Comparative Study of Bituminous Mixes Modified by EVA and Crumb Rubber

Sawant P.A.*
PG Student ,Civil Engg. Department,
Rajarambapu Institute of Technology,Sakharale,India.
e-mail: pravinsawant008@rediffmail.com

Kulkarni S.S. **
Professor, Civil Engg. Department,
Rajarambapu Institute of Technology, Sakharale ,India
e-mail:sushma.kulkarni@ritindia.edu

***Abstract*—** A good wearing course play very important role for the protection of flexible pavement. Bitumen wearing course in the hot climate area not been performing good on heavy traffic volume highways with life of wearing course not exceeding four years due the brittleness caused by oxidation of binder. Use of bituminous mixes modified by Ethylene vinyl acetate and crumb rubber in the construction of flexible pavement is gaining importance because of many reasons. EVA and Crumb rubber is non biodegradable materials. Addition of this type of materials in the bituminous mixes increase the strength and life of flexible pavement. Conventional bitumen does not have attraction with water. When bitumen is used in flexible pavement during and after rainy season there is possibility of formation of potholes. Bitumen is not good with high air voids, due to which cracks are developed in the flexible pavement. The present work is carried out to find solutions on potholes and cracks formation in case of flexible pavement by the replacement of bitumen by EVA and crumb rubber in various percentages like 2 %, 4%, 6% by the weight in 60/70 grade bitumen.

Keywords- *Flexible pavement, Polymer modified binders, Crumb Rubber, Ethylene Vinyl Acetate.*

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I. INTRODUCTION

Bitumen has been widely used in India for the construction of flexible pavements for more than a century. Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations in asphalt binder performance and this has led to early developments of distress symptoms like cracking, rutting, raveling, undulations, shoving and pot holing of bituminous surfacing. A polymer is chemical compound where molecules are bonded together in long repeating chains. These materials, polymers, have unique properties and can be tailored depending on their intended purpose. By adding small amount of polymers to bitumen, the life span of the road pavement may be considerably increased. In the present study effect of waste crumbed tyre and Ethylene Vinyl Acetate on rheological properties of 60/70 penetration grade is evaluated.

II. EARLIER STUDIES

Piotr Radziszewski [1] based on his study on strength properties of asphalt concrete modified with fine rubber from scrap tyres concluded that bitumen mixtures with rubber bitumen binders are more resistant to rutting than neat bitumen. It is found that mixtures with fine rubber modified binders are more resistance to low temperature cracks. It is also concluded that the optimum modifier content is 17%.

Praveen Kumar [2] based on his laboratory study on rheological properties of crumb rubber modified bitumen concluded that the physical properties like penetration, ductility and softening point are improved due to addition of crumb rubber. It is also found that complex modulus increases with increase in modifier content but the phase angle decreases with increase in modifier. The increase in complex modulus and decrease in phase angle is an indication of higher resistance to deformation as compared to unmodified bitumen.

G.D.Airey et al. [3] reported that modified bitumen using crumb rubber showed an improvement in the performance of pavements over the base binders as a result of the interaction of crumb rubber with base binders. Due to this interaction, the viscosity, physical and rheological properties of the modified bitumen are improved.

N.P. Krut'ko et al [4] based on laboratory investigation concluded that ethylene vinyl acetate enhances the heat resistance of modified bitumen. The physical properties of Ethylene Vinyl Acetate modified bitumen shows reduction in penetrability, increase in softening point and decrease in thermal susceptibility. The deformation behavior of EVA modified bitumen showed increased resistance to permanent deformation at 5% of modifier content.

III. MATERIAL AND METHOD

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A. Base Bitumen.

The bitumen used should have the following properties.

Grade of bitumen used in the pavement should be selected on the basis of climatic conditions and their performance in the past.

It is recommended that the bitumen should be accepted on certification by supplier (along with the testing results) and the State project, verification samples. The procedures for acceptance should provide information, on the physical properties of the bitumen in timely manner.

The physical properties of bitumen used which are very important for pavements are shown below. Each State should obtain this information (by central laboratory or supplier tests) and should have specification requirements for each property except specific gravity.

