A Review on Discard Rubber Waste in Flexible Pavement

Pradeep Kumar Gautam[1], Pawan Kalla[2], Ajay Singh Jethoo[2]
[1]Department of Civil Engineering, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur-302017(INDIA)
[2]Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur-302017(INDIA)
Email- 2014rce9037@mnit.ac.in
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Abstract:Management of discard tire waste has emerged as serious problem around the globe. Research has shown that use of tire waste as additive in hot mix asphalt improve the rheological properties of mix, thus improving overall service life of flexible pavement. This paper reviews prominent studies in the field of using discarded tire waste as additive to hot mix asphalt and its effect on various strength and durability characteristics on hot mix asphalt mixes (HMA).

Keywords: Hot mix asphalt, waste rubber tire, sustainable development, waste management.

1. INTRODUCTION

Sustainable development has emerged as hot topic in 21st century. On one hand, the mismanaged exhaustive use of non-renewable resource has led to their scarcity; at the same time, a huge quantity of industrial waste is being produced around the globe. This mishandling of resource has led researchers to find an alternative to optimize the use of nonrenewable resource and utilize the constantly produced industrial waste.

Every year huge quantity of tire is discarded as waste. Consistent growth in automobile is eventually leading to increase in discarded waste every year.

It has been estimated that the quantity of waste rubber tire (WRT) accumulation in landfill is increasing at the exponential rate of 20% every year. Waste rubber tires being toxic, hazardous and non-biodegrable material, when disposed as landfill lead to leaching problem and if incinerated produce toxic gases [1], this is the reason why many a times it is also referred as black pollution. A number of studies have been conducted by researchers around the globe to find the sustainable disposal method for WRT. The most successful use have been in consuming waste tire as additive in hot mix asphalt to improve the life of flexible pavement. Research have established that using the waste as filler improve strength and durability characteristics of flexible pavement.

2. MECHANISM OF ADDING RUBBER WASTE TO BITUMEN

WRT is added to HMA in two ways, these are wet mixing process and dry mixing process. In wet mixing process, rubber waste is mixed to the binder at elevated temperature till a homogeneous mix is obtained. Fine bitumen particles get absorbed by the rubber particles making them swell resulting in an overall hard and viscous bitumen. The quality of binder obtained depend upon the type of mixing equipment used i.e. high shear or low shear mixing equipment. A low shear mixer is a simple tank provided with paddler to enable mixing process, while high shear mixercontain a more sophisticated mechanism. Where the scope of low shear mixer is limited to mixing bitumen with modifying additive at a constant temperature; in high shear mixing is proceeded using hydrodynamic shear with consistent temperature increment during mixing process so as to ease the mixing process and produce a more homogeneous mix.[2]. Wet mixing incorporate fine rubber particle 100% passing 2 mm or finer sieve size.

In dry mixing method, rubber particles are mixed with well graded aggregates. Hence, in dry mixing, the waste act more like fine aggregate and filler material instead of adhesive[3]. Energy consumed in dry mixing is comparatively less than that in wet mixing. The rubber particle size distribution of rubber particle in dry mixing lie between 4.75mm-2mm.

2.1 Working principle of rubber waste in HMA

Upon addition, waste rubber tires absorbs light aromatic oil fractions resulting in swelling of rubber particles forming a gel like structure. This result in an overall dense mixture resulting in high viscosity. This continues till rubber particle start disintegrating. Hence, the phenomena is dependent on various factors like The rate of reaction between rubber particles and base binder depend on mixing time, temperature, speed, production methods (ambient or cryogenic grinding), particle size, specific surface area, chemical composition (i.e., amount of natural rubber), and morphology of rubber particles. [4].

3. EFFECT OF DISCARDED RUBBER WASTE ON HMA PROPERTIES

3.1 Strength Properties

Incorporation of rubber tire waste as additive improve overall strength and durability characteristics of hot mix asphalt. The influence of WRT on performance of open graded friction course was demonstrated in a study. Here, the waste was added in proportion of 10%, 15% and 20% and each mix was tested for strength and durability properties [5].

Durability properties was observed increasing up to 15% addition of WRT, indicated by cantabro loss test and indirect tensile strength test. Similar were the results in another study where crumb rubber was added in bituminous concrete mixes in proportion of 5%, 10%, 15% and 20% [6]. Addition was waste was with wet mixing process. Test result indicated improved flexibility, rutting and fatigue resistance properties of mixes upon addition of WRT.

