DENSITY AND COMPACTION CHARACTERISTICS OF WMA USING ADDITIVES

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Abstract

Warm mix asphalt (WMA) is an emerging technology that can allow asphalt to be produced and compacted at a significantly lower temperature. Several new processes have been developed to reduce the mixing and compacting temperatures without scarifying the quality of resulting pavement. One of the processes is by adding chemical additives in the mix. The additives added with the aggregates improve the compactibility of the mixture and reduces the rutting potential of the pavement. WMA offers many significant advantages such as energy saving, decreased emission and fumes, decrease binder aging and extend paving season into the cold-winter months and at places located at high altitudes. One of the WMA processes utilizes Sasobit®, a synthetic long chain Fischer-Tropsch wax. Sasobit® can be blended with the binder at a terminal or in the asphalt tank. Sasobit® was shown to improve the compactability of mixtures and overall reduction in air voids. The addition of Sasobit® increases the rutting potential of asphalt mix. The rutting potential will increase with decreasing mixing and compaction temperatures. In this thesis warm mix asphalt is designed for Dense Bituminous Macadam (DBM) of grade 2 with the addition of Sasobit® and test for compactability characteristics and property of asphalt mixture against deformation are carried out.

Keywords: *Dosage, Indirect tensile strength, Rutting.*

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1. INTRODUCTION

Warm Mix Asphalt (WMA) is a new technology which was introduced in recent years. WMA is gaining attention all over the world because it offers several advantages over conventional asphalt concrete mixes. The benefits include (1) Reduced energy consumption in the asphalt mixture production process; (2) Reduced emissions, fumes, and undesirable odours; (3) More uniform binder coating on aggregate which should reduce mix surface aging; and (4) Extended construction season in temperate climates. WMA requires the use of additives to reduce the temperature of production and compaction of asphalt mixtures.

Traditional HMA is usually produced at temperatures between 140 and 180°C (284 and356°F) and compacted at about 80 to 160°C (175 to 320°F). The temperature of the asphalt mix has a direct effect on the viscosity of the asphalt cement binder and thus compaction. As hot mix asphalt temperature decreases, its asphalt cement binder becomes more viscous and resistant to deformation, which results in a smaller reduction in air voids for a given compactive effort. The goal of the WMA process is to reduce the high temperatures at which traditional asphalt mixes are produced and placed without adversely affecting these properties. Its benefits are reduction in the energy consumption that is required to heat traditional HMA to temperatures. The aim of lowering of Hot Mix Asphalt operating temperature is to

- Reduce the high asphalt operating temperature keeping the primary physical and mechanical characteristics of Hot Mix Asphalt.
- Lowering of Hot Mix Asphalt operating temperature is based on binder viscosity reduction in specified range of temperature.
- Reduction of binder viscosity enables the complete coating of aggregates in lower temperature.

1.1 Objectives

- To compare the properties of WMA to that of HMA for the DBM mix (grading 2) specified by MoRT&H.
- To determine and compare the volumetric properties and stability of bituminous mix produced using HMA and Sasobit® as warm mix additive.
- Comparison of Indirect Tensile strength value of WMA produced at varying temperatures.
- To evaluate the rutting performance of WMA at different mixing temperatures using Rolling Compactor cum Rut Analyser (RCRA) equipment.

2. LITERATURE REVIEW

In 1956, Prof. Ladis Csanyi, Iowa State University, realized the potential of foamed bitumen for use as a soil binder. Since then, foamed asphalt technology, which allows lower mixing temperatures, has been used successfully in many countries. The original process consisted of injecting steam into hot bitumen. In 1968, Mobil Oil Australia, which had acquired the patent rights for Csanyi’s invention, modified the original process by adding cold water rather than steam into the hot bitumen. The bitumen foaming process then became more practical [4].Conoco was later licensed to market foamed asphalt in the U.S. and further advanced the technology and evaluated the product as a base stabilizer both in the laboratory and in the field. [8]

In the early 1970s, Chevron developed mixture design and thickness design methodologies for paving mixtures (base, open-graded, and dense-graded) stabilized with Emulsified asphalt. In 1977, Chevron published their "Bitumuls Mix Manual" as a practical guideline, which contains much valuable information for specifying, designing, and producing emulsion-stabilized mixtures. Later, other similar guidelines followed (FHWA, 1979; Asphalt Emulsion Manufacturers Association [AEMA], 1981). [1]

