A Study On Marshall Stability Properties Of Warm Mix Asphalt Using Zycotherm A Chemical Additive

Rohith N.* , J.Ranjitha +
*P.G. Scholar, Highway Technology, DSCE, Bangalore

+ Assistant Professor, Dept. Of Civil Engineering, DSCE, Bangalore

Abstract

The Warm Mix Asphalts (WMA) is modified Hot Mix Asphalt(HMA) which is produced, laid and compacted in temperature which is lower than conventional HMA. The WMA is produced by mixing chemical additives to the conventional mix to improve the pavement performance. In this study an attempt is made to compare the Marshall properties of WMA produced with the chemical additive: "ZycoTherm" and HMA 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, with an additive dosage rate of 0.1% by weight of the binder. The optimum binder content was to be found out individually for the mixture for different mixing temperatures and additive dosage rate. The laboratory study concludes that Stability & Marshall properties were improved for the WMA mix by the addition of the additive.

1. Introduction

In general the WMA technology is now evolved with reducing the production or mixing temperature of the asphalt mix for up to 40º C by adding additives to the conventional asphalt paving mix. This is a technology which allows the mixing, lay down and compaction of asphalt mixes at lower temperatures compared to HMA. In case of WMA technology due to the addition of additive to the paving mix, the temperature required for heating the aggregate is less that is around 120º C. Thus it reduces the fuel consumption and greenhouse gases.

The world focus on the development of WMA technologies may be traced back to two distinctive events: the 1992 United Nations' discussions on the environment and the 1996 Germany's consideration to review asphalt fumes exposure limits. The United Nations' discussions resulted in the 1997 Kyoto Accord, which formalized a commitment by the signatory states to reduce greenhouse gas emission to the 1990 levels, while the Germany's review of asphalt fumes exposure limits lead to the formation of a partnership forum (The German BITUMEN Forum) to discuss these considerations. Reduction of mixing and placement temperatures became the obvious answer and triggered the development of WMA concepts and technologies (Croteau and Tessier 2008) [1].

1.1 Objective and Scope

The objective is to study the effect of mixing temperatures of the mix of DBM Grade 2, adopting mid size gradation for HMA and WMA. The present study includes the preparation and testing of laboratory specimens for Marshall Test of HMA mix at 155°C, 130°C and 115°C temperature and WMA mix at 130°C and 115°C temperature with additive dosage rate of 0.1% by weight of binder, to the required specifications.

2. Literature Review

The WMA technologies can be classified broadly as those

- That use water in the mix
- That use organic additive or wax in the mix
- That use chemical additives or surfactants mix.

Xijuan Xu, (2011) [2] Warm Mix Asphalt is low-carbon, environmentally friendly asphalt mixture. This kind mixture not only save resources, reduce harmful gap emissions, but also to maintain the asphalt mixture in a better use of quality. In the article, by adding additives to reduce the viscosity of asphalt, we reach the effect of reducing the temperatures of mixture mixing and compaction. At the same time, we do experiment on study high temperature stability, low temperature crack resistance and water stability, the result show that Warm Asphalt Mix gets excellent performance.

Graham and Brian (2005) [3] studied about Aspha-Min use in Warm Mix Asphalt. Two aggregates, granite and limestone were used. The Superpave gyratory compactor was used to determine the mixture compactibility at different temperatures. Mixes were compacted at 149° C, 129° C, 110° C and 88° C, with mixing temperature about 19° C above the compaction temperature. The additive Aspha-min was added at rate of 0.3% by mass of the mix.

Stacey Amy (2008) [4] evaluated warm mix asphalt technology by using Sasobit. In this study the nominal maximum aggregate size of Superpave 9.5mm and 12.5mm were used. The mix is produced using penetration grade 64-22 binder, designated by VDOT SM-9.5A mixture and VDOT SM-12.5A mixture. The super pave gyratory compactor was used for the compaction. Mix production was carried out at different temperatures of 149ºC, 162ºC and 121ºC. WMA additive Sasobit was added at a rate of 1.5% by weight of the binder. The results concluded using of the additive lowered the air voids and improved the compactibility.