3.2 Ageing properties

Ageing take place in two phase a) short term ageing during construction phase and b) long term ageing due to traffic load and environment factors. Use of amorphous poly alpha olefin (APAP) polymer along with WRT to improve the ageing properties of HMA has shown positive results. APAP was added in proportion of 0%, 4% and 6% and 15% WTR. Each sample was subjected to short term and long term ageing. For short term ageing analysis thin film oven test was used proceeded as per ASTM D1754. Test was proceeded at 163ºC observation taken at every one hour interval till five hours. The test sample was then subjected to long term ageing using pressure vessel technique. Rheological characteristics was studied as per ASTM D7175 using smart pave 101 rheometer. FTIR was used to analyse characterization of asphalt binder. Result showed penetration and softening point decreasing linearly with time. Improvement to resistance to permanent deformation and fatigue cracking[7].

3.3 Fatigue Property of HMA

Use of discarded rubber waste improves the rutting and fatigue resistance properties of mixes compared to normal binder, increase viscosity, hence increasing mixing temperature [8]. Researchers have studied the effect of discarded rubber tire waste on fatigue behaviour in concrete pavement/ rubberized concrete[9]. WTR of size 1-4, 10, 16mm were used in 10, 20 and 30% in rigid pavement. Bending strength loss was dependent on particle size of rubber. Increase in rubber proportion in mix improved the plastic performance of mix indicating increasing flexibility of concrete. Addition of 10% rubber with 10mm particle size gave best result, no permanent deformation

4. RUBBER WASTE WITH OTHER WASTE

Studies have established that use of waste rubber tires improves the overall rheological properties of binder, however, possess low storage stability at elevated temperature. To improve this properties, research have been conducted where this phenomena have been controlled with the used of chemical additives like sulphur and styrene–butadiene–styrene (SBS). Use of plastic waste have shown efficient in improving this property.

A recent study used thermoplastic to improve high temperature storage properties of WRT modified binder. Results of the study were in align with other studies where, inclusion of thermoplastic improves the long term storage property of overall mixture. Inclusion of both waste also improved strength properties, resistance to moisture condition and fatigue property of mixes [10].

Similarly, use of discarded rubber and plastic waste as additive to improve binder properties has also been evaluated. Here, the effect of modified binder on bituminous concrete mixes was studied. Plastic and rubber waste was added as individual additive to conventional binder in proportion of 4, 6, 8, 10% and 5, 10, 15% respectively, another series of HMA mix was prepared containing combination of rubber and plastic waste in proportion of 4% plastic, 5% rubber; 6% plastic, 10% rubber and 8% plastic and 15% rubber waste, at a mixing temperature of 200-220º C. Study concluded that inclusion of rubber and plastic waste improved the strength and durability properties of the mix , minimized the construction cost. Best waste containing 10% rubber waste performed better than mixes containing plastic waste, giving higher marshal value of 13.10kN and 10.54kN [1].

4.1 Field study

Researchers have also studied use of grounded rubber tire as rejuvenating agent in dense graded mix prepared with 30% Recycled Asphalt Pavement (RAP). Here, dry mixing method was used for addition of WRT. Three dense graded mix were prepared one containing no rejuvenator, other with rejuvenator and third WRT as rejuvenator. To study the mechanical and durability property. 70/100 pen graded binder was used. SEM was carried to investigate dispensation of blended aged and virgin binder where no evidence of agglomeration was observed, fine interlocking with conventional mastic asphalt was observed. Inclusion of WRT improved dry ITS, resulting in higher TSR. To assess the dynamic mechanical characteristics, ITSM test was performed at three different temperature i.e. 5º C, 20º C and 35º C. at low temp least stiffness modulus was obtained. Resistance to permanent deformation was analyzed by repeated load axial teat by measuring ultimate strain and strain rate percentage. Percentage accumulated strain was observed higher marginally, strain rate was observed same. Based on laboratory investigation, field trial was conducted. Here, two pavement section of road, field investigation carried out after eight month of laying including cold winter season. Macro structure change was analyzed using sand patch test here known volume of material in the surface and subsequent measurement of total area covered, recognized in term of mean temperature depth. Test was conducted at seven randomly selected points, complied with minimum value range. Micro texture analysis of pavement was consulted to evaluate skid resistance, British pendulum method was used to evaluate on seven longitudinal equidistant point found to fulfill required criteria, indicating improved road safety. Over study concluded using discarded rubber waste give higher OBC, no change in volumetric properties and decrease in thermal sensitivity was observed.[11]

5. CONCLUSION

A lot of research has been conducted around the world that support use of discarded rubber waste as additive for HMA preparation. Doing so leads to increase in strength, durability properties of flexible pavement. However, the proportion in which the waste can be added depend upon type of binder used, particle size distribution of waste rubber tire and environmental condition of area where construction has to be carried out. Overall using discarded tire waste not only helps in improving service life of flexible pavement but also helps in easing out landfill pressure, thus adding sustainability to overall construction project.

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