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Evaluation of Marshall Properties of Warm Mix Asphalt using Sasobit

Renugadevi. A
[*] PhD Scholar, Techno Global University, Meghalaya, India
& Assistant Engineer in Tamilnadu Highways Department

Abstract
With increasing concerns of global warming and increasing exhaustion of greenhouse gases, the asphalt industry is looking for alternatives for hot mix asphalt (HMA).Warm Mix Asphalt (WMA) is a fast emerging new technology which has a potential of revolutionizing the production of asphalt mixtures. WMA technology allows the mixing, lay down and compaction of asphalt mixes at significantly lower temperatures compared to Hot Mix Asphalt (HMA). The technology can reduce production temperatures by as much as 30 percent. Asphalt mixes are generally produced at 150º C or greater temperatures depending mainly on the type of binder used. WMA mixes can be produced at temperatures of about 120ºC or lower. In this study an attempt has been made to compare HMA and WMA with organic additive (Sasobit) with various dosages on the Marshall properties for Dense Bituminous Macadam(DBM) Grade 2. The adopted mixing temperatures for HMA was 155°C,130°C and 115°C and the mixing temperatures for WMA was 130°C and 115°C. The laboratory study concludes that Stability & Marshall properties were improved for the WMA mix by the addition of the additive.

Keywords: Warm mix asphalt, Sasobit, Marshall properties.

Introduction

Need for WMA

Overexploitation of the country's resources has resulted environmental degradation of resources. India's carbon dioxide emissions were roughly 2 billion tonnes in 2012. India is among the world's worst performers when it comes to the overall environment. A 2014 study by Yale University ranked India 155th out of 178 nations on an overall environmental performance index. On air pollution, we ranked last. The costs of these failures are high. A recent report in the New York Times estimated that air pollution in India may cost us over three years in life expectancy. This does not even count the costs of air pollution in infant mortality, disease and reduced productivity. WHO latest surveys show that India has the world's worst air pollution, and has 13 of the 20 most polluted cities of the world.

Transportation is one of the major global consumers of energy, currently representing between 20% to 25% of aggregate energy consumption and CO2 emissions and a strong growth has been projected in all sectors with the same proportion from Transportation. Energy efficient technologies are developed to response to the problems and also considered in construction phases of asphalt mixes for road construction. Over the year, Hot Mix Asphalt (HMA) is the common technique that been used in the road construction industry and produced at 160ºC. The high temperature can emit the pollution dust, particulate matter (PM), fumes and variety of gaseous to environment such as carbon monoxide, nitrogen oxides and sulphur dioxide. These gases contribute to the global warming problems. In India the Supreme court has banned the use of Hot mix asphalt (HMA) plants in metropolitan cities like Delhi to reduce CO_2 emission. With environmental emission laws forever being tightened by time may be right for India to tilt its way towards environmental friendly technology. Warm Mix Asphalt (WMA) is a fast emerging new technology which has a potential of revolutionizing the production of asphalt mixtures. Warm Mix Asphalt (WMA) is a new technology which was introduced in 1995 in Europe.WMA is gaining attention all over the world in recent times.

For many years, the asphalt industry has thought about energy savings and environmental benefits in asphalt production processes. Additionally, environmental awareness has been increasing rapidly over past ten years when air pollution reduction targets ratified by the European Union with the Kyoto Protocol have encouraged efforts to reduce pollution. HMA industry is exploring for technological improvements which will allow them to reduce high asphalt mix production temperatures

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but will not change asphalt mix workability and physical mechanical properties. HMA is produced at temperatures between 140°C–180°C and compacted at temperatures between 120°C – 160°C. These temperatures ensure that aggregate is dry, the asphalt binder coats the aggregate and HMA is workable. For asphalt mixes containing polymer modified binders even higher temperatures are used. Temperature of the asphalt mixture has a direct impact on binder's viscosity as well as compaction. With the decreasing temperature of HMA mixture the binder of asphalt mixture becomes thicker, more resistant to deformation and more poorly compacted. Finally, the binder becomes so hard, that compaction is impossible. Production of warm mix asphalts and half-warm mix asphalts is one of those efforts to reduce pollution and to use other lower temperature asphalt mix benefits.

