EFFECT ON PHYSICAL PROPERTIES OF MODIFIED BINDERS ON ADDITION OF WMA ADDITIVES

[1]Ashok Julaganti, [2]Rajan Choudhary, [3]Eleena Gao
[1]Research Scholar,ndian Institute of Technology Guwahati,India
[2]Assistant Professor,Indian Institue of Technology Guwahati,India
[3]Former M. Tech Student,Indian Institue of Technology Guwahati,India
[1]j.ashok@iitg.ernet.in, [2]rajandce@iitg.ernet.in

Abstract— **Binder properties plays an important role in the performance of bituminous mixes. In order to achieve higher performance under heavy axle loads and high temperature variations, use of modified binders in surface course (wearing courses) is now a day's very common practice on India highways. Bituminous mixes with modified binders demands normally 10-30°C higher production temperatures compared to that of mixes with neat binders. Warm Mix Asphalt (WMA) refers to the technologies that allow a 20°C to 50°C decrease in the production, placement and compaction temperatures of bituminous mixes with the help of organic additives, chemical additives or foaming processes.**

This paper presents the results on the effect of addition of WMA additives on physical properties of modified binders. Two WMA additives viz. Sasobit® (an organic additive) and Evotherm J1 (chemical additive) are used in this study. Two modified binders; Crumb Rubber Modified Bitumen grade 55 (CRMB 55) and Polymer Modified Bitumen grade 70 (PMB 70) are used in this study. Physical properties of CRMB and PMB are evaluated on addition of different percentages of Sasobit® (1%, 2% and 3%) and Evotherm J1 (0.4%, 0.5% and 0.6%) by weight of binder. Physical characteristics of binder with and without WMA additives are evaluated in both un-aged and aged conditions. Results of this study showed that the addition of Sasobit® and Evotherm J1 increases the aging resistance of binders.

Keywords— **Modified Binders, WMA, Evotherm, Sasobit®**

I. Introduction

Hot mix asphalt (HMA) is most commonly used paving material from many decades. It is produced through a combination of aggregates which are uniformly mixed and coated with bitumen at around 150°C. These high production temperatures leads to high fuel consumption and emissions into atmosphere. For example, a typical drum mix plant having a production rate of 2 lakh tonnes of asphalt mix in a year would emit about 13 tons of carbon monoxide (CO), 5 tons of volatile organic compounds (VOC), 0.4 tons of sulphur oxides, 2.9 tons of nitrogen oxides and about 0.65 tons of total Hazardous Air Pollutants (HAP) during the same period [1].

Warm Mix Asphalt (WMA) refers to technologies that allow a reduction in mixing and compaction temperature of asphalt mixes either through lowering the viscosity of asphalt binders or by increasing the workability of a mix at lower temperatures [2]. The reductions in viscosity of binder or increase in workability of mix is achieved through the addition of different additives. With the WMA technologies, the production temperatures and fuel consumption can be lowered by about 20 to 30% respectively in comparison to HMA [3, 4, and 5]. In addition to energy savings, WMA also offers other following advantages such as; late season paving or extended paving season, better workability and compaction, increased usage of Reclaimed Asphalt Pavement (RAP), improved working conditions, and decreased aging of binder [6].

Since WMA technologies are newly introduced in India, a continuous research is under progress to examine the effect of WMA technologies or additives on performance of different binders and mixes used in India.