Elie and Edward (2011)[5] conducted laboratory test for the CECABASE Warm Mix Additive using an aggregate of a size 19.0mm as specified by Caltrans Standard specification and NDOT specification for Road and Bridge construction. PG 64-28 polymer modified asphalt binder was used for the study. Temperature of 160ºC and 132ºC were maintained for the preparation of HMA and WMA mixes respectively. CECABASE warm mix additive was added to asphalt binder at a rate of 0.4% by weight of binder. Mix design was carried out according to Caltran and NDOT specification for the HVEEM design method.

3. Materials and Methodology

Plain bitumen of Viscosity Grade 30(VG 30) was used for the preparation of specimens. The basic test results of the bitumen are tabulated in Table 3.1

The aggregates which have good and sufficient strength, hardness, toughness and soundness have to be chosen. Crushed aggregates produce higher stability. The properties of bituminous mix are very much dependent on the aggregate size and their grain size distribution. Ministry of Road Transport and Highway (MoRTH) specifies the gradation for different layers of the bituminous courses. The tests conducted to check the physical properties and there results are tabulated in Table 3.2.

Table 3.1 Physical Properties of Bitumen

Sl. No	Tests	Results	Range, As per IS:73
1	Viscosity Test at 135°C (cSt)	361	minimum 350
2	Penetration Test (dm)	68	60-70
3	Ductility Test (cm)	79	minimum 75
4	Softening point (°C)	48	45-55
5	Flash point (°C)	300	minimum 175
6	Fire point (°C)	330	minimum 175
7	Specific Gravity	1.02	minimum 0.99

Table 3.2 Physical Properties of Coarse Aggregates

Sl. No.	Tests	Results	MoRTH Specifications for DBM
1	Specific gravity	2.62	-
2	Crushing Value	24.2%	-
3	Abrasion Value	31.0%	Max. 35%
4	Impact Value	20.80%	Max. 27%
5	Water Absorption	0.25%	Max. 2.0%
6	Flakiness Index	13.0%	Max. 15%
7	Elongation Index	16.0%	Max. 20%

3.1 ZycoTherm

ZycoTherm is WMA additive developed by Zydex Industries, Gujarat, India. This is an odour free, chemical warm mix additive that has been engineered to provide significantly improved benefits over current WMA technologies by offering lower production and compaction temperatures, while simultaneously enhancing the moisture resistance of pavements by serving as an antistrip. Mixes that have been modified with ZycoTherm can be produced at 120°C - 135°C for and compacted at 90°C - 120°C. Overall, ZycoTherm offers temperature reductions depending on the properties of the mix. ZycoTherm has built in antistrip mechanism that allows it to dually function as an antistrip as well as a warm mix additive. The additive is

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universally compatible with all types of modified as well as unmodified binders. This included Polymer Modified Bitumen and Crumb Rubber Modified Bitumen binders. It does not affect binder grading or change any other binder properties. The additive ZycoTherm in packed condition is shown in Fig.3.1

3.3 Doping of Zycotherm

For the present study 0.1% was adopted as the additive dosage for preparation of the specimens. ZycoTherm was added 0.1% volumetrically or by weight (ZycoTherm density: 1.01 gm/cc) using 2.5ml plastic syringe and the molten bitumen 155 ^{0}C (311 ^{0}F) was stirred manually using a glass rod while adding ZycoTherm and additional stirring for 10 minutes was done for uniform mixing of the additive with the bitumen. The doping of additive with the binder is shown in Fig. 3.3.

Fig. 3.1 Zycotherm, In Packed Condition

Fig. 3.2 Doping of Zycotherm

3.4 Dense Bituminous Macadam Grade 2

Dense Bituminous Macadam Grade 2 is selected as base layer. The bituminous mix design is done as per Marshall Mix design of MS-2, and the gradations for these mixes are obtained from MoRTH (2004). The aggregate grading composition of DBM is tabulated in Table 3.4. The typical S-curve for DBM mix gradation is shown in Fig. 3.4.