Types of asphalt mixtures

Asphalt mixtures according to their mixing temperature and energy consumed for the heating process of materials are divided into:

- **Cold mix asphalt (CMA)** – asphalt mixture produced at an ambient temperature using bitumen emulsion or foam.
- **Half warm mix asphalt (HWMA)** – asphalt mixture produced at a temperature below water vaporization.
- **Warm mix asphalt (WMA)** – asphalt mixture produced at a temperature range of 120°C to 140 °C.
- **Hot mix asphalt (HMA)** – asphalt mixture produced at a temperature range of 150°C to 180°C in relation with the used binder.

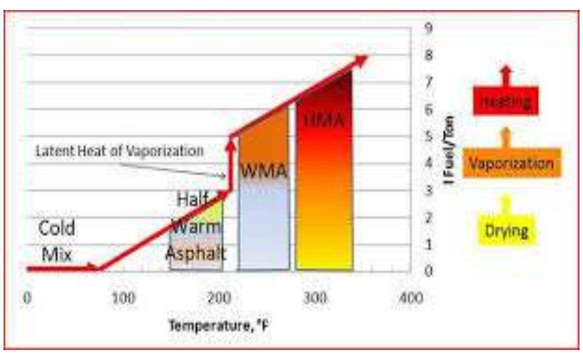

Fig 1: Classification by temperature range

Warm mix asphalt technologies

a) By use of water
b) By use of Water bearing additives
c) By use of organic additives
d) By use of chemical additives

Objectives

- To determine the suitability of Sasobit in Warm Mix asphalt (WMA) applications physical lab tests.
- To study the effect of Sasobit on the properties of Dense Bitumen Macadam at different concentrations.
- To determine the Optimum Bitumen Content of HMA and Sasobit added WMA.
- To compare the Marshall properties of HMA and WMA.

Materials and methods

Coarse and fine aggregate

According to IS 383:1963 aggregates which are retained on 4.75 mm IS Sieve is defined as coarse aggregate and which will pass through 4.75 mm IS Sieve is defined as fine aggregate. The Ministry of Road Transport and Highways (MORTH) recommended gradation as per nominal maximum size of aggregate (NMSA) 19 mm for DBM. The laboratory test results of aggregates have been given in Table 1.

Table 1: Gradation for DBM (Gr-2) (MORTH-Rev V)

IS Sieve(mm)	% passing (range)	%passing (adopted)
45		
37.5		
26.5	100	100
19	90-100	95
13.2	56-88	72
9.5		
4.75	16-36	26
2.36	4-19	11.5
1.18		
0.6		
0.3	2-10	6
0.15		
0.075	0-8	4

Binder

Bitumen acts as a binder in DBM mix. VG 30 grade bitumen is taken for study.

Filler

For this study, stone dust i.e. Quarry dust has been used as filler for DBM composition respectively. The

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filler also improve the binding property between the aggregate.

Table 2: Laboratory test result of aggregates

Test of Aggregates	Requirement	Lab Results
Impact Value (IS 2386-Part IV)	Max 27%	26.45%
crushing value (IS 2386-Part IV)	Max 45%	39%
Abrasion Value (IS 2386-Part IV)	Max 35%	29.80%
Specific Gravity (IS 2386- Part III)	2.5-3	2.63
Flakiness & Elongation Index (IS 2386-part IV)	Max 35%	31%
Water absorption (IS 2386 Part III)	Max 2%	0.50%

