Application of Crumb Rubber as Modifier in Bitumen

Birendra Kumar Singh1, Martand Siroliya2

1Resident Engineer 2Assistant Professor
12Department of Civil Engineering

1Highway Engineering Consultant 2UIT-RGPV, Bhopal

Abstract— Crumb rubber modified bitumen (CRMB) has been identified as a special type of bitumen whose properties can be improved by the addition of crumb rubber, thus improving the physical properties of bitumen. This modifier makes bitumen more resistant to temperature variations, weather and high traffic loads; it reduces the maintenance costs and improves driving comfort. This paper reviewed the use of this modifier in pavement.

Key words: Crumb Rubber, Bitumen, Modifiers, Pavements, Durability, Marshal

I. INTRODUCTION

Road transport has acquired dominant position amongst the various modes of transportation system due to its flexibility, door-to-door service, reliability and speed. In India, road transport carries about 90% of passenger traffic and 70% of freight transport. So road traffic and the traffic intensity have been increasing, therefore increasing the load bearing capacities of the road are necessary. Investigations in India and countries abroad have revealed that properties of bitumen and bituminous mixes can be improved to meet requirements of pavement with the incorporation of certain additives or blend of additives. These additives are called “BitumenModifiers” and the bitumen premixed with these modifiers is known as modified bitumen. Poor performance of bituminous mixtures under increased traffic volume and heavier axle load has been led to the increased use and development of modified binders. The introduction of scrap rubber into asphalt pavement has the potential for reducing the waste problem.

It is estimated that over 33 lakh kilometers road exist and out of which around 50% is bitumen coated [1]. More than 290 million scrap tyres have been disposed of in the United States every year, and approximately 67% of these have been utilized for applications such as tire-derived fuel, molded products, and crumb rubber [2]. Repeated applications of traffic load causes structural damage to asphalt pavements in the form of fatigue cracking of asphalt bound layer and rutting along wheel tracks. Use of reclaimed rubber from ground automotive and light truck tires reduces reflective and thermal cracking, suppress traffic noise, increase resistance to studded tire wear, and reduce the environmental impact of tire disposal [3].

II. LITERATURE REVIEW

In the last decade several engineers and researchers showed interest in the use of CRMB. Open-graded friction course (OGFC), which consists of an open gradation mostly of coarse size aggregate with little fines, has been a special purpose mixture that has been used in pavement surfacing around the world. Punith V. S. et al (2012) studied the use and properties of OGFC mixtures containing reclaimed polyethylene modified binder (RPEB), crumb rubber modified binder (CRMB), and neat 60/70-grade binder with cellulose fibers. The typical benefits of an OGFC mixture have been identified as: increased surface permeability, noise reduction, and enhanced surface friction, especially in wet conditions. Laboratory tests had been carried out in this study to evaluate open-graded friction course mixture properties by adopting two different types of Marshall Compaction.

Merusi Filippo et al. (2011) added several different modifiers, including polymeric materials, recycled crumb rubber, and synthetic waxes, to a base bitumen. All blends had been studied with special reference to their chemical composition and subjected to a solubility test consisting of a controlled immersion in kerosene results were interpreted on the basis of the compositional characteristics which determine the interactions occurring between bitumen and modifiers.

Praveen K. et al. (2010) investigated that the improvement of binder, it is necessary to add the polymers to bitumen. In this study, two types of polymer — ethylene vinyl acetate (EVA), a plastomer, and linear styrene-butadiene styrene (SBS), an elastomeric — and crumb rubber (CR) were used. Testing has been performed at higher temperatures ranging from 46 to 82°C in increments of 6°C at a frequency of 10 rad/s in the range from 0.1 to 100 rad/s before and after aging. It has been observed that the rheological properties of bituminous binders had changed after modification. There is an improvement in rheological properties of the neat bitumen after mixing with modifiers.

