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Formulation of Modified Dense Graded Bituminous Macadam with Low Density and High-Density Polythene Waste with Zycotherm Admixture : A Review

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ABSTRACT

This study presents the use of waste polythene in flexible pavement construction. Reclaimed plastic waste derived as carry bags from kitchen and pond liner polyethelene as LDPE and plastic bottle caps as HDPE have been used as additive in flexible pavements. In this study we will also add a fix percentage of Zykotherm (ZycoTherm is an odor free additive that increases moisture resistance while lowering mixing and compaction temperature up to 65°F. Purposes of using above materials are to utilize environmentally unacceptable waste material and to develop a better material mix to resist increased traffic load, temperature effect and pressure resulted in cracks in the pavement surface. In the proposed study the plastic waste will be cleaned and cut into a size such that it passes through 2-3mm sieve using shredding machine. In this study we are presenting review of literatures presenting utilization of plastic in construction industry

Keywords : Bacteria, Concrete, Fibers, Strength, Self Healing, Material, Admixtures.

I. INTRODUCTION

Bitumen is used as a binder in pavement construction. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per definition given by the American Society of Testing Materials bitumen has been defined as “Mixtures of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide.”

Bitumen found in natural state known as asphalt contains large quantities of solid mineral matter. When petroleum crude is refined in a refinery, they are separated by fractional distillation in the order of decreasing volatility. On distillation of the residual bituminous residue, straight-run bitumen is obtained.

This bitumen is known as penetration grade bitumen or steam refined petroleum bitumen.

The grades of bitumen used for pavement construction is known as paving grades and that used for water proofing of structures is known as industrial grades. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed.

review on HMA and recycling waste material technology. It will investigate the different types of technology currently used in industry to achieve stable and binding properties for an ideal bitumen mix. The literature review will also explore current industry practices for producing and testing polythene for construction industry and the current issues being faced in terms of field performance and also look at mix design methods used for HMA.

II. LITERATURE SURVEY

Shubham Bansal et al (2017) The research paper focused on utilizing waste materials like discarded waste materials like plastic, polythene bags, bottles, rubber tyres etc as partial replacement of bitumen to develop a modified binder, for making bituminous concrete mix. To simulate with the field conditions, 'Marshall Stability Analysis' was performed on the samples prepared by partially replacing 'Optimum Bitumen Content' with waste plastic (4%, 6%, 8% and 10%) and crumb rubber (5%, 10% and 15%). Experimental results demonstrate that partial substitution of bitumen with waste plastic results up to 16% increment in strength whereas with rubber material, about 50% increment in strength was observed as compared to the conventional mix (CM). Laboratory testing results indicate that by using waste materials, bituminous concrete of required strength and density can be obtained and an environment friendly green pavement can be prepared with less material cost.

The results stated that use of rubber tyres and waste plastic bottles improves the strength and overall durability of the BC mix by increasing its overall performance manifold. Therefore with application of these waste materials in the fixed proportions, targeted characteristics of BC can be achieved. Use of discarded waste materials like rubber tyres and discarded plastic bottles in bituminous concrete mix may aid in minimizing the construction cost of the roads. Moreover it may also contribute in preventing the environmental pollution caused by the dumping of such waste materials in ground.

Aditya Bhardwaj et al (2017) the research paper presented variation of the properties of bitumen on addition of waste plastic at different percentage. The paper further stated various applications and advantages of Bitumen.

The conclusion derived from the research paper stated that by adding waste plastic to the bitumen the properties of bitumen has been optimized. Not only waste plastic improved the properties of bitumen but also improve the properties of bituminous mix. Thus, the use of waste plastic ultimately improves the performance and quality of flexible pavement. As plastic are non-biodegradable and also harmful to environment thus, disposal of plastic is a matter of great concern therefore use of waste plastic in the road construction is an effective way of disposal of waste plastic.