Table 3.4 Composition of Dense Bituminous Macadam (DBM) Layer (MoRTH-2004)

Grading	2	Passing at Mid Point Gradation	Total Weight of Aggregate (kg)
Nominal Aggregate Size	25mm		
IS Sieve(mm)	Cumulative % by wt of total aggregates passing		
37.5	100	100	-
26.5	90-100	95	0.06
19	71-95	83	0.144
13.2	56-80	68	0.180
4.75	38-54	46	0.264
2.36	28-42	35	0.132
0.3	7-21	14	0.252
0.075	2-8	5	0.108
Below 0.075	100	100	0.06
			Total 1.2 kg
Bitumen Content % by mass of total mix		Min 4.5	

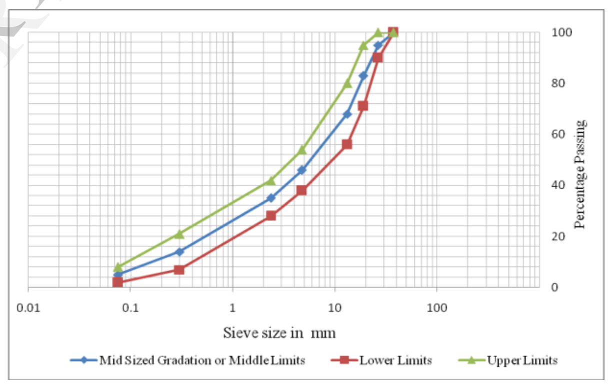

Fig. 3.3 Typical S curve for DBM mix

3.6 Marshall Test

The Marshall Test was carried out on HMA mixes by varying the bitumen contents of 4.5%, 5.0%, 5.5%, 6% and 6.5% at mixing temperatures of 115°C, 130°C and 155°C and WMA mixes with varying bitumen contents of 4.5%, 5.0%, 5.5%, 6% and 6.5% at mixing temperatures of 115°C and 130°C for an additive dosage rate of 0.1% by the weight of the binder. Three specimens were prepared for each binder content. The specimens' were compacted manually (75 blows per side) using Marshall Compaction Hammer. To determine the Optimum Binder Content (OBC) of the mixes on maximum stability, maximum unit weight and 4 percent air voids is considered. The test was carried out according to the ASTM: D: 1559-65.

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4. Marshall Test Results and Discussions

The Marshall Test results of HMA for DBM at 155°C, 130°C and 115°C is presented in Table 4.1(a), (b), (c) respectively. The Marshall properties of specimens with 0.1% WMA additive at 130°C and 115°C are shown in the Table 4.2 (a) and (b) respectively. The graphs were plotted for bitumen content and Marshall Stability, Bulk density and Air voids. The bitumen content corresponding to maximum stability, Bulk density and 4.0% air voids was obtained and the average of the three bitumen contents was calculated and treated as optimum bitumen content (OBC). OBC values of HMA and WMA for DBM different temperature is tabulated in Table 4.3

Table 4.1 (a) Marshall Test results of HMA for DBM at 155°C

Properties	HMA at 155°C			
Binder	5%	5.5%	6%	6.5%
Stability (kN)	12.09	11.57	11.5	10.79
Flow (mm)	4.50	4.80	5.00	5.30
Bulk Density(kg/m³)	2344	2372	2385	2375
Percent Air Voids Va(%)	4.24	2.44	1.3	1.07
VMA %	15.73	15.24	14.14	13.88
VFA %	73.06	83.97	90.90	92.27

Table 4.1 (b) Marshall Test results of HMA for DBM at 130°C

Properties	HMA at 130°C			
Binder	5%	5.5%	6%	6.5%
Stability (kN)	11.12	8.42	6.68	6.45
Flow (mm)	4.10	4.53	4.97	5.43
Bulk Density(kg/m³)	2343	2366	2365	2362
Percent Air Voids Va(%)	4.29	2.70	2.13	1.59
VMA %	15.78	15.46	16.04	15.88
VFA %	72.80	82.54	86.75	89.97

