Performance Evaluation of Sasobit Modified Warm Mix Asphalt

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***Abstract*—In the road construction industry, many environmental and health issues have been increasing due to harmful gas and dust emissions. For that reason, the industry has provided a variety of technologies and additives to lower the production temperatures of asphalt mixtures. Warm-mix asphalt (WMA) is one of the newest and most popular techniques among others. Its road performance and workability can be equal to or better than hot mixture asphalt. Sasobit is one of the organic additives that can be used to decrease the binder viscosity and increase the workability of asphalt. It decreases the viscosity at the melting point of the wax and allows the asphalt mixtures to be compact at lower temperatures. Sasobit-modified warm mixture asphalt is normally made by adding specific sasobit percentage from the bitumen quantity when the aggregate is dry mixed. The mixing temperature of sasobit warm mixture asphalt may be reduced by 30–60°C when compared with hot mixture asphalt (HMA). As a result, it allows for a 30% reduction in energy consumption as well as a reduction in most hazardous gas and dust emissions.**

***Keywords*—Sasobit, warm mixture asphalt, workability, hot mixture asphalt, mixing temperature, compaction temperature**

I. Introduction

Due to its advantages for the environment and capacity to enhance the engineering qualities of asphalt binders and mixtures, Warm Mix Asphalt (WMA) technology has grown in popularity in the pavement building industry [1].When compared to the control hot mix asphalt, warm mix asphalt is made, laid, and compacted at temperatures 10°C to 40°C degrees lower [2]. In any case, the performance of the mix has been questioned due to the lower mixing temperatures. In light of this, it is anticipated that the WMA mixes would be thoroughly evaluated and characterized to ensure adequate performance [3]. Because of its capacity to reduce the viscosity of the asphalt binder, Sasobit is referred as as an asphalt flow improver both during the asphalt mixing process and during laydown operations [4]. Sasobit WMA's performance in terms of resistance to rutting and cracking can be equal to or better than hot mixture asphalt [5]. Warm mix asphalt can easily be supplemented with Sasobit, which appears to be a practical technique for lowering mixing and compaction temperatures [6]. This research evaluate the optimum mix parameters for sasobit-modified WMA by adding range of 1%,2%,3%,4% and 5% percentages of sasobit additive from bitumen quantity while analysing the performance of the asphalt mixture to achieve the maximum benefit. Furthermore, evaluate the performance of sasobit modified WMA by adding optimum content of sasobit additive from bitumen quantity and check the engineering properties of the asphalt mixture with the mixing temperature range of 140°C and 145°C and compaction temperature range of 100, 105, 110, 115, and 120 °C to get maximum performance.

II. Methodology

The Marshall test was performed in the laboratory and the procedure was evaluated in following sections.

A. Collecting Materials

Sasobit additive and the bitumen was collected from the Bitumix (PVT) Ltd company, Homagama, Srilanka. The fresh aggregate was collected from the crusher plant near the Pitumpe, Padukka.

B. Asphalt Binder Selection

For asphalt binder, Bitumen (PG- 60/70) was selected with fresh aggregates to make the marshal mix designs.

C. Sample Preparation

In this research, 5 samples of aggregate-asphalt binder mix was used, each with the range of 4, 4.5, 5, 5.5 and 6% of asphalt binder content. Then, based on the performance of each sample blend, the optimum asphalt binder content was determined.

D. Optimum Binder Content Selection (OBC)

The optimum asphalt binder content was selected based on the graphs of combined results of Marshall Stability, Marshall Flow, density, Unit weight and Void in Mineral Aggregates (VMA) of each sample blend.

E. Mix Design Process

First, fresh aggregates for the samples were collected and sieved according to the ICTAD (Institute for Training and Construction Development) Wearing coarse type(II) aggregate gradation. Aggregate samples were heated on lab ovens at 150-170°C for 14 hours. Then the bituminous binder was heated at 170 °C for 2 hours. Then preheated specified bitumen content (4%-6%) mixed with aggregate samples at specified temperature of 160°C. After that the asphalt mix transferred into the pre heated mold and compacted at 150°C using the Automatic Marshall compactor to prepare the Marshall blend sample. 75 blows were applied for the both side of the asphalt sample.