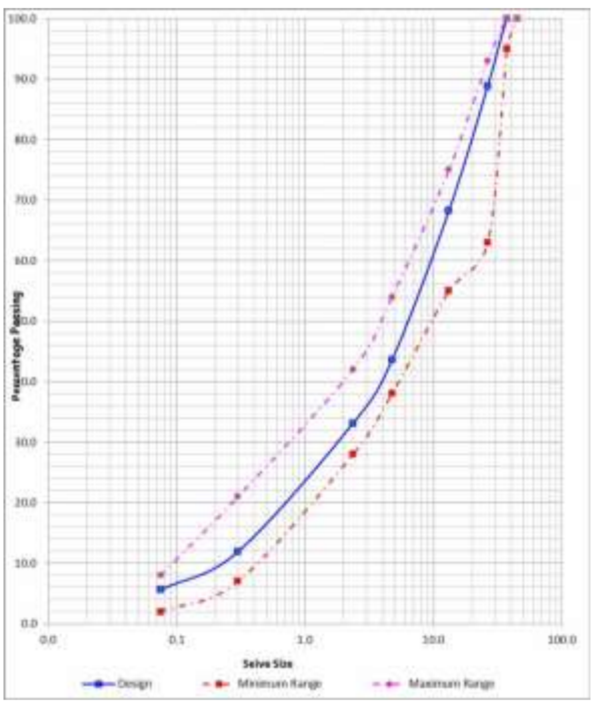

Fig 2: Sieve size(x axis) vs % finer(y axis)

Sasobit (Additive)

SASOBIT is a long-chain aliphatic hydrocarbon that is produced by Sasol Wax in South Africa using the Fischer-Tropsch process. Its molecular chain length lies in the range of 40 to more than 115 carbon atoms. In contrast the molecular chain lengths of paraffin are naturally found in bitumen range from 22 to 45 carbon atoms. This explains why SASOBIT has quite different physical properties to the paraffin's normally present in bitumen. Therefore, they are not directly comparable. The melting point range of SASOBIT is between 85°C - 115°C.

Sasobit is completely soluble in bitumen at temperatures in excess of 115°C. It forms a homogeneous solution with base bitumen on stirring and produces a marked reduction in the bitumen's viscosity. This enables mixing and handling temperatures of the asphalt to be reduced by 10°C–30°C. Temperature reductions of up to 50°C can be reached by process optimization between the mixing plant and paving. This in turn results in a significant reduction of bitumen fumes emissions and CO_2 (= energy savings) during such operations. During cooling the Sasobit crystallizes out and forms a lattice structure in the bitumen which increases the asphalt stability.

The benefits of using **Sasobit in WMA** are numerous and include:

- Lower plant mixing temperatures, from 300 °F to 250 °F, allows for up to a 19% **fuel cost savings** to the contractor.
- Lower mixing temperatures at the plant leads to a reduction in emissions which in turn leads to a reduction in overhead costs related to emissions control.
- Lower mixing temperatures will **minimize oxidative hardening** of the asphalt and this will lead to reduced thermal cracking of the pavement and potentially a longer lifetime.
- When produced at normal temperatures **longer haul distances**, as well as a longer **construction season** become possible.
- Lower emissions during the paving operation provide a healthier work environment for the contractors and the neighborhood in case of a residential project.
- Sasobit® is **versatile,** safe and is easily blended into the binder at the terminal or into the mix at the Hot Mix Plant.

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Fig 3: Sasobit Prills

Analysis of DBM

The design of dense bituminous macadam (DBM) consists of individual gradation of various available aggregates, proportioning of aggregates of different gradation to meet the desired specifications and finding out the optimum binder content for conventional VG – 30 Bitumen as per Marshall Method of mix design.

There are two major features of the Marshall method of designing mixes namely :

• Density – Void analysis
• Stability – Flow analysis

The Marshall stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature of 60°c. The flow value is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test. (The flow value may also be measured by deformation in units of 0.01 mm.)