Table 4.1 (c) Marshall Test results of HMA for DBM at 115°C

Properties	HMA at 115°C			
Binder	5%	5.5%	6%	6.5%
Stability (kN)	7.42	7.65	8.26	5.68
Flow (mm)	3.50	3.67	3.77	4.03
Bulk Density(kg/m³)	2320	2334	2364	2361
Percent Air Voids Va(%)	5.22	4.03	2.14	1.67
VMA %	16.59	16.62	16.05	15.94
VFA %	68.54	75.73	86.66	89.55

Table 4.2 (a) Marshall Test results of WMA with 0.1% of Additive at 130°C

Properties	HMA at 130°C			
Binder	5%	5.5%	6%	6.5%
Stability (kN)	11.9	11.4	11.1	10.2
Flow (mm)	4.0	4.3	4.4	4.6
Bulk Density(kg/m³)	2345	2351	2365	2361
Percent Air Voids Va(%)	4.21	3.3	2.1	1.67
VMA %	15.7	16.0	16.1	15.94
VFA %	73.2	79.2	86.9	89.5

Table 4.2 (b) Marshall Test results of WMA with 0.1% of Additive at 115°C

Properties	HMA at 115°C			
Binder	5%	5.5%	6%	6.5%
Stability (kN)	8.1	8.6	9.20	8.00
Flow (mm)	4.7	5.3	6.0	6.6
Bulk Density(kg/m³)	2328	2338	2352	2344
Percent Air Voids Va(%)	4.90	3.85	2.7	2.3
VMA %	16.3	16.5	16.5	16.5
VFA %	69.9	76.6	83.9	85.8

Table 4.3 OBC values of the HMA and WMA mix

Description	Maximum Stability		Bulk Density		% Va	OBC
	Stability (kN)	B. C	Gb kg/m³	B C	BC	
HMA at 155° C	12.09	5	2385	6	5.06	5.4
HMA at 130° C	11.1	5	2366	5.5	5.09	5.2
HMA at 115° C	8.3	6	2364	6	5.5	5.8
WMA at 130°C	11.9	5	2365	6	5.1	5.37
WMA at 115°C	9.2	6	2352	6	5.45	5.8