After 24 hours of curing at water bath, the compacted asphalt samples were heated at 60°C for 30-40min at water bath before testing. After that, Marshall Flow and stability tests were carried out for HMA samples using a Marshall testing machine accordance of the AASHTO T245-97(2001). Then optimum binder content was selected based on the graphs of combined results of Marshall Stability, Marshall Flow, density, Unit weight and Void in Mineral Aggregates (VMA).

Sasobit WMA samples were prepared by adding 1, 2, 3, 4, and 5% range of Sasobit from the weight of that optimum bitumen content. After that the mix design process was conducted with the mixing temperature of 140°C and 110°C compaction temperature. Then Marshall Test is conducted accordance of the AASHTO T245-97(2001).

After finding the optimum sasobit content, WMA samples were prepared using that optimum sasobit content. Then Following the previous mix design process for the different mixing temperature range of 135,140 and 145°C and compaction temperature range of 100, 105, 110, 115, and 120°C.

F. *Data Analysis*

Conducted the Marshall test for the asphalt samples of 4-6% bitumen content. Analysed the results and selected the optimum bitumen content.

Conducted the Marshall test for each sasobit WMA specimens. After that the test results of stability, flow density, unit weight for sasobit modified WMA samples were evaluated using graphs and charts. Then using the plotted graphs optimum mix parameters for sasobit WMA was determined and compared the results with HMA control sample.

Conducted the Marshall test for each WMA specimens which were prepared with different mixing and compaction temperatures. After that, the Marshall stability and flow test results for WMA samples were evaluated to check the temperature effects.

III. Results and Discussion

A. *Optimum Binder Content*

TABLE I. Marshall and Volumetric Properties of HMA Specimens

AC (%)	Va (%)	VMA (%)	VFA (%)	Unit Weight (Kg/m³)	Stability(KN)	Flow (0.25mm)
4	7.0	15.9	55.7	2.378	17.58	9
4.5	5.5	15.7	64.6	2.398	16.63	9.9
5	3.8	15.2	75.2	2.424	14.51	9.9
5.5	2.5	15.2	83.5	2.437	15.69	10.9
6	2.0	15.8	87.6	2.432	13.55	12.0

According to the requirement of ICTAD specification, the Marshall Stability should be greater than 8KN, Marshall Flow should be in 8 - 14 range, VMA value should be minimum 14 %, and Air voids should within the limit of 3-5%.

Analyzing the above results in accordance with ICTAD requirements, 4.8 % of bitumen content satisfied the required conditions.

B. *Optimum mix parameters for Sasobit modified WMA*

TABLE II. Marshall and Volumetric Properties of The Sasobit Modified WMA

SASOBIT Content	Air Voids (Va) (%)	VMA (%)	Stability (KN)	Flow (0.25mm)	Unit Weight (Kg/m³)	Density (Kg/m³)
HMA Control Sample	4.915	15.189	15.085	9.600	23.926	2.439
SASOBIT 1%	3.353	14.262	11.272	15.600	24.224	2.466
SASOBIT 2%	3.258	14.177	14.976	13.200	24.212	2.468
SASOBIT 3%	3.237	14.158	15.500	10.600	24.217	2.469
SASOBIT 4%	4.115	14.938	14.960	12.200	23.997	2.446
SASOBIT 5%	4.915	15.648	14.060	13.400	23.797	2.426

