Bitumen Mix Design with Waste Plastic: A Critical Review

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Abstract— Industrialization and population is increasing day by day leading to the increase in the amount of waste plastic. Plastic is a non-biodegradable substance i.e. it is not decomposed by bacteria easily. So, dumping it causes soil pollution which leads to decrease in the fertility of soil. Another way of getting rid of plastic is by burning it, which also produces a lot of harmful gases and leads to increase in air pollution. Soil and air pollution both are harmful for the environment. Waste plastic can be used in bitumen as a modifier. In this paper we will discuss the variation of the properties of bitumen on addition of waste plastic at different percentage.

Keywords: Non Bio-degradable, Pollution, Environment

I. INTRODUCTION

Bitumen is one of the oldest known engineering materials. It has been used for thousands of years in various ways, e.g. as adhesive, sealant, preservative, waterproofing agent and pavement binder. Ancient inhabitants directly used the natural bitumen which is usually in the earth's surface. In the early 1900s, refined bitumen was first produced by refining crude oil in the USA. Since then, the world consumption of bitumen has increased rapidly, most of which was used in road construction. According to a joint publication of Asphalt Institute and Eurobitume in 2011, the current world consumption of bitumen is approximately 102 million tons per year, 85% of which is used in various kinds of pavements. In fact, the chemistry composition of produced bitumen is very complex and variable; and the properties of produced bitumen are closely related to the crude oil sources and the refinery processes. By selecting good crude oil or proper refinery processes, some good bitumen properties can be obtained. However, the limited oil resources for producing good-quality bitumen and the lack of effective control actions during refinery, as well as the driving force of earning the maximum economic benefits, made industries pay more attention on bitumen modification. Additionally, pavement industry has developed rapidly all over the world during the last few decades, especially in developing countries. Following the rapid development, increased traffic load, higher traffic volume, and insufficient maintenance led to many severe distresses (e.g. rutting and cracking) of road surfaces. The harsh reality was demanding more on bitumen quality. In order to obtain bitumen with enhanced quality, an increasing number of investigations also began to focus on bitumen modification. Among all attempted or investigated modification methods of bitumen, polymer modification has been one of the most popular approaches.

Polymer modification of bitumen is the incorporation of polymers in bitumen by mechanical mixing or chemical reaction. During the last 40 years, more and more researchers began to concentrate themselves on polymer modification of bitumen and a rapidly increasing number of research articles have been published since 1970s. In these, the various investigated polymers included plasterers (e.g. polyethylene (PE), polypropylene (PP), ethylene-vinyl acetate (EVA), ethylene-butyl acrylate (EBA)) and thermoplastic elastomers (e.g. styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), and styrene- ethylene/butylene-styrene (SEBS)), although none of these were initially designed for bitumen modification. These polymers were reported to lead to some improved properties of bitumen, such as higher stiffness at high temperatures, higher cracking resistance at low temperatures, better moisture resistance or longer fatigue life. In, an extensive summary was given that an effective polymer modification results in a thermodynamically unstable but kinetically stable system in which the polymer is partially swollen by the light components of bitumen. Some important factors, including the characteristics of the bitumen and the polymer themselves, the content of polymer and the manufacturing processes, determine the final properties of polymer modified bitumen (PMB). As polymer content increases, phase inversion may occur in some PMBs: from bitumen being the dominant phase to polymer becoming the dominant phase. However, an ideal microstructure for PMB contains two interlocked continuous phases, which determines the optimum polymer content for bitumen modification. With these two interlocked continuous phases; PMB usually shows better overall performance with respect to mechanical properties, storage stability and cost-effectiveness.

In addition to the reported advantages, researchers also encountered various challenges, including high cost, some PMBs' high temperature sensitivity, low ageing resistance, poor storage stability and the limited improvement in elasticity. In this, the combination of bitumen oxidation and polymer degradation was reported to cause PMB's ageing propensity, which seems especially challenging for some unsaturated polymers, e.g. SBS. The poor storage stability of some PMBs usually results from the poor compatibility between polymer modifiers and bitumen which is controlled by polymers' and bitumen's different properties such as density, molecular weight, polarity and solubility. The chemical structure and reactivity of polymers, however, are also supposed to affect their compatibility with bitumen, which may have a direct relationship with the resulting PMB properties. In order to conquer these challenges, researchers have tried different categories of solutions, such as saturation, sulfur vulcanization, adding antioxidants, using hydrophobic clay minerals, functionalization and application of reactive polymers (which also can be considered as new functionalized products).

