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Special Issues on Bitumen and Bitumen Modification for Use in Hot Mix Asphalt (HMA): Review

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Abstract - *Bitumen is a grey to dark black coloured compound. It is obtained by fractional distillation of petroleum. In road industry, bitumen plays a very important role. In order to enhance properties and performance of bitumen, a wide variety of modifiers have been applied to it. Among them, crumb rubber, polymers, waste plastics have been mainly used. The aim of this paper is to review the use of these materials as a bitumen modifier for hot mix asphalts.*

***Key Words*: Bitumen modifier, hot mix asphalt, bitumen modified asphalt.**

1. INTRODUCTION

Bitumen is one of the oldest and well known engineering materials. It has been used for thousands of years in different ways, e.g. as sealant, an adhesive, preservative, waterproofing agent, coating material and pavement binder. Ancient inhabitants directly used the natural bitumen which is normally found in the earth's surface. In the early 90's, refined bitumen was first produced by refining crude oil in the United States. Since then, the world consumption of bitumen has increased rapidly, most of which was primarily used in road construction industry. The chemical composition of produced bitumen is very complex and varies accordingly. The produced bitumen possesses properties which are closely related to the crude oil sources and the refinery processes. Some of the good bitumen properties can be obtained by selecting good crude oil or proper refinery processes. However, the limited oil resources for producing good-quality bitumen, the lack of effective control actions during refinery and driving force of earning the maximum economic benefits made industries to pay more attention on bitumen and its modification.

2. PRESENT SCENARIO

Pavement industry has developed rapidly all over the world, especially in developing countries during the last few decades. Owing to this rapid development, increased traffic load, very high traffic volume and inadequate maintenance are responsible to cause many severe distresses such as rutting and cracking of road surfaces. Since all paved roads including even the best designed and constructed roadways are susceptible to deteriorate over the time due to traffic load, material ageing or environmental effects. Owing to all these considerations the harsh reality was demanding more on bitumen quality. An increasing number of investigations have already began to focus on bitumen modification in order to obtain bitumen with enhanced quality. At present, various modifiers are being added to bitumen and tested in order to enhance its performance characteristics. Numbers of bitumen additives have been widely employed and tested to obtain the results as per requirements. Still experiments are performing in concern with bitumen modification with new additives and filler materials.

3. RELATED WORK

3.1 Properties of Asphalt and Asphalt Binders

Hot Mix Asphalt (HMA) is a composition of a mixture of asphalt binder and a graded aggregate ranging from coarse to very fine particles. The binder can be modified with treatment of aggregates. HMA is the compound which could be made from new or recycled material. Asphalt binders were most commonly characterized by their physical properties. The physical properties of asphalt binder directly explain how it will perform as a HMA pavement. New binder tests and specifications are developed to characterize asphalt binders for use in HMA pavement more accurately. These specifications and tests were specially designed to address HMA pavement performance parameter including rutting, fatigue, cracking and thermal cracking (Highway design manual Chapter 630: Flexible Pavement).

Hot Mix Asphalt (HMA) is largely influenced by its constituents like asphalt binder and aggregate. Mineral aggregates consist of 80% and 90% of the total volume or 94% to 95% of the mass of Hot Mix Asphalt (HMA). The quality of mineral aggregates used for road-paving materials had been specified by its various parameters such as the toughness, hardness, crushing strength, soundness (durability), cleanliness, particle shape, angularity, surface texture and water absorption. Hence it was found to be important to maximize the quality of the mineral aggregates

to ensure proper performance of the flexible pavement. Various tests have been used to examine the properties of aggregates .These tests include aggregate impact value test, aggregate crushing test, abrasion test, soundness test, specific gravity test, water absorption test,etc.

Bitumen is a compound obtained by fractional distillation of petroleum. Asphalt is a compound obtained by adding an inert material to bitumen. Bitumen characteristics are evaluated by various parameters such as penetration index, softening point, viscosity, fire and flash point, specific gravity, water absorption etc,. Another most important parameters influencing performance of bitumen is Marshall Stability and flow test. The purpose of the Marshall Stability and flow test is to determine the stability and flow values of asphaltic specimens. The Marshall method of mix design made use of the values obtained as well as the unit weight and the voids in the total mix to determine an optimum mix design. Marshall Stability governs the stability and strength of bitumen, weathering characteristics, resistance to bleeding and flushing, and resistance to infiltration of water. (Christopher M. Smemoe, 1994).

Various tests are being traditionally performed on bitumen specimen in order to evaluate its performance. These tests include penetration test, softening point test, fire and flash point test, ultimate tensile strength test. Modified bitumen is being traditionally evaluated for these tests and results are being compared with standard results.