(a) Penetration
(b) Ductility
(c) Softening point

B. Polymer (Ethylene-vinyl acetate)

A polymer is chemical compound where molecules are bonded together in long repeating chains. These materials, polymers, have unique properties and can be tailored depending on their intended purpose. Polymers are both man made and are naturally occurring. Ethylene vinyl acetate (also known as EVA) is the copolymer of ethylene and vinyl acetate. The weight percent vinyl acetate usually varies from 10 to 40 with the remainder being ethylene. It is a polymer that approaches elastomeric materials in softness and flexibility, yet can be processed like other thermoplastics. The material has good clarity and gloss, low-temperature toughness, stress-crack resistance hot-melt adhesive waterproof properties, and resistance to UV radiation. EVA has a Active "vinegar" odor and is competitive with rubber and vinyl products in many electrical applications. Fig.1 shows Structure of EVA. and Fig.2 shows EVA granules.

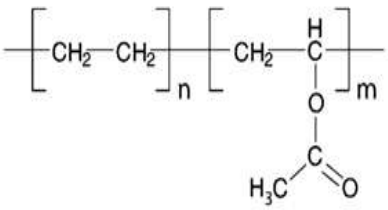

Fig.1 Structure of EVA

Fig.2 EVA Granules

C. Crumb Rubber

Crumb rubber is very effective in the clean-and-seal method. This process works best in the early spring or late fall when the cracks are open. Although crumb rubber will crack in the winter, it will re-heal during warmer weather. A double jacket smelter is needed to maintain proper temperature of the product during application.

The rubber used was a sample of reclaimed car tyres. 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. This means that the tyre was torn apart at room temperature and then ground as opposed to being frozen before grinding. Information provided by the supplier and is an indication of content only as below.

Table.1 Typical Constitution 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

Fig.3 Picture of Crumb Rubber.

IV. RESULTS AND DISCUSSION

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a) Penetration Test

Penetration test is the test on bitumen to grade the material in term of its hardness. The bitumen is softened to a pouring consistency between 75˚C and 10˚C above the approximate temperature at which bitumen softens. The sample material is thoroughly stirred to make it homogenous and free from air bubbles and water. The sample material is then poured into the containers to a depth at least 15 mm more than the expected penetration. The sample containers are cooled in atmosphere temperature not lower than 13˚C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25˚C for a period of one hour. The difference between the initial and final penetration readings is taken as the penetration value. From Lab. Tests it is found that the penetration value of bitumen decreases with increase in EVA content. Effect of CR and EVA on penetration of bitumen are shown in fig.4

The decrease in penetration value is an indication of increased stiffness of binder. The penetration value of bitumen is reduces by 44% for 6% of EVA content. The percentage reduction in penetration value in crumb rubber is about 31% for 6% of crumb rubber content.

b) Ductility Test

In the flexible pavement construction where bitumen binders are used, it is of significant importance that the binders form ductile thin films around the aggregates. This serves as a satisfactory binder in improving the physical interlocking of the aggregates. The bitumen sample is melted to a temperature of 75 to 100˚C above the approximate softening point until it is fluid. It is strained through 90 micron sieve, poured in the mould assembly and placed on a brass plate, after a solution of glycerine and dextrin is applied at all surfaces of the mould exposed to bitumen. After 30 to 40 minutes, the plate assembly along with the sample is placed in water bath maintained at 27˚C for 30 minutes. After trimming the specimen, the mould assembly-containing sample is replaced in water bath maintained at 27˚C for 85 to 95 minutes. The sides of the mould are now removed and the clips are carefully hooked on the machine without causing any initial strain. The pointer is set to zero, the machine is started and the two clips are pulled apart horizontally at a uniform speed of 50 +/- 2.5mm per minute. While the test is in operation, it is checked whether the sample is immersed in water at depth of at least 10mm. The distance, at which the bitumen thread of each specimen breaks, is recorded (in cm) to report as ductility value. The minimum ductility value of A35 & S35 grade bitumen is 50 cm at 27˚C. All other grades, the ductility value is 75 cm at 27˚C. The ductility value of bitumen vary from 5 to over 100 for different bitumen grades .In case of bitumen modified by EVA the ductility of bitumen reduces with increase in concentration of EVA. The percentage decrease in ductility is about 23% for 6% of EVA content. The Percentage decrease in ductility is about 18% for 6% of crumb rubber content. Effect of CR/EVA on ductility shown in fig. 5

c) Softening Point

Sample material is heated to a temperature between 75 and 100˚C above the approximate softening point until it is completely fluid and is poured in heated rings placed on metal plate. To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerine and dextrin. After cooling the rings in air for 30 minutes, the excess bitumen is trimmed and rings are placed in the support at this time the temperature of distilled water is kept at 50˚C. This temperature is maintained for 15 minutes after which the balls are placed in position. The temperature of water is raised at uniform rate of 50˚C per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate by sinking of balls. The temperature at the instant when each of the ball and sample touches the bottom plate of support is recorded as softening value .

