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Enhancement In Properties of Bitumen Using Rubber As Modifier – A Review

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Abstract

Bitumen, a binding material practiced in the construction of flexible pavements, is being modified with materials like polymers, rubber, fibres, nanomaterials since long. The present review discussed utilization of rubber in the modification of bitumen in a brief manner. The paper discusses different forms of rubber mainly crumb rubber, processed waste crumb rubber, high pressure water jet crumb rubber, scrap tire rubber, epoxidized rubber, liquid rubber, hybrid rubber system, rubber silicone etc. The enhancement in the properties of bitumen using rubber as modifier is discussed.

Introduction

Bitumen is a dark or black coloured solid material gained as a byproduct from fractional distillation of petroleum and consists of 95% hydrocarbons (87% carbon and 8% hydrogen), sulphur, nitrogen, oxygen and traces of transition metals. The heteroatoms tend to impart polarity and functionality to the molecules [1]. Heavy metals like Nickel and Vanadium sometimes present in the form of inorganic oxides and salts [2, 3]. Bitumen consists of asphaltenes dispersed into an oily matrix of maltenes. Asphlatenes are the highly polar, complex aromatic materials and have highest average molecular mass among bitumen constituents [4]. Maltenes are again divided into aromatic hydrocarbons, resins, and saturates [5]. Actually bitumen is a mixture of polar and non-polar components where polar components impart elasticity while non-polar components provide viscosity to bitumen. Bitumen is brittle and hard in cold environment which leads to low temperature cracking. It becomes soft in hot environment causing rutting on roads [6]. Sometimes at quite high temperatures bitumen start melting or bleeding which

decrease the performance of road [7-9]. If bitumen is exposed to oxygen for longer periods of time then this will result in cracking of bitumen. Moreover, when comes in contact with water bitumen get separated from the aggregate due to which potholes are formed on the road. Bitumen is derived from petroleum hence it is quite costly. To overcome all these shortcomings, bitumen is modified with variety of modifiers out of which rubber as a modifier gives quite promising results. The thermo mechanical properties of bitumen actually depends on complex colloidal structure of bitumen and this is an interesting field for researchers because bitumen is being used in road paving applications [10].

Rubber as modifier in bitumen

Rubber falls in the category of elastomer generally used as a modifier in bitumen. The performance of crumb rubber (recycled from waste tires) modified bitumen and SBS modified bitumen was compared. 8.0% CR content was the optimum content [11]. Yousefi studied the consequence of different mixtures of synthetic and natural rubbers alongwith different polyethylenes on the properties of bitumen. Polybutadiene rubber- polyethylene mixtures formed a physical network in bitumen medium but styrene butadiene random copolymer, natural rubber and Styrene- ethylene- butylene- styrene block copolymer did not form such a network. SBR- PE was the best mixtures that enhanced the properties of bitumen [12]. Modifiers like triblock poly (styrene-b-butadiene–b-styrene) (SBS), diblock poly (styrene-b-butadiene) rubber (SBR) and high cure ground tire rubber can decrease oxidative aging rates and thus decrease the stiffening of asphalt which occurs due to oxidation. This will naturally enhance the life of pavement [13]. The effect of SBS on aging of asphalt also has been studied. Specimens of SBS modified bitumen and bitumen were aged conferring to rolling thin film oven test (RTFOT) and pressure ageing vessel (PAV) respectively. Then properties of aged specimens were examined using different tests. FTIR studies confirmed that after ageing, SBS modified bitumen undergo less oxidation than bitumen. Thus SBS as a modifier result in less ageing of bitumen [14]. Nejad *et al.* modified 60/70 bitumen and vacuum bottom bitumen with crumb rubber using SHRP and classic methods and proved that the crumb rubber tends to enhance the elasticity of bitumen. Crumb rubber modified bitumen cannot be used for longer periods of time because bitumen mixtures which contain high amount of CR (26%) only had proper storage stability [15] Processed waste crumb rubber of about 5.0-10.0% by weight of bitumen was used, it enhances

Marshall Stability, strength, fatigue life which further increases the durability of road [16]. Gonzalez *et al.* examined the role of adding polymeric additives on technological and rheological properties of crumb tire modified bitumen. 10.0 wt.% CR was mixed with bitumen with the support of a rotor stator mixer at 8200 rpm for 30 minutes at 180 °C in order to synthesize CR modified bitumen. The additives were added to the mixture and blended together. The additives used were polyphosphoric acid, SBS, linker, FT wax, polyoctenamer. The additives improved storage and loss moduli and reduced loss tangent. Polyoctenamer and polyphosphoric acid were the best among all the additives [17].The performance of bitumen modified with crumb rubber was improved by adding polyphosphoric acid and vestenamer additives. This in turn enhanced the resistance towards cracking and rutting at low and high temperatures respectively [18]. An innovative technique involving crumb rubber gained from scrap tires using a high pressure water jet method was also investigated. Resulting crumb rubber had smaller particle size than the conventional one and used as a modifier in bitumen. The new crumb rubber was a much better material that can be used in road construction purpose [19]. Junior *et al.* used scrap tire rubber (STR) as a modifier instead of SBS. Four different percentages of STR were used to modify the asphalt. The properties of STR modified asphalt were compared with SBS modified asphalt. Although the properties of SBS modified asphalt were much better than STR modified asphalt but still STR was a good alternative and can be used in place of SBS. Moreover large amount of scrap tires can be disposed of in an environmental friendly way [20]. Devulcanised tyre rubber-heavy oils blend (liquid rubber) had a wide probability to be used as a modifier in bitumen for future use. Liquid rubber bitumen mixes have proper storage stability because they have high solubility [21]. Senise *et al.* tested the hybrid systems prepared by mixing of polymers like (EVA, EBA, SBS, EPDMs) with model rubber modified bitumen (10.0 wt.% CTR) followed by treatment with sulphur. The modified bitumen was examined by technological and rheological techniques, Fluorescence microscopy and Modulated Scanning Calorimetry. A complicated system was formed which comprises of several phases mainly asphaltene rich phase, polymer rich phase, un-decomposed rubber particles and dissolved rubber chains that finally results in increment of in service properties and storage stability. Hybrid system containing SBS showed sulphur cross linking reactions and a continuous network of SBS, hence considered best in performance [22]. Ramez *et al.* investigated the role of ENR (epoxidized natural rubber) as a