Shankar S. and Prasad C.S.R.K et al. (2009) Observed that high traffic intensity, over loading of trucks, and significant variation in temperature of the pavements have been responsible for earlier development of distress symptoms. The properties of bitumen and bituminous mixes can be improved to meet the basic requirements to use crumb rubber modified bitumen and resulted in much improve characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content. Jae Lee Soon et al. (2009) investigated that recycling of hot-mix asphalt pavements containing a crumb rubber modifier (CRM) has been an area of interest, as CRM had been used in asphalt paving materials approximately 40 years ago. Studies on the recycling of rubberized asphalt concrete materials have focused mainly on the mixture properties at the location of in-field paving. However, for the long-term performance characterizations, there has been a need to investigate the aging properties of rubberized binders and the subsequent recycling properties of these aged rubberized binders. Xiao Feipeng et al. (2009) discussed that predicting the fatigue life of asphalt mixtures has been a difficult task due to the complex nature of materials behavior under various loading and environmental conditions. The utilization of an artificial neural network (ANN) in predicting the fatigue life of beams were made with two different rubber types (ambient and cryogenic),
two different reclaimed asphalt pavement (RAP) sources, four rubber contents (0, 5, 10, and 15%), and tested at two different testing temperatures of 5 and 20°C.

Neutag. L. et al. (2008) Studied use of crumb rubber in asphalt mixtures from 1920s. The biggest part of research work in this field has been done in the United States during the last 15 years. Properties of the modified bitumen had been verified with the standard penetration tests, density and softening point ring and ball as well as the performance tests bending beam rheometer, dynamic shear rheometer and force ductility. Mohamed A.A. et al. (2008) Determined visco–elastic properties of crumb rubber modified bitumen with antioxidants (CR30) by the means of rheological measurement. This measurement led to a better knowledge of bitumen behavior that occurs when subjected to different thermal and mechanical conditions, as seen during road construction and services in the field. Ali M.A (2007) observed that rheological weakness of the conventional bitumen has been generated as an increasing interest in the use of polymer modifiers to enhance properties of conventional bitumen. Results indicated an improvement on the engineering properties and the performance with the modification. It can be concluded that CR30 additives can be considered as an interesting modifier of the bitumen.

Hamzah M.O. et al. (2006) discussed that scrap tire usage in road construction started many years ago and modification of bitumen with crumb rubber in road paving applications has been growing rapidly over the last four decades. The properties of base bitumen and crumb rubber modified with antioxidant using a Dynamic Shear Rheometer (DSR). The rheological properties of modified bitumen have been compared with unmodified 80/100 bitumen. Singh K.P. (2006) observed that CRMB must be used as soon as possible since its quality can start to deteriorate as early as 6 hours after production. Crumb rubber can degrade, if its use has been delayed thereby losing its vital properties such as elasticity and viscosity. Crumb rubber tends to separate and settle down in the bitumen. If some crumb rubber particles have been settled to the bottom of the transport tanker or contractor’s storage tank, the CRMB at the top may have quality, which is inferior to pure bitumen.

Palit S. K et al. (2004) used crumb rubber (CR) obtained from discarded truck and bus tires to modify 80/100 penetration grade asphalt cement. Fatigue and permanent deformation characteristics, temperature and moisture susceptibility, and oxidative aging have been some of the performance indicators of mixes evaluated. CR modified mixes had been found to have improved fatigue and permanent deformation characteristics, also showed lower temperature susceptibility and greater resistance to moisture damage compared to normal mixes.

Zhong X. G. et al. (2002) investigated the potential application of rubber-modified asphalt in railroad track-beds by measuring its shear modulus and damping ratio. Shear modulus and damping ratio had also been conducted on typical subgrade soils. Column tests had been conducted on subgrade soil samples and the crumb rubber-modified asphalt (CRMA) mix samples with different rubber contents and rubber types. CRMA has been a material with high shear stiffness and damping ratio, making it a very attractive material for vibration attenuation of railroad track-beds.

Mustaque H. et al. (1999) Stated that, fracture and tensile characteristics of asphalt concrete mixtures affect the structural performance of pavements, particularly under low-temperature conditions. The tensile and fracture properties of asphalt-rubber (AR) concrete mixtures that formed the basis for the recommendation of an optimum asphalt mixture design incorporating crumb rubber from scrap tires.