Michele Porto et al (2019) the research paper presented two principle sections which included investigation of bitumen in terms of chemical structure and microstructural systems and focuses on bitumen modification from different aspects for assessing the effectiveness of the introduced additives and polymers for enhancing the engineering properties of bitumen in both paving and industrial applications

The results stated that while plastomer-modified bitumens was suitable for improving the permanent deformation resistance of the bituminous compounds and asphalt concrete mixtures over high stresses, the absence of elasticity at low temperature limited the application of these bitumins. The field recorded data, as well as experimental works, showed that plastomer-modified bitumens, such as polyethylene and polypropylene, are the most common plastomers resulting in compatibility problems. This was due to their non-polar chemical nature. Despite the thermal and aging stability of plastomer-modified bitumens due to the absence of double bonds, the main problem resides in the stability of the blend (polymer + bitumen) during storage and difficulties to disperse them homogenously in the bitumen matrix. Thermoplastic elastomer copolymers, owing to their elastic component, was usually more effective than plastomers for bitumen modification in pavement applications. The modification ranges from low-modified containing 3% polymer to a high level with polymer content of 7%. Bitumen modification via styrene butadiene styrene (SBS) as the most commonly used elastomer has numerous benefits, including the improved thermal susceptibility, increased softening point, and slight decrease of penetration value at 25 _C. In addition, it was observed that SBS can moderate the increase of stiffness due to oxidation processes. Bitumens modified with thermosetting polymers show a high elasticity and no viscous behavior.

Asphalt mixtures produced with thermosetting polymer-modified bitumen have excellent adhesive ability, excellent resistance to deformation, excellent fatigue performance, and high stiffness modulus. Even though the PmBs with thermosetting plastics have relatively high adhesion to the mineral particles and high strength they are not common for paving applications.

This waS because the technological properties of PmB was almost immediately deteriorated by these polymers due to their hardening properties; secondly, the rigidity of the PmB is increased at low temperatures, which results in increased thermal sensitivity; thirdly, the use of TP complicates the system and raises its price; and, finally, the effectiveness of thermosetting plastics usually appears due to their large quantities in bitumen (more than 10 wt%)

Natural rubber latex has potential for improving bitumen binder performance by enhancing the thermal sensitivity, flexibility, stability, and stripping. In addition, its inherent elastomeric properties proved its high potential in improving long-term pavement performance of asphalt concrete by increasing rutting resistance, fatigue life, etc. Natural rubber also decreases the optimum binder content in asphalt concretes, increasing its density and stability. However, natural rubber was a highly valuable biomaterial compared to other biopolymers, hence natural rubber has been commercialized into synthetic rubber. This was mainly because of the very large difference between the available produced amount and the demand.

Krzysztof Blazejowski et al (2018) the research paper presented the modification of commercially available road bitumen 50/70 (EN 12591) by recycled rubber and synthetic poly (butadiene) in the presence of sulfur donor. Modification was carried out at 190°C and 220°C. Under such conditions, devulcanization of rubber took place. Prolonged heating in the presence of sulfur caused that devulcanized rubber and poly (butadiene) to revulcanize.

In order to reduce the cost of preparing polymer modified bitumen, it was proposed to replace part of poly (butadiene) with the waste product: recycled rubber. In this process, rubber in a degraded form is a substrate for the production of PMB.

Pre-devulcanized rubber was next used for creating the joint net with polybutadiene in the process of cross-linking.The devulcanization and cross-linking were carried out at different times at temperatures 190°C and 220°C. The modification process carried out at 220°C with 10% of rubber content was very fast, whereas for samples with 15% of rubber, the optimal modification time is 8 hours. Modification at 190°C requires a longer time. Most of the obtained products meet all standards (PMB 45/80-55 and PG 70-22 according to AASHTO-MP1). Particularly noteworthy was their behavior at low temperatures.