The softening point of neat bitumen is 46˚C which increase tom76˚ C when EVA content is increase to 6%.The percentage increase in softening point is about 65% for 6% of EVA content. The percentage increase in softening point is about 13% for 6% of crumb rubber content. Thus EVA and crumb rubber have positive effect on softening point. The softening point of bitumen increase with increase in EVA and crumb rubber content. This is an indication of improved temperature susceptibility of binder. The effect of CR/EVA on softening point shown in fig.6

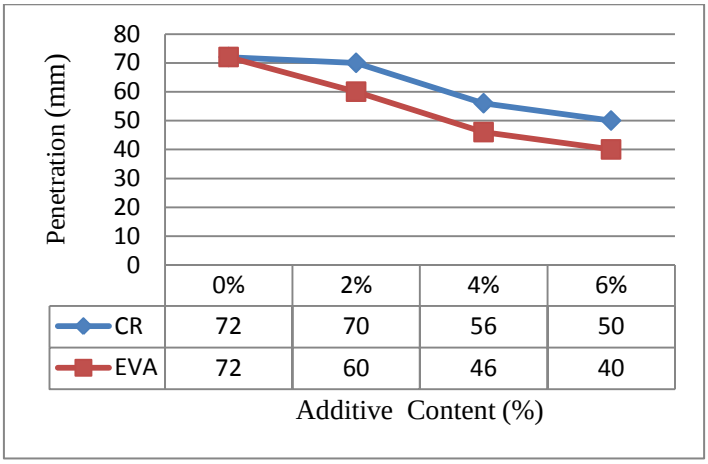

Fig. 4 .Effect of CR/EVA on penetration value.

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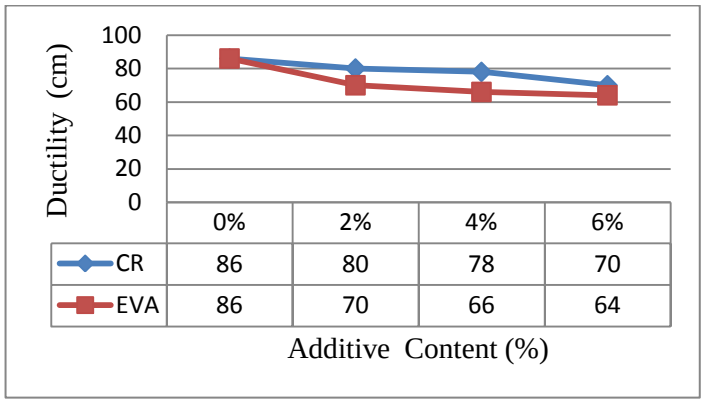

Fig. 5 Effect of CR/EVA on Ductility Value.

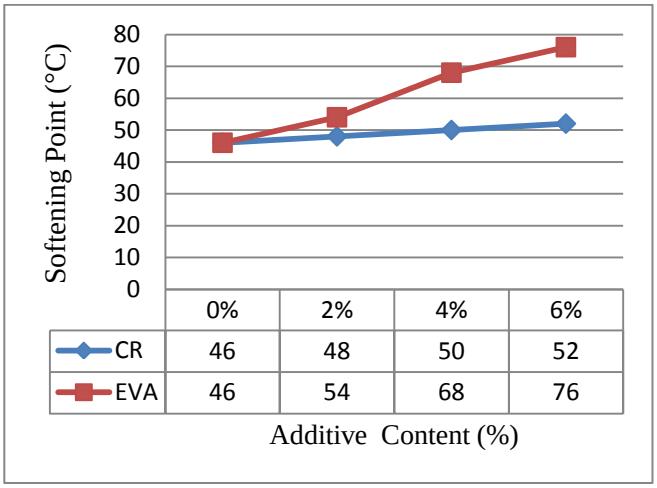

Fig.6 Effect of CR/EVA on Softening point.

d) *Marshall Stability Test*

Marshall Stability test result shows that stability increase and flow decreases with introduction of polymer in pure bitumen, thus the Marshall Stability 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 6% concentration; however the stability value for 6% polymer content is more in EVA as compared to Crumb Rubber. Similarly, the decrease in flow is more pronounced in EVA as compared to Crumb Rubber. The effect of polymer on stability as shown in Fig. 7.

