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Study on Behavior of Warm Mix Asphalt Using Zycotherm

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Abstract: ***The asphalt industry has been aware of the energy savings and environmental benefits warm mix asphalt technologies. Keeping these two reasons in view, they came up with an idea of using warm mix asphalt technology which uses chemical additive. Using this technology, they can considerably reduce the temperature of asphalt pavement when compared to normal asphalt pavements. Warm mix asphalt is one technology that is gaining popularity in the industry in response to this effort. The Warm Mix Asphalts (WMA) which is produced, laid and compacted in temperature which is lower than conventional mix. 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" with an additive dosage rate of 0.1% by weight of the binder and increasing the stability and workability of bituminous concrete mix by reducing OBC And Finding the best mixing percentage of Zycotherm to obtain a fully compacted bituminous layer for Semi Dense Bituminous cover (SDBC). The laboratory study concludes that Stability & Marshall properties were improved for the WMA mix by the addition of the additive.***

Keywords: Zycotherm, Marshall Stability, Warm Mix Asphalt, Semi Dense Bituminous cover, Bitumen

1. Introduction

Bitumen is a sticky, black and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product, Bitumen is a thermoplastic material and its stiffness is dependent on temperature. The temperature vs stiffness relationship of bitumen is dependent on the source of crude oil and the method of refining. It is assessed that the present world utilization of bitumen is roughly 102 million-tones every year. Around 85% of all the bitumen created is utilized as the cover as a part of black-top for streets. It is additionally utilized as a part of other cleared regions, for example, airplane terminal runways, auto parks and footways. Ordinarily, the creation of black-top includes blending sand, rock and smashed rock with bitumen, which goes about as the coupling operators. Different materials, for example, polymers, may be added to the bitumen to modify its properties as indicated by the application for which the black-top is eventually proposed.

A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) environment friendly (v) economical and so on. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one. The present research work tries to identify some of the issues involved in this art of bituminous mix design and the direction of current research. Asphalt concretes are widely used in pavements. Permanent deformation happens when pavement does not have sufficient stability, improper compaction and insufficient pavement strength. From practical experiences it is proved that the modification of asphalt binder with polymer additives, offers several benefits. To enhance various engineering properties of asphalt many modifiers such as styrene based polymers, polyethylene based polymers, polychloroprene, various oils have been used in asphalt.

Zycotherm material as an additive allows the mixing lay down, and compaction of asphalt mixes at significantly lower temperatures compared to hot mix asphalt. Initially overview of pavement types, layers and their functions are discussed followed by brief introduction on warm mix design.

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.

2. Literature Review

2.1 Elie Y. Hajj and Edward M. Cortez(2011)

Elie and Edward (2011)[1] led lab test for the CECABASE Warm Mix Additive utilizing a total of a size 19.0mm as indicated by Caltrans Standard particular and NDOT detail for Road and Bridge development. PG 64-28 polymer altered black-top fastener was utilized for the study. Temperature of 160ºC and 132°C were kept up for the arrangement of HMA and WMA blends individually. CECABASE warm blend added substance was added to black-top cover at a rate of 0.4% by weight of folio. Blend configuration was completed by and NDOT particular for the HVEEM design method.

2.2 Graham and Brian (2005)

Graham and Brian (2005)[2] 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.

2.3 Stacey Amy (2008)

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.

2.4 Xijuan Xu, (2011)

Xijuan Xu, (2011)[5] 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.

3. Materials and Methodology

The following are the materials used in the study
1) Bitumen of 80/100 Penetration grade.
2) Course aggregates.
3) Fine aggregates.
4) Filler materials.
5) Zycotherm (Chemical additive).