Murat Karacasu et al (2015) the research paper conducted a number of static and dynamic creep tests on RMA mix specimens with different rubber sizes and contents, and a series of resonant column tests were conducted to evaluate the shear modulus and damping values. To simulate the stress-strain response of traffic-induced loading, the measurements were taken for different confining pressures and strain levels.The results of the study indicated that rubber modification increases stiffness and damping ratio, made it very attractive material for use in road construction. However the grain size of the rubber was very important. Although RMA may cost up to 100% more than regular asphalt, the advantages it brings, such as an increased service life of the road and proper waste utilization contributing to a more sustainable infrastructure, may justify the added cost.
Creep stiffness was dependent on the type of loading, regardless if it was static or dynamic. It was highly dependent on the strain level at which the creep value was determined and also strongly influenced by the rubber particle size and texture. The particle size affects the shear modulus and damping ratio. It was concluded that the rubber-modified asphalt Concrete mitigates vibrations generated by traffic loading and results in reduced damage from cyclic straining. The use of polymer-modified bitumen provides improved longevity and marked whole-life cost benefits, increasing the sustainability of pavements.

Minakshi Singhal et al (2016) the research paper aimed on use of modified bitumen by using plastic waste for road construction. The modified bitumen mix presented better binding property, stability, density and more resistant to water.

The results stated that the coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. So, the use of waste plastics and crumb rubber for flexible pavement is one of the best methods for easy disposal of waste plastics. These processes were ecofriendly and socially highly relevant, giving better infrastructure .The addition of waste plastic modifies the properties of bitumen. When compared to standard results the modified bitumen presented fine result. The optimum content of waste plastic to be used was between the ranges of 5% to 10%. The backlogs such as bleeding was reduced in hot temperature region. Plastic had property of absorbing sound, which reduced the sound pollution of heavy traffic. The waste plastics thus can be put to use and it ultimately improves the quality and performance of road. Total material cost of the project was reduced by 7.99%

Vishal Rasal et al (2018) the research paper represented an effort in production of modified bituminous mix and coated aggregates. Aggregates were coated with 6%, 8%, 10% of high density polyethylene and 8%, 10%, 12% of crumb rubber were mixed in bitumen. Different moulds were prepared with different combinations and compared with conventional bitumen mixes by conducting

Marshall Stability test to check its strength, flow value, stability value. Optimum percentage of crumb rubber was found to be 8%. Then crumb rubber percentage was kept constant and HDPE percentage was varied as 6%, 8%, 10% highest stability was achieved for all mix with 8% CRMB combination with 10% of HDPE giving more satisfied results comparing to conventional bitumen.

The conclusion derived from the results stated that Penetration values and softening points of plain bitumen can be improved by modifying it with addition of crump rubber. Optimum binder content for conventional bitumen was found to be 4.5% .Optimum value of crumb rubber in CRMB was found to be 10%. Dry Process (polymer coating of aggregates) is more useful as compared to Wet Process (adding polymer in the binder) for manufacturing modified mixtures, as it can accommodate higher amount of waste plastic as modifier and results more stable mixtures. In addition with 10% crumb rubber optimum content of HDPE was found to be 8%. Using waste rubber and plastic reduces threat to environment and also improve the road quality.

Dhruv Padhya and Yogesh Alwani (2018) the research paper presented numerous application of various filler materials with bitumen to increase the pavement life. Aging of binder is the major draw-back of asphalt pavement for long service life point of view. Generally aging of binder is caused due to climatic condition which ultimately leads to cracks on pavement, rutting, fatigue cracks, which cannot withstand the changing environment and increased traffic loads, finally the pavement of failure takes place. To overcome this problem, modification in the properties of VG-30 bitumen was done by adding Elastomer Styrene-Butadiene-Styrene (SBS) and Nano Silica Powder (Nano SiO2) in suitable dosages. The short-term aging properties of bitumen were investigated using thin film oven test (TFOT).