From this test it is observed that stability value of bitumen increases from 13.17KN to 20.16 KN for bitumen modified by 6% CR. Increase in stability value is an indication of improved resistance to rutting. Marshall stability of bituminous mix increase from 13.17KN to 22.50 KN for bitumen modified by 6% of EVA

Table 2 Amount of raw material for specimen

CR/EVA %	Wt.of CR/EVA(gm)	Wt.Of Bitumen(gm)	Wt.of Agg.(gm)
0	0	60	1140
2	1.2	58.8	1140
4	2.4	57.6	1140
6	3.6	56.4	1140

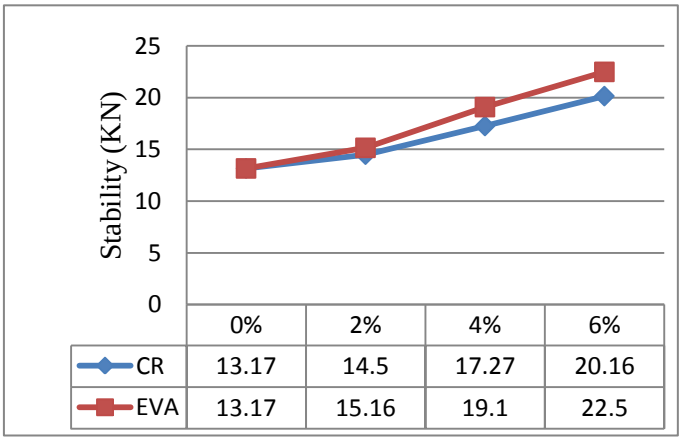

Fig. 7 Effect of CR/EVA on Marshall Stability

Table 3.Effect of CR and EVA on Marshall Stability

Content %	Marshall Stability (KN)	
	Crumb Rubber	EVA
0	13.17	13.17
2	14.50	15.16
4	17.27	19.10
6	20.16	22.50

V. CONCLUSION:

The penetration value of bitumen is decreasing with increase in EVA and CR content in bitumen. The decrease in penetration value is an indication of increased stiffness of binder. The penetration value of bitumen is reduces by 44% for EVA and about 31% for CR at 6% of EVA/CR content. The softening point of neat bitumen increases with increase in the EVA and CR content. This is an indication of improved temperature susceptibility of binder. The softening point of neat bitumen increases from 46ºC to 76ºC for 6% of EVA content. Whereas for CR, increase in softening point is from 46˚C to 52ºC for 6% of CR content. Thus CR and EVA modification improves the thermal susceptibility of binder. The ductility of the neat bitumen is reduces with increase in EVA and CR content in bitumen. The reduction in ductility is not desirable; however the Optimum value of modifier content can be determined on the basis of minimum requirement of ductility. Thus it is found that the addition of EVA and crumb rubber obtained from waste tyre,

increases the stiffness and improves temperature susceptibility of bitumen. The CR modification brings fairly similar improvement in the Marshall properties as EVA modification. The effects are pronounced in case of EVA modified bitumen.

It is observe that Use of polymer Improve Different property of Flexible pavement like Strength of the road increased (increased Marshall Stability Value),

Better resistance to water and water stagnation, No stripping and have no potholes, Increased binding and better bonding of the mix, Increased load withstanding property, Overall consumption of bitumen decreases, Reduction in pores in aggregate and hence less rutting and raveling, Better soundness property, Maintenance cost of the road is almost nil, The road life period is substantially increased. Thus it may be concluded that the bitumen modification by Crumb Rubber and Ethylene Vinyl Acetate are beneficial, economical and environmental friendly.

VI. ACKNOWLEDGMENT

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