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Effect of warm mix additives on mixing, laying and compaction temperatures of warm mix binders

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ABSTRACT

Increased environmental awareness and strictness in emissions regulations have led to development of Warm Mix Asphalt (WMA). The potential of WMA in reducing the energy consumption as compared to Hot Mix Asphalt (HMA) is becoming more and more attractive nowadays. The goals for the WMA are to lower the mixing and compacting temperatures by reducing the viscosity of the binder, and using the same HMA plants to produce mixes that still meet specifications. The benefits of WMA include reduced emissions, decreased energy (fuel) consumption, reduced asphalt oxidation and early traffic opening. Several technologies of WMA are available today such as Aspha-min, Sasobit, Evotherm, WMA-Foam and Asphaltan B. Viscosity of the binder is used to determine its mixing, laying and compaction temperatures.In the present study Brookfield Viscometer is used for determination of the viscosity of bituminous binders with different combinations of additives at different temperatures ranging from 90ºC to 160ºC. Two binders VG 30 and CRMB 55, and two additives Sasobit and Evotherm are used. The results shows that the viscosity of the bituminous binders varies exponentially with the temperature and linearly with respect to the dose of Warm Mix additives and the mixing temperature can be reduced by 20ºC to 25ºC while laying and compaction temperature can be reduced by 10ºC to 15ºC by using these additives.

Introduction

The Indian road network consists of 200 km of Expressways, 70934 km of National Highways, 154522 km of State Highways, 863241 km of Major District Roads, 2450559 km of Rural Roads and 574516 km of other roads (includes urban roads and project roads)[7]. Most of these roads are of flexible type and thus uses HMA (Hot Mix Asphalt). It is often mixed at temperatures of 149ºC to 176ºC depending upon the type of binder.[1] Rising energy cost and increased environmental awareness have brought attention to the potential benefits of Warm Mix Asphalt (WMA) binders.

WMA is produced by incorporating additives into asphalt mixtures to allow production and placement of the mixture at temperatures well below the temperatures of conventional hot-mix asphalt (HMA). Warm Mix Asphalt (WMA) is the process of using additives to reduce the mixing temperatures of HMA by 10ºC to 35ºC [9]. Benefits such as reduced plant emissions, improved compaction in the field, extension of the paving season into colder weather, and reduced energy consumption at the plant may be realized with different applications. Lower production temperatures may also increase mixture durability by reducing production aging of the mixture.

However, this area is quite new and research on different additives available commercially is in very primitive stage. The present investigation was conducted to study the influence of different doses of warm mix additives on the viscosity of the binder. The reduction in viscosity can be advantageously used to reduce the mixing, placing and compaction temperatures of the Warm Mix Asphalt.

Warm Mix Additives

Various types of additives are available in the market, which are used to reduce the viscosity of the bitumen and thus reduces the mixing, placing and compaction temperatures of the binder. Some most commonly used additives are:

Aspha-min Zeolite

Aspha-min zeolite is hydro-thermally crystallised silicate of natrium-aluminum. It contains approximately 21% water by weight and is released in the temperature range of 85-180°C. Aspha-min is added to an asphalt mixture at a rate of 0.3% by mass of the mix, which enables approximately a 30°C reduction in production and placement temperatures. [2]

Sasobit

Sasobit is a product of Sasol Wax International and has been marketed in Europe and Asia since 1997. Sasobit is a mixture of long chain hydrocarbons produced from coal gasification. It does not contain ash-forming materials (metals) or hetero-atoms such as chlorine, sulphur, nitrogen and oxygen. Therefore, it has good oxidation and ageing stability and may be stored indefinitely. Sasobit's melting point is at about 100°C and it is completely soluble in bitumen at temperatures above 120°C, and it does not separate out on storage. It reduces viscosity at working temperatures which makes the asphalt easier to be processed. [5]

Asphaltan B Wax

Asphaltan B is a low molecular weight esterified wax that enables the application of asphalt blends at lower temperatures by reducing viscosity. It is recommended to use it at the rate of 2 to 4% of weight relative to the binder. It can be added to the asphalt mixing plant or directly at the binder producer and it can