Kuennen reported that emulsified asphalt mixes are popular in rural settings where distances from HMA plants and lower traffic volumes may preclude HMA. Further, cold-mix plants have a lower initial cost than conventional HMA plants, are more easily transported, and may be situated anywhere without Environmental Protection Agency (EPA) permits due to their lack of emissions. Furthermore, they are amenable to mixes with high percentages of reclaimed asphalt pavement. [5]

In 1994, Maccarone et al., studied cold-mixed asphalt-based foamed bitumen and very high binder content emulsions and concluded that the use of cold mixes for use on roads was gaining acceptance worldwide due to energy efficiency and lower emissions. In fact, they stated that, "Cold technologies represent the future in road surfacing". [6]

In 1995, Shell Bitumen filed a patent to cover a warm-mix asphalt technique that used a two-component technique, of Shell Global Solutions, described an innovative WMA process that was tested in the laboratory and evaluated in large-scale field trials (in Norway, the United Kingdom, and the Netherlands) with particular reference to the production and placement of dense-graded wearing courses. Shell's work resulted in the development of WAM-Foam®. [2]

Jenkins et al., introduced a new process involving a half-warm foamed bitumen treatment. They explored the concepts and possible benefits of heating a wide variety of aggregates to temperatures above ambient but below 212°F before the application of foamed Bitumen. Preheating aggregates enhanced particle coating, mix cohesion, tensile strength, and Compaction. This is particularly beneficial for mixes containing reclaimed asphalt pavement (RAP) or densely graded crushed aggregates. [3]

3. METHODOLOGY

The purpose of this study was to evaluate the laboratory performance of warm mix asphalt mixtures with additives (Sasobit®) for Dense bituminous macadam (DBM) Grade-2. After the determination of gradation, Marshall stability tests were conducted to determine the volumetric properties of the specimens; and rutting properties using Rolling Compaction and Rut Analysis (RCRA) Equipment for different mixing temperatures.

The coarse aggregates used in the present study are crushed hard rock passing 40mm, 20mm, 12mm and 6mm sieve sizes. The quarry dust passing 2.36mm sieve is used as mineral filler. Various tests conducted to determine basic properties of aggregates are given in Table, 3.1. VG-30 (60/70) penetration grade bitumen is used in the present study. The tests conducted to determine the basic properties of bitumen are shown Table 3.2.

Table -3.1: Physical properties of Coarse aggregates.

SI. No.	Properties	Test method	Obtained values	IS Specifications
1	Crushing value	IS-2386 part IV	25.1 %	Max 30%
2	Abrasion value	IS-2386 part IV	34.38%	Max 35%
3	Impact value	IS-2386 part IV	23.9%	Max 27%
4	Combined Flakiness and Elongation index	IS-2386 part I	21.56%	Max 30%
5	Water absorption test	IS-2386 part III	0.25%	Max 2%

Table-3.2: Physical properties of Bitumen.

SI. No.	Properties	Test method	Obtained values
1	Penetration(mm) (100g, 25˚C, 5 sec)	IS: 1203 - 1978	65
2	Softening point(˚C)	IS: 1205 -1978	52.4
3	Ductility at 25˚C (mm)	IS: 1208 -1978	100
4	Specific gravity	IS: 1202 -1978	1.01
5	Flash point test(˚C)	IS: 1209 -1978	280
6	Fire point test(˚C)	IS: 1209 -1978	315

Aggregate gradation greatly influences the performance of the pavement layers. For the design purpose binding course layer, Dense Bituminous macadam (DBM) of Grade 2 is selected. Table 3.3 shows obtained gradation for DBM Grade-2.

Table -3.3: Combined obtained gradation of DBM Grade-2

Sieve size (mm)	40 mm	12 mm	6 mm	Dust	Obtained Gradation	Lower limit	Upper limit
	26%	25%	19.0%	30%			
37.5	100	100	100	100	100.0	100	100
26.5	81.05	100	100	100	95.1	90	100
19	53.45	100	100	100	87.9	71	95
13.2	0	100	100	100	74.0	56	80
4.75	0	5	92	100	48.7	38	54
2.36	0	0.3	17	99.4	33.1	28	42
0.3	0	0	12	30	11.3	7	21
0.075	0	0	5	10	4.0	2	8