The design steps for the design of bituminous mixes are given below:

- Selection of grading of aggregate to be used
- Selection of aggregates to be employed in the mix.
- Determination of the proportion of each type of aggregate required to produce the design grading.
- Determination of the specific gravity of the aggregate combination and of the asphalt.
- Making trial specimens with varying asphalt contents.
- Determination the specific gravity of each compacted specimen.
- Stability test on each specimen.
- Calculation of the percentage of voids, VMA and the % voids filled with bitumen in each specimen
- Selection of the optimum bitumen content from the data obtained
- Checking the values of Marshall – Stability, flow, voids in total mix and voids filled with bitumen obtained at the optimum binder content, with the design requirements. The design may be repeated if fails to fulfill the design requirements

Results and discussion

Parameters used

Evaluating specific gravity of an aggregate, some definitions of specific gravity are proposed:

- Bulk specific gravity (Gmb) of the mix

Gmb = (Mmix bulk volume of mix) (1)

- Bulk specific gravity (Gsb) of aggregates

Gsb= Mass of aggregate / volume of (aggregate mass +air void in aggregate + absorbed bitumen) (2)

- Theoretical maximum specific gravity (Gmm) of the mix

Gmm = Mmix / volume of (mix−air voids) (3)

- Air voids (VA)

VA = (1− (Gmb / Gmm)) ∗100 (4)

- Voids in mineral aggregates (VMA)

VMA = (1− ((Gmb / Gsb)∗ Ps)) ∗100 (5)

- Voids filled with bitumen (VFB)

VFB = ((VMA−VA) / VMA) * 100 (6)

Table 3: Stability Vs % of Sasobit

Tempe rapture °C	**Bitumen with different % of sasobit**					
	0%	**1%**	**2%**	**3%**	**4%**	**5%**
115	11.53	12.51	13.71	14.63	15.31	15.19
125	11.89	13.56	16.02	15.91	15.56	15.55
135	12.64	14.31	16.72	16.31	16.19	15.87
155	13.42	14.78	16.82	16.57	16.49	16.21

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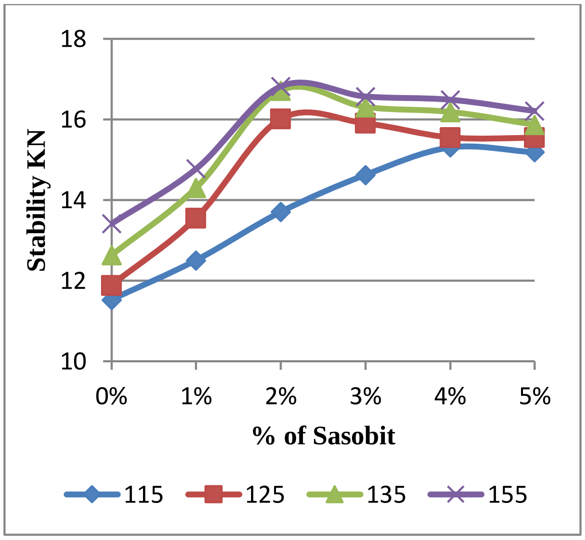

Fig 3: Stability Vs % of Sasobit

Table 4: Flow Vs % of Sasobit

Tempe rapture ºC	Bitumen with different % of sasobit					
	0%	**1%**	**2%**	**3%**	**4%**	**5%**
115	3.71	3.53	3.69	3.86	4.06	4.27
125	3.23	3.31	3.47	3.56	3.94	4.2
135	3.11	3.16	3.25	3.46	3.87	4.07
155	2.94	2.97	3.02	3.23	3.71	4.1