In this project **80/100** Penetration grade of bitumen is chosen and comparison WMA with varying dosage of additive is chosen. The strength of WMA is compared with WMA with varying dosage of additives. Marshall Stability test is carried out on these moulds to determine the strength of bitumen mix with different dosage of additive

3.1 Bituminous Concrete Mix Design:

3.1.1 Objective of Bituminous Mix Design:

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through the fine filler that is smaller than 0.075mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. The objective of the mix design is to produce a bituminous mix by proportioning various components so as to have-

1) Sufficient bitumen to ensure a durable pavement
2) Sufficient strength to resist shear deformation under traffic at higher temperature
3) Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic
4) Sufficient workability to permit easy placement without segregation
5) Sufficient resistance to avoid premature cracking due to repeated bending by traffic
6) Sufficient resistance at low temperature to prevent shrinkage cracks

3.1.2 TESTS

The following are the tests conducted on the materials:
Test on coarse aggregate:
1) Specific Gravity
2) Abrasion test
3) Impact test
4) Crushing value

Test on Bitumen:
1) Softening point
2) Penetration test
3) Ductility test
4) Specific Gravity

4. Methodology

4.1 Marshall Stability Test:

The Marshall Stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute.

4.1.1 Procedure

In the Marshall test method of mix design compacted samples are prepared for each additive content. In the Marshall test method of mix design compacted samples are prepared for each additive content. All the compacted specimens are subject to the following tests:

- **Marshall Stability Test**

The Marshall method was originally developed by Bruce Marshall Mississippi State Highway Department formulated this test and is applicable to hot mix design of bitumen and aggregates of maximum size 2.5 cm. In India, bituminous concrete mix is commonly designed by Marshall Method. This test is extensively used in routine test programmes for the paving jobs. The stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature of 600^{0}C. The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test.

Doping of Zycotherm: For the present study **0.1%**, **0.2%**, **0.3%** 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°C 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.

Approximately 1200gm of aggregates and filler is heated to a temperature of 175-190°C. Bitumen is heated to a temperature of 121-125°C with the percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of 154-160°C. The mix is placed in a preheated mould and compacted by a rammer with 75 blows on either side at temperature of 138- 149°C. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the Zycotherm content in the next trial by **0.1%** and repeat the above procedure. Number of trials is predetermined. The prepared mould is loaded in the Marshall Stability test. The sample is taken out of the mould after few minutes using sample extractor.

4.1.2 Specimen Preparation

Approximately 1200gm of aggregates and filler is heated to a temperature of 175-190°C. Bitumen is heated to a temperature of 121-1250C with the percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of 154-160°C. The mix is placed in a preheated mould and compacted by a rammer with 75 blows on either side at temperature of 138-149°C. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the Zycotherm content in the next trial by **0.1%** and repeat the above procedure. Number of trials is predetermined. The prepared mould is loaded in the Marshall Stability test. The sample is taken out of the mould after few minutes using sample extractor.

Table 4.1: Gradation for Bituminous Mix

Sieve size in mm	*% wt retained*	*Wt of aggregate in Gm*
Aggregate Impact Value	14.88	24% maximum
Los Angeles Abrasion test	11.22	30% maximum
Aggregate crushing test	16.76	30% maximum
Specific Gravity Test • Coarse Aggregates • Fine Aggregates • Filler Materials	2.68 2.62 3.02	2.9% maximum 2.9% maximum 3.1% maximum

4.1.3 Data Analysis

a) Basic Test Results and Tables

Table 4.2: Properties of Coarse Aggregates

Test	Results	MORT&H Specifications
Penetration (100 gram. 5 seconds at 25°C) (1/10* of mm)	92	50-70
Softening Point. °C (Ring & Ball Apparatus)	48	Min 47
Ductility at 27°C (5 cm/minute pull) (cm)	>100	Min 75
Specific Gravity	0.99	Min 0.99
Filler Materials	240	Min 220