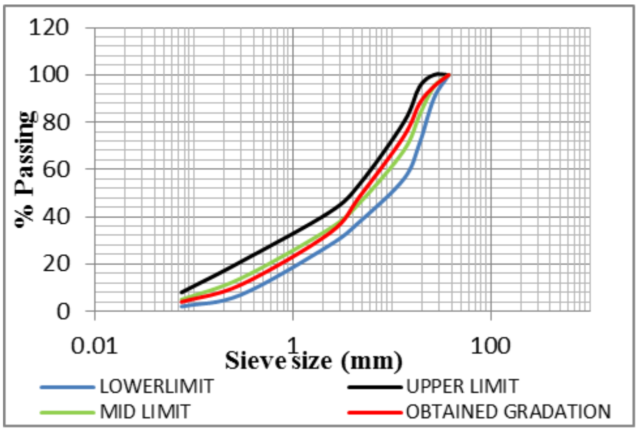

Fig -3.1: Combined obtained gradation of DBM Grade-2

3.1 Marshall Stability Test

The Marshall stability tests were conducted with varying percentage of binder content to determine the optimum binder content for HMA. Tests were also conducted for WMA to determine its volumetric properties with Sasobit® as additive at OBC for different mixing temperatures (120˚C, 130˚C, 140˚C). The tests were conducted according to IS specifications. The Marshall stability test results obtained are presented in Table -3.4 to Table -3.7

Table -3.4: Marshall Stability test results for HMA

SI. No	Properties	HMA
1	Optimum binder content in (%)	5.0
2	Stability (Kg)	1140
3	Flow (mm)	5
4	Bulk density (gm/cc)	2.27
5	Volume of air voids in (%)	3.38
6	VMA (%)	18.7
7	VFB (%)	59.16

Table -3.5: Marshall Stability test results for WMA at 120˚C

SI. No	Properties	WMA AT 120˚C Sasobit® percentage		
		1.5%	**2%**	**2.5%**
1	Stability (Kg)	1304	1329	1287
2	Flow (mm)	4.75	4.8	4.15
3	Bulk density (gm/cc)	2.31	2.34	2.30
4	Volume of air voids in (%)	7.85	6.74	8.35
5	VMA (%)	17.12	16.11	17.57
6	VFB (%)	54.13	58.20	52.45

Table -3.6: Marshall Stability test results for WMA at 130˚C

SI. No	Properties	WMA AT 130˚C Sasobit® percentage		
		1.5%	**2%**	**2.5%**
1	Stability (Kg)	1333	1436	1330
2	Flow (mm)	4.77	5	4.4
3	Bulk density (gm/cc)	2.29	2.37	2.34
4	Volume of air voids in (%)	8.65	5.30	6.67
5	VMA (%)	17.83	14.82	16.06
6	VFB (%)	51.51	64.25	58.44

Table -3.7: Marshall Stability test results for WMA at 140˚C

SI. No	Properties	WMA AT 140˚C Sasobit® percentage		
		1.5%	**2%**	**2.5%**
1	Stability (Kg)	1217	1229	1360
2	Flow (mm)	4.25	4	4
3	Bulk density (gm/cc)	2.33	2.32	2.31
4	Volume of air voids in (%)	7.04	7.48	7.75
5	VMA (%)	16.39	16.79	17.02
6	VFB (%)	57.04	55.42	54.49