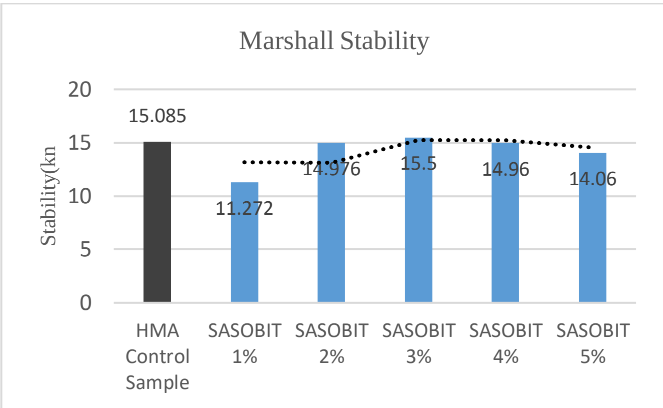

Fig. 1. Marshall Stability results of the Sasobit modified WMA

Fig. 1 shows that as the sasobit percentage increases, the marshall stability values also increased within the range of 1-3% of sasobit samples. After the 3 to 5% of sasobit, Fig 1, shows that the marshall stability values were decreased. Moreover, all the values listed in TABLE II met the specified requirements of the ICTAD specification. Highest marshall stability values showed 2% and 3% of sasobit. Furthermore, when compared with the HMA control sample, the 3% of sasobit shows the maximum stability value. A higher marshall stability value indicates that an asphalt mixture can withstand the higher loads before deforming and failing. Also, it measure the strength and ability to resist deformation under the applied load of the asphalt mixture. Moreover, it is proven that by adding sasobit the strength of the WMA marshall mixture can be increased when compared with HMA. Therefore the 3% of sasobit shows that the optimim sasobit content when analyzing the marsahll stability values.

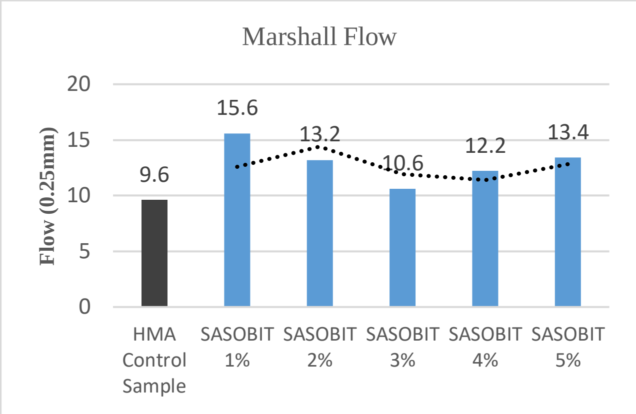

Fig. 2. Marshall Flow results of the Sasobit modified WMA

The marshall flow value is measured by the deformation of the asphalt mixture as it flows laterally under the specified load and temperature conditions. The higher marshall flow values indicated that the asphalt mixture is relatively softer and it can lead to rutting under high traffic loads. Therefore lower flow values indicated that the asphalt mixture is stiffer and resists deformation under high traffic loads. Therefore lower flow values were more preferable. According to Fig. 2, when sasobit content increased 1-3% the marshall flow values were significantly decreased and at 4-5% sasobit content, the Marshall flow values increased. Also, it clearly shows that the 3% of sasobit is the lowest flow value. Furthermore, when compared with the HMA control sample the flow value of sasobit 3% is higher than the HMA mixture. It suggests that by adding sasobit, the asphalt mixture becomes relatively soft, more workable during construction and advantageous in achieving proper compaction. Therfore, it can be suggested that the 3% of sasobit is the most preferred content when analyzing the results of marshall flow.

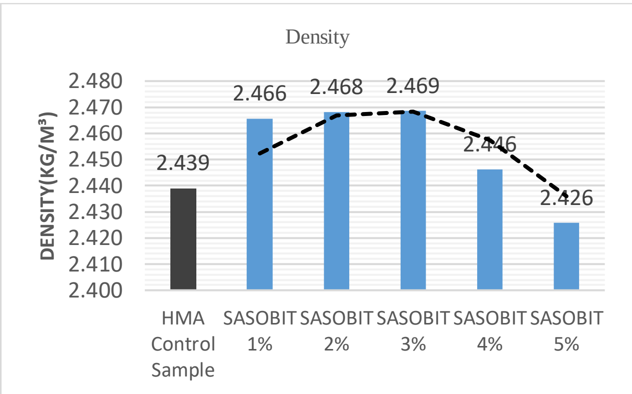

Fig. 3. Density results of the Sasobit modified WMA specimens

According to Fig. 3, when the content of sasobit increases up to 1 to 3%, the density of the bitumen mixture increases, and the density of the mixture decreases from 4 to 5% sasobit. Higher density values indicated that the asphalt mixture has been well compacted and can lead to improve the durability and resistance to rutting and cracking under the highly traffic roads. Fig.3 shows that the highest density value was the 3% of sasobit and when it compared with the HMA control sample, the sasobit WMA mixture is more densly compacted than HMA mixture. Therefore, it can be suggested that the 3% of sasobit is most suitable content when analysing the above results.

