ISSN: 2456 - 1819
EIJO: Journal of Civil Engineering, Architecture, Interior Design and Innovative Research (EIJO–CEAIDIR)
Einstein International Journal Organization (EIJO)
Available Online at: www.eijo.in
Volume – 3, Issue – 1, January – February 2018, Page No. 01 - 05

A Review Study on the use of Crumb Rubber in Conventional Bitumen

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Abstract: The most dominant mode of the transport in India is the Road Transport, carrying close to 90% of the passenger traffic & 70% of the freight transport. In India, flexible pavement type of construction is preferred over the rigid pavement type of construction due to its various advantages such as low initial cost, maintenance cost, etc. Therefore, among the surfaced roads, maximum is the contribution of the bituminous pavements. Bitumen has been widely used in India for the construction of flexible pavements for more than a century. Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations in asphalt binder performance and this has led to early developments of distress symptoms like cracking, rutting, raveling, undulations, shoving and pot holing of bituminous surfacing. CRMB is suitable for pavements submitted to all sorts of weather conditions, highways, traffic denser roads, junctions, heavy duty and high traffic sea port roads etc. It is a durable and economical solution for new construction and maintenance of wearing courses. This paper presents a review study of use of Crumb Rubber in conventional Bitumen.

Keywords: Waste Tyre Rubber, Bitumen, Crumb Rubber, Flexible Pavement.

1.0 Introduction

India has a road network of over 4,689,842 kilometres in 2013, the second largest road network in the world. It has primarily flexible pavement design which constitutes more than 98% of the total road network. India being a very vast country has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. So to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved. There are many modification processes and additives that are currently used in bitumen modifications such as styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA) and crumb rubber modifier (CRM). Crumb rubber is a term usually applied to recycled rubber from automotive and truck scrap tires. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles further. The particles are sized and classified based on various criteria including color (black only or black and white).

1.1 Crumb Rubber Modified Bitumen

Crumb Rubber Modified Bitumen (CRMB) is hydrocarbon binder obtained through physical and chemical interaction of crumb rubber (produced by recycling of used tyres) with bitumen and some specific additives. The Flextal range of CRMB offers binders which are stable and easy to handle with enhanced performances. Crumb rubber or waste tyre rubber, is a blend of synthetic rubber natural rubber, carbon black, antioxidants, fillers, and extender type of oils which are soluble in hot paving grade. Asphalt rubber is obtained by the incorporation of crumb rubber from ground tyres in asphalt binder at certain conditions of time and temperature using either dry process (method that adds granulated or crumb rubber modifier (CRM) from scrap tires as a substitute for a percentage of the aggregate in the asphalt concrete mixture, not as part of the asphalt binder) or wet processes (method of modifying the asphalt binder with CRM from scrap tires before the binder is added to form the asphalt concrete mixture). There are two different methods in the use of tyre rubber in asphalt binders; first one is by dissolving crumb rubber in the asphalt as binder modifier. Second one is by substituting a portion of fine aggregates with ground rubber that does not completely react with bitumen.

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2.0 Literature Review On Crumb Rubber

Navarro et al. studied the rheological characteristics of ground tire rubber-modified asphalt. The experiment was performed in a controlled-stress Haake RS150 rheometer. The study aimed at comparing the viscoelastic behaviour of five ground tyres rubber modified with unmodified asphalt and polymer-modified (SBS) asphalt. The study displayed that rubber-modified asphalt improved viscoelastic characteristics and therefore has higher viscosity than unmodified binders. Thus, the asphalt rubber is expected to better enhance resistance to permanent deformation or rutting and low temperature cracking. The study also found that the viscoelastic properties of rubber-modified asphalt with 9% weight are very similar to SBS-modified bitumen having 3% weight SBS at −10°C and 7% weight at 75°C.

Mashaan et al investigated the rheological properties of asphalt rubber for various combination factors of crumb rubber content and blending conditions. The dynamic shear rheometer (DSR) test was conducted to evaluate the engineering properties of asphalt binder reinforced with crumb rubber at 76°C. Specification testing was performed at a test frequency of 10 rad/s which is equivalent to the car speed of 90 km/h. Test specimens of 1 mm thick by 25 mm in diameter were formed between parallel metal plates. The study displays increases in G^*, G', and G'' and decrease in phase angle (δ). Thus, the modified asphalt became less susceptible to deformation after stress removals. The study also presented a considerable relationship between rheological parameters (G^*, G', G'', and δ) and softening point in terms of predicting physical-mechanical properties regardless of blending conditions.

Natu et al observed that the unmodified and crumb rubber modified binders with the same high temperature PG rating do not show similar viscoelastic behaviour over a range of frequencies. It was also concluded that the unmodified and crumb rubber modified mixtures containing binders with the same high temperature PG rating do not show similar viscoelastic behaviour over a range of frequencies. Mixtures containing the same PG rated binders performed similarly if their performance was evaluated at a frequency and temperature at which the binder high temperature PG rating was determined.

