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A Review on Partial Replacement of Bitumen by Waste Oil, Plastic and Tire in Flexible Pavement

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ABSTRACT

Around the world Bitumen is defined as a sticky, highly viscous liquid or semi-solid that can be found in some natural deposits or obtained as a by-product of fractional distillation of crude petroleum. It is a key challenge in the highway industry to scale back the dependence on fossil fuels. So, the current challenge for the road industry is to use renewable materials that are bio-materials not subjected to depletion in partial replacement of bitumen, thus making the sector less dependent on petroleum-based products. Waste oil that is disposed of on land or sea without pre-treatment has a negative impact on the environment. Plastic waste refers to the significant amount of plastic that isn't recycled and ends up in landfills or, in the developing world, is thrown into uncontrolled dump sites. Most tires, especially those fitted to motor vehicles, are manufactured from synthetic rubber. At the same time, the continuous increase in the number of vehicles indicates the need for roads with better quality and engineering design. To reduce the use of non-renewable materials, waste oil, waste plastic and used tyres can be used in their correct ratios to produce partially modified bitumen.

Keywords : Bitumen, Waste oil, Waste plastic, Waste tire, Marshall Stability Test.

I. INTRODUCTION

Traditional petroleum bitumen is widely utilised in the pavement industry worldwide as a residue from the rock oil refining process. However, gradually decreasing petroleum reserves and increasingly strict environmental regulations have triggered the search for sustainable methods to supply bitumen substitutes in the transportation and highway engineering sectors. This renewable source of energy is efficient, cost-effective and environmentally friendly, which may well be a good economic asset to any country. India produces sixty million tonnes of waste every year. About thirty million tonnes are dumped at landfill sites. The project is to switch the bitumen with these wastes that are generated in the course of life, like waste vegetable oil, waste tires, and waste plastics. Waste vegetable oil (WCO) may be a material for further reuse since it can become an environmental pollutant thanks to elimination issues and also the potential pollution of water resources. Some researchers indicated that the addition of waste cooking oil enhances bitumen characteristics and increases asphalt pavement quality. The oil is a

medium to heat and melt the crumb rubber in order for it to begin to degrade. India's waste tyres account for about six to seven percentage of the world total. With the local tyre industry growing at 12% every year, waste volumes are rising. Vehicle tyres eventually end up in landfills, and these can cause serious environmental problems. The employment of waste tyres in sports fields, pavements and construction materials will be a very important approach to reducing waste rubber in large quantities at landfill sites and adding value within the industry. The addition of crumb rubber (CR) to change bitumen is widely used to solve the environmental problem of tyres and to develop high-quality, hot bituminous mixes. Plastic waste is considered an environmental pollutant because it's not biodegradable. Therefore, there's been an increase in the use of recycled materials in pavement. Polyethylene terephthalate (PET) could be a thermoplastic that's commonly used in the manufacturing of containers and bottles. Improvement in rutting resistance was observed by incorporating PET into mixtures and binders. The goal of this research is to develop a sustainable binder that might be used as an alternate binder for flexible pavement. This will be achieved by adding waste cooking oil, plastic and crumb tyre rubber to the binder of the flexible pavement by partially replacing the bitumen within the binder mixture. This may significantly reduce the environmental effects caused by the waste disposal and also the expense of the bitumen.

II. LITERATURE REVIEW

Francisco Javier Navarro et.al, (2010) "Novel recycled polyethylene/ground tirerubber/bitumen blends for use in roofing applications: Thermo-mechanical properties",This paper states that the effect of recycled polymers, such as ground tire rubber (GTR) andrecycled polyethylene (RPE), on the thermal and rheological properties of modified bitumen blends. RPE would mainly improve the high in-service temperature properties by largely increasing material elastic and viscous properties in this temperature region. As a result, RPE/GTR/bitumen blends with 25 wt. % of both recycled polymers, seems to be an attractive alternative to roofing and waterproofing membranes made from virgin polymers, showing similar or even improved properties.

Peiliang Cong et.al, (2012) "Investigation of asphalt binder containing various crumb rubbers and asphalts", This paper states that the Crumb rubbers (CRs) have been proposed for the pavement because it is a waste materials and crumb rubbers modified asphalt pavement shows excellent performance. The effects of the asphalt, crumb rubber types and crumb rubber contents on the properties of crumb rubbers modified asphalt binders were investigated. The properties of crumb rubbers modified asphalt with 80/100 are better than that of modified asphalt with 60/80 at high and low temperature. Based on laboratory investigations and obtained results in this research, it may be concluded that the addition of CR increases the values of the softening point, elastic recovery, viscosity, complex modulus, and rutting parameter, and decrease the values of penetration, ductility and phase angle.