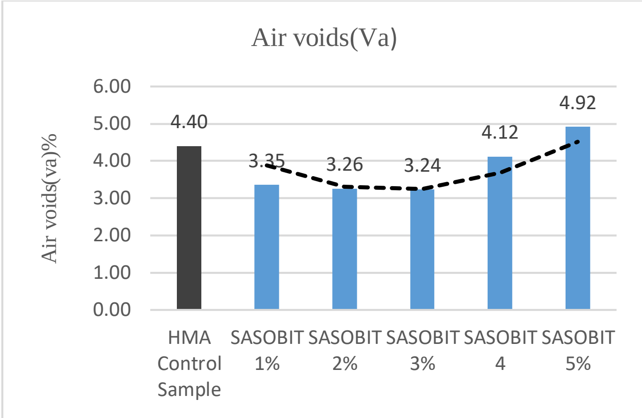

Fig. 4. Air void results of the Sasobit modified WMA

According to the Fig.4, all the values were within the specified requirements of the ICTAD specification. The highest air void value is the 5% of sasobit and the lowest air void value indicated the 3% of sasobit content. Lower air void values suggested that the asphalt mixture was densly compacted and it's normally caused to improve the durability. When compared with the HMA sample, air voids of 3% sasobit lower than HMA.

C. *Effects of the Mixing and Compaction Temperatures on the Performance of Sasobit Modified Warm Mix Asphalt*

TABLE III. Marshall And Volumetric Properties Of The Sasobit WMA With Mixing And Compaction Temperature Ranges

Sample No.	Va (%)	VMA (%)	Stability (KN)	Flow (0.25mm)	VFA (%)
HMA Control Sample	2.49	13.75	15.09	13.20	79.83
M 135, C 100	4.12	14.94	12.06	12.80	72.43
M 135, C 105	2.61	13.60	15.09	11.60	80.82
M 135, C 110	4.27	15.07	12.66	11.60	71.68
M 135, C 115	2.57	13.57	12.66	13.20	81.04
M 135, C 120	2.49	13.50	14.39	9.60	81.53
M 140, C 100	2.77	13.75	12.66	12.40	79.83
M 140, C 105	4.00	14.84	10.90	11.60	73.03
M 140, C 110	3.11	14.05	13.24	11.20	77.83
M 140, C 115	3.44	14.34	13.24	12.40	76.02
M 140, C 120	3.54	14.43	14.96	12.40	75.44
M 145, C 100	4.11	14.94	12.06	11.20	72.46
M 145, C 105	3.95	14.79	13.24	10.80	73.31
M 145, C 110	3.63	14.51	13.84	12.80	74.97
M 145, C 115	3.23	14.15	14.30	9.20	77.19
M 145, C 120	3.18	14.11	15.56	9.20	77.44

M-Mixing Temperature, C- Compaction Temperature

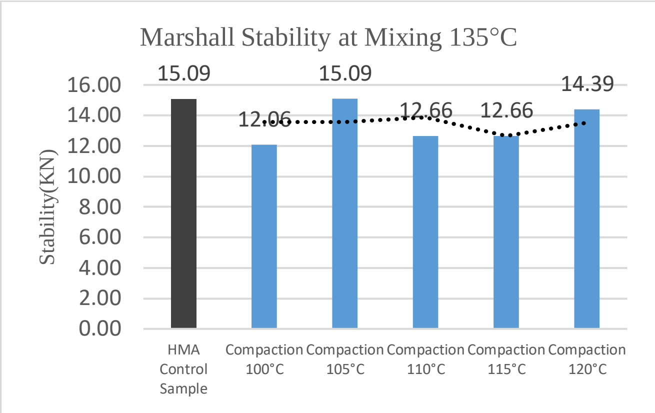

Fig. 5. Marshall Stability results of the Sasobit modified WMA with 135 °C Mixing temperature

The Fig. 5 illustrates the stability values for compacted in 100, 105, 110, 115, 120 °C temperatures and mixed in 135 °C temperature of sasobit modified warm mix asphalt samples. According to the above graph highest value of stability shows in 105 °C compacted sasobit modified WMA when comparing with hot mix asphalt (HMA) control sample.