Along with technical aspect, economical aspect is of course a huge driving force for the choice of technology. Different kinds of pavements have different demands on

performance. From the economic aspect, it is not always better to achieve higher performance for a road. Only when the technology is cost-effective, can people get the maximum benefits from it and can it become popular. As for PMB, the cost is quite relevant with the dosage of the added polymer, while the polymer dosage usually has important influences on the final degree of PMB performance. So before constructing a road, the designers must know what is the needed degree of performance for the road and then decide to use PMB or not, and use how much. Currently, most of the world consumption of bitumen is still base bitumen. As the climate and traffic conditions vary in different countries, the percentage of PMB in all the used bitumen also varies in different countries. Even for a single country, the percentage varies during different years. According to the data released by European Asphalt Pavement Association (EAPA), the percentage of PMB consumption in all the yearly used bitumen for paving is usually less than 20% in most European countries during the last 3 years. The detailed data for each country can be seen in. Regarding the polymer dosage, Eurobitume claimed that a typical SBS polymer content is around 3.5% by weight in the final product, based on an internal industry review relating PMB within Europe.

This paper focuses on bitumen polymer modification for road construction, aiming to give a comprehensive overview of the development of bitumen polymer modification over the last 40 years, the challenges people encountered and the solutions researchers came up with as well as their varying success. First, a historical perspective is given in the following with an in-depth discussion on the most popular polymers and their associated technical developments. After this, the potential development of bitumen polymer modification in the future is analyzed. Finally, some conclusions are presented and some recommendations are given.

II. LITERATURE REVIEW

Athira R Prasad et al (2015) Says that the bitumen which is conventional material used in the road construction can be partially replaced by the waste plastic and rubber. They added rubber and PET in 3%, 4.5%, 6%, 7.5%and 8% in bitumen and found that the optimum content was obtained at 6%. Thus according to their study the use of plastic in 6% by weight of bitumen improves the pavement stability. And they found the use of PET bottle is best. Therefore the disposal of rubber and PET is best in the road construction.

Anurag V. Tiwari et al (2015) As plastics has non-biodegradable characteristics and Are also harmful to human health therefore disposal of waste plastic is of great concern to the environmental engineers. The roads in India are mostly flexible type and made of bituminous concrete. As bitumen is been extracted from naturally occurring crude oil therefore has its limitation on the availability therefore there is the need of an alternative material. Their papers compose of literature and processes for use of waste plastic in the construction of roads. And also aims to reduce the environmental pollution created by plastic in economic way by using the plastic waste in the construction of road.

Bright Aforla et al (2015) According to them by adding waste plastic the property of bitumen has increased. With two per cent of polymer composition with AC-10 bitumen can give AVC-20bitumen properties which will finally help in improving the marshal stability design life strength and other desirable property. The asphalt pavement shows saving in usage of bitumen as consumption of waste plastic increases. The disposal of waste plastic in the bituminous pavement construction is therefore a permanent solution and hence which establish the safe and healthy environment.

Mahesh M Barad (2015) Explains that modified bitumen by polymer shows good properties as compare to normal bitumen. But if we add more per cent of plastic in bitumen the blend gets separates on cooling. And which finally affect the properties of bitumen. In the dry process the aggregate are coated with plastic. The aggregate coated with plastic shows the improved binding properties as due to increased area of contact between bitumen and polymer.

S.Rajasekaran et.al (2013) Explains that by coating the aggregate with the polymer has many advantages and which ultimately helps in improving the flexible pavement quality not only it improve the pavement quality but also improve the aggregate quality. This technology also helps in the disposal of waste plastic obtained from the domestic and industrial packing materials. The dry process is more valuable as it dispose the 80 % of waste polymer in eco-friendly way. And use of polymer reduces the equivalent bitumen quantity and therefore reducing the construction cost of road.

Sasane Neha .B et al (2015) Explains that the addition of plastic is the innovative technology which strengthens the road construction and also increases the life of road. As the plastic content increase the property of bitumen and aggregate also increases compared to conventional flexible pavement the flexible pavement with the added plastic has good results. According to marshal stability test the optimum use of plastic is up to 10%.

Moghaddam and Karim (2012) reported that the utilization of waste material in asphalt pavement and reduce environmental pollution as well. Form their it is concluded that Polyethylene Terephthalate (PET) reinforced mixtures possess higher stability value, flow, fatigue life in comparison with the mixture without PET.