The empirical tests including penetration and softening points were conducted to check for binder consistency.

The results stated that it was difficult to blend Nano SiO2 with bitumen and heating simultaneously. Softening point increased on increasing the % of Nano SiO2 and was maximum for 4% content after aging. This enabled bitumen to perform well at high temp and resist deformation for the same. Ductility value of modified bitumen increased rapidly before and after aging. Specific gravity also increased when % of additive was increased. Viscosity also increased for increase in amount of Nano SiO2. Penetration value decreased considerably. Maximum hardness was achieved for 2%Nano SiO2. TFOT results showed that loss of weight on heating bitumen added with Nano SiO2 kept on increasing, thus it had noticeable effect of heat.

A. Gandhimathi and S. Abinaya (2017) the research paper proposed the use of shredded waste plastic bottles (PET) for the modification of bitumen binder with particular focus on the development of an effective pavement material that utilizes the plastic waste while catering to the needs of varying climatic conditions prevailing in India and also the heavy loads on pavements. This research presented the study on the methodology of using waste plastic bottles (PET) in modifying bituminous binders and the various tests performed on 60/70 grade bitumen. A detailed analysis of the engineering properties such as Penetration test, Ductility test, Viscosity test, Softening point test and Specific Gravity test were conducted on both conventional and modified bitumen samples for various percentages of replacements such as 0, 10, 20 and 30% respectively. This PET modified bitumen showed improved quality with % of optimum replacement falling between 10 to 20%.

The Comparison results of the penetration values of 0% modified bitumen with various % of modifications indicated a decrease by 1.54%, 42.57% and 72.31% for 10%, 20 % and 30% plastic modified bitumen respectively. The Ductility values of 0% modified bitumen with various % of modifications showed a reduction in the ductility value by 3.64%, 46.88% and 44.83% for 10%, 20 % and 30% plastic modified bitumen respectively. the float test values for 0% modified bitumen and other % of modified bitumen, the float test value indicates an increase in the viscosity values by 19.74%, 27.15% and 71.59% for 10%, 20 % and 30% plastic modified bitumen respectively. On addition of 10% plastic to the bitumen the softening point value increased by 5.42%. For addition of 20% plastic to the bitumen the value is decreased by 0.85% and for addition of 30% plastic to the bitumen the test results increased by 18.23%. The specific gravity test result values on addition of 10% plastic to the bitumen remained the same as that for conventional bitumen but the value increased by 5.36% and 53.57% for 20% and 30% plastic modifications respectively. The results led to the conclusion that the optimum replacement of bitumen by plastic (PET) falls between 10 to 20%.

Piyush G. Chandak et al(2019) the primary objective of the research paper was to discover the optimum content of using the identified wastes to replace bitumen and aggregates of rural roads. Numbers of laboratory tests were carried out on modified mixtures to understand the aptness and optimum content of the wastes in construction of rural roads. The strength property of the naturally available soil was analyzed for the rural roads in Karad. The California bearing ratio test analysis and their outcomes were employed to assess the strength of the subgrade. Further, based on the suitability of identified wastes in bituminous layer, IITPave software was used to analyze the performance of rural roads of the study area. Using the IITPave software, design charts were created based on utilizing the wastes for rural roads in Karad, District – Satara, India. The results stated that Partial substitution of aggregates by e-waste and partial substitution of bitumen by crumb rubber or plastic is technically feasible. As per IS:SP:98, with the dry process, plastic waste can be used to partially replace bitumen by 7% and 10% by waste rubber to form a modified bitumen in bituminous layer having 5.5% optimum bitumen content. The analysis suggested that the partial replacement of aggregates using e-waste alone is 7.5%. Results stated that e-waste combined with plastic or crumb rubber can be effectively utilized in the pavement section having high stability value. Partial replacement of bitumen by 7% plastic with 7.5% e-waste and by 10% rubber with 7.5% e-waste was possible and gives optimum results. The design charts need to be site specific to avoid premature failure of roads and not solely rely on the general guidelines provided by the design manuals. It was suggested that the maximum depth/thickness should be 150 mm for base course while any extra depth/thickness be constructed as sub-base.