Nair et al used a Haake rotational viscometer to measure the viscosity of the soft asphalt samples while the viscosity of the blown asphalt samples is measured on a capillary rheometer. The tests were conducted to study the flow behaviour on the modification of asphalt with liquid natural rubber (LNR). The findings are as follows; for soft asphalt, the temperature dependence on viscosity is prominent up to 100°C and subsequently marginal. The addition of 20% LNR results in the maximum viscosity. Activation energy of flow of soft bitumen increased, while that of blown asphalt decreased on addition of LNR.

Zaman et al. found that the viscosity of asphalt cement increases with the addition of rubber, and rubber-modified asphalt-cement samples show a more uniform and higher resistance against loading as the amount of rubber increased. The degrees of shear-thickening and shear-thinning behaviour decreased by increasing the amounts of rubber in asphalt cement. The liner dynamic viscosity was increased by increasing the amount of rubber in asphalt cement.

Piggott et al. studied that the vulcanized rubber had a large effect on the viscosity of the asphalt cement. The viscosity, measured at 95°C, increased by a factor of more than 20 when 30% vulcanized rubber was added to the mixture. In contrast, the devulcanized rubber had only a very small effect. The viscosity test also showed that there is no danger of gel formation when rubber is mixed with hot asphalt cement.

Mashaan et al reported that the softening point value increases as crumb tuber content increases in the mix. The increase of rubber content in the mix could be correlated to the increase in the asphaltenes/resins ratio which probably enhanced the stiffening properties, making the modified binder less susceptible to temperature changes.

Liu et al. studied the main factor in the increase in softening point can be attributed to crumb rubber content, regardless of type and size. The increase in softening point led to a stiff binder that has the ability to enhance its recovery after elastic deformation.

Mashaan et al. studied that the rubberized asphalt binder was evaluated in terms of binder elasticity and rutting resistance at high temperature. The higher crumb rubber content appears to dramatically increase the elastic recovery and ductility. According to his study, the ductility test conducted at low temperature was found to be a useful indicator of brittle behaviour of bitumen. Latex contents in the range from 3 to 5% were found to result in nonbrittle behaviour in the ductility test at 5°C whereas the unmodified bitumen failed by brittle fracture in the same test.

Nair et al. found that the ductility decreased in the case of soft bitumen with increasing concentration of liquid natural rubber while some improvement was noticed in the case of blown bitumen at 10% loading. The ductility is measured at 27°C and pulled apart at a rate of 50 mm/min. Modified bitumen binders showed a significant enhancement on the elastic recovery, and, in contrast, the ductility decreased with respect to unmodified binders

Bahia and Anderson studied the mechanism by which binder properties may change at low temperature. This mechanism which is called physical hardening occurs at temperatures next to or lowers than the glass transition temperature and causes significant hardening of the asphalt binder. The rate and magnitude of the hardening phenomena have been observed to increase with decreasing temperatures and is reported to be similar to the phenomena called physical aging on amorphous solids. The physical hardening can be explained using the free volume theory which introduced the relationship between temperature and molecular mobility. The free volume theory includes the molecular mobility dependent on the equivalent volume of molecules present per unit of free space or free volume. Based on the free volume theory, when amorphous material is cooled from a temperature above its glass transition temperature, molecular adjustments and the collapse of free volume rapidly show a drop in temperature. At that temperature, the structural state of the material is frozen-in and deviates from thermal equilibrium due to the continuous drop in kinetic energy. Hence, it has been postulated that, in order for physical hardening to happen in binders, temperatures must be higher than the glass transition temperature.

Mahrez et al investigated ageing effects on viscoelastic properties of rubberized asphalt using the Dynamic Shear Rheometer (DSR). The binders were aged with the Thin Film Oven Test (TFOT), the Rolling Film Oven Test (RFOT), and the Pressure Ageing Vessel (PAV). This research found that ageing influences the rheology of rubberized asphalt. The mechanical properties of aged binder improved by increased complex modulus and decreased phase angle. The aged samples were characterized by higher stiffness and elasticity, due to an increase in the elastic (storage) modulus, G'. The high value of G' is an advantage since it improved further the rutting resistance during service.

Conclusion

On the basis of various studies done by authors, Following conclusions are drawn:

1. By using the recycled rubber powder, there can be improve in the properties of asphalt used in road and also cleans not only help the environment but also to the final price of asphalt producer.
2. The use of rubber and PET in roads can solve the problem of environmental damage which can be caused by their disposal.
3. The biggest advantage of using rubberized bitumen is that the road life increases in comparison to the normal bitumen whereas the cost increases on the road.
4. Addition of waste tyres as rubber aggregate modifies the flexibility of surface layer.
5. Problem like thermal cracking and permanent deformation are reducing in hot temperature region.
6. Rubber has property of absorbing sound, which also help in reducing the sound pollution of heavy traffic roads.
7. Waste rubber tyres thus can be put to use and it ultimately improves the quality and performance of road.
8. Conventional stone aggregate can be saved to a certain quantity.

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