Francisco Javier López-Moro et.al, (2013) "Microscopic analysis of the interaction between crumb rubber and bitumen in asphalt mixtures using the dry process", This paper states that a microscopic study for the modification of bitumen with crumb rubber was carried out to investigate its application in asphalt mixtures using the dry process. The modification involved the transfer of maltenes to the rubber and carbon black to the bitumen, causing the absorption of the lighter-oil fractions of bitumen. This resulted in an improvement in a asphalt pavement, with an increased stiffness and a higher resistance to permanent deformation relative to

asphalt pavements made with conventional bitumen or an SBS-polymer-modified bitumen. The role played by carbon black in bitumen modification is not negligible and could be as important as the rubber.

Davide Lo Presti et.al, (2015) "Recycled Tyre Rubber Modified Bitumen for road asphalt mixtures: A literature review", This paper states that, the benefits of using rubber modified asphalts are being more widely experienced and recognized, and the incorporation of tyres into asphalt is likely to increase. The technology with much different evidence of success demonstrated by roads built in the last 40 years is the rubberised asphalt mixture obtained through the so-called ''wet process'' which involves the utilisation of the Recycled Tire Rubber Modified Bitumen (RTR-MBs). A proof of this statement is given by the state of California (USA)where since 2005 a government mandate supports the increasing adoption of these technologies in asphalt mixture and the usage of rubberised asphalt pavements needs to reach at level of at least 35% of the total weight of asphalt paving materials produced in the country. The main reason of this mandate is the prediction of substantial savings in the long term.

Md Maniruzzaman A, Aziz et.al, (2015) "An overview on alternative binders for flexible pavement", This provides states that an overview of the probable materials that could be used as an alternative binder. The materials obtained from biowaste sources, such as bio/oils, polymer, plastic, rubber and waste cooking oil retrieved from waste materials show promise and discussed. Alternative binder may have significantly different aging characteristics. Consequently, rolling thin/film oven and pressure aging vessel may not adequately represent plant and field aging. Further research is needed to make them satisfactory replacement of bitumen on an industrial scale and be a sustainable source of binder for flexible pavement.

Johnson Kwabena Appiaha et.al, (2016) "Use of waste plastic materials for road construction in Ghana", This paper forms part of research to solve two main problems in Ghana: firstly, the management of municipal solid waste (MSW), secondly, the formation of potholes on roads due to excessive traffic and axle weight. This study examines the effect of blending waste thermoplastic polymers, namely High-density polyethylene (HDPE) and Poly propylene (PP). It was observed that polypropylene polymer, showed profound effect on homogeneity and compatibility with slight linear increment in the viscosity, softening and penetration values as against relatively high changes for HDPE modified bitumen. The most compatible and incompatible blends for HDPE were respectively observed at 2% and 3% polymer loading. The use of waste commodity plastics in binder modification carries the advantage of a cheap and effective means of enhancing conventional bitumen binder performance characteristics and is an alternative way to utilise plastic waste.

Utibe J.Nkanga et.al, (2017) "Characterization of Bitumen/Plastic Blends for Flexible Pavement Application", This paper states that waste plastic materials can improve desired properties of bitumen mix for repairs construction flexible pavements. Various proportions of polymeric material (5%, 10% and 15%) blended with bituminous mix where characterized. The result showed that the bitumen/plastic blend has higher Marshall stability of range 14.03 to 14.80 compared to conventional bituminous mix sample which was 11.35KN. The results from the proportions of aggregate and quarry dust used in the sieve analysis showed ratio 50:50tobemore appropriate forthe bitumen/plastic blends. It also provesthat the waste plastics can be usedefficiently for road repairs and construction resulting in more sustainable and better roads withhigh performance and durability.

Md Tareq Rahmen et.al, (2017) "Use of waste cooking oil, tire rubber powder and palm oil fuel ash in partial replacement of bitumen", This paper states that bitumen is a heavy hydrocarbon source from petroleum refineries as a by-product which is widely used as binder for flexible pavement this research focused on the effect of adding waste cooking oil tire rubber power and palm oil fuel ash to reduce the percentage of bitumen in the mixture where palm oil fuel ash was applied as additive. This method of recycling these waste materials solves the issue of littering can ensure a cleaner environment, results when compared with neat bitumen as control sample to assess the feasibility of new mixture to be used in industrial scale. This research shows that up to 15% replacement of bitumen is possible and this could produce equal or better performance in terms of stability, flow and rutting resistance.

