Comparative Study of Eva and Waste Polymer Modified Bitumen

Mohammed Sadeque, K. A. Patil

Abstract**—**Polymer-modified bitumen is used to combat different pavement distresses and to increase the life span of pavement. Unmodified bitumen cannot perform better with the range extreme minimum and maximum pavement temperatures. The polymers commonly used to modify the bitumen are ethylene vinyl acetate (EVA) styrene butadiene styrene (SBS). The aim this study to compare the performance of EVA modified bitumen with the bitumen modified by waste low density polyethylene (LDPE), polypropylene (PP) obtained from waste carry bags and waste tyre rubber (CR) to encourage the use of waste polymer whose disposal is big problem today, in place of costly virgin polymer. From the experimental study, it was found that waste polymers are also effective in improving the properties bitumen as that of virgin polymer.

Keywords**—**Waste plastic, LDPE, PP, Modified bitumen, EVA.

I. Introduction

HUGE quantity of waste plastic are produced every year. Whereas the amount of waste is being recycled is not enough to solve the problem. Disposal of waste materials including waste plastic bags is a serious problem in developing countries, Improper dumping of these non degradable plastic bags causes clogging of drains, reduced soil fertility and create aesthetic problem etc. The aim of this study is to evaluate the performance of waste polymer, LDPE and PP obtained from waste plastic carry bag, and waste tyre rubber to modified bitumen and compared their properties with those of bitumen modified by EVA. Waste utilization is an attractive alternative that not only reduces the cost of bitumen modification but also solve the problem of waste disposal to certain extent. Some of the studies done this field during last decade are summarized here.

Murphy et al. [1] based on their experimental studies on bitumen modified with recycled polymers reported that, some of the waste polymers showed potential for enhancing the properties of bitumen but other are not. The addition of polyethylene increases the softening point although viscosity value remains low. In this case, they showed some tendencies to separate from the bitumen. The addition of polypropylene increased the softening point but viscosity remains same. The blends with low density polyethylene and ethylene vinyl acetate are worthy for further consideration.

Sinan et al. [2] reported that the specimens prepared with 165^0C mixing temperature and 30 minute mixing time for 4% HDPE have the highest stability and the smallest flow, and thus the highest Marshall Quotient. A stability increase indicates that the HDPE-modified mixes are much stronger than the bitumen concrete mix with unmodified bitumen.

Esmaeil Ahmadinia et al. [3] concluded that with increase in polyethylene tetra phthalate (PET) content into the mixture, the Marshall Stability first started to increase significantly, but then decrease after 6%. However, the Marshall Flow started with an initial decrease, which was followed by an increase with the introduction of more PET into the mixture. Due to their high Marshall Quotient, the PET increased the stiffness level of the mixture improving its resistance against permanent deformation.

Hadidy et al. [4] based on study on the utilization of LDPE in Stone Mastic Asphalt mixtures conclude that Penetration at 25^0C will generally decrease as LDPE content increases, which indicates an improved shear resistance in medium to high temperatures. Softening point tend to increase with the addition of LDPE, which indicates improvement in resistance to deformation.

The performance of bitumen can be improved by addition of waste plastic. The optimum waste plastic content is found to be 5% by weight based on the thermal stability results [5].

Praveen Kumar [6] based on his study on crumb rubber modified bitumen concluded that changes in physical properties of bitumen like penetration, softening point and penetration index are improved with addition of crumb rubber. Complex modulus increases with increase in modifier and decreases with increase in temperature. However, phase angle decreases with increase in modifier and increase with increase in temperature. Increase in complex modulus and decrease in phase angle of modified binder indicate higher resistance to deformation as compared to neat bitumen.

Mixing polyolefin and crumb rubber may obtain enhanced rheological properties at both low and high in service temperature. The blend containing 3.5 wt% EVA/LDPE and 3.5 wt% crumb rubber appears to be an interesting formulation in order to obtain a better behavior of bitumen in a wide range of temperature [8].

II. Materials

A. Base Bitumen

For present study 60/70 penetration grade bitumen, obtained from Shell Corporation India is used as base material. The physical characteristic of the base bitumen is shown in Table I.