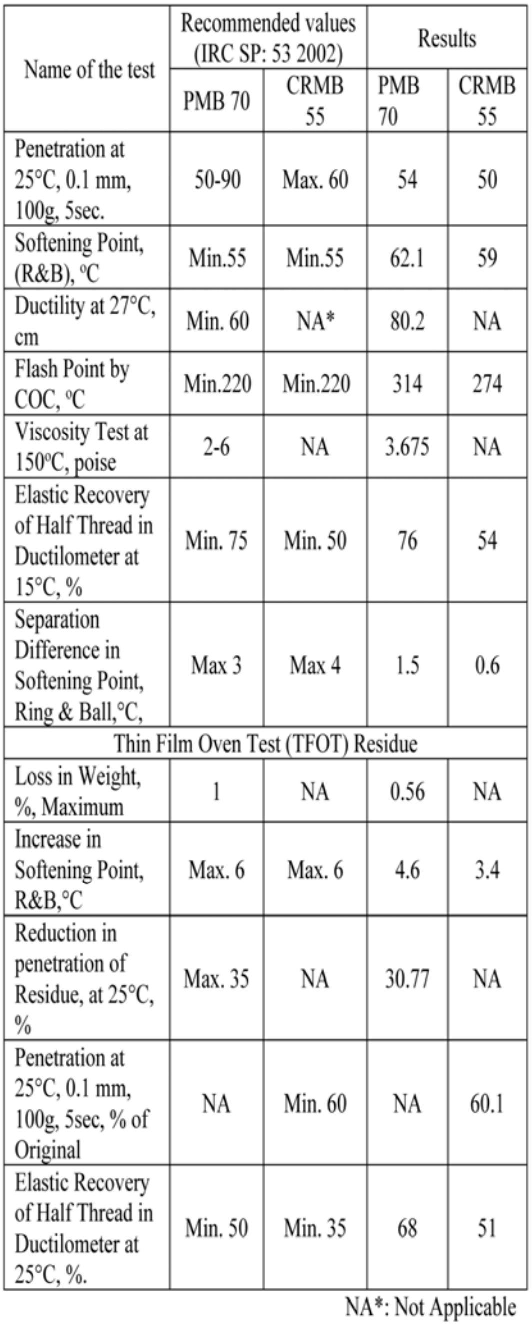
Sasobit is a paraffin wax that is obtained in the coal gasification process using the Fischer-Tropsch (FT) process. It has a long chemical chain length of 40-115 carbon atoms with a melting point of about 80 – 115°C, and is completely soluble at 120 °C. Addition of Sasobit® helps to reduce the viscosity of asphalt binder at temperatures greater than 120°C (above its melting point) [9, 10] and increases the viscosity of binder at mid-range temperature i.e. at 60°C (below its melting point) [8, 11]. At temperatures below its melting point, Sasobit forms a crystallization structure inside the binders which imparts stability to the binders [4]. Sasobit® improves adhesion characteristics of the binder [12] and helps to decrease the viscosity of the recycled binders and increases the rutting potential [2].

Evotherm is an additive, developed by MeadWestvaco Asphalt Innovations, USA. It includes a combination of emulsification agents, surfactants, polymers, and adhesion promoters to improve coating, workability, and compaction at lower temperatures [5]. It helps to reduce the internal friction between aggregate particles during the compaction of bituminous mix. Evotherm technology is delivered in three forms: Evotherm ET (Emulsion Technology), Evotherm DAT (Dispersed Asphalt Technology) and Evotherm 3G (Third Generation). In this study Evotherm J1, one form of Evotherm 3G is used.

II. Experimental Plan

Two modified asphalt binders viz. PMB 70 and CRMB 55 used in this study, are recommended in India, for regions having a maximum atmospheric temperature of 35°C to 45°C and minimum pavement temperatures betweeen 10°C to -10°C [13]. These binders were obtained from TikiTar Industries, Gujarat. Both PMB 70 and CRMB 55 were tested for their physical characteristics as per the IRC SP: 53-2002 specifications [13] and results are presented in Table 1.

Table 1. Physical Characteristics of PMB 70 and CRMB 55



Name of the test	Recommended values (IRC SP: 53 2002)		Results	
	PMB 70	CRMB 55	PMB 70	CRMB 55
Penetration at 25°C, 0.1 mm, 100g, 5sec.	50-90	Max. 60	54	50
Softening Point, (R&B), °C	Min.55	Min.55	62.1	59
Ductility at 27°C, cm	Min. 60	NA*	80.2	NA
Flash Point by COC, °C	Min.220	Min.220	314	274
Viscosity Test at 150°C, poise	2-6	NA	3.675	NA
Elastic Recovery of Half Thread in Ductilometer at 15°C, %	Min. 75	Min. 50	76	54
Separation Difference in Softening Point, Ring & Ball,°C,	Max 3	Max 4	1.5	0.6
Thin Film Oven Test (TFOT) Residue				
Loss in Weight, %, Maximum	1	NA	0.56	NA
Increase in Softening Point, R&B,°C	Max. 6	Max. 6	4.6	3.4
Reduction in penetration of Residue, at 25°C, %	Max. 35	NA	30.77	NA
Penetration at 25°C, 0.1 mm, 100g, 5sec, % of Original	NA	Min. 60	NA	60.1
Elastic Recovery of Half Thread in Ductilometer at 25°C, %.	Min. 50	Min. 35	68	51

