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Experimental Studies to Assess the Effect of Sasobit Additive on the Marshall Properties of Warm Mix Asphalt

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Abstract

Increased environmental awareness and stricter emissions regulations have led to the development of Warm Mix Asphalt (WMA) to reduce the high mixing temperatures of regular hot mix asphalt (HMA). Its benefits are reduction in energy consumption during production and reduced emissions during production and placement. The three most tested methods are WAM Foam, Aspha-min zeolite and Sasobit wax. All three methods reduce the viscosity of the binder at a certain temperature range, allowing the aggregate to be fully coated at lower temperatures than in HMA production. In the present study, an attempt is made to determine the optimum dosage of sasobit for Warm Mix Asphalt with lime and cement as fillers and for this optimum dosage Warm Mix Asphalt is designed using the Marshall Method of mix design. From the results, the optimum dosage of sasobit obtained is 2% for Lime and 3% for the cement treated WMA mix. For this optimum dosage the Warm Mix Asphalt mix is designed with a bitumen content of 5.64% and 5.76%, respectively. The performance in terms of Marshall Properties of Warm Mix Asphalt with sasobit additive is better when compared to the Warm Mix Asphalt without additive.

Keywords*: - Warm Mix Asphalt, Lime, Cement, Sasobit, Marshall Properties.*

INTRODUCTION

Warm Mix Asphalt (WMA), a new paving technology that originated in Europe, is one of those efforts. WMA technology allows the mixing, laying and compaction of asphalt mixes at 30°C to 40°C lower temperatures compared to Hot Mix Asphalt (HMA). 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). This technology, which is already in use in the USA and a number of European countries and on a trial basis in India as well, has a great potential of full-scale use in the country because of its inherent advantages in terms of the reduction of greenhouse gas emissions and economy in construction (because of less fuel consumption in construction) as well as elimination of suspected health hazards to construction workers. Filler acts as one of the major constituents in a bituminous concrete mixture. The superiority and stability of bituminous mixtures are influenced by several features together with the gradation of aggregates and type and amount of filler materials. Fillers not only fill voids in the coarse and fine aggregates but also affect the ageing characteristics of the mix. Suitable material combinations have been found to result longer life for wearing courses depending upon the percentage of filler and type of fillers used.

LITERATURE REVIEW

The development of WMA was initiated in Europe in the late 1990s primarily in response to the need for greenhouse gas reduction under the Kyoto Protocol. The key to the production of hot mix is providing sufficient temperature to reduce the viscosity of the asphalt to adequately coat the aggregate and enable compaction of loose mix. WMA achieves adequate coating by reducing the asphalt viscosity in a number of innovative ways, and a number of WMA additives and processes have been developed over the last 15 years. Federal Highway Administration (FHWA), National Asphalt Pavement Association (NAPA), Asphalt Institute (AI), and contractors and consultants identified four WMA technologies: Aspha-Min, Sasobit, Asphaltan-B, and WAM-Foam. New WMA technologies such as Evotherm, Rediset, WMX, REVIX, LEA (Low Energy Asphalt) and Double Barrel Green were later developed within the US. Now-a-days Warm Mix Asphalt (WMA) is widely used all over the world because of numbers of advantages as compared to Hot Mix Asphalt (HMA). The various studies have shown that the properties of additives, fillers and mixing and compacting temperature have significant effect on the performance of warm asphalt concrete pavements. Type of additive used in Warm Mix Asphalt play a significant effect on the properties of Asphalt mix such as Marshall Properties, ageing characteristics permanent deformation, fatigue cracking and moisture susceptibility. Studies have shown that based on type of additive and type of binder used, optimum dosage will be selected. Among various types of additives Wax based additives are found to be very effective. Sasobit is a new Wax material where researchers are carrying out studies worldwide to assess the suitability of the material to use as an additive in Warm mix technology.

1. ***Qian Qin et al (2015),*** studied the effect of increasing Sasobit concentration confined to unaged asphalt binders. Four Asphalt binders with different types and grades, were used as control binders in this study 1 and 3 percent Sasobit loading concentrations (by weight) were selected for this study because 3% is typically the maximum loading concentration, above which the low temperature performance of Sasobit modification may be negatively affected The Sasobit modified asphalts binders were prepared by heating the asphalt to 150°C and adding Sasobit pellets with gentle stirring. The modified asphalt was kept at 150°C for approximately an hour with occasional stirring. Test methods involved are Nuclear Magnetic Resonance (NMR) Differential Scanning Calorimetry (DSC) Dynamic Shear Rheometry (DSR). Upon the addition of 3% Sasobit®, the black space plots of Sasobit modified binders lose their single curve characteristics. TTS appears to be lost at temperatures above 30°C for 3% Sasobit. The deviation from TTS is speculated to be from microstructural changes caused by the incorporation of Sasobit into asphalt binders leading to different stress relaxation functions within the binder. With the addition of up to 3% Sasobit, no significant changes in binder stiffness in terms of $G^*(\omega)$ or $\eta^*(\omega)$ are observed. It appears that the low temperature viscoelasticity of Sasobit modified MB, MN1-3 and MN1-4 is dominated by the asphalt binder matrix at Sasobit concentrations less than 3%. Three percent Sasobit is not sufficient to exert a significant low temperature rheological impact. Overall, the DSC and DSR results

indicate that Sasobit (with addition of no greater than 3% by weight) does not negatively influence the low temperature physical properties of the binders investigated.

2. ***Devendra K et al. (2014),*** investigated WMA technologies with and without PMB 40 grade mix to attain the required performance of pavement characteristic. From this study it is possible to prepare PMB 40 mixes at 120 ºC temperature using Warm mix - Adhesion Promoter. Warm Mix Asphalt (WMA) is an innovation in paving technology which offers reduced mixing temperatures, when compared to traditional Hot Mix Asphalt (HMA) mixed at 150 to 160° C. A reduction in mixing temperatures results in reduced CO2 emissions, increased sustainability, improved working conditions for construction and maintenance crews, extended paving season and financial benefits derived through lower production costs. Hence Warm Mix is the Future of Asphalt Mixtures.