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TABLE I
CHARACTERISTICS OF BASE BITUMEN

Penetration, 25^{0}C, 100g, 5s (dmm)	67
Ductility, 25^{0}C, 5cm/min (cm)	>120
Softening point (^{0}C)	40
Marshall Stability (kN)	16.38
Flow (mm)	3.05

B. Aggregate

Aggregate grading used for Marshall Stability test is shown in the form of grading curve in the Fig. 1. Bitumen content is taken as 5% for all the samples prepared for Marshall test.

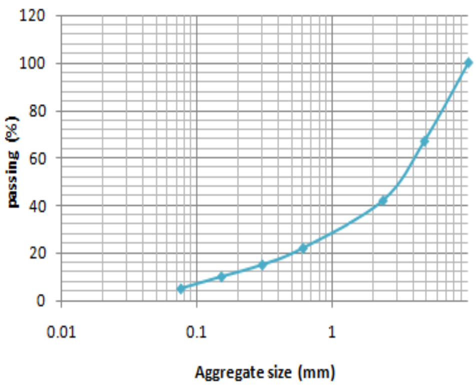

Fig. 1 Aggregate grading

C. Ethylene Vinyl Acetate

Ethylene vinyl acetate (EVA) is the copolymer of ethylene and vinyl acetate. This polymer has good barrier properties, low temperature toughness and water proofing properties. Molecular structure of ethylene vinyl acetate is shown in Fig. 2.

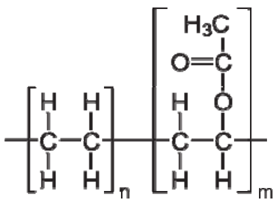

Fig. 2 Molecular structure of EVA

D. Low Density Polyethylene (LDPE)

Polyethylene belongs to polyolefin of polymers, it is a thermoplastic polymers. Many types of polyethylene exist but low and linear density and high density polyethylene are the most common. High Density Polyethylene (HDPE) is used when; strength, heat tolerance, stiffness and shrinkage are required. They are commonly used in food packaging, like milk bottles, soft drink bottles, and industrial drums for chemical. Low density polyethylene (LDPE) is used where impact strength, toughness and high elongation are important. Some applications of LDPE include carry bags bread packaging, sandwich bags, house wares, toys, buckets, wire and cable jacketing, carpet. The molecular structure of polyethylene is shown in Fig. 3.

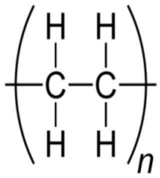

Fig. 3 Molecular structure of polyethylene

E. Polypropylene (PP)

Polypropylene is the lightest known industrial polymer. It is produced by polymerization of propylene. Polypropylene is a stiffer material than polyethylene. Polypropylene has good heat and chemical resistance, resistance to deformation at elevated temperatures, high stiffness, surface hardness and toughness at normal temperatures. The properties of waste LDPE and PP used in present study are shown in Table II. The waste LDPE and PP are obtained from the waste plastic bag in the form of pellets, manufacture by a minor local industry from Aurangabad state of Maharashtra India. The molecular structure of polypropylene is shown in Fig. 4.

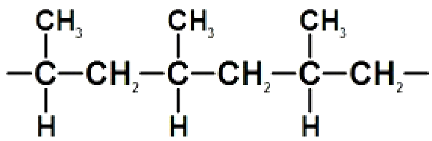

Fig. 4 Molecular structure of polypropylene

TABLE II
PROPERTIES OF WASTE LDPE AND PP

Type of Polymer	Melting Point	Relative Density
LDPE	105-112 ^{0}C	0.910-0.916
PP	152-158 ^{0}C	0.866-0.884

F. Waste Tyre Crumb Rubber

The rubber used was a sample of reclaimed car tyres shredded into fine fibers. Apart from use as a bitumen modifier, this rubber is also used for playground surfaces and athletic tracks, carpet backing, brake pads, roofing and cattle mats. The sample used was derived from ambient grind of waste tyres. Table III contains typical constituent of crumb rubber as indication of content only.