NA*: Not Applicable

Sasobit and Evotherm J1 are the two WMA additives used in this study. Sasobit® was available in the form of pellets and Evotherm J1 (one form of 3G technology) was available in the form of thick viscous liquid. Three different percentages of Sasobit® (1%, 2%, and 3%) and Evotherm J1 (0.4%, 0.5%, and 0.6%) were used in this study. These percentages of WMA additives were selected for this study on manufacturer's recommendation. To prepare a homogenous blend of binders with WMA additives, a standard procedure was adopted. The binders were first preheated to a temperature around 120°C, thereafter the required dosages of WMA additives were added and mixed thoroughly for 15 minutes, using a mechanical stirrer. Different blends prepared were then tested for penetration, softening point, ductility, viscosity, and elastic recovery. These blends were also further subjected to short term aging through Rolling Thin Film Oven (RTFO) at 163 ± 0.5 °C for 85 minutes. Aged samples from the RTFO were recovered and tested for penetration and softening point, to see the effect on aging characteristics of CRMB and PMB binders after the addition of Sasobit® and Evotherm J1.

A. *Penetration Test*

Penetration test was performed according to IS 1203. In this test, a needle of specified dimensions is allowed to penetrate into a bitumen sample, under a known load (100 g), at a fixed temperature of 25°C, for 5 seconds. The penetration is defined as the distance travelled by needle into the bitumen measured in one tenth of a millimetre (1/10 mm).

B. *Softening Point Test*

Softening point is a temperature at which a phase change occurs in the bitumen. In this test, a steel ball of 3.5 g is placed on a sample of bitumen contained in a brass ring and suspended in a water or glycerine. The bath temperature is raised by 5°C per minute and the bath temperature is recorded when the ball from a softened bitumen reaches 25 mm below the ring. This test was conducted according to IS 1205.

C. *Viscosity Test*

Viscosity is the property of bitumen by virtue of which it offers resistance to flow. This test was conducted using Brookfield Rotational Viscometer in accordance with ASTM D 4402-06. In this test, viscosity is measured by allowing a cylindrical spindle no. 21 to rotate at a constant speed (20RPM) submerged in a bitumen sample.

D. *Ductility Test*

Ductility of a bitumen sample is measured as the distance to which a standard briquette of bitumen can be stretched at specified speed (50mm/min) and standard temperature (27°C) before breaking. This test was performed according IS 1208.

E. *Elastic Recovery Test*

The elastic recovery of a modified bitumen sample is measured by the percentage to which the bitumen sample will recover to its original length after application and release of stress. This test was performed according IRC SP 53 2002.

F. *Rolling Thin Film Oven Test*

Rolling Thin Film Oven (RTFO) was used for short term aging of the bitumen samples. In this test, 35gm of binder is poured into the glass bottle and placed in a rack in the oven maintained at 163 ± 0.5°C. The rack is rotated on a horizontal axis for 85 mins. This test was conducted according to ASTM D2872.

III. Results and Discussions

A. *Physical Characteristics of Modified Binders with Sasobit® under Un-aged and Aged Conditions*

Penetration values of different blends of PMB and CRMB with Sasobit® are shown in Fig. 1 and 2. Penetration values are found to decrease with the increase in the addition of Sasobit. The decrease in penetration values are maximum at the first percentage (1%) of Sasobit® in case of both CRMB and PMB. With higher concentrations of Sasobit® (i.e. 2% and 3%) the reduction in penetration values is less.