3. ***Satya Kumar M et al (2013),*** describes the studies carried out using hydrated lime, fly ash and Phosphogypsum as fillers that improve performance in multiple ways to create high performance asphalt pavements. This study was conducted to find the effect of mineral fillers in Hot Mix Asphalt with polymer modified bitumen as binder. From this study, the creep characteristics, the stiffness modulus values and the dynamic modulus shows that the most advantageous filler among the three investigated fillers is hydrated lime and the other two fillers shows improvement from the mix prepared using other two fillers. From the test results it is concluded that, by the addition of 1.5% hydrated lime addition by the total weight of the mix, the indirect stiffness modulus value increased by 103.6%, while by the addition of phosphor gypsum and fly ash in the same amount increased the indirect stiffness values by 16.9% and 11.4% respectively. Also, when 1.5% hydrated lime added to the total weight of the mix, the dynamic modulus value increased by 68.35%, while by the addition of phosphor gypsum and fly ash in the same amount increased the dynamic modulus values by 8.2% and 4.3% respectively. The most advantageous filler among the three investigated fillers is hydrated lime.

4. ***Kanitpong et al. (2007),*** conducted studies on the properties and performance of F-T paraffin (Sasobit®) modified binders and mixes found: (1) the mix workability was improved, particularly with polymer modified binders, (2) higher resistance to densification under simulated traffic, and (3) a "neutral" effect on the resistance of asphalt mixes to moisture damage with relatively high mix temperatures (however, at relatively low mix temperatures some damage was observed, possibly due to the detrimental effects of trapped moisture in themix).

5. ***Graham c Hurley (2006)*** determined the applicability of Evotherm® to typical paving operations and environmental conditions commonly found in the United States, including the performance of the mixes in quick traffic turn-over situations and high temperature conditions. Superpave gyratory compactor (SGC) results indicated that Evotherm® may lower the optimum asphalt content; however, it is currently recommended to determine the optimum asphalt content with a typical PG graded binder, and then substitute the Evotherm® emulsion.

MATERIALS AND METHODOLOGY

Aggregates

The coarse aggregates consist of clean, hard, durable, crushed rock free of disintegrated pieces, organic and other deleterious matter. Aggregate mainly consisting of both coarse and fine aggregates. Basic engineering tests are conducted on aggregates.

Table 1 Test on Aggregates

Particulars of Tests	Test results	Requirements as per MORT&H
Aggregate impact value, %	21.2	Max 24%
Los Angeles abrasion value, %	23.6	Max 30%
Combined Flakiness and Elongation index,%	27.58	Max 35%
Water absorption, %	0.15	Max 2%

Bitumen

Bitumen acts as a binder to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix. It exhibits both viscous as well as elastic properties at the normal pavement temperatures. Though at low temperature it behaves like an elastic material and at high temperatures its behaviour is like a viscous fluid. See Table 2.

Mineral Filler

Mineral filler consists of very fine, inert mineral matter that is added to the bituminous mix, to increase the density and enhance strength of the mixture. These fillers should pass through 75 micron IS Sieve. The fillers may be cement, stone dust, fly ash or hydrated lime. The filler materials used in the study are lime and cement. It is taken as 2% by weight of aggregate. Specific gravity of Lime and Cement is found to be 2.34 and 3.10 respectively.

Additive

Wax based sasobit has been used in the present study. Specific gravity of sasobit is 0.92.

Table 2 Tests on Bitumen

Bitumen Test	**Test Results**		**Requirements as per IS 73-2013**
	VG-30	**VG-30 + Sasobit**	
Penetration at 25°C	63	55	50-70
Softening point (Ring & Ball), °C	53	62	47-57
Flash point, °C	278	267	Min 220
Fire point, °C	295	287	Min 220
Ductility @27 °C, cm	85	92	Min 75
Specific gravity	1.02	1.03	Min 0.99

MARSHALL METHOD OF MIX DESIGN

Marshall Stability test of a mix is defined as maximum load carried by a compacted specimen at a standard test temperature at 60°C. This method used to test stability applicable to hot mix design of bitumen and aggregates of maximum size 19mm. In this method, resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at a rate of 50 mm per minute. The flow value is the deformation the Marshall Test specimen under goes during the loading up to the maximum load in 0.01mm units. The method used to measure the optimum bitumen content.

There are two major features of Marshall Stability method of designing mixes are:

- Density voids analysis
- Stability flow test.

Aggregate Gradation

The aggregate gradation (Grading-II) was adopted for bituminous concrete mixes as per MoRT&H (V revision) specifications.

Table 3 Aggregate Gradation for Bituminous Concrete (Gr-II)

Sieve Size, mm	% Passing (Specified)	% Passing (Mid Limit)
19	100	100
13.2	79-100	89.5
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.60	26-38	32
0.30	18-28	23
0.15	12-20	16
0.075	4-10	7

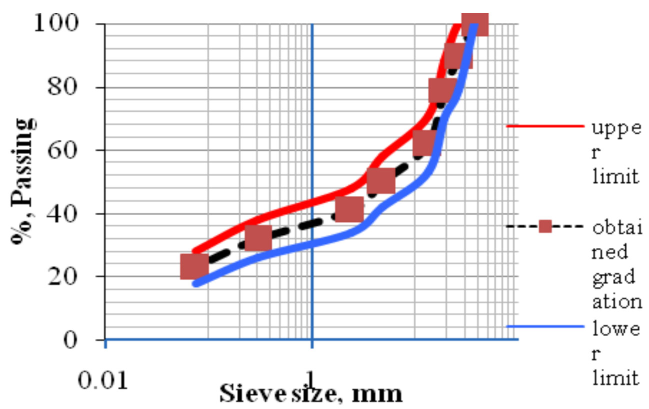

Fig 1 Aggregate Gradation

Marshall Stability Test

The specimens were kept in a thermostatically controlled water bath maintained at 60±100C for 30 to 40 minutes. The specimen was taken out, placed in Marshall Test head and tested to determine the Marshall Stability value, which is the maximum load in kg before failure, and the flow value, which is deformation of specimen in mm up to the maximum load. The equipment used was strain controlled with a strain rate of 5 cm/min. The corrected Marshall Stability value of each specimen was determined by applying appropriate correction factor, if the average height of the specimen is not exactly 63.5mm.

The graphs were plotted Marshall Stability, Flow, Bulk Density, Air voids and Voids filled with bitumen V/s bitumen content. From the graphs the optimum bitumen content is the bitumen content corresponding to maximum stability, maximum bulk density and 4% air voids.