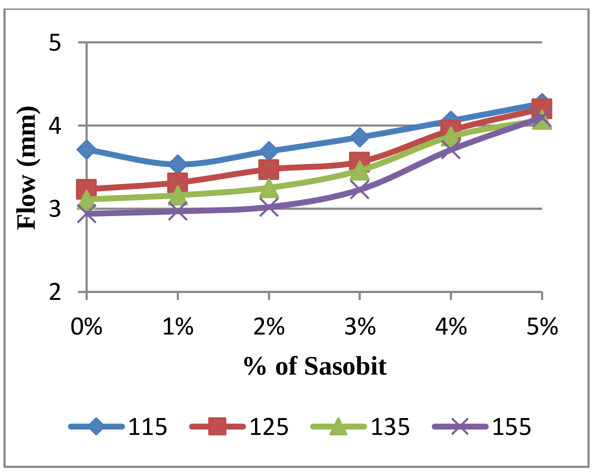

Fig 4: Flow Vs % of Sasobit

Table 5:Density Vs % of Sasobit

Tempe rapture ºC	Bitumen with different % of sasobit					
	0%	**1%**	**2%**	**3%**	**4%**	**5%**
115	2.36	2.41	2.43	2.44	2.45	2.46
125	2.37	2.42	2.45	2.46	2.46	2.47
135	2.41	2.44	2.46	2.46	2.47	2.49
155	2.44	2.45	2.47	2.48	2.49	2.51

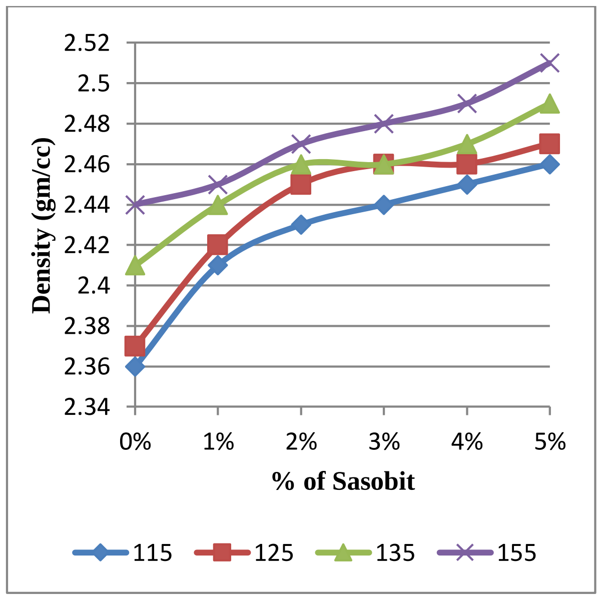

Fig 5: Density Vs % of Sasobit

Table 6:Air voids Vs % of Sasobit

Tempe rapture ºC	Bitumen with different % of sasobit					
	0%	**1%**	**2%**	**3%**	**4%**	**5%**
115	5.30	3.86	3.06	2.56	2.63	2.33
125	5.11	3.37	2.68	2.37	2.31	1.94
135	4.54	3.11	2.30	2.18	1.87	1.39
155	3.79	2.61	1.97	1.6	1.35	1.00

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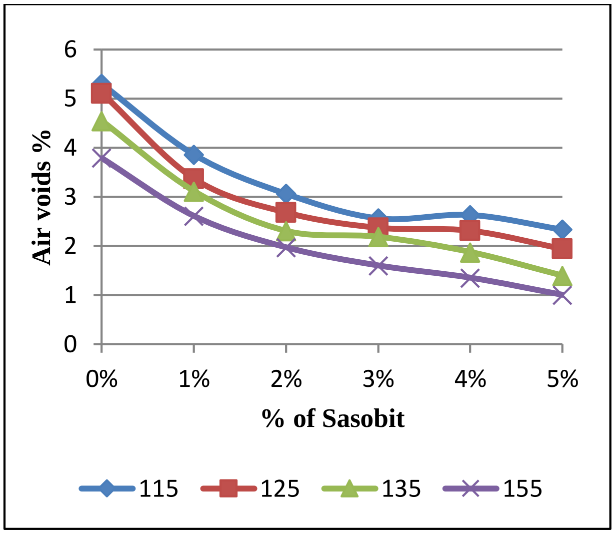