As per IS 2386, properties of aggregates and their specifications are tabulated as follows:

Table 1: Aggregate properties and their specification

Sr No	Aggregate property	Specifications
1.	Toughness (Aggregate impact Value)	Wearing course ≤35% Base course ≤45%
2.	Hardness (Abrasion Test)	Wearing course ≤30% Base course ≤50%
3.	Aggregate shape	Angular is preferred
4.	Soundness	The avg. Loss in weight after 10 cycles: -When tested with sodium sulphate≤ 12% -When tested with magnesium sulphate ≤ 18%
5.	Crushing strength	Wearing course ≥30% Base course ≥45%
6.	Specific gravity	2.6 to 2.9
7.	Water absorption	≤0.6%

As per IS 1201-1220, the properties of bitumen and their specifications are tabulated as follows:

Table 2. Bitumen properties and their specifications

Sr. No	Bitumen property	Specification
1.	Penetration Index	30/40 and 80/100 commonly used
2.	Ductility	Min.value:50 cm
3.	Viscosity	Time in sec required for 50 ml of material to flow through orifice
4.	Softening Point	35˚c-70˚c
5.	Specific Gravity	1.02-0.97:pure bitumen
6.	Flash and Fire Point	Flash Point min. Value for pavement bitumen:175˚c
7.	Water absorption	≤0.2%

3.2 Modified Bitumen

3.2.1 Rubber Modified HMA

Large no. of modifiers are use to enhance the performance characteristics of bitumen. Among those crumb rubber is used as bitumen modifier since 1930's (Yildirim, 2007).Crumb rubber is most commonly used and traditionally accepted as a bitumen modifier. A blend of reclaimed ground tire rubber reacted with asphalt cement at elevated temperature was used as a binder in various types of bituminous construction, rehabilitation and maintenance. This blend was called "asphalt-rubber" and it consists of 18 to 26% ground tire rubber by total weight of the blend. Generally for asphalt-rubber HMAs, the Marshall flow increased, the Voids in Mineral Aggregate (VMA) was to be slightly increased , the binder content increased but the stability decreased.("Investigation and Evaluation of Ground Tire Rubber in Hot Mix Asphalt" by Freddy L. Roberts, Prithvi S. Kandhal, E. Ray Brown and Robert L. Dunning).

The advantages of crumb rubber modified bitumen over normal mixes include longer fatigue life, lower potential for permanent deformation, higher resistance to crack initiation, greater resistance to moisture damage of mixes and lower temperature susceptibility.(Palit et al. 2004; Kok et al. 2012; Wang et al. 2012). Crumb rubber added in the bitumen in different proportions and with different sizes. (Gopal et al. 2002).

Fig -1: Mixing Of Coated Aggregate And Crumb
(Source: Vishal Rasal1, L Nokfho K, P.M.Wale, Mrunalini Kasar, Anjali Thorat, Raunak Solanki, Ishan Dharmadhikari)

3.2.2 The Polymer Modification

Polymer modifiers are mainly used to extend service life of the composition by enhancing the binder's adhesion, elasticity and cohesion. The early pavement distress shall be also reduced by polymer intrusion. The direct benefit observed due to polymer modification is that of improved resistance to permanent deformation. The polymer modified asphalt could withstand about four to ten times more load cycles before rutting of various specified depths even though it was made from higher percentage asphalt. The response to the fatigue is directly related to the creep response of the binder which was measured by the tensile strength and elastic recovery. The cause of loss of adhesion is due to stripping of asphalt from the aggregates. The commonly used polymers include styrene-butadiene-styrene copolymer, styrene-butadiene rubber, latex, ethylene vinyl acetate copolymer (EVA), polyethylene, and polypropylene (King et al. 1986).Each polymer offers unique advantages.

3.2.3 Utilisation of Waste Plastics

Utilisation of waste plastics is most discussed and popular way of bitumen modification. Referring the report from the Central Pollution Control Board (2015), nearly 12 million tons of plastic products are consumed every year in India. Approximately 60% of which is converted into waste. Numbers of experiments were performed to analyze and evaluate the use of waste plastics as bitumen modifier. Through which it was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive upto 12% by weight. The softening point of the modified bitumen increased with the addition of plastic additive upto 8% by weight. Also the strength, fatigue life and other desirable properties of bituminous concrete mix have improved even under adverse water logging conditions. (Dr.R.Vasudevan and S.Saravanavel 2006) .He has suggested a modified technique to make the use of waste plastic in flexible pavement. He referred a process as Dry Process. A modified technique was developed in such a way that the stone aggregate was coated with molten polymer and the polymer waste coated aggregate (PCA) was used as the raw material for flexible construction. It was observed that PCA showed better binding property and it has no stripping, less voids and higher Marshall Stability value.

3.2.4 Stone Matrix Asphalt and Asphaltic Concrete Using Modifiers

Stone matrix asphalt (SMA) is defined as one of the bituminous mixes that cause a minimum rutting problem, and is used in the construction of road as a wearing course. Stone matrix asphalt was developed in Germany in the mid-1960s and has been used successfully by many countries in the world because it is highly resistant against rutting. (M. S. Ranadive, H. P. Hadole, S. V. Padamwar 2018). Stone matrix asphalt is based on the concept of stone-to-stone contact. Engineers are trying very hard in order to increase the performance of Asphalt Concrete which is commonly used as a wearing coat in different ways. Different types of fibres and polymers are added to the AC mix, which offers better performance characteristics as compared to conventional mixtures. The artificial fibre which is the fibre extracted from refrigerator door panels (FERD) used as the filler material. FERD gives better results against rutting and deformation in flexible pavements. (Chowdary and Raghuram 2013).

4. CONCLUSION

This review intended to provide interested readers with the significance of bitumen modification. Our review focused on the use of rubber tires, waste plastics and polymers as very effective modifiers for the improvements of asphalt pavement material.

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