RESULTS

In this study, WMA mixes are prepared by using graded aggregates, lime and cement as mineral filler and sasobit as additive. Initial studies were carried out by varying the sasobit content from 1% to 3%, the Marshall properties including OBC were determined.

Determination of optimum dosage of sasobit

Marshall Properties of Warm Mix Asphalt Prepared Using Lime (2%) as Filler and Sasobit (0%, 1%, 2% and 3%).

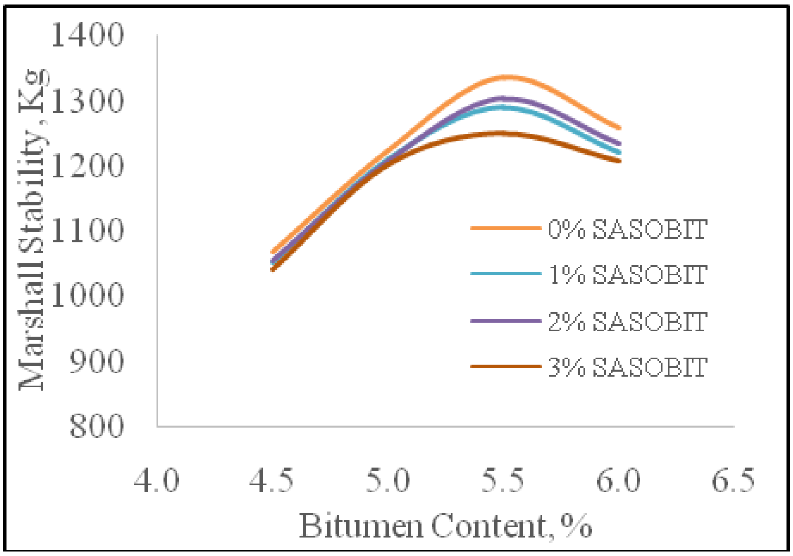

Fig 2 Marshall Stability V/s Bitumen Content

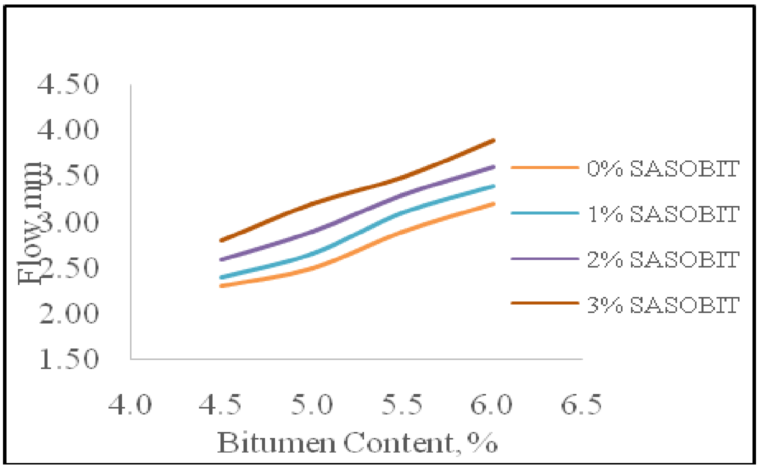

Fig 3 Flow V/s Bitumen Content

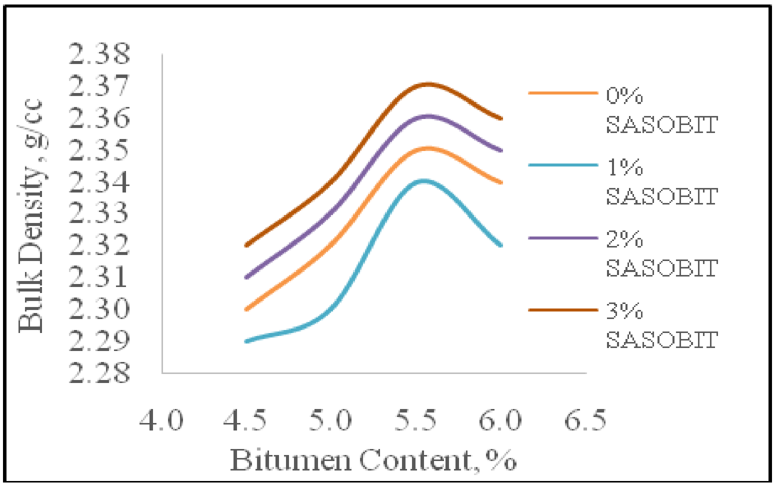

Fig 4 Bulk Density V/s Bitumen Content

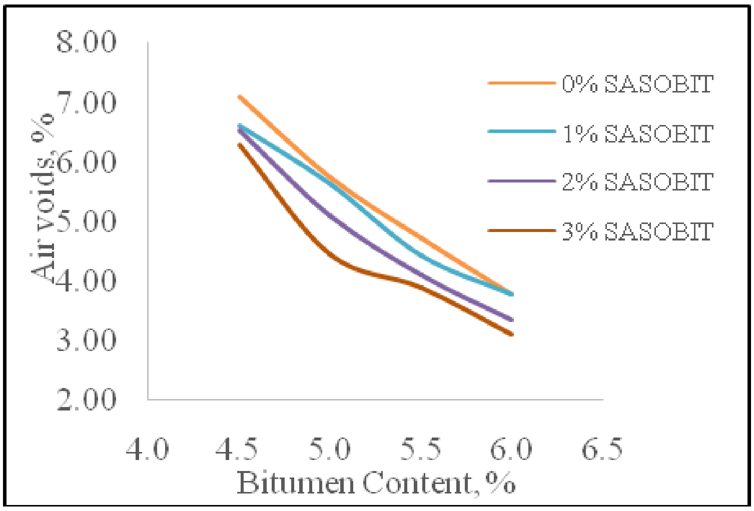

Fig 5 Air voids V/s Bitumen Content

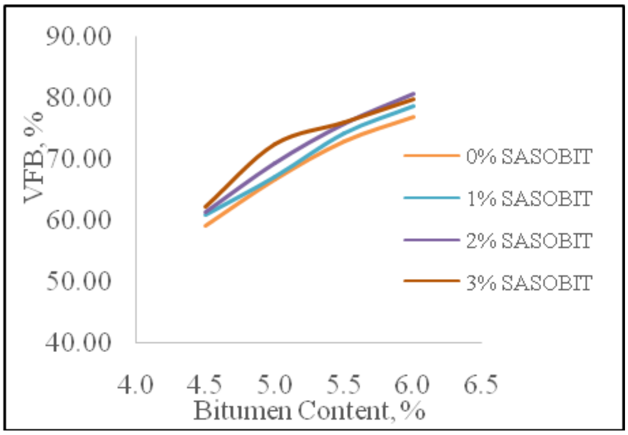

Fig 6 VFB V/s Bitumen Content

Marshall Properties of Warm Mix Asphalt Prepared Using Cement (2%) as Filler and Sasobit (0%, 1%, 2% and 3%).