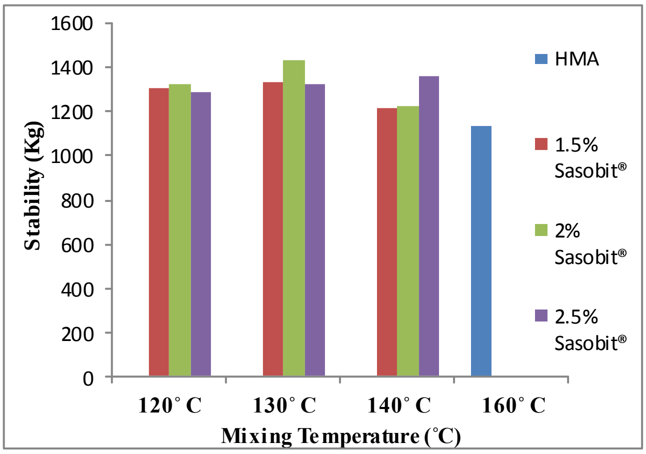

Fig -3.2: Relation between Stability and various mixing temperatures

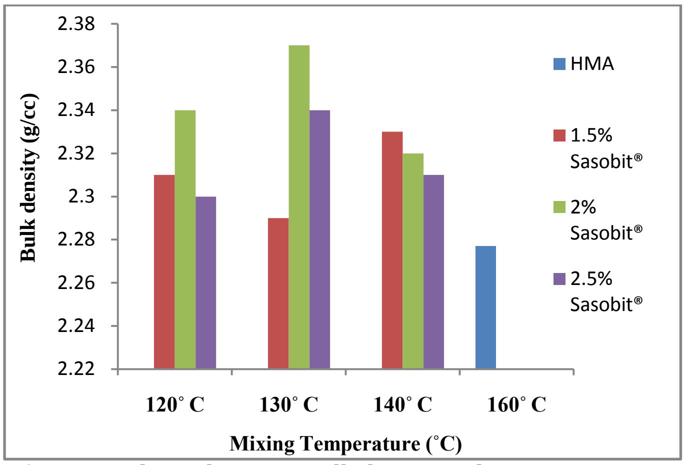

Fig -3.3: Relation between Bulk density and various mixing temperatures

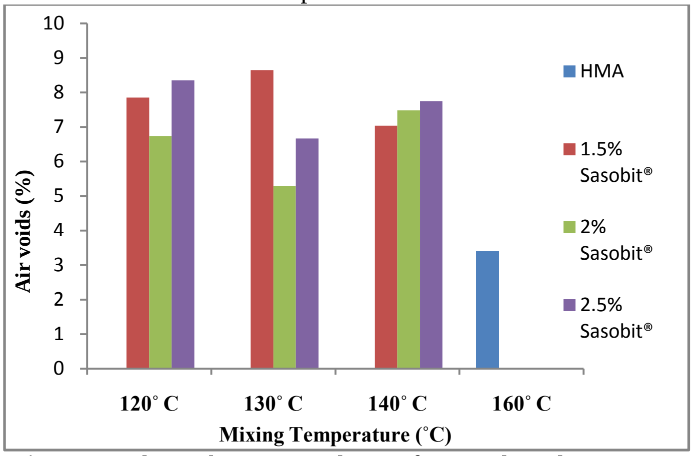

Fig -3.4: Relation between Volume of air voids and various mixing temperatures

3.2 Indirect Tensile Strength Test (ITS):

The indirect tensile strength test was conducted on unconditioned specimens casted at OBC with additive percent corresponding to maximum stability obtained from Marshall stability test for each mixing temperature. The specimens were soaked in water bath at 25±1˚C for 2 hours and tested for load at failure. The results of indirect tensile strength test performed on DBM mix are presented below.

Table -3.8: Results of Indirect tensile strength test.

Temperature (˚C)	Indirect tensile strength (N/mm^2)
110	0.252
120	0.349
130	0.376
140	0.30
HMA	0.303

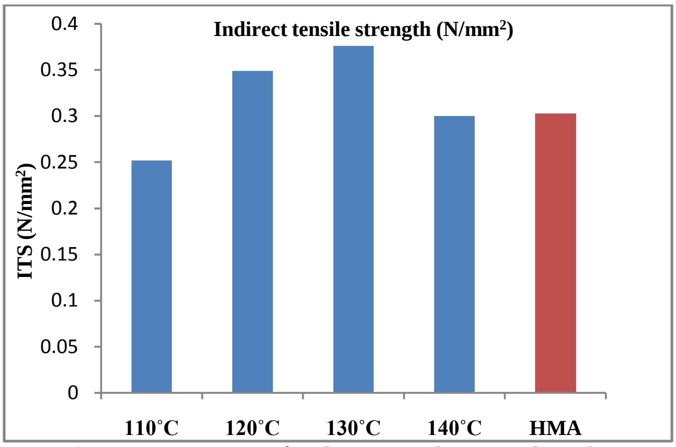

Fig -3.5: Variation of Indirect tensile strength with gradation

3.3 Rutting Characteristics

The DBM specimens of Grade 2 and height 63.5mm were casted at OBC with Sasobit® and analysed for rut depth of 12mm at a tyre pressure of 8.4 Kg/cm^2 for various mixing temperatures and field temperatures (30˚C and 60˚C).

Table -3.9: Relationship between number of passes at varying rutting temperatures for DBM at different mixing temperatures.

Rutting Temperature (˚C)	Number of passes			
	Mixing temperatures of DBM			
	HMA	120˚C	130˚C	140˚C
30	10700	12900	15200	13700
60	3900	3950	4200	4150