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also be added to polymer modified binders. Similar to Sasobit, it acts as an asphalt flow improver by increasing compactability and resistance to rutting. The melting point of Asphaltan B is approximately 99°C and it allows reduced production temperatures. [4]

Evotherm

Evotherm is a non-proprietary technology based on a chemical process that includes additives to improve coating and workability, adhesion promoters and emulsion agents. The Evotherm product is delivered in the form of an emulsion with a relatively high asphalt residue (approximately 70%). Unlike traditional asphalt binders, Evotherm is stored at 80°C (176°F). The water in the emulsion is released from the Evotherm as steam when it is mixed with the hot aggregate. The resulting warm mix appears like a hot mix in terms of coating and colour. [6]

Experimental Program

In the present study different Warm Mix Binders are prepared by mixing different doses of additives. The variation of their viscosity with temperature is then studied. The Brookfield viscometer is used for this purpose.

Materials Used

The materials which are used in the present study are as follows:

Binders

VG 30 and CRMB 55 are the two binders which were taken in the present study.

Additives

Two additives which are commercially available were taken (Figure 2.1).

i. Sasobit :- The different doses of sasobit used in this study are 0.5%, 1.0%, 1.5% and 2.0%, by weight of the binder.

ii. Evotherm :- The different doses of evotherm used in this study are 0.2%, 0.4% and 0.6%, by weight of the binder.

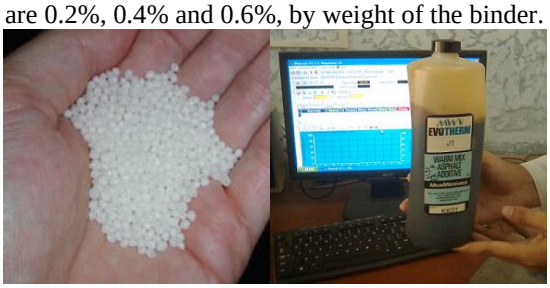

Figure 2.1 Sasobit and Evotherm

Preparation of Samples

The two additives were used to prepare 14 types of Warm Mix Binders. In addition to this, two samples of neat binders (one of VG 30 and another of CRMB 55) were also taken to compare the results. The bitumen was heated to a fluid condition and mixing of different additives was performed in the laboratory with a mechanical stirrer at a frequency of 1550 rpm. From these 16 types of binders, samples are taken for testing at eight different temperatures viz. 90ºC, 100ºC, 110ºC, 120ºC, 130ºC, 140ºC, 150ºC and160ºC. Thus a total of 128 samples are tested for viscosity.

Tests Conducted

The viscosity tests on the samples were conducted using Brookfield Viscometer. The torque required to maintain a constant rotational speed of a cylindrical spindle while submerged in the sample at a constant temperature is used to measure the relative resistance to rotation. The measured torque and measured speed are used to determine the viscosity of the binder.[3] The Brookfield Viscometer is connected to the computer and it is operated with the help of software "Rheocalc".

Test Results

The results obtained from laboratory tests on two binders with different doses of additives are as follows.

Variation in Viscosity

The results of viscosity tests on Warm Mix binders are given in Tables 4.1 to 4.4

Mixing, Laying and Compaction Temperatures

The mixing, laying and compaction temperatures of the bituminous mix is determined with respect to the viscosity of the binder. Mixing should be done at the temperature when viscosity is around 0.2 Pa.s (200 cP) while the laying and compaction should be done when viscosity is around 5 Pa.s (5000 cP). [8]

Based on the variation of the viscosity, the variation in the mixing, laying and compaction temperatures is determined and tabulated in Tables 4.5 to 4.8.