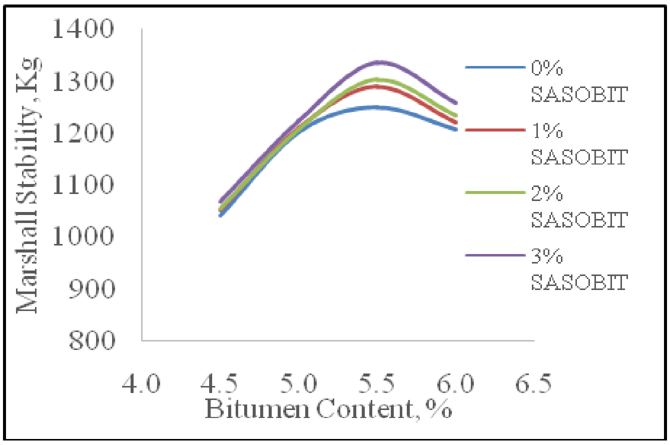

Fig 7 Marshall Stability V/s Bitumen Content

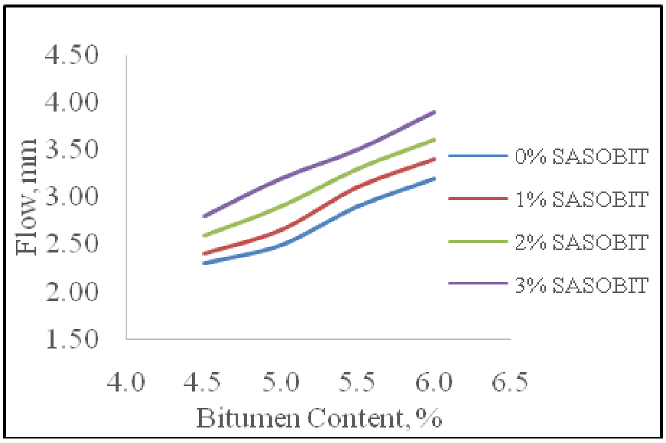

Fig 8 Flow V/s Bitumen Content

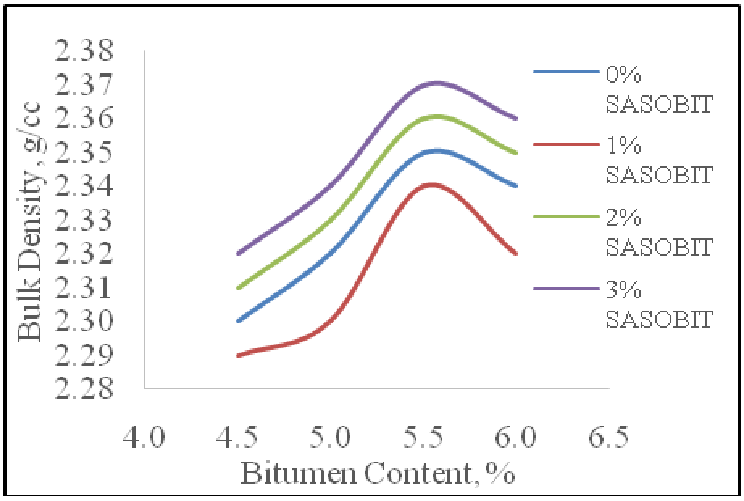

Fig 9 Bulk Density V/s Bitumen Content

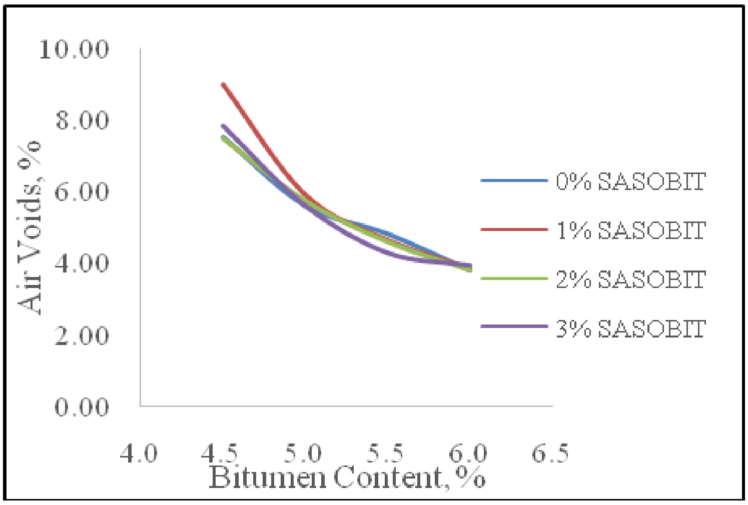

Fig 10 Air voids V/s Bitumen Content

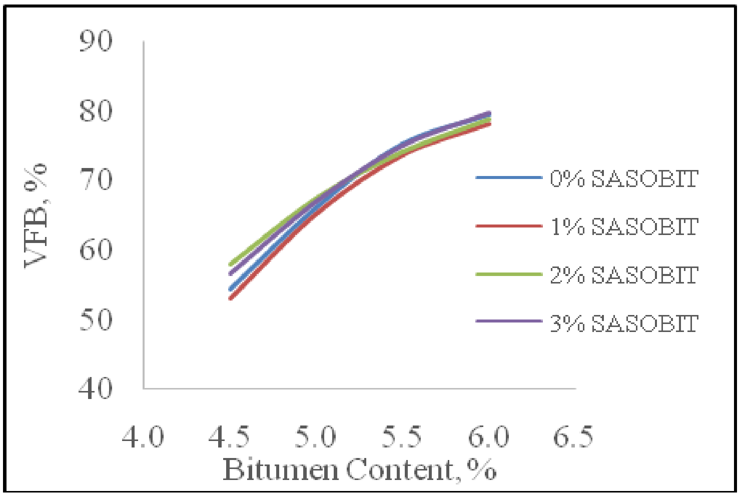

Fig 11 VFB V/s Bitumen Content

Determination of Optimum Bitumen Content

Marshall Properties of Warm Mix Asphalt Prepared Using Lime (2%) As Filler and Sasobit (0%).