TABLE III
TYPICAL CONSTITUENTS OF CRUMB RUBBER

Material	Content (%)
Natural rubber	25-50
SBR/Butadiene content	5-30
Carbon black	25-30
Processing agents	20-25
Acetone extraction	3.5-9
Ash content	10
Benzene Extraction	4-6

III. EXPERIMENTATION

Waste LDPE and PP modified bitumen is prepared in laboratory by heating bitumen at 200^{0}C and waste plastic mixed and stir for one hour. The penetration test is carried out by standard bitumen penetration test apparatus, measured in terms of 1/10th of mm under weight of 100gm for 5 second at 25^{0}C. The softening point is determined by ring and ball method. The ductility is determined in terms of centimeter at 27^{0}C.

IV. Result and Discussion

The effect of waste polymer and EVA on penetration is shown in Fig. 5. There is general trend of decreasing penetration value with increase in polymer concentration in bitumen. At temperature above 160^{0}C polymers are in melt condition, they absorbs some oil and release low molecular weight fraction into the bitumen, which increases the viscosity of modified bitumen, by the end of mixing process, and by the time it cools harden mixture is formed, give rise lower penetration value [7]. The decrease in penetration at 10% additive content is more in LDPE and PP modified bitumen as compared to EVA modified bitumen, where as in CR modified bitumen it less than that of EVA modified bitumen. The decrease in penetration value of bitumen indicates increase in stiffness and shear resistance of binder.