Junyan Yi et.al, (2018) "Preparation of bio-bitumen by bio-oil based on free radical polymerization and production process optimization", The paper states that the Bio-oil produced during the production of biodiesel is a burden to the environment. Recycling and utilization of bio-oil as a substitute for pavement bitumen can help to build an environmentally–friendly and clean infrastructure. In this study, the bio-bitumen was prepared by bio-oil based on free radical polymerization. Different kinds of bio-bitumen products were produced by reacting bio-oil with an initiator and an accelerator solution at different reaction conditions. The orthogonal experimental method was employed to determine the optimal bio-bitumen production process by evaluating the indices of viscosity, rutting factors and fatigue factors. The test results show that the optimal mass proportions of bio-oil: initiator: accelerator solution is 100:1:2. Materials with these mass proportions should react at 100C for 2 h to yield the best bio-bitumen product.

Ruikun Dong et.al, (2018) "Chemical and microscopic investigation of co-pyrolysis of crumb tire rubber with waste cooking oil at mild temperature", This study focused on the feasibility and effectiveness of the application of waste cooking oil in desulfurizing and degrading rubber particles through co-pyrolysis of them at mild temperature (240–280C). Results showed that solubility of rubber powder reached above 60 wt.% after pyrolysis in wastecooking oil, which increased with higher temperatures and more of oil, while increased to a maximum at 2h and then decreased with the extension of time. The rubber hydrocarbon contentdecreased greatly, and dramatic reduction of carbon, hydrogen and sulphur elements happened according to component and elemental analyses. De-sulphurised and degraded crumb tire rubber with smaller fineness was obtained through the proposed method, showing a potential to improve the compatibility with neat bitumen, to decrease the production temperature of modified bitumen. In addition, the incorporation of waste cooking oil into bitumen can disposehigh quality waste so as to alleviate the waste cooking oil-related food safety issue.

Lorenzo Paolo Ingrassia et.al, (2019) "Renewable materials in bituminous binders and mixtures: Speculative pretext or reliable opportunity?", This paper states that, the Bitumen is the most employed binder in road pavements and derives from petroleum, which is a non-renewable resource that is progressively depleting. So, the study on adding renewable materials in bitumen binders is important. Based on the analysis of available literature, it is evident that the use of renewable materials in bituminous binders and mixtures has significant environmental and economic benefits, such as the reduction of carbon footprint, the reduction of petroleum- based products, the recycling of industrial by-products and wastes, the decrease of materials to be disposed of in landfills. But the renewable material possesses a series of fundamental requirements in terms of availability,

handling, logistics and performance. Evaluations related to the possible effects on workers' health and on the environment as well as on safety issues are also fundamental. The literature review shows that the use of renewable materials is very promising. The main outcomes in terms of performance can be the bio-oils, regardless of their origin, typically provide a fluxing/softening effect, which improves the performance of the bituminous material at low and intermediate temperatures but negatively affects the high-temperature performance.

Dr. S. L. Hake et.al, (2019) "Utilization of plastic waste in bitumen mixes for flexible pavements", The paper states that the situation of present way of life is an entire restriction on the utilization of waste plastic can't be put, in spite of the fact that the waste plastic taking the substance of a demon for the present and the future age. In this way transfer of waste plastic is a difficult issue inclusive due to their non-biodegradability and unaesthetic view. In the present research work created procedures to utilize plastic waste for development motivation behind adaptable asphalts will be survey. In regular street making process bitumen is utilized as folio. Such bitumen can be adjusted with squander plastic pieces and bitumen blend is made which can be utilized as a best layer of adaptable asphalt. The plastics from PET jugs to be utilized in blends for examine work. The measurements of plastic of 5 %, 7.5%, 10 %, 12.5% and 15 % utilized as substitution of bitumen. The advance plastics content is 10% with 5.25 % of bitumen content. Bitumen is bonded with the aggregate by means of plastic which acts as a binder. With the increase of waste plastic in bitumen increases the properties of aggregate and bitumen. Use of waste plastic in flexible pavements shows good result when compared with conventional flexible pavements. It is observed that, using plastic waste in bituminous mixes, the life of the road is increased and hence the maintenance expenditure is reduced. From cost analysis of the project, it is observed that, percentage cost reduction for one cum material mix is 5.18%.