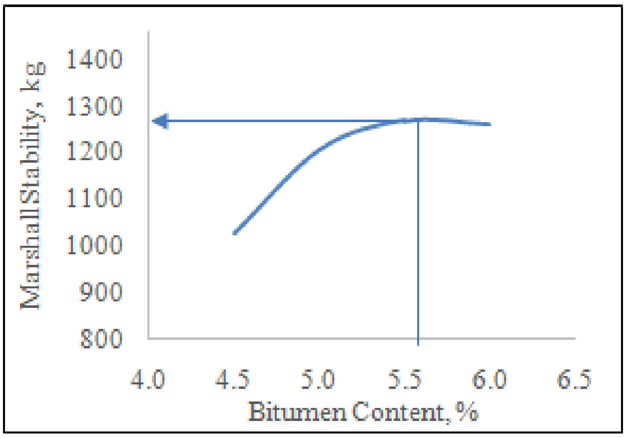

Fig 12 Marshall Stability V/s Bitumen Content

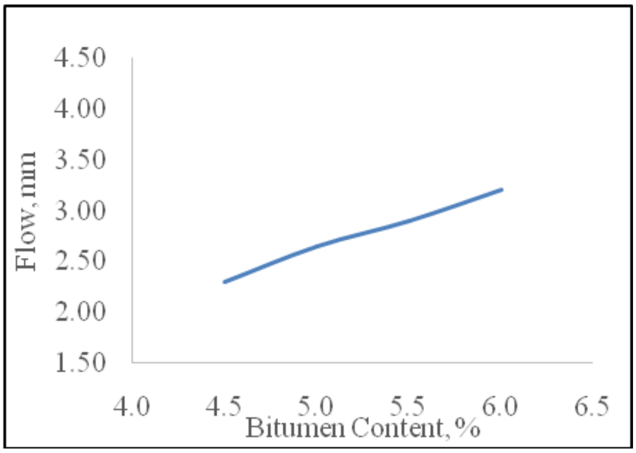

Fig 13 Flow V/s Bitumen Content

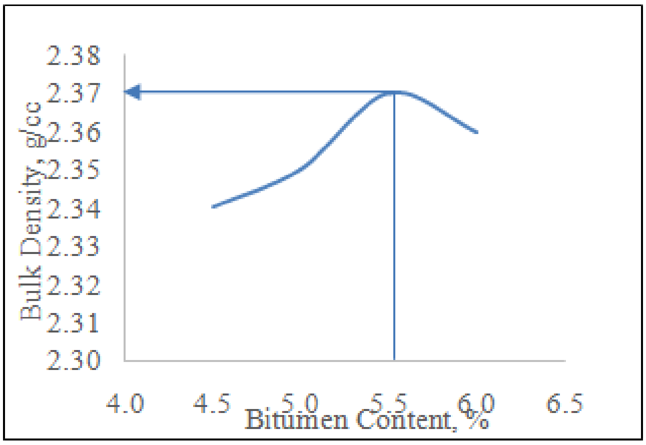

Fig 14 Bulk Density V/s Bitumen Content

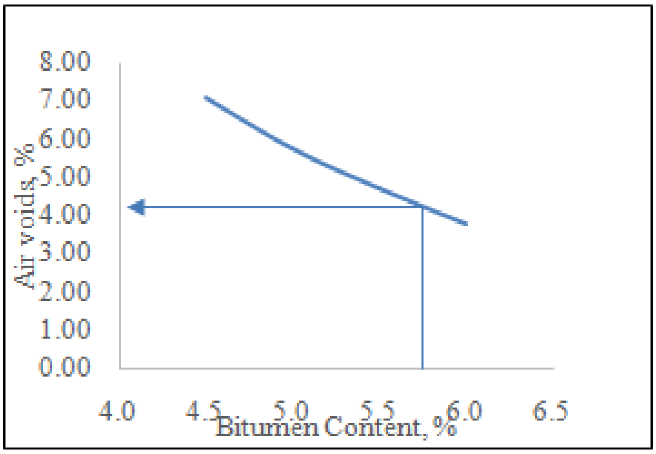

Fig 15 Air voids V/s Bitumen Content

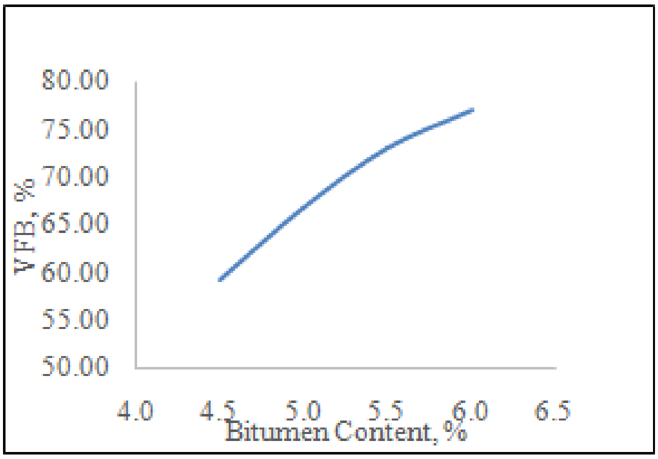

Fig 16 VFB V/s Bitumen Content

Table 4 Marshall Properties of Warm Mix Asphalt prepared using Lime (2%) and Sasobit (0%) at Optimum Bitumen Content

Marshall properties	Test result	Requirements as per Table 500-11 of MoRT&H
Optimum Bitumen Content, %	5.78	Min 5.4
Marshall Stability, kg	1265	Min 900
Flow, mm	3.0	2.0 – 4.0
Air voids (Vv), %	4.64	3.0 – 5.0
VMA, %	18.06	Min 14
VFB, %	74.30	65 -75

Marshall Properties of Warm Mix Asphalt Prepared Using Lime (2%) As Filler and Sasobit (2%).