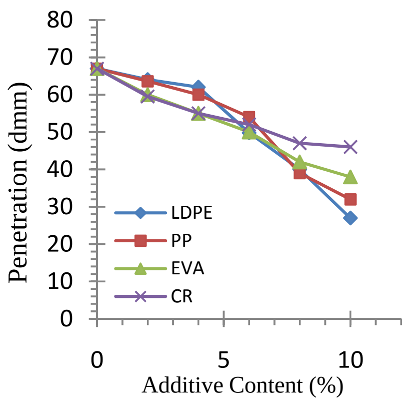

Fig. 5 Effect of polymer additives on Penetration

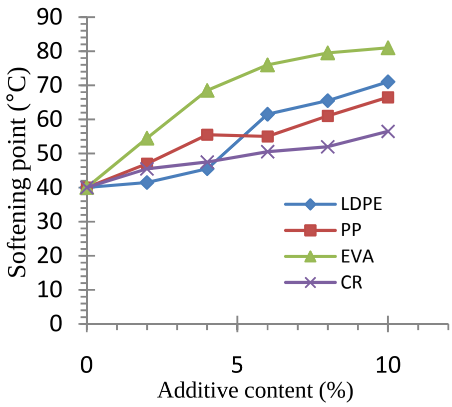

Fig. 6 Effect of polymer additives on softening point

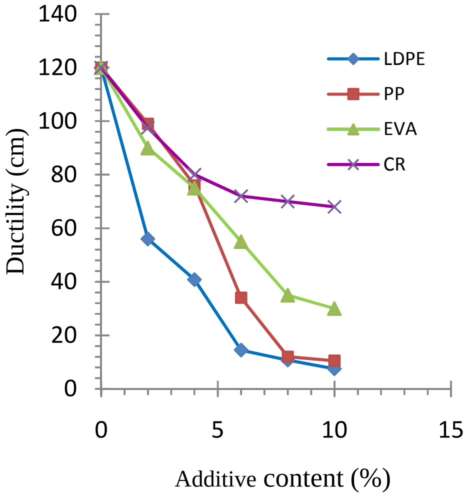

Fig. 7 Effect of polymer additives on ductility

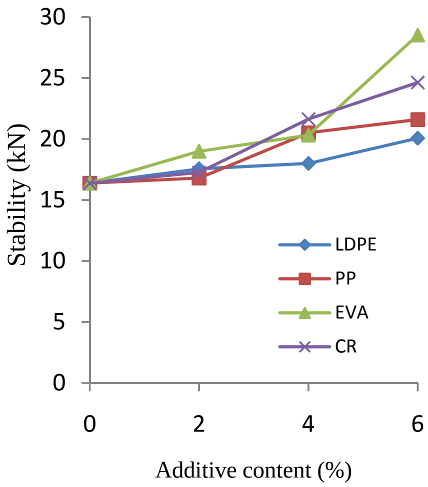

Fig. 8 Effect of polymer additives on stability

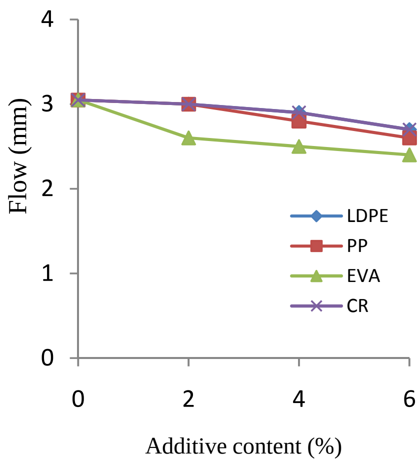

Fig. 9 Effect of polymer additives on flow

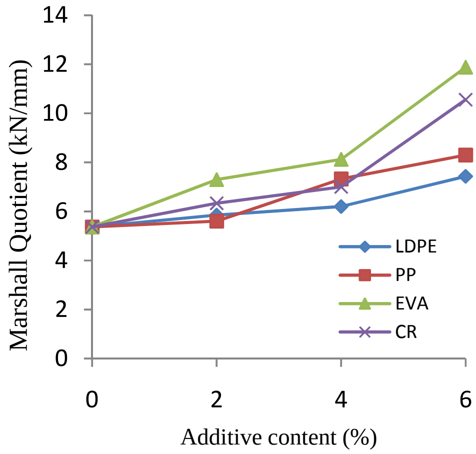

Fig. 10 Effect of polymer additives on Marshall Quotient

Experimental study reveals that the softening point of bitumen is increasing with increase in polymer content. The softening point for neat bitumen was 40ºC, which increase to 71ºC, 66.5ºC, 56.5ºC and 81ºC for 10% LDPE, PP, CR and EVA respectively, as shown in Fig. 6. Increase in softening point is an indication of greater temperature susceptibility. The effect of waste LDPE and PP on softening point is close to EVA.

The ductility of bitumen decreases with increase in polymer concentration. In case of LDPE and PP ductility of modified bitumen is rapidly decreasing with increase in concentration of LDPE and PP as compare to EVA. Whereas for CR modified bitumen reduction in ductility is less as compared to EVA. The variation of ductility with concentration of polymer is shown in Fig. 7. It is necessary to decide optimum dose of these waste polymer by considering minimum ductility requirement criteria.

Marshall stability test result shows that stability increase and flow decreases with introduction of polymer in pure bitumen, thus the Marshall Quotient increases. This indicates improvement in resistance to permanent deformation or rutting. The trend of increase of stability is approximately same for all polymers for up to 4% concentration; however the stability value for 6% polymer content is more in EVA as compared to waste polymer. Similarly, the decrease in flow is more pronounced in EVA as compared to waste polymer. The effect of waste and virgin polymer on stability, flow and Marshall Quotient are shown in Figs. 8, 9, and 10 respectively.

V. Conclusion

The observations brought out through the experimental studies on neat bitumen and bitumen modified by waste polymer and EVA have been summarized as below.

With the introduction of polymer in bitumen tends to decrease the penetration and increase the softening point. This is an indication of increased shear resistance and temperature susceptibility of binder. In general the physical properties of the bitumen modified by waste PP, LDPE and CR are better than the neat bitumen and comparable with EVA. By considering the factor of minimum requirement of ductility, the optimum waste polymer content is about 4 to 5% by weight of bitumen.

The Marshall stability increases and flow decrease in virgin as well as waste polymer modified bitumen, which indicate increase in resistance to rutting. The improvements in Marshall Properties of waste polymer modified bitumen are somewhat less than EVA modified. It is concluded that use of these waste plastic could be better alternative to use for modification of bitumen, as it will be much economical and solve the problem waste disposal to some extent.

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