Table 4.3: Gradation Values

Sieve size in mm	*Lower limit*	*Higher limit*	*Middle limit*	*Obtained limit*
13.2	100	100	100	100
9.50	90	100	95	94.25
4.75	35	51	43	49.36
2.36	24	39	31.5	36.92
1.18	15	30	22.5	25
0.30	9	19	14	18.75
0.075	3	8	5.5	7.88

b) Gradation

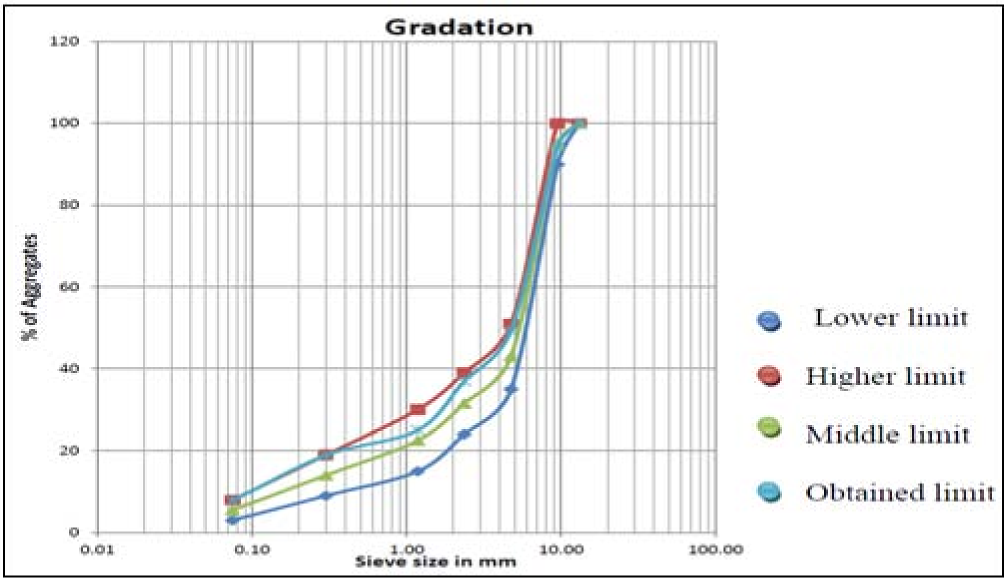

Figure 4.1: Graph showing Gradation for Aggregates

Calculation of Optimum Binder Content:
OBC = BC % at max (Bulk Density + Marshall Stability) / 2
OBC = (5+5)/2
OBC = 5%

(Bulk Density and Marshall Stability values are taken from bellow graphs).