Ashok Pareek et al (2012) the research paper carried out conventional bitumen and polymer modified binder. Its rutting resistance, indirect tensile strength and resilient modulus of the bituminous concrete mix with polymer modified bitumen was significantly improved. Bitumen modified with polymer offers a combination of performance related benefits as the physical properties of the bitumen was improved without changing the chemical nature of it.

The results stated that performance of Polymer Modified Bitumen was better than that of conventional bitumen (60/ 70). Polymer modified bitumen was found to have a high elastic recovery (79%). Modified bitumen has better age resistance properties. The loss in weight on heating in thin film oven is 6 times higher as compared to conventional bitumen of 60/70. When PMB was used Marshall

Stability of the mix increases by 27%. The rutting resistance of the polymer modified bitumen was significantly higher. The indirect tensile strength of the bituminous concrete mix with polymer modified bitumen was 20% higher at 30 °C. Resilient modulus of the mix prepared with PMB was significantly higher at the test temperatures of 30 to 40 °C.

Priyanshi Bhargava and Tapas Singh (2018) the research paper focused on flexible roads made of bitumen, as comprise majority of the roads in India. It was possible to improve the performance of bituminous mixes used in the surfacing course of road pavements, with the help of various types of additives to bitumen such as polymers, rubber latex, crumb rubber treated with some chemicals, etc. The LDPE (Low Density Polyethylene Such as Waste Plastic Bags) as modifiers was used to improve the physical properties of bitumen. The research was further executed towards determination of Physical Properties of bituminous mix modified with varying dosage of LDPE modifier and selection of optimal dosage of LDPE modifier for modification of bitumen.

Shirish N Nemade and Prashant V Thorat (2013) the research paper stated in concern to type of polymer that as type of polymer waste was concerned, wet process was suitable for any type of polymeric waste (rubbery or plastic) or any size and form (either strand or powder). By the actual experimentation, optimum results for polymer waste at different composition was obtained. The results stated polyolefin waste can be loaded upto 6% HDPE, LDPE upto 6%, PP upto 4% crumb rubber upto 4% and mixture of crumb rubber and HDPE waste upto 8% (4% + 4%) in road construction.

Results concluded that Plastics increases the melting point of the bitumen. The use of the innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50oC and torrential rains create havoc, leaving most of the roads with big potholes. It was expected that in near future strong durable and eco-friendly roads which will relieve the earth from all types of plastic-waste. The combination of wet and dry process can be used, part of the plastic waste was coated on aggregate for improvement of impact and crushing strength of aggregate by applying dry process and remaining part of plastic waste is mixed in bitumen by applying wet process therefore the total loading of plastic waste can be increased as well as the improvement in mechanical properties will occurred.

Greg White and Gordon Reid (2019) the research paper investigated two waste plastic products for asphalt binder modification and extension, known as MR 6 and MR 10, were added to penetration-grade bitumen in the laboratory. The samples were tested for the index properties contained in the British modified binder specification, as well as high temperature Performance Grading. The investigation included 50/70 and 100/150 penetration grade bitumen with 4-8% (by mass) waste plastic content, tested at 52-82°C. Waste plastic modification significantly improved the high temperature Performance Grading. The harder 50/70 penetration grade bitumen produced a harder modified binder and the difference between 4% and 6% waste plastic content was significantly greater than the difference between 6% and 8%. The MR 6 modified binder was more elastomeric and had greater resistance to deformation than MR 10.

The conclusion stated that MR 6 and MR 10 modified bitumen exhibited properties similar to common Australian multigrade and polymer modified binders, but MR 6 exhibited more elastic response to load than

MR 10, which contrasts with the manufacturers advertised intent for the two products.