A. Rangaraj et.al, (2019) "An experimental investigation on partial replacement of bitumen using rubber tyre", The paper states that the Bitumen is most widely used in the world for road construction. In India, bitumen demand was expected to reach 122 million tonnes by the analysis made in 2018, so we want some alternatives for future use. This research is based on partial replacement of bitumen by using waste rubber tyre chips as a percentage of 0%, 5%, 10%, 15% respectively. From the test conducted for bitumen, we can say that better properties in 15% have efficient result while comparing to other proportion used. We conclude that by using waste rubber tyre chips as a partial replacement of bitumen in road construction as 0%, 5%, 10%, 15%, 20%. Standard tests were conducted for both replaced bitumen and bitumen. After analysing the tests, the results of partially replaced bitumen was more efficient than normal bitumen. The properties of bitumen such as ductility, viscosity, softening point, penetration values improved in all the aspects when rubber is added, which may help in increasing the life span of the flexible pavements.

Abbas Mohajerani et.al, (2020) "Recycling waste rubber tyres in construction materials and associated environmental considerations: A review", This study compiles and reviews this research with a focus on geotechnical engineering applications, such as earthworks and infrastructure construction. The applications of waste rubber in construction materials includes cementitious concrete, asphalt concrete, and granular materials for earth structures. Rubber, as a partial replacement for aggregate in road base and sub-base layers, adversely affected the California Bearing Ratio (CBR) of the graded aggregate base course. Crumb rubber, when used as a sand replacement in flowable concrete fill,

improved ductility and strength-to-weight ratio. Rubber, as a partial replacement for aggregate in road base and sub-base layers, adversel affected the California Bearing Ratio (CBR) of the graded aggregate base course. Further comprehensive studies on the leachate analysis of concrete, asphalt concrete and other construction and road materials incorporating waste rubber for heavy metals and PAHs, for products with exposure to air, are recommended.

Ana Jiménez del Barco Carrión et.al, (2020) "Optimisation of liquid rubber modified bitumen for road pavements and roofing applications", This paper states that Polymer Modified Bitumen (PMBs) are largely used for pavement and roofing membranes applications with Styrene-Butadiene-Styrene Block copolymer (SBS) playing a major role in both markets despite its constantly increasing price due to the rising demand for quality bitumen modifiers combination with heavy oils, and a wax denominated Ethylene Bis Stearamide (EBS). As a result, an optimum combination of temperature and cost of PMBs as design targets the proposed optimal composition of bitumen, LR and EBS blends for pavement engineering and roofing applications are being validated in the laboratory in terms of performance-related properties and ageing. Further research will look at the performance of asphalt mixtures and roofing membranes manufactured with the designed binder. Other research should look also a comparing the environmental impact of the proposed solutions.

Nyaradzo Kamoto et.al, (2020) "Production of modified bitumen from used engine oil, coal tar and waste tyre for construction applications". This paper states that the bitumen is a semi- solid hydrocarbon product which is produced by removing the lighter fractions such as liquid petroleum gas from heavy crude oil during the refinery processes of crude oil. The most common method for its manufacture is fractional distillation of atmospheric residue from vacuum distillation where waxy distillates are used. To reduce the expenses for its production from crude petroleum, used engine oil, coal tar and used tyres from automobiles can be used in their correct ratio to produce bitumen. The process involves heating and mixing using a high- speed shear mixer. The oil is a medium to heat and melt the crumb rubber so that it will begin to degrade (depolymerize). The aim of the study was to produce bitumen from the correct ratios of used engine oil, coal tar and used tyres and this was achieved. The three raw materials used were purified to remove impurities, rubber tires were shredded. Future studies should include optimization of pre-treatment methods of used oil and optimization of mixing process variables to obtain maximum bitumen yield. Further size reduction of rubber crumbs to reduce the temperature and required time for rubber melting needs to be optimized as well.

Xiong Xu et.al, (2020), "Sustainable Practice in Pavement Engineering through Value- Added Collective Recycling of Waste Plastic and Waste Tyre Rubber". This study aimed to investigate the recycling mechanisms of waste PET-derived additives under the treatment of two amines, triethylenetetramine (TETA) and ethanolamine (EA), and characterize the performances of these additives in modifying rubberized bitumen, a bitumen modified by waste tyre rubber. To this end, infrared spectroscopy and thermal analyses were carried out on the two PET- derived additives (PET–TETA and PET– EA). The recycling method developed in this study not only helps alleviate the landfilling problems of both waste PET plastic and scraptyres, but also turns these wastes into value-added new materials for building durable pavements. Their performances in modifying rubberized bitumen containing 18% CR were evaluated through both chemical and rheological analyses. Further studies can be carried out on the performances of bituminous mixtures incorporated

with the two waste materials in both laboratory and field.