Discussion on Results

The results show that the viscosity of the bituminous binders varies exponentially with the temperature and linearly with respect to the doses of Warm Mix additives. Evotherm is more effective than Sasobit, this can be deduced from the fact that the viscosity which is achieved by addition of 2% sasobit, is achieved by the addition of only 0.6 % evotherm. The mixing temperature can be reduced by 20ºC to 25ºC while laying and compaction temperature can be reduced by 10ºC to 15ºC by using these additives (ie Sasobit or Evotherm). It would result in less environmental hazards in terms of Emissions, Environmental pollution, and the most important less energy consumption.

Conclusions

The following conclusions are drawn from the present study carried out on the Warm Mix Binders.

- The viscosity of the Warm Mix Binders varies exponentially with respect to the temperature.
- The addition of Sasobit and Evotherm to the bitumen reduces its viscosity even when the temperature is constant.
- The dose requirement of Sasobit is more than that of the Evotherm.
- Addition of Warm Mix Additives (Sasobit and Evotherm) reduces the mixing temperature by 20 ºC to 25 ºC and laying and compaction temperature by 10 ºC to 15 ºC.

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Table 4.1 Viscosity of VG 30 with Sasobit

Temperature (ºC)	Viscosity with Sasobit dose (cP)				
	0%	0.50%	1.00%	1.50%	2.00%
90	16325	12775	11325	9350	7550
100	5575	4850	4675	4050	3560
110	3000	2725	2300	1925	1800
120	1450	1125	1050	975	925
130	900	800	725	600	550
140	575	500	450	375	325
150	350	275	250	225	200
160	250	225	200	175	150

Table 4.2 Viscosity of CRMB 55 with Sasobit

Temperature (ºC)	Viscosity with Sasobit dose (cP)				
	0%	0.50%	1.00%	1.50%	2.00%
90	13200	12350	11700	9175	7600
100	5200	5150	5100	4350	3700
110	2950	2650	2350	2075	1950
120	1400	1350	1250	1125	975
130	775	750	650	575	475
140	500	450	400	350	300
150	325	300	250	225	175
160	250	225	200	175	125

Table 4.3 Viscosity of VG 30 with Evotherm

Temperature (ºC)	Viscosity with Evotherm dose (cP)			
	0.00%	0.20%	0.40%	0.60%
90	16325	11500	10225	9150
100	5575	4725	3675	3025
110	3000	2475	1925	1775
120	1450	1150	1000	900
130	900	800	675	550
140	575	475	400	275
150	350	300	325	225
160	250	225	200	150

Table 4.4 Viscosity of CRMB 55 with Evotherm

Temperature (ºC)	Viscosity with Evotherm dose (cP)			
	0.00%	0.20%	0.40%	0.60%
90	13200	10600	7125	6550
100	5200	4025	3150	2550
110	2950	2000	1700	1575
120	1400	1200	925	675
130	775	725	575	500
140	500	425	350	275
150	325	300	250	200
160	250	200	175	125

Table 4.5 Mixing, Laying and Compaction temperatures of VG 30 and Sasobit blend.

Sasobit Content (%)	Mixing Temperature(ºC)	Laying and Compaction Temperature(ºC)
0.00	170	105
0.50	165	98
1.00	160	96
1.50	155	94
2.00	150	92

Table 4.6 Mixing, Laying and Compaction temperatures of CRMB 55 and Sasobit blend.

Sasobit Content (%)	Mixing Temperature(ºC)	Laying and Compaction Temperature(ºC)
0.00	170	103
0.50	165	102
1.00	160	101
1.50	155	95
2.00	145	92

Table 4.7 Mixing, Laying and Compaction temperatures of VG 30 and Evotherm blend.

Evotherm Content (%)	Mixing Temperature(ºC)	Laying and Compaction Temperature(ºC)
0.00	170	105
0.20	165	98
0.40	160	95
0.60	152	92

Table 4.8 Mixing, Laying and Compaction temperatures of CRMB 55 and Evotherm blend.

Evotherm Content (%)	Mixing Temperature(ºC)	Laying and Compaction Temperature(ºC)
0.00	170	103
0.20	160	95
0.40	157	92
0.60	150	91