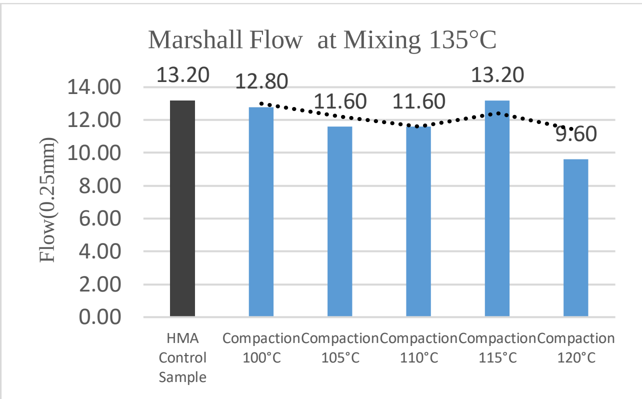

Fig. 6. Marshall Flow results of the Sasobit modified WMA with 135°C Mixing temperature

The graph shows in Fig. 6 compares the flow values of compacted samples in the 100,105,110,115,120 °C temperatures and mixed in 135 °C temperature of sasobit modified warm mix asphalt. In sharp contrast to this ,lowest flow value were seen in 105 and 110 °C compacted sasobit modified warm mix asphalt samples when comparing with HMA control sample.

The graph in Fig. 7 shows that the stability values for compacted in 100,105,110,115,120 °C temperatures and mixed in 140 °C temperature of sasobit modified warm mix asphalt samples. In conclusion highest value of stability shows in 120 °C compacted sasobit modified warm mix asphalt when comparing with hot mix asphalt (HMA) control sample.

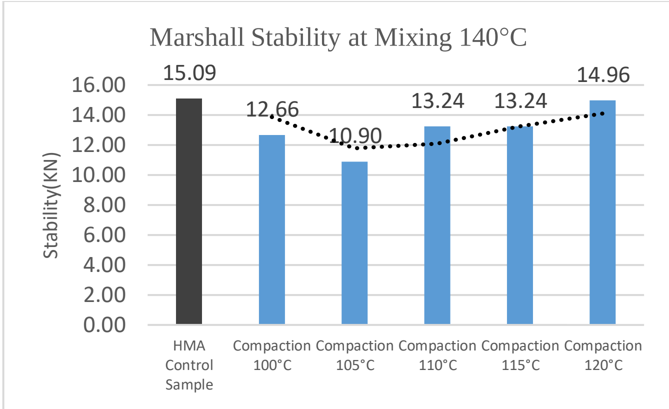

Fig. 7. Marshall Stability results of the Sasobit modified WMA with 140°C Mixing temperature

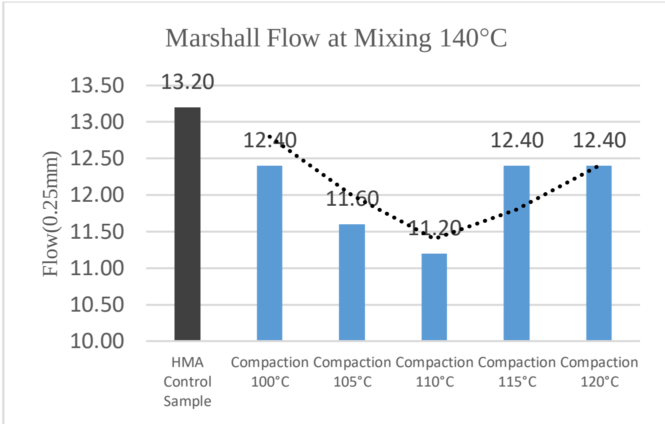

Fig. 8. Marshall Flow results of the Sasobit modified WMA with 140°C Mixing temperature

The Fig. 8 illustrates the flow values of compacted samples in the 100,105,110,115,120 °C temperatures and mixed in 140 °C temperature of sasobit modified warm mix asphalt. However, the flow was lowest at all time for the 110 °C compacted sasobit modified warm mix asphalt samples when comparing with HMA control sample.