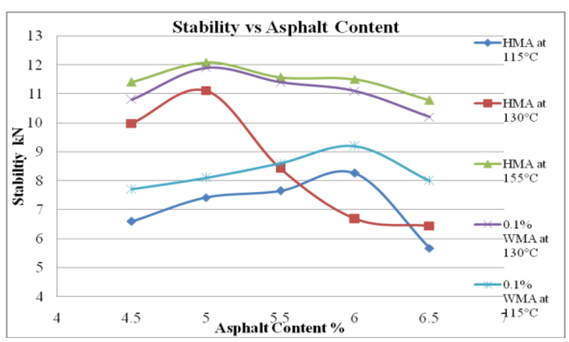

Fig. 4.1 (a) Marshall Stability Value vs Asphalt Content

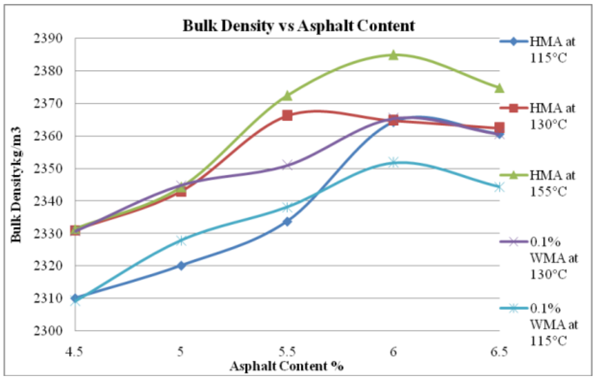

Fig. 4.1 (b) Bulk density Value vs Asphalt Content

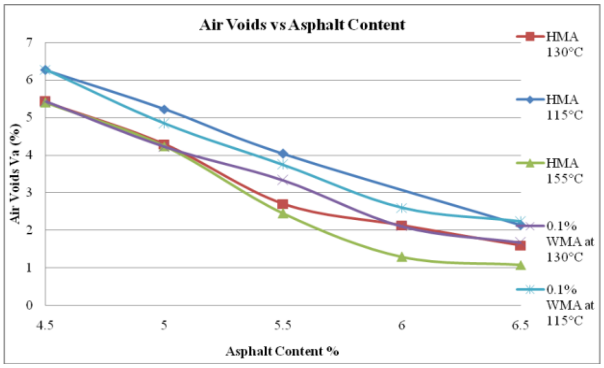

Fig. 4.1 (c) Bulk density Value vs Asphalt Content

Fig. 4.2 (a) to (c) shows the relationship of Marshall Properties with bitumen content for DBM mix with different additive rate at different temperature. (a) Stability, (b) Bulk density (Gb) and (c) Percentage air voids (Vv).

The Marshall Stability values for the HMA and WMA specimen of DBM Grade 2 vary with the variation in temperature as well as the additive dosage rate. The stability value for the HMA mix at 155°C was 12.09kN. At 130°C the HMA mix had a stability of 11.01kN and the stability of WMA mix is 11.9kN due to the addition of ZycoTherm at a dosage rate of 0.1% At 115°C the HMA mix had a stability of 8.9kN and the stability of WMA mix is 9.2kN which is due to the addition of ZycoTherm at a dosage rate of 0.1%. This show the stability values of the mix was improved at 130°C and 115°C with the addition of the Zycotherm additive.

Initially the increase in the binder content increased the bulk density but further increase in bitumen content decreases the bulk density for both HMA and WMA mix at all temperatures and considered additive dosage rate. The Bulk density for the HMA mix at 155°C was 2385kg/m³, at 130°C the HMA mix had a Bulk density of 2366kg/m³ and the Bulk density of WMA mix is 2365kg/m³ with the addition of ZycoTherm at a dosage rate of 0.1%. At 115°C the HMA mix had a Bulk density of 2364kg/m³ and the Bulk Density of WMA mix is 2352kg/m³ with the addition of ZycoTherm at a dosage rate of 0.1%. This shows that the bulk density of the WMA mix is lesser than the HMA mix.

The air voids reduces with the increase in the binder content, the HMA mix at 155°C has air voids of 5.40, 4.24, 2.44, 1.29 and 1.07% for increasing binder content, HMA mix at 130°C has air voids of 5.59, 4.29, 2.70, 2.13 and 1.59% for increasing binder content, HMA mix at 115°C has air voids of 6.26, 5.22, 4.03, 2.14 and 1.67% for increasing binder content. At 130°C, WMA with 0.1% additive has the air voids 5.4, 4.21, 3.3, 2.1, 1.67%, and at 115°C WMA with 0.1% and 0.2% additive has the air voids 6.30, 4.90, 3.85, 2.7, 2.3%. Also the voids filled with asphalt (VFA) and VMA is increased with increase in the binder content for both the mix.

The optimum bitumen content obtained of HMA and WMA for DBM grade 2 mixes was different at different temperature. Optimum bitumen content of HMA mix at 155° C is 5.4% , HMA at 130°C is 5.20%, HMA at 115°C is 5.8%, the OBC for WMA with 0.1% additive at 130°C and 115°C is 5.37% and 5.8% respectively.

5. Conclusions

The Marshall Stability value of HMA specimens produced at 155°C has good stability values. When compared with HMA specimens, the stability and Marshall Properties of WMA specimens prepared at 130°C and 115°C were improved by the addition of Zycotherm at an additive dosage rate of 0.1% by weight of the binder.

The optimum binder content for the HMA mix at 155°C was found out to be 5.4% and WMA mix at 130°C with 0.1% of ZycoTherm was found out to be 5.37%. This concludes that the optimum binder content for HMA and WMA mix are different with varying the temperature and additive dosage rate, so the OBC should be found out individually for both HMA and WMA mix for varying temperatures and additive dosage rate.

6. Recommendations

In the present laboratory investigations the WMA mix produced using ZycoTherm at 130°C with additive dosage rate of 0.1% showed good results when compared with the HMA mix produced at 130°C. The

WMA mix with 0.1% of ZycoTherm at 130°C is recommended to use in practise.

7. References

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