Arjita Biswas et.al, (2020) "Performance comparison of waste plastic modified versus conventional bituminous roads in Pune city: A case study", This study evaluates the deterioration rates of waste plastic modified bituminous roads as compared to normal bituminous roads in the metro city of Pune, India. The study reveals that the deterioration rate for plastic roads is slower as compared to conventional bituminous roads it can be concluded that the addition of waste plastic to the bituminous mix has delayed the early deterioration of roads. The substitution of bitumen with waste plastic (8% in this study) will indirectly save on costly bitumen which in turn will make these roads further beneficial. Also, the effective utilization of the waste plastic for the preparation of the modified bitumen will result in a substantial increase in its scrap value, which otherwise is an undesirable waste material that is littered all over the urban areas. The study will help to encourage the field engineers and local bodies to use a modified bituminous mix with waste plastic.

Sand Aldagari et.al, (2021) "Investigating aging properties of bitumen modified with polyethylene-terephthalate waste plastic", This paper examines the merits of using recycled polyethylene terephthalate (PET) in bitumen to improve short and long-term aging of bituminous composites used in roadway constructions The rheological and chemical changes that occurred with aging were captured by a dynamic shear rheometer (DSR) and a Fourier transform infrared (FTIR) spectroscopy. The outcome of this study exploits the synergy between two waste streams including waste vegetable oil and waste plastics to produce a sustainable modifier for roadway construction to extend their service life while promoting resource conservation and recycling. The study further examined the merits of functionalizing PET with waste vegetable oil to enhance PET compatibility with bitumen. The study outcomes showed oil-treatment of plastic granules not only does improve asphalt performance, but also delays its aging; this can be attributed to enhanced interactions at the plastic-bitumen interface reducing the diffusion of oxygen into the bulk, as well as bio-oils reacting with free radicals before they react with asphalt.

Avani Chopra et.al, (2021) "Major application and impact after modified bituminous with Nitrile rubber and Thermoset", This paper states that nitrile has certain unique properties which are suitable for the road surface that is. resistant to oil, resistant to fuels, resistant to acids, high tensile strength etc. Some research has been carried out using nitrile in bitumen andthe results have been encouraging. Nitrile Rubber and Thermosets (Bakelite, Furan Resin & Epoxy Resin) shall be replaced with bitumen to prepared a Modified Bituminous Mix, whose properties was studied upon. This result in saving of nearly 10–15% of the bitumen consumed per year. The aim of this research is to investigate the possibility of Nitrile Rubber and Thermosets (Bakelite, Furan Resin & Epoxy Resin) as a partial replacement of bitumen for Modified Bituminous Mix with equal ratio of Nitrile Rubber and Thermosets (Bakelite, Furan Resin & Epoxy Resin) then. The study is intended to further explore the possible usage of Nitrile Rubber and Thermosets in Indian flexible pavement design.

III. SUMMERY OF LITERATURE

From referring the above journals, we have summarised that the bitumen can be partially modified with waste materials likes used oils, used plastics and waste tyre rubber.

- Waste oil such as cooking oils and engine oils can be used and plastics such ah PET (polyethylene terephthalate) and HDPE (High Density Polyethylene) plastics can be used and

waste tyres such as RTR (Recycled Tyre Rubber), Liquid Rubber (LR) and GTR (Ground Tyre Rubber) can be used.

- The tests for Bitumen include penetration test, softening point test, Ductility test, Viscosity test, Flash and fire point test.
- Tyre Rubber were shredded and grinded into small particles and steel in the tyres were removed by magnets and fabrics are removed by air separators.
- Fromthe tests conducted above we have summarised that optimum percentage of oil tobe used is 5-20%, Plastic wt. of 2%-15%, RTR 50%.
- By referring the above journals, we are combining all three waste materials and replacing bitumen partially by trial-and-error method.

IV. CONCLUSION

The goal of this project was to replace some bitumen with waste cooking oil, waste plastic, and tires, resulting in a low percentage of bitumen in binder mixture for the construction of flexible pavement.

- In developing countries like India, where resources are scarce and efficient maintenance of bituminous roads is required every year, implementation of roads using waste cooking oil, plastic and tyres can bring significant economic savings for the local authorities who spend every year on pre- monsoon maintenance of city roads.
- The substitution of bitumen with waste cooking oil, plastic and tyres will indirectly save on bitumen, which in turn will make these roads even more beneficial.
- Also, the effective utilisation of waste materials like cooking oil, plastic and tyre for the preparation of the modified bitumen will result in a substantial increase in its value, which otherwise is an undesirable waste material that is littered all over the urban areas.

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