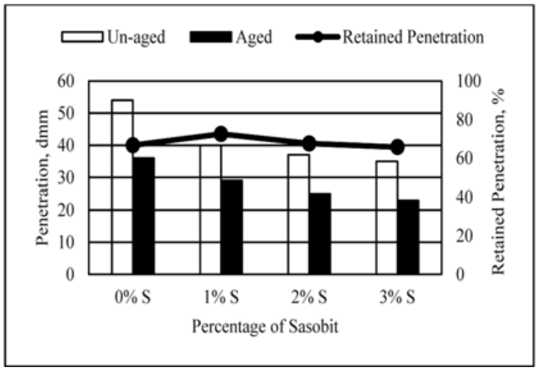


Fig. 1: Penetration v/s % of Sasobit® for PMB in un-aged & aged condition

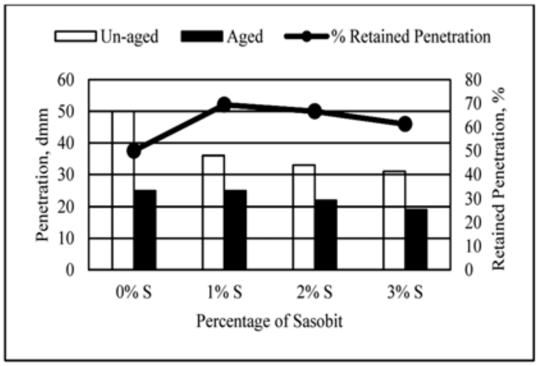


Fig. 2: Penetration v/s % of Sasobit® for CRMB in un-aged & aged condition

Modified binders blended with different percentages of WMA additives were also short term aged using RTFO at 163 ± 0.5 °C for 85 minutes. Penetration values and percentage of retained penetration of different aged blends are also presented in Fig. 1 and 2. Percentage of retained penetration is calculated using the following equation;

$$\% \text{ Retained Penetration} = \frac{\text{Penetration value of Aged Binder}}{\text{Penetration Value of Unaged Binder}} \times 100 \quad (1)$$

Retained penetration values are higher for blends with WMA additive Sasobit® compared to that of neat binder, which shows that addition of Sasobit® increases the aging resistance of the binder. Retained penetration values shows a slight decrease with the increase in the Sasobit® percentage and are higher in case of CRMB binder compared to PMB binder.

Softening point values of different blends of PMB and CRMB with WMA additives under un-aged and aged conditions are presented in Fig. 3 and 4. Softening point values of modified binders increases with the addition of Sasobit®. An increase of about 21°C and 17°C is observed with the addition of 3% Sasobit® with CRMB and PMB binder respectively under un-aged condition. Increase in softening after aging of blends with PMB and Sasobit® is less compared to the increase in neat PMB binder.

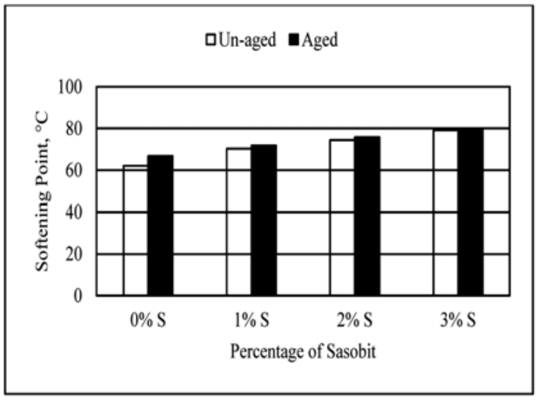


Fig. 3: Softening Point v/s % of Sasobit® for PMB 70 in un-aged & aged condition

Viscosity results of modified asphalt binders with Sasobit® obtained through Brookfield rotational viscometer at 150°C under un-aged conditions is shown in Fig. 5. Addition of Sasobit® reduces the viscosity of both the modified binders. Addition of Sasobit® helps to reduce the viscosity of asphalt binder at temperatures above its melting point (80-115°C). With the addition of 3% Sasobit®, a decrease of about 15-20% in viscosity values is observed in case of the two modified binders. The decrease in the viscosity of due to addition of Sasobit® is more in CRMB compared to PMB.

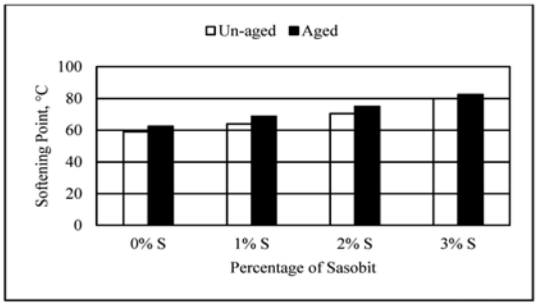


Fig. 4: Softening Point v/s % of Sasobit® for CRMB55 in unaged & aged condition

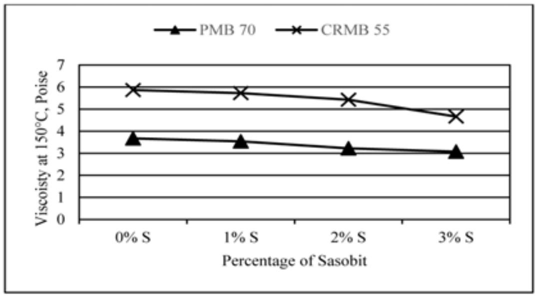


Fig. 5: Viscosity v/s % of Sasobit® for PMB 70 and CRMB 55

Table 2 presents the results of ductility and elastic recovery conducted on the modified binders with different percentages of Sasobit®.