modifier in bitumen. ENR were mixed with 80/100 bitumen in varying percentages by weight of bitumen (3.0% to 12.0%). Modified bitumen was analyzed for empirical and rheological properties. ENR tends to decrease the temperature susceptibility and enhanced fatigue behavior and rutting resistance at low and high temperatures respectively. Bitumen modified with 6.0% ENR was found to be the optimally modified bitumen [23].Varied percentages of rubber silicone (1.0%, 2.0%, 3.0%, and 5.0%) were added to asphalt. Six samples were prepared for each percentage and examined according to Marshall Method. Rubber-Silicone as a modifier enhanced the Marshal stability, air voids, and reduced the flow and bulk density of asphalt mixture. It also improved the flexible nature of the mix and decreased the permanent deformation [24]. 9.0 wt.% CR was mixed with bitumen at temperatures (between 90 °C and 250 °C) for 90 minutes. At low temperatures, there was no difference in cross linked network of rubber, means interaction between swollen rubber particles and bitumen is responsible for the rheological properties of modified bitumen. There was partial decomposition of cross linked network of rubber at high temperatures; hence the processing temperature during the synthesis of crumb tire modified bitumen directly affects the rheological properties of bitumen [25]. G.D. Airey used two bitumen samples: paraffinic and naphthenic bitumen. Six SBS modified bitumen were prepared by blending SBS copolymer with the two types of bitumen at three percentages of SBS 3%, 5% and 7% by the weight of bitumen between 170 °C and 185 °C. The results indicated that SBS modification results in enhancement of rheological properties of modified bitumen. SBS absorb light fractions of bitumen, swells and rubber elastic network in the modified bitumen was formed. Moreover paraffinic bitumen shows greater polymer modification as compare to naphthenic bitumen. This becomes more evident at higher polymer content, higher temperatures and lower frequencies (26). Since many years crumb rubber from waste tyres of vehicles were also being used as modifier in bitumen. Crumb rubber and bitumen shows physical interaction where CR absorbs some constituents of bitumen and swells by the process of diffusion [27]. Kim *et al.* studied the rheological behavior of crumb rubber modified asphalt binders. Crumb rubber was taken in three different percentages of 10%, 15%, 20% and mixed with binder of performance grade (PG) 64-22 at 177 ^{o}C under 700 rpm for 1hr. Virgin and modified binders were subjected to rheological tests (flow behavior, elasticity, loading and temperature dependence). The outcomes showed that crumb rubber as a modifier give better

resistance against permanent deformation as well as enhances the penetration resistance of asphalt binder [28]. Naeem *et al.* studied the effect of different mixing variables like mixing time, temperature, speed and device on the properties of CRMB. They used wide range of mixing parameters like high shear mixer and mechanical stirrer as mixing device, 30, 60, 90, 120, 180 min of mixing time, 1000, 2000, 3000 rpm of mixing speed and 180 °C and 200 °C of mixing temperature. CR and bitumen concentration were kept fixed and effect of mixing variables was studied. The outcomes showed that high shear mixers lead to higher viscosity of mixes as compare to mechanical stirrer. Moreover the mixing temperature of 180 ^{o}C was selected as optimum temperature for synthesis of CRMB having stable viscosities. Hence high shear mixers should be preferred as these require low interaction temperature, speed and time [29]. Another research program compared the performance of SBS, CR and CCR (combination of CR and SBS) modified asphalt after ageing by examining their microstructure and rheological properties. They concluded that CR modified asphalt is better than SBS and CCR modified asphalt in terms of performance [30]. Table 1 gives the change in property of bitumen with the use of different forms of rubber modifier.

Table 1: Type of rubber modifier and change in property of bitumen

Type of polymer	Change in property	Reference Number
Crumb Rubber	Enhance elasticity, resistance against permanent deformation	11,15, 28
SBR	Decrease oxidation of asphalt	13
SBS	Less ageing of bitumen, enhance rheological properties	14, 26
Processed waste crumb rubber	Increases strength	16
High pressure water jet crumb rubber	Less temperature susceptibility, more storage stability	19
Scrap tire rubber	Can substitute SBS	20
Liquid rubber	Enhances storage stability	21
Hybrid systems	Better storage stability	22
Epoxidized natural	Decrease the temperature	23

rubber	susceptibility and enhance rutting resistance	
Rubber silicone	Decrease permanent deformation	24

Conclusion

The present review explains effect of rubber modifier in enhancement of various properties of bitumen. It can be stated that crumb rubber as a modifier shows quite promising results in a wide temperature range. Rubber as a modifier can decrease oxidation of bitumen which result in less ageing of bitumen, decrease temperature susceptibility and permanent deformation, enhance rutting resistance and rheological properties. Being an elastomer, it provides higher flexibility to the pavement so that later can bear heavy traffic loads yet there is urgent need to adopt measures which can increase the storage stability of rubber modified binders.

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