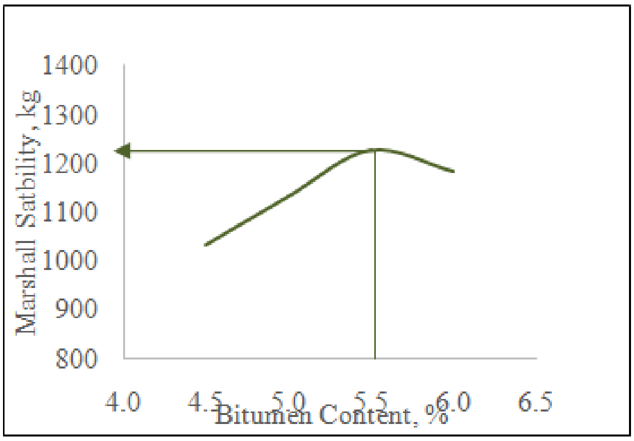

Fig 17 Marshall Stability V/s Bitumen Content

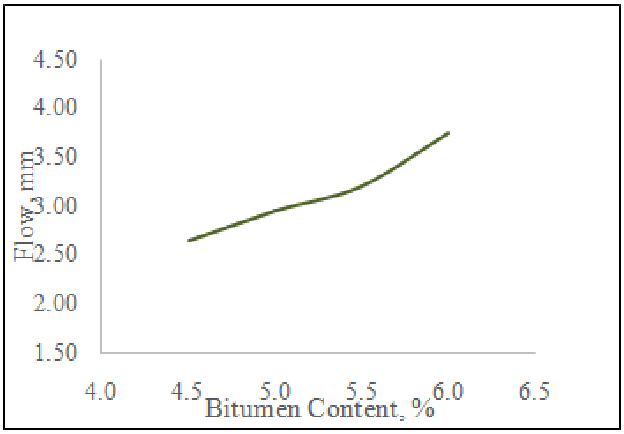

Fig 18 Flow V/s Bitumen Content

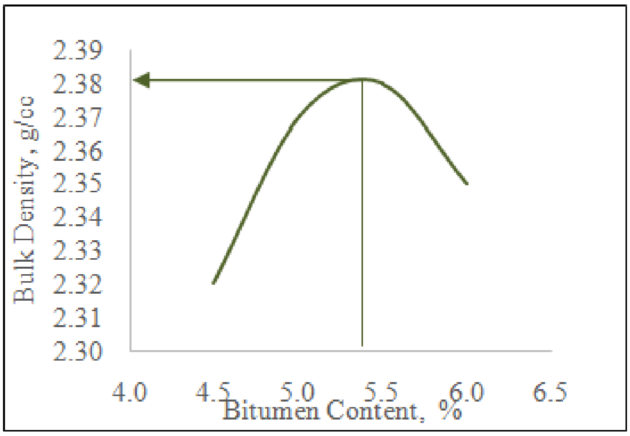

Fig 19 Bulk Density V/s Bitumen Content

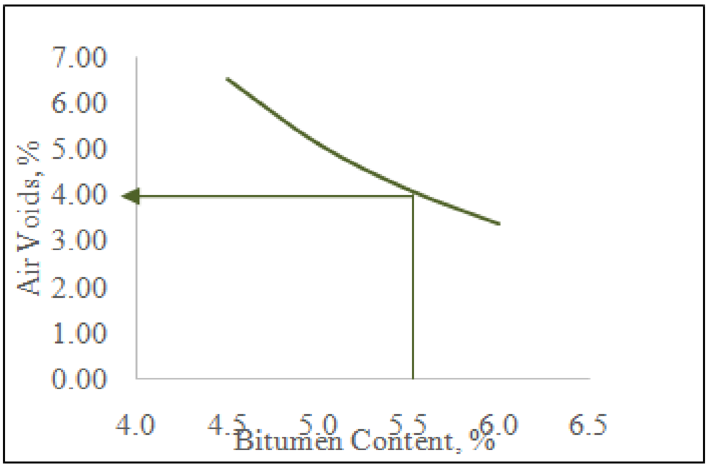

Fig 20 Air voids V/s Bitumen Content

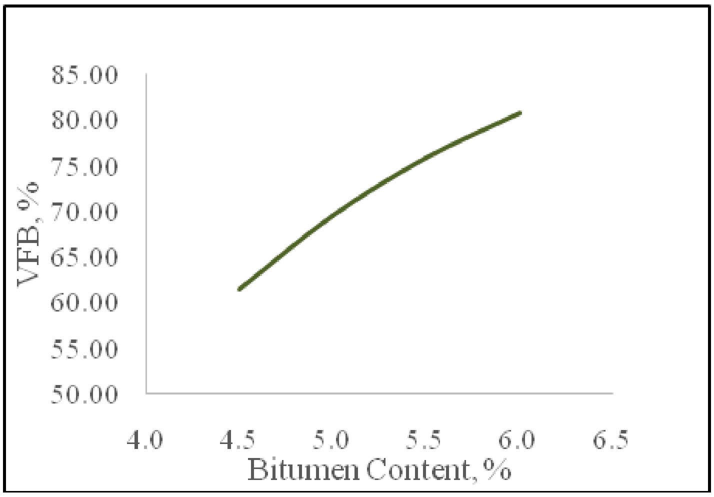

Fig 21 VFB V/s Bitumen Content

Table 5 Marshall Properties of Warm Mix Asphalt prepared using Lime (2%) and Sasobit (2%) at Optimum Bitumen Content

Marshall properties	**Test result**	**Requirements as per Table 500-11 of MoRT&H**
Optimum Bitumen Content, %	5.64	Min 5.4
Marshall Stability, kg	1310	Min 900
Flow, mm	2.90	2.0 – 4.0
Air voids (Vv), %	4.41	3.0 – 5.0
VMA, %	17.51	Min 14
VFB, %	74.80	65 -75

Marshall Properties of Warm Mix Asphalt Prepared Using Cement (2%) As Filler and Sasobit (0%).