Table 2: Ductility and Elastic Recovery of Warm Asp halt Binders

Binders	Percentage of Sasobit®	Ductility at 27°C	Elastic Recovery at 15°C
PMB 70	0	80.2	76
	1	68	68
	2	66	64
	3	60.1	60.1
CRMB 55	0	-	54
	1	-	50
	2	-	48
	3	-	42

Ductility test is not performed on CRMB as it is not required as per IRC SP 53 2002 Specifications. In case of PMB, ductility value decreases with the addition of Sasobit. Elastic recovery is also found to decrease in case of both PMB and CRMB binder with the addition of Sasobit®. Reduction in elastic recovery values is less in case of CRMB compared to that of PMB. Decrease in the ductility and elastic recovery values indicates an increase in the stiffness of the binder on addition of Sasobit® at ambient temperature.

Sasobit®, being an organic additive helps in reducing the viscosity of binder at temperatures greater than its melting point (80-115°C) and the same is observed from the viscosity results in case of PMB and CRMB. Addition of Sasobit® increases the stiffness of the binder below its melting point. The same trend is observed through penetration and softening point results.

*B. **Physical Characteristics of Modified Binders with Evotherm under un-aged and aged Conditions***

Three percentages of WMA additive Evotherm J1 (0.4%, 0.5%, and 0.6%) are added to make blends with PMB and CRMB. Results of penetration values of un-aged and aged binders with different percentages of Evotherm J1 are shown in Fig. 6 and 7. Penetration values decreases with the addition of Evotherm J1. Reduction in the penetration values are maximum at first percentage of Evotherm J1 (0.4%).

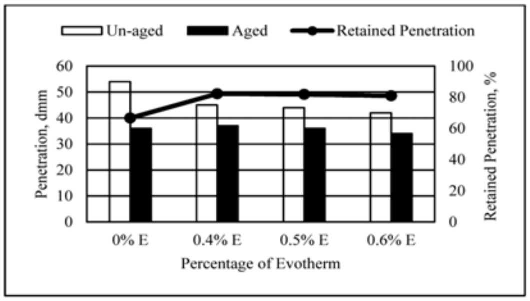


Fig. 6: Penetration v/s % EvothermJ1 for PMB 70 in un-aged & aged condition

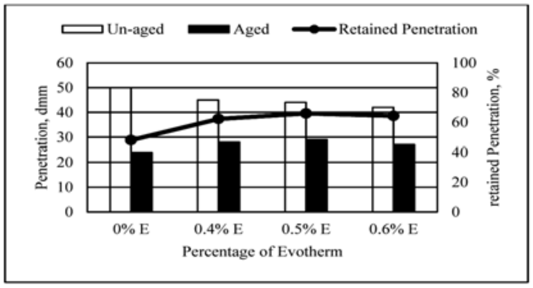


Fig. 7: Penetration v/s % EvothermJ1 for CRMB 55 in un-aged & aged condition

Retained penetration values of binders with EvothermJ1 are higher compared to the one without Evotherm J1 in case of with both CRMB and PMB. Increase in the concentration of the Evotherm J1 has negligible effect on the retained penetration values. Retained penetration values of blends with PMB are higher compared to CRMB.