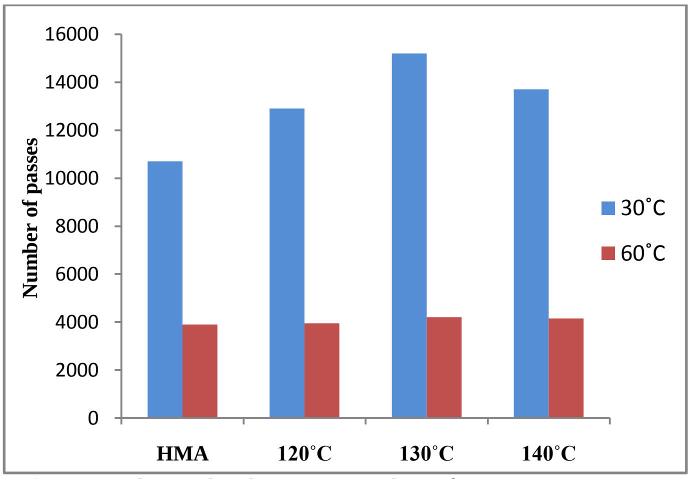

Fig 3.6: Relationship between number of passes at varying rutting temperatures.

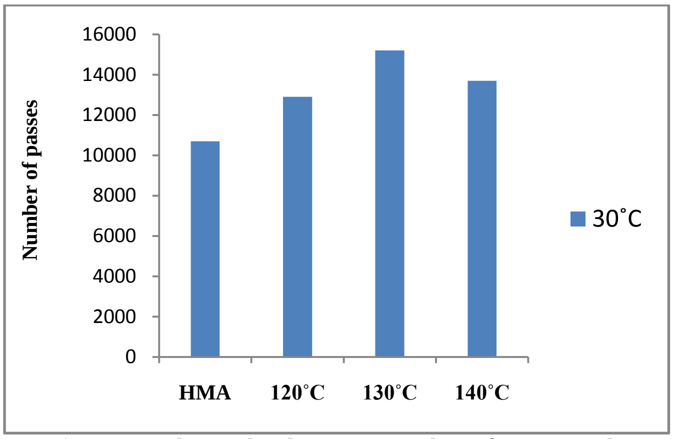

Fig -3.7: Relationship between number of passes and temperature at 30˚C.

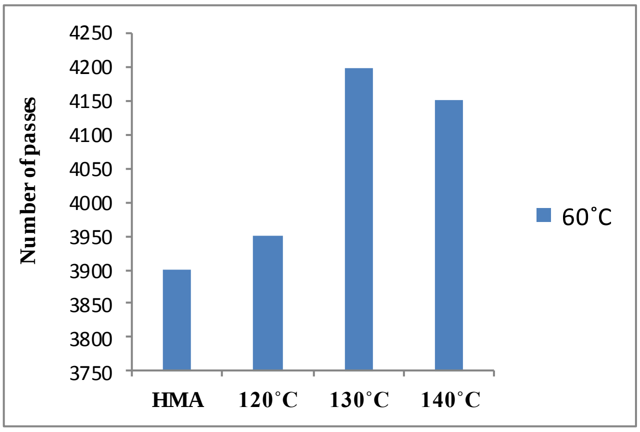

Fig -3.8: Relationship between number of passes and temperature at 60˚C

4. CONCLUSIONS

In the present study, the importance was to add the warm mix additives to Dense Bituminous Macadam (DBM) mix and to evaluate the various mix properties like Marshall Stability, flow, bulk density, voids in the mix and VFB. Also Indirect Tensile Strength was investigated for OBC and Rutting test was done for various field temperatures.

- The OBC was found to be 5% for HMA at 160˚c temperature.
- The maximum stability for 60/70 grade bitumen is achieved at 130˚C temperature with 2% dosage rate. Among 120˚,130˚, 140˚C temperature ,the 130˚C temperature shows better and maximum stability
- From Marshall stability test, it can be concluded that there is an increase in stability up to 25% at 130˚C for 60/70 grade bitumen after adding Sasobit® to the mix .Hence the warm mix additive of 2% Sasobit® at 130˚C temperature can be used as an alternative for HMA.
- The addition of WMA additive Sasobit® improves the bulk density of the mix by 4.08%. Hence 130˚C temperature with additives shows better and maximum bulk density.
- The Indirect tensile strength of a mix with WMA additive was 24% higher than HMA. i.e., this shows that the WMA additive play important role in increasing the strength of the specimen. Hence the WMA specimen at 130˚C temperature with 2% Sasobit® additive dosage meets the requirement of HMA specimen of 160˚c temperature.
- The rutting test conducted with Rolling Compactor cum Rut Analyser (RCRA) equipment for rutting temperature of 30˚C shows maximum number of passes at 130˚C with Sasobit® of 2% dosage. There is an increase in 42% with the addition of additive. As the rutting temperature increases to 60˚C, there is a considerable decrease in number of passes. Even though the maximum number of passes is showed by WMA at 130˚C with Sasobit®.

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