Fig 6: Air voids Vs % of Sasobit

Table 7: VFB Vs % of Sasobit

Tempe rapture °C	Bitumen with different % of sasobit					
	0%	**1%**	**2%**	**3%**	**4%**	**5%**
115	66.58	72.19	75.63	77.91	77.36	78.77
125	67.30	74.37	77.49	78.89	79.03	80.82
135	69.53	75.61	79.44	79.89	81.39	83.84
155	72.70	78.03	81.17	83.02	84.42	91.19

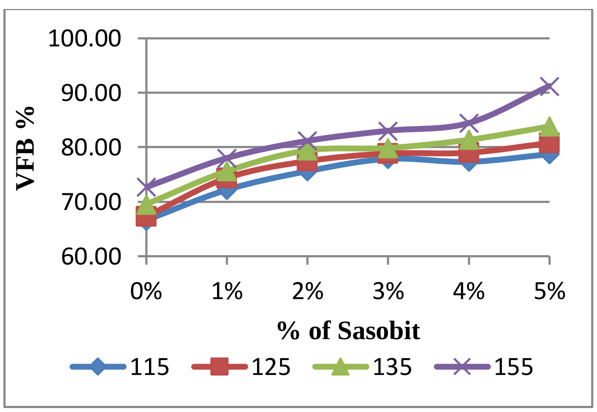

Fig 7:VFB Vs % of Sasobit

Table 8: VMA Vs % of Sasobit

Tempe rapture °C	Bitumen with different % of sasobit					
	0%	**1%**	**2%**	**3%**	**4%**	**5%**
115	14.73	13.36	12.55	12.00	11.95	11.57
125	14.56	12.93	12.22	11.83	11.67	11.23
135	14.07	12.70	11.88	11.66	11.28	10.76
155	13.41	12.26	11.59	11.16	10.81	10.50

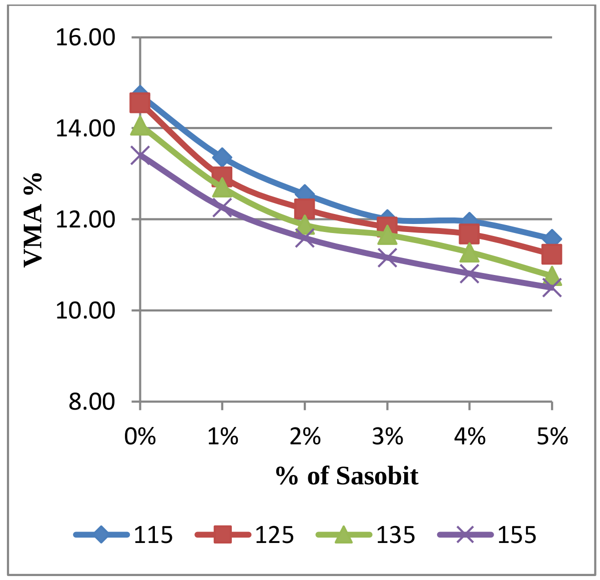

Fig 7:VMA Vs % of Sasobit

Conclusion

- Optimal amount of was found to be 2% by weight of bitumen.
- The mixing was successful at lower temperature of 135 ºC compared to conventional mix at 155 ºC. THus the production temperature was reduced by 30ºC
- Stability and Density of mix improved with addition of Sasobit.
- Flow, Voids Filled with Bitumen (VFB) of Warm Mix Asphalt increased with increase in temperature at optimum content of Sasobit.
- Air voids and Voids in Mineral Aggregates (VMA) of WMA with Sasobit decreased as compared to conventional HMA

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Author Biblography

	**Renugadevi. A** Completed my B.E (Civil Engineering) in 2003 and M.E in Structural Engineering in 2005. Completed Ph.D in the area of "warm mix asphalt technology" in the year 2014. Currently working as Assistant Engineer in Tamil nadu Highways Department. Areas of interest are Design of RCC and steel structures, Pavement Engineering. Life member of IRC. Email: renukanak@gmail.com