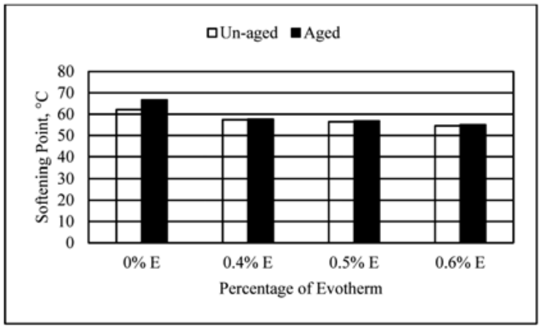


Fig. 8: Softening Point v/s % EvothermJ1 for PMB 70 in unaged & aged condition

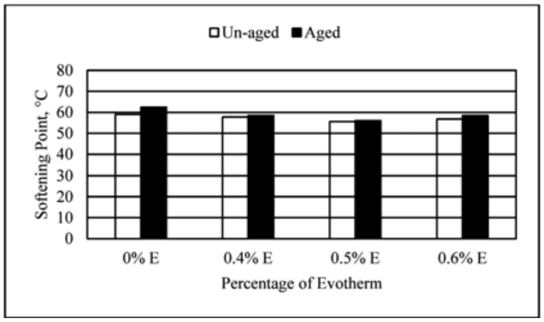


Fig. 9: Softening Point v/s % EvothermJ1 for CRMB 55 in unaged & aged condition

As seen from the softening test results presented in Fig. 8 and 9, there is no significant change on softening point of CRMB and PMB binders with the addition of Evotherm J1. A maximum decrease of 7.6°C and 2.2°C is observed in the softening point values of PMB 70 and CRMB 55 respectively, with the addition of 0.6% Evotherm J1.

Also there is no significant increase in the softening point value of aged blends with Evotherm J1. The increase in the softening point values are almost same (in between 0.25 to

0.5°C) with increase in the percentages of Evotherm J1 in case of PMB, whereas the increase in softening values does not show any trend with the increase in percentage of Evotherm J1 in case of CRMB.

There is a slight reduction in viscosity is observed on addition of Evotherm J1 with both PMB 70 and CRMB 55 and this decrease is higher in CRMB compared to PMB. A decrease of about 12% and 19 % in viscosity values is observed at 0.6% of Evotherm J1 in CRMB and PMB respectively.

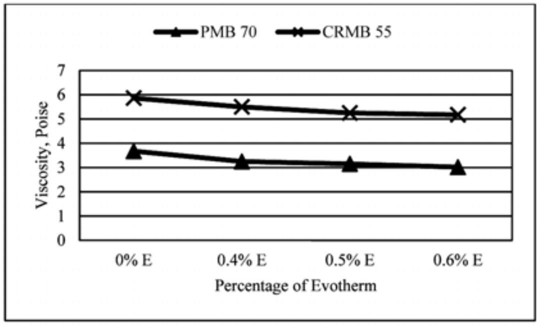
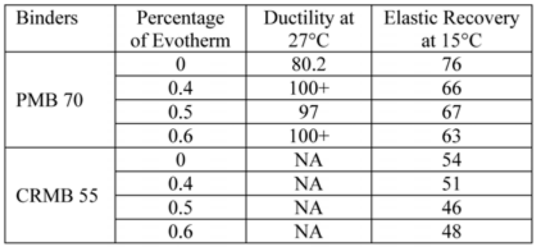


Fig. 10: Viscosity v/s % of EvothermJ1 for PMB 70 and CRMB 55

Ductility and elastic recovery of modified binders with different percentages of Evotherm J1 are presented in Table 3. Addition of Evotherm J1 makes the PMB more ductile whereas elastic recovery values for both the binders show a slight decrease with the increase in the percentage of Evotherm.

Table 3: Ductility and Elastic Recovery of binders containing Evotherm



Binders	Percentage of Evotherm	Ductility at 27°C	Elastic Recovery at 15°C
PMB 70	0	80.2	76
	0.4	100+	66
	0.5	97	67
	0.6	100+	63
CRMB 55	0	NA	54
	0.4	NA	51
	0.5	NA	46
	0.6	NA	48

Addition of Evotherm J1 did not show any significant effect on the penetration and softening point values of PMB and CRMB binder. However, the addition of Evotherm J1 has reduced the viscosity of the binder. Also, Evotherm J1, being a chemical additive, increases the workability of the binder at lower temperatures through surface interaction between aggregates and binder.

IV. Conclusions

Physical properties of both PMB and CRMB with different WMA additives were tested and the following conclusions were drawn 6

Penetration values of both PMB and CRMB are found to decrease with the addition of Sasobit® and Evotherm J1. The reduction in penetration values with Sasobit® is found to be higher compared to that of Evotherm J1 in case of both binders.

Addition of Sasobit® has increased the softening point of PMB and CRMB. Addition of Evotherm J1 has slightly reduced the softening point of both binders.

Addition of Evotherm J1 (chemical additive) to PMB and CRMB did not show any significant effect on penetration and softening point.

Viscosity of both modified binders has reduced with the addition of Sasobit® and Evotherm J1. And, the decrease in the viscosity is found to be higher in case of CRMB compared to that of PMB.