Hossain M. et al. (1998) studied the development of a chunk rubber asphalt concrete mix design for low volume road construction using local aggregate, shredded tire rubber chunks and a cationic emulsion. Different combinations of chunk rubber content, emulsion content and fly ash content had been tested. Marshall Stability values decreased for increasing rubber contents. The Marshall Stability results, some of these mixes appeared to be suitable as binder courses or stabilized drainable bases for low volume roads.

McQuillen J.L. et al. (1990) discussed the use of reclaimed rubber from ground automotive and light truck tires to reduce reflective and thermal cracking, suppress traffic noise, increase resistance to studded tire wear, and reduce the environmental impact of tire disposal.

III. INVESTIGATIONS AND RESULTS

The crumb rubber modified bitumen, penetration value had come down from 66 to 58, while softening point has been improved from 420°C to 520°C and considerable reduction in the Ductility from 80cm to 47cm[1]. Fatigue lives of the CR modified mixes can be expected to be at least two times longer than that of normal asphalt mixes. CR modified mixes displayed lower potential for permanent deformation compared to normal mixes. Rutting potential of paving mixes as the test could produce similar trends as had been observed in the case of the more complex repeated indirect tensile test [5]. Modified bitumen improved the conventional properties such as softening point and 5°C ductility and also enhanced bitumen blends properties at high in-service temperatures, showing favorable mechanical properties at temperatures for which neat bitumen undergoes permanent deformation [6]. Modified mixes have higher Marshall Stability values as compared to the control mix. A stability increase of nearly 24%.Mixes with modified binders displayed higher flexibility at lower temperatures because of lower resilient modulus and higher stiffness and tensile strength at higher temperatures [7].

CRMB is substantially stiffer than Un-modified bitumen; compaction of asphalt mix containing CRMB should begin promptly to adequate compaction in the pavement [8].

CR-modified binders will be suitable for moderately high temperature zone and low cost roads where cost is a major concern [9].

The dynamic shear rheometer has been used to characterize the rheological properties of the modified and unmodified binder’s result of the rheological changes, the mechanical properties of aged 1% CR30 and binders show
improvement, by increased complex modulus and decreased phase angle [10].

The abrasion loss of the porous asphalt mixtures can be reduced significantly with the addition of modifiers or additives. Modification with crumb rubber improved the indirect tensile strength of porous asphalt mixtures. The fatigue life of OGFC mixtures was found to increase by 50% using the modified binders, i.e., CRMB or RPEB, compared to mixtures with 60/70-grade binder and cellulose fibers. Skid resistance does not appear to be affected by binder type or modification. Skid resistance appears to be a function of aggregate shape, texture, and gradation [12].

For CRMA with 20% rubber content, the average damping ratio is approximately 9.5%. For the asphalt mix without crumb rubber, the damping ratio is approximately 5.5%. Stiffness of asphalt mixes increases slightly with the increase of the rubber content. In addition to rubber content that affects the shear modulus and damping of asphalt mixes, such as air void content, rubber type, aggregate grading, and different mix and compaction methods [14].

Bitumen could reach very high softening points and shear modulus by using crumb rubber for modification. Conventional bitumen could refine to high-quality binder by adding crumb rubber of scrap tires and thus directly change and optimize different specifications e.g. fatigue resistance, deep and high temperature behavior, viscosity and elasticity [15].

Crumb rubber modified binder improved with high temperature properties. The resistance to rutting has been improved with a reduction in the particle size of the crumb rubber modifier.

IV. CONCLUSION AND DISCUSSION

Use of modifiers such as CRMB is having following effects: Rheological and physical properties of bitumen have been changed. Fatigue behavior of crumb rubber modified mixes has been found to be significantly improved compared to normal mixes. Also Modified bitumen improved the conventional properties such as softening point, ductility, and bitumen blends properties. Modified mixes have been expected to yield longer lives due to better ageing. CRMB sets faster than unmodified bitumen. The abrasion loss of the porous asphalt mixtures can be reduced significantly. Adding crumb rubber to asphalt increases the damping ratio of asphalt mixes.

REFERENCES