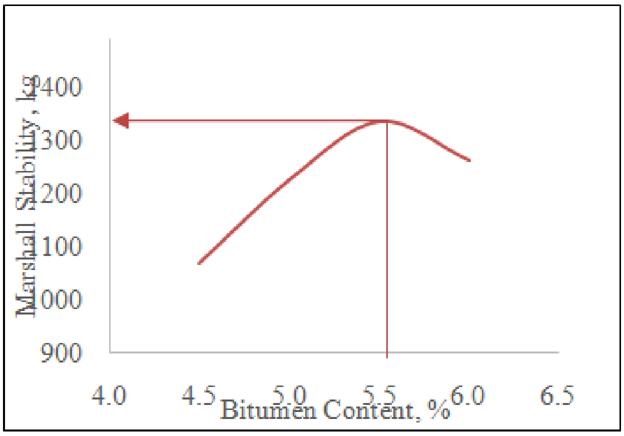

Fig 22 Marshall Stability V/s Bitumen Content

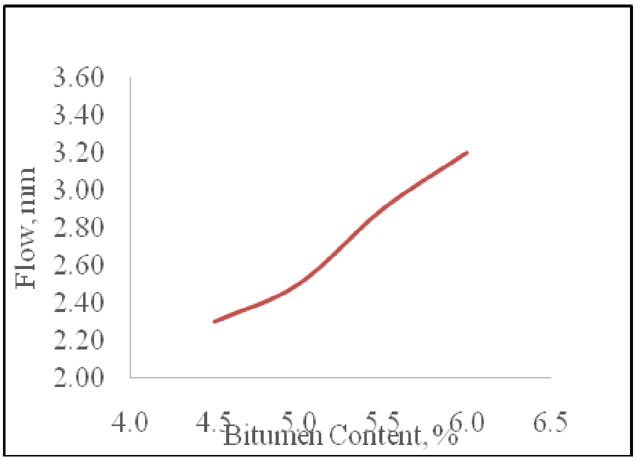

Fig 23 Flow V/s Bitumen Content

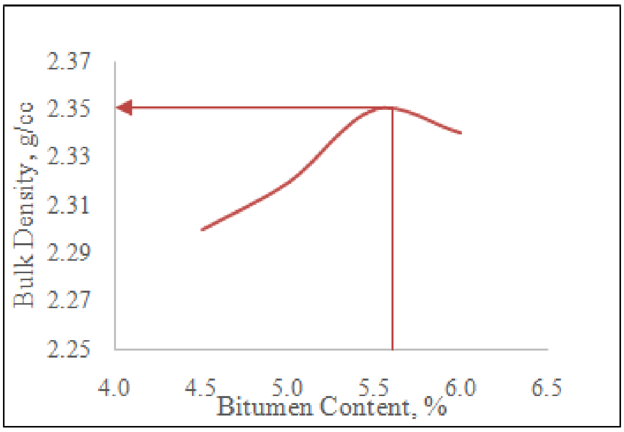

Fig 24 Bulk Density V/s Bitumen Content

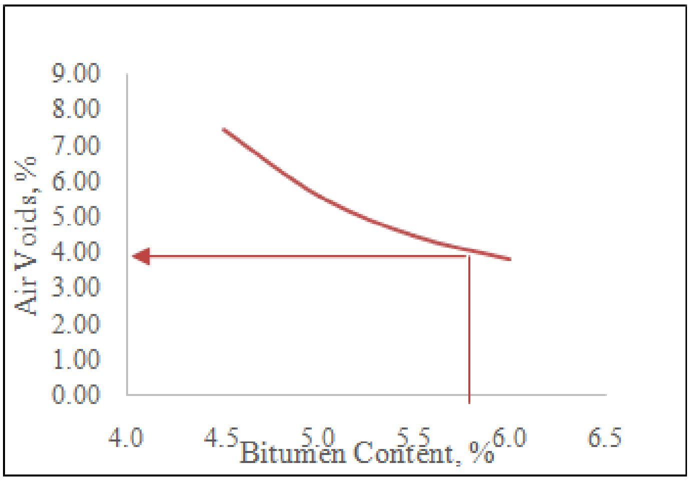

Fig 25 Air voids V/s Bitumen Content

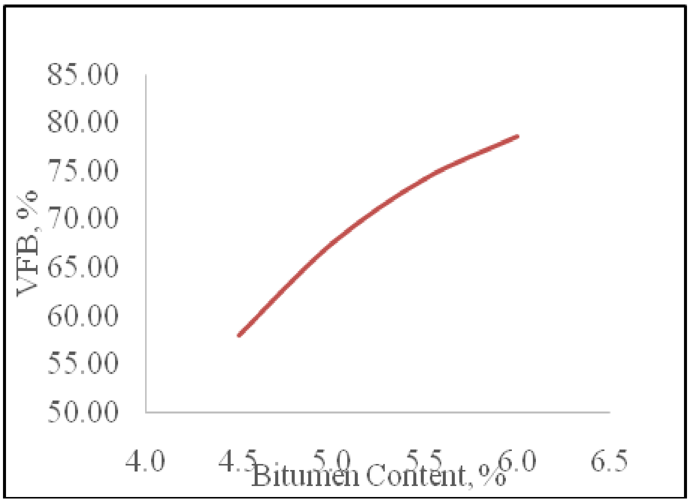

Fig 26 VFB V/s Bitumen Content

Table 6 Marshall Properties of Warm Mix Asphalt prepared using Cement (2%) and Sasobit (0%) at Optimum Bitumen Content

Marshall properties	**Test result**	**Requirements as per Table 500-11 of MoRT&H**
Optimum Bitumen Content, %	5.85	Min 5.4
Marshall Stability, kg	1298	Min 900
Flow, mm	3.30	2.0 – 4.0
Air voids (Vv), %	4.10	3.0 – 5.0
VMA, %	17.52	Min 14
VFB, %	76.32	65 -75

Marshall Properties of Warm Mix Asphalt Prepared Using Cement (2%) As Filler and Sasobit (3%).