Addition of WMA additives has reduced the elastic recovery values of both PMB and CRMB.

Ductility value of PMB has increased with the addition of Evotherm J1 and decreased with the addition of Sasobit®.

Addition of Sasobit® and Evotherm has increased the aging resistance of the binders.

References

[1] United States Environmental Protection Agency, “Hot Mix Asphalt Plants – Emissions Assessment Report”, Emissions Monitoring and Analysis Division, Office of Air Quality Planning and Standards, United States Environmental Protection Agency, Research Triangle Park, NC, December 2000.

[2] Lee, S. J., Amirkhanian, S., Park. N. W. and Kim, K. W., (2009), “Characterization of Warm Mix Asphalt Binders Containing Artificially Long-Term Aged Binder”, Construction & Building Materials, Elsevier, 25, pp. 2371-2379.

[3] Hurley, G. C., and Prowell, B. D., (2005), “Evaluation of Aspha-Min Zeolite for Use in

Warm Mix Asphalt", NCAT Report 05-04, National Center for Asphalt Technology.

[4] Hurley, G. C., and Prowell, B. D., (2005), "Evaluation of Sasobit for Use in Warm Mix Asphalt", NCAT Report 05-06, National Center for Asphalt Technology.

[5] Hurley, G. C., and Prowell, B. D., (2006), "Evaluation of Evotherm for Use in Warm Mix Asphalt", NCAT Report 06-02, National Center for Asphalt Technology.

[6] Kandhal, P. S., (2010) "Warm Mix Asphalt Technologies: An Overview," Journal of the Indian Road Congress, IRC, 71(2), pp. 143-152.

[7] Newcomb, D., "An Introduction to Warm Mix Asphalt," National Asphalt Pavement Association, Lanham, Maryland, 2006.

[8] Biro, S., Gandhi, T., and Amirkhanian, S. N., (2009), "Midrange Temperature Rheological Properties of Warm Asphalt Binders", Journal of Materials in Civil Engineering, ASCE, 21(7), 316-323.

[9] Gandhi, T., and Amirkhanian, S., (2007), "Laboratory Investigation of Warm Asphalt Binder Properties – A Preliminary Investigation", Proceeding of the 5th International Conference on Maintenance and Rehabilitation of Pavement and Technological Control, Park City, 2007

[10] Yero, A. S., and Hanin, M. R., (2010), "Influence of Organic Wax on Bitumen Characteristics", American Journal of Engineering and Applied Sciences, pp. 245-269.

[11] Akisetty, C.K., Gandhi, T., Lee, S.J. and Amirkhanian, S., (2010), "Analysis of Rheological Properties of Rubberized Binders Containing Warm Asphalt Additives", Canadian Journal of Civil Engineering, 37, pp. 763-771.

[12] Mogawer, W. S., Austerman, A. J., & Bahia, H. U., (2011), "Evaluating the effect of warm-mix asphalt technologies on moisture characteristics of asphalt binders and mixtures", Journal of the Transportation Research, Transportation Research Record Board, 2209(1), 52-60.

[13] IRC: SP: 53-2002, "Guidelines on Use of Modified Bitumen in Road Construction", Indian Roads Congress, 2002.

[14] Su, k., Mae kawa, R., and Hachiya, Y., (2009), "Laboratory Evaluation of WMA Mixture for Use in Airport Pavement Rehabilitation", Construction and Building Materials, 23, pp. 2709-2714.

[15] Rubio, M. C., Martinez, G., Baena, L., and Moreno, F., (2012), "Warm Mix Asphalt: an Overview", Journal of Cleaner Production, Elsevier, pp. 76-84.

[16] "Specification for Road and Bridge Works", 5th Revision, Ministry of Road Transport and Highways, Government of India, published by Indian Roads Congress, 2013.

[17] IRC: 111-2009, "Specifications for Dense Graded Bituminous Mixes", Indian Roads Congress, 2009.

[18] IS 73:2006, "Paving Bitumen — Specification", Indian Standard, Bureau of Indian Standards, 2006.

[19] IS 1201 to IS 1220:1978, "Methods for Testing Tar and Bituminous Materials", 1st Revision, Indian Standard, Bureau of Indian Standards, 1978.

[20] Chowdhury, A., and Button, J.W., (2008), "A Review of Warm Mix Asphalt", Report SWUTC/08/473700-00080-1, Texas Transportation Institute - Technical Report, USA.