 Viscosity= minimum 2500cp.

– Adhesion agents:

Properties- Good binding to improve adhesion characteristics.

B. Formulation:

Ingredients	Proportion
Bitumen	750 ml
Crumb Rubber	180 gm
Extender Oil	50 ml
Resin	10 gm

C. Wet method:

– First clean the tank properly of bitumen mixer.
– Take 99% pure bitumen and heat it but make sure that the heating would not be greater than 220^{o} c.
– Fill the tank with heated bitumen. Add crumb rubber into it. After adding crumb rubber the temperature of mix gets cool down.
– Reheat the mix at 190^{o}c to 200^{o}c.
– Stir the mix for 30 min at 3000 rpm.
– Digestion of rubber into bitumen starts.
– Add oil and resin into heated mix when mix temp is between 180^{o} c to 218^{o}c and maintain the temp between 150^{o} c to 180^{o}c.
– Stir the total mix for 20 min.
– Take the mix into other tank and measure the viscosity.
– Keep the mix for 24 hr.

VI. PROCESS OF MAKING SBS MODIFIED CRMA

A. Process ingredients:

– Crumb Rubber:

Properties- 30 mesh size,Specific gravity= 1.10-1.25, Gives swelling after mixing into bitumen,Mix into hot mix bitumen in closed vessel.

– Bitumen:

Properties- 99% pure,More compatible with ingredients which to be added.

– SBS:

Properties- 4 to 6% use for higher softening point and elastic recovery,1% SBS usage gives 3^{o}c higher temp.

– Extender oil:

Properties- Polycyclic aeromatic natured oil, Flash point >180oc,% of aeromatic unsaturated hydrocarbon content>55 Viscosity= minimum 2500cp.

– Adhesion agents:

Properties- Good binding to improve adhesion characteristics.

B. Formulation:

Ingredients	Proportion
Bitumen	750 ml
Crumb Rubber	150 gm
SBS	50 gm
Extender Oil	40 ml
Resin	10 gm

C. Wet method:

– First clean the tank properly of bitumen mixer.
– Take 99% pure bitumen and heat it but make sure that the heating would not be greater than 220^{o} c.
– Fill the tank with heated bitumen. Add crumb rubber into it. After adding crumb rubber the temperature of mix gets cool down.
– Add SBS into bitumen-crumb rubber mix.
– Reheat the mix at 190^{o}c to 200^{o}c.
– Stir the mix for 30 min at 3000 rpm.
– Digestion of rubber-SBS into bitumen starts.
– Add oil and resin into heated mix when mix temp is between 180^{o} c to 218^{o}c and maintain the temp between 150^{o} c to 180^{o}c.
– Stir the total mix for 20 min.
– Take the mix into other tank and measure the viscosity.
– Keep the mix for 24 hr.

VII. FUTURE WORK TO BE DONE

I. Compare the behavior of SBS in asphalt and crumb rubber asphalt (CRMA).
II. Testing the SBS added asphalt.
III. Morphology behavior of SBS added asphalt.
IV. Compare the mechanical properties of SBS added asphalt and CRMA.

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