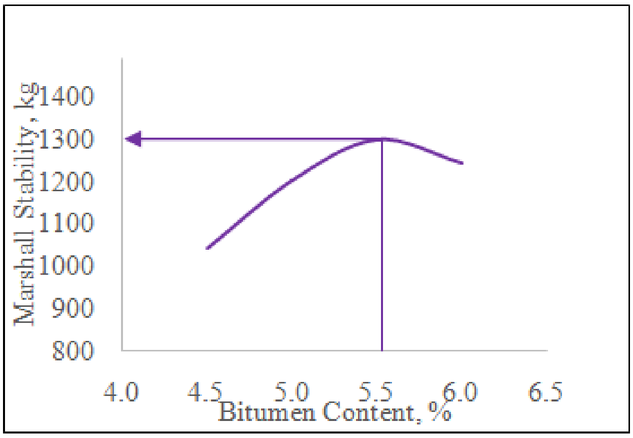

Fig 27 Marshall Stability V/s Bitumen Content

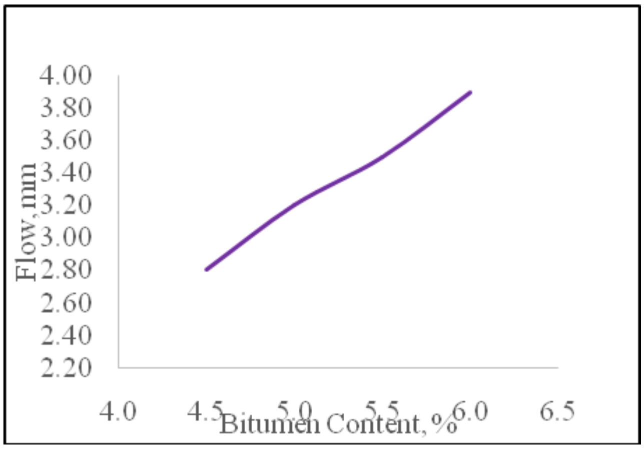

Fig 28 Flow V/s Bitumen Content

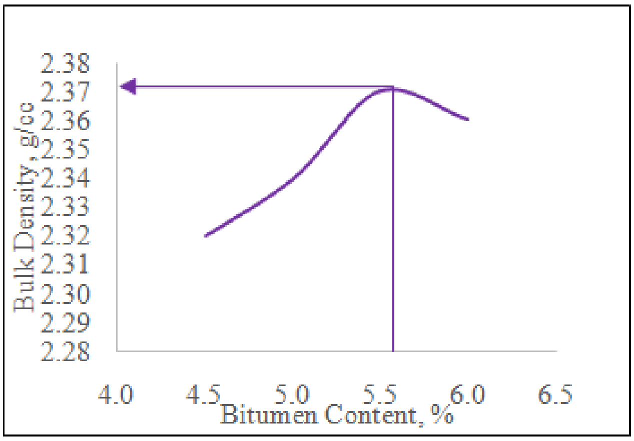

Fig 29 Bulk Density V/s Bitumen Content

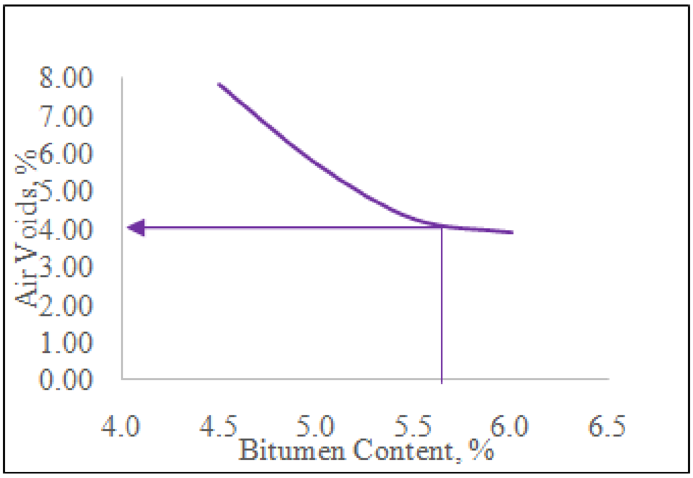

Fig 30 Air voids V/s Bitumen Content

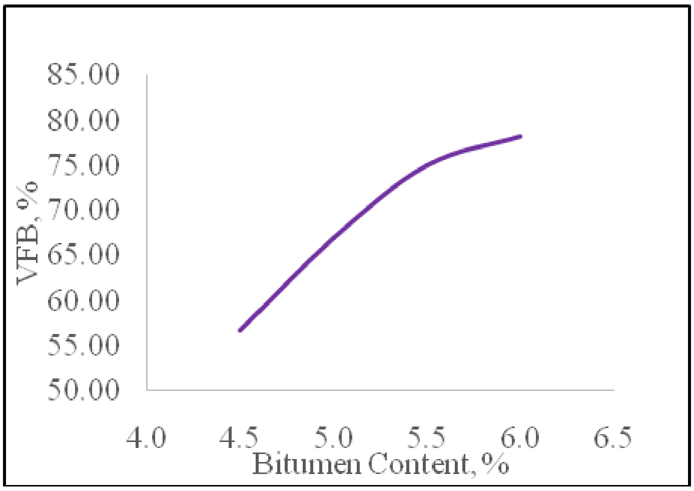

Fig 31 Marshall Stability V/s Bitumen Content

Table7 Marshall Properties of Warm Mix Asphalt prepared using Cement (2%) and Sasobit (3%) at Optimum Bitumen Content

Marshall properties	**Test result**	**Requirements as per Table 500-11 of MoRT&H**
Optimum Bitumen Content, %	5.76	Min 5.4
Marshall Stability, kg	1257	Min 900
Flow, mm	3.70	2.0 – 4.0
Air voids (Vv), %	4.12	3.0 – 5.0
VMA, %	17.43	Min 14
VFB, %	75.07	65 -75

CONCLUSIONS

i. From the Marshall Properties, the optimum dosage of sasobit for Warm Mix Asphalt prepared using lime (2%) as mineral filler is found to be 2%. The optimum dosage of sasobit for Warm Mix Asphalt prepared using cement (2%) as mineral filler is found to be 3%.

ii. The optimum bitumen content of the Warm Mix Asphalt mix prepared at optimum dosage of Sasobit using lime (0%), lime (2%) and cement (0%), cement (2%) as mineral filler by Marshall method of mix design are found to be 5.78, 5.64% and 5.85, 5.76% respectively.

iii. The performance of Warm Mix Asphalt in terms of Marshall properties prepared using sasobit as additive, lime (2%) as mineral filler performing better when compared to the Warm Mix Asphalt prepared using sasobit as additive, cement (2%) as mineral filler.

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