The propensity for wet blended waste plastic modified to not fully digest or to segregate after mixing, and to determine if more consistent results was achieved from different waste plastic pellet size, shape and density. Comparison of waste plastic modified asphalt properties to properties of otherwise comparable asphalt produced with polymer modified and multigrade binders, and to compare asphalt and binder properties when waste plastic was wet blended compared to when it was dry mixed. The benefits of waste plastic as an alternate modifiers of asphalt binder was significant and an objective evaluation of the economic and environmental benefit for products producing comparable performance was required.

Greg White and Gordon Reid (2018) the research paper assesses the use of three commercially available recycled plastic products for bituminous binder extension and modification in asphalt mixtures. Using a dry mixing process, shredded and pelletized recycled waste plastics replace 6% of the binder volume. Comparative laboratory testing of two typical UK asphalt mixtures indicated that asphalt containing the recycled waste plastic products showed improved deformation resistance and fracture resistance compared to conventional 40/60 penetration grade binder. The viability of imported recycled plastic waste use in Australian asphalt mixtures was also evaluated. One of the three recycled plastic products was expected to be a cost effective alternate to M1000 or A35P and another is expected to be a viable alternate to A20E, at a significant cost saving. Partial replacement, without performance enhancement, of C320 bitumen was not viable due to the high cost of recycled waste plastic importation.

Recycled plastic waste was demonstrated to improve, compared to conventional 40/60, the fracture and deformation resistance of typical asphalt mixtures in the UK. It was expected that the recycled waste products would produce similar performance to M1000 or A35P (MR10) and A20E (MR6) in Australian asphalt mixtures. If verified, this comparable performance presents a potential cost saving of $120-460 per tonne of bituminous binder, equivalent to 2-5% of the cost of produced, constructed and finished asphalt. It was recommended that further laboratory research validate the expected performance of the recycle plastic products compared to typical Australian asphalt binders and that a field trial validates the digestion and distribution efficiency of drum-based asphalt production plants.

V. Suganpriya et al (2016) the research paper assessed the stabilization of the bitumen containing crumb rubber waste in shredded form by performing basic tests such as Penetration Test, Ductility Test, Softening Point Test, Viscosity Test and Flash & Fire Point Tests. On the basis of the performance of the modified bitumen, the range of optimum percentages of crumb rubber waste were selected for investigations related to Bituminous Concrete Mixes such as Semi Dense Bituminous Concrete (SDBC). Marshall Values, namely Marshall Stability Value, Marshall Flow Value, Voids present in air, Voids in Aggregates and Voids in Bitumen, determined from Marshall Stability Test, serve as the benchmark values to assess the quality of Bituminous Concrete.

The results stated that the presence of crumb rubber reduces the air voids which prevents the moisture absorption and also prevent oxidation of bitumen due to entrapped air. The enhancement of Marshall Stability value, stripping and other design parameters and this may prevent formation of potholes. Crumb rubber content for Semi Dense Bituminous Concrete (SDBC) was found to be 6%. Crumb rubber content Bulk Density of SDBC increases by 1.03%. Crumb rubber content Percent Air voids in SDBC mixes reduces by 20.75%. Crumb rubber content Percent

Voids in mineral aggregates (VMA) of SDBC mixes reduces by 5.34%. Crumb rubber content Percent Voids filled with bitumen (VFB) of SDBC mixes is increased by 5.72%.

III. Conclusion

The researchers have tried to find the variation in H.M.A, W.M.A., and C.M.A. which occurs due to temperature effect, properties and admixture in a mix, following are the outcomes of literature review:

- ✓ Determine the effect of polythene in a mix.
- ✓ Determine that non degradable waste can be utilize in construction industry.
- ✓ Find out that LDPE doesn't have tensile strength
- ✓ Determine that H.M.A is comparatively more stable than others.

Zykotherm is a admixture which can increase the binding

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