Wegan and Nielsen (2001) studied microstructure of polymer modified binders in bituminous mixtures by preparing thin sections of the specimen and analyzing that thin section by infrared Fourier transform spectrometer. When thin sections were illuminated with the UV-light, the polymer phase emits yellow light, fine and course aggregate often appear green, the bitumen phase is black and air voids or cracks appear with a yellow –green color

Rahman and wahab (2013) use recycle polyethylene terephthalate (PET) as partial replacement of fine aggregate in modified asphalt in their investigation. In term of economic value, it shows that this recycled PET could reduce cost of road construction because this recycled material is cheaper than bitumen and easy to obtain, which also improves the level of performance and the service life of the road. It can be concluded from their study that the application of recycled PET modified asphalt gives more

advantage compared to the conventional asphalt mixture especially in termed of permanent deformation.

III. MATERIAL: BITUMEN

Indian Standard Institutions defines bitumen as a black or dark brown non crystalline soil or viscous material having adhesive properties derived from petroleum crude either by natural or by refinery processes. In other words bitumen is any adhesive and solid mixture of hydrocarbons that are found naturally in tar, asphalt, mineral waxes, etc. used for constructing the road surface and roofing material. It is mainly used for:

- Construction of roads, platforms, runways etc.
- Water proofing
- Mastic flooring
- Canal lining
- Damp proof course

Advantage of bitumen:

- Production of bitumen is economical
- Rheological and physical properties of bitumen bring versatility
- Favourable melting point
- Bitumen can go under recycling
- Adhesive in nature

It is estimated that 102 million tonnes bitumen is used by the world and around 85% of the bitumen produced are used as a binder in road construction. It is also used in other pavements such as airport runways, car parking's, footways etc.

Road surface with cluttered bitumen may cause bleeding in hot weather and may develop cracks in cold weather possess fewer loads bearing capacity and can cause serious damages because of higher axial load in present conditions due to rapid infrastructure development. In the both terms length and quality, India has to raise its transportation system. Generally, production of asphalt comprises blending crushed rocks, fine aggregate with bitumen, which acts as a binding agent. Materials such as polymers could be added to alter its chemical and physical properties according to the use for which the asphalt is basically destined. Around the world, road authorities are realizing the use of modified bitumen is profitable in the road construction. Polymer modified bitumen is developed as one of the best construction material used for the flexible pavement. It reduces medium and long term cost as the roads are less exposed to defects. This reduces maintenance cost, which is not only a financial problem but also a traffic problem as road has to be closed for repairing or maintenance. Using waste plastic as enhancer in bituminous mix not only modify the properties of mix but also solve the problem of disposal of plastic and also creates employment to plastic collector.

IV. CONCLUSION

This paper reviews the achieved advances and encountered challenges in the field of bitumen polymer modification during the last 40 years. The largely discussed technical developments include the application of some popular plasterers (PE, PP, EVA and EBA) and thermoplastic elastomers (SBS, SIS and SEBS), saturation, sulfur vulcanization, adding antioxidants, using hydrophobic clay minerals and functionalization (including application of reactive polymers). Based on this overview, needed future developments of polymer for bitumen modification were analyzed and the following conclusions and recommendations are drawn:

1) Polymer modification has been proven to be an effective way to improve bitumen properties to some extent by many researchers and has been used widely in practice. However, the currently popular polymer modifiers have various disadvantages limiting their application. Some important problems with bitumen polymer modification are still not well understood. More efforts are supposed to be made to prate a further development.
2) Researchers tried various solutions to remove drawbacks of currently used polymer modifiers, among which saturation, functionalization (including application of reactive polymers) and using extra additives (sulfur, antioxidants and hydrophobic clay minerals). These solutions do overcome some disadvantages of PMB, but most cause some new problems. So more research needs to be carried out in the future to solve these problems and find new ways to modify bitumen effectively and cheaply.
3) Since it is currently challenging to perfectly achieve all expected PMB properties at the same time, some compromised ways might be optional for the future development of bitumen polymer modification: greatly enhancing the properties with an acceptably high cost, significantly reducing the cost with relatively poor properties or their combinations. Functionalization is considered as a promising way to enhance the properties of currently used polymers and develop new-type polymer modifiers with much greater success in the future.
4) It is recommended that future research on bitumen polymer modification pay more attention to the following points:
   - Function development of enhancing adhesion with aggregates for polymer modifiers;
   - Long-term performance of PMB; and
   - Recyclability of PMB.

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