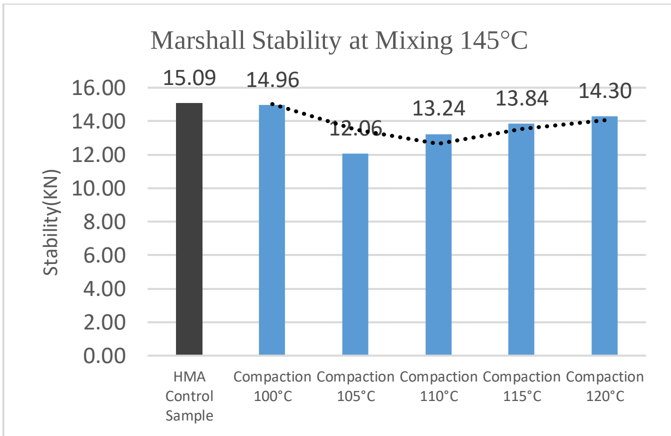

Fig. 9. Marshall Stability results of the Sasobit modified WMA with 145°C Mixing temperature

The graph shows in Fig.9 is describing the results of stability values for compacted in 100,105,110,115,120 °C temperatures and mixed in 145 °C temperature of sasobit modified WMA samples. The graphs shows highest value of stability in 120 °C compacted sasobit modified WMA when comparing with HMA control sample.

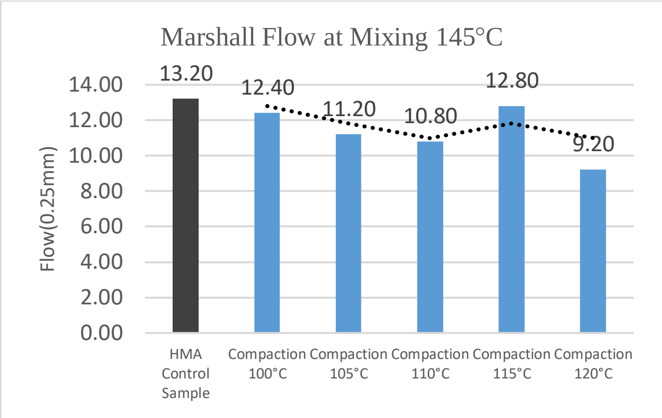

Fig. 10. Marshall Flow results of the Sasobit modified WMA with 145°C Mixing temperature

The graph in Fig. 10 shows the marshall flow changes of compacted samples in the 100,105,110,115,120 °C temperatures and mixed in 135 °C temperature of sasobit modified WMA. It is clear from the graph that, lowest flow value were seen in 110 and 120 °C compacted sasobit modified WMA samples when comparing with HMA control Sample.

IV. Conclusion

From this Study, the following conclusions can be made:

1. The highest Marshall Stability value shows the 3% sasobit modified WMA specimen and it is higher than the HMA control mixture.
2. All the samples apart from 1% sasobit modified WMA are within the range of Marshall Flow which is required in ICTAD specifications. 3% sasobit WMA is lowest Flow value among other samples and when compared with the HMA, it's higher than the HMA control sample.
3. When consider about the Density, the 3% sasobit WMA shows the highest density and it is more densly compacted than the HMA specimen.
4. All the sasobit modified WMA samples are within the range of Air Voids which is required in ICTAD specifications
5. From the mixing temperature ranges of 130, 135 and 140°C with the compaction of 100,105,110,115,120 °C, the highest Marshall Stability value shows the 145°C mixing and 120°C compaction sasobit-modified WMA specimen and its performance is better than the HMA control mixture.
6. When considering about the Marshall flow, from the mixing temperature ranges of 130, 135 and 140°C with the compaction of 100,105,110,115,120 °C, the lowest flow value shows the 145°C mixing and 120°C compaction sasobit-modified WMA specimen and it is also stiffer than the HMA control mixture and resists rutting under high traffic loads.

According to the results shown in Table II and III, all the Marshall and volumetric properties are within the requirements of ICTAD specification. The results and graphs shows that the 3% sasobit WMA sample has indicated the highest Stability and density values and lowest flow value among other WMA samples. Moreover, results shows that its performance and workability were better than the HMA specimen. Furthermore, analyzing all the details of Marshall and volumetric properties can conclude that the 3% sasobit modified WMA is most preferable and optimum sasobit content for the Sri Lankan contest as it follows all the requirements mentioned by ICTAD specification. Moreover, analyzing the results of mixing and compaction temperature ranges of WMA, at 145°C mixing and 120°C compaction, the Sasobit-modified WMA shows the best performance among all other specimens.

V. References

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