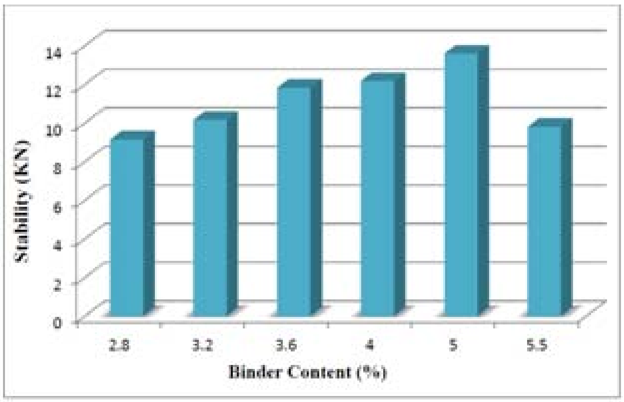

Figure 4.2: Comparison of Stability of Varying Bitumen Content

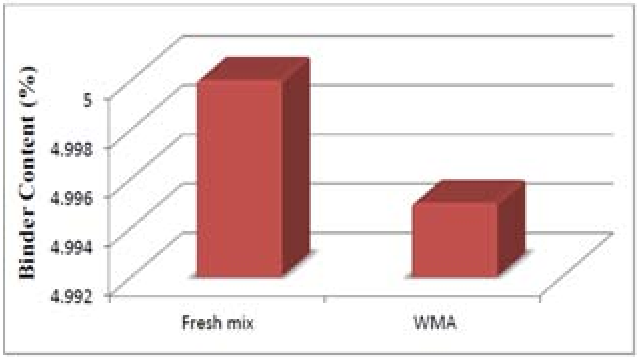

Figure 4.3: Comparison of Fresh Mix and WMA With Respect to Bitumen Content

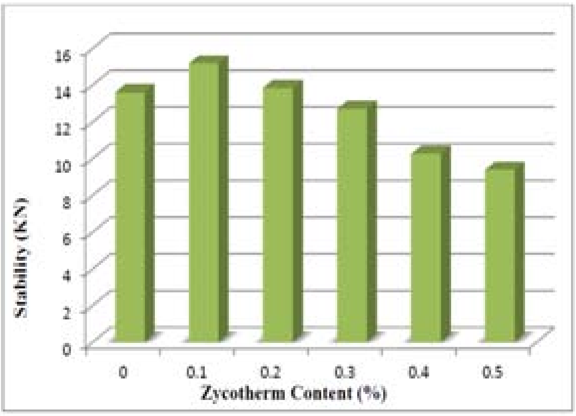

Figure 4.4: Comparison of Stability of Varying Zycotherm Content

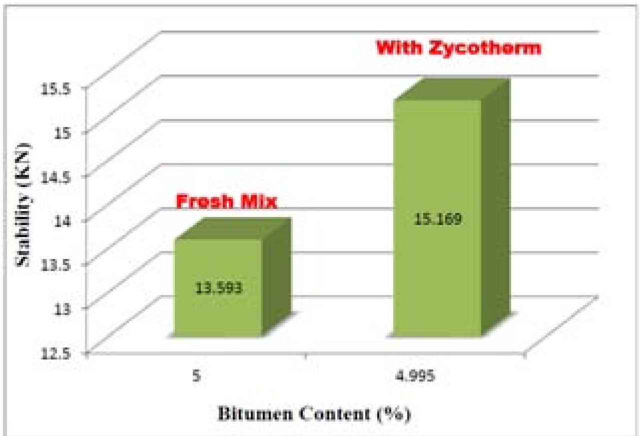

Figure 4.5: Comparison of Fresh Mix and WMA With Respect to Stability

5. Results and Conclusion

5.1 Result

Table 5.1: Marshall Property Results of Fresh Mix for SDBC Layer

% of Bitumen	Weight of Bitumen (gm)	Height(cm)	Diameter	Wt of specimen in air	in water	Gb	Gt	Vv	Vb	VMA	VFB	Proving ring	Stability	Flow value
		6.20	10.00	1243	705	2.310			6.533			385.000	9.101	4.150
		6.20	10.00	1235	710	2.351			6.649			390.000	9.220	4.200
2.8	33.6	6.25	10.00	1146	700	2.569	**2.561**		7.266			385.000	9.101	4.550
Avg						**2.410**		**5.890**	**6.816**	**12.706**	**53.644**		**9.141**	**4.300**
		6.25	10.00	1193	725	2.550			8.242			425.000	10.047	4.300
		6.30	10.00	1229	731	2.468			7.977			435.000	10.283	4.700
3.2	38.4	6.30	10.00	1285	734	2.332	**2.545**		7.538			430.000	10.165	4.800
Avg						**2.450**		**3.730**	**7.919**	**11.649**	**67.980**		**10.165**	**4.600**
		6.20	10.00	1281	735	2.345			8.527			495.000	11.702	6.300
		6.15	10.00	1216	732	2.513			9.138			500.000	11.820	6.500
3.6	43.2	6.20	10.00	1196	730	2.567	**2.530**		9.335			505.000	11.938	5.800
Avg						**2.475**		**2.173**	**9.000**	**11.173**	**80.551**		**11.820**	**6.200**
		6.40	10.00	1212	738	2.557			10.331			520.000	12.293	6.400
		6.25	10.00	1218	735	2.522			10.189			510.000	12.056	6.700
4.0	48.0	6.30	10.00	1277	732	2.343	**2.514**		9.467			515.000	12.175	6.400
Avg						**2.474**		**1.591**	**10.061**	**11.652**	**86.346**		**12.175**	**6.500**
		6.25	10.00	1227	730	2.468			12.465			560.000	13.238	4.150
		6.30	10.00	1218	732	2.504			12.646			585.000	13.829	4.200
5.0	60.0	6.35	10.00	1242	725	2.402	**2.478**		12.133			580.000	13.712	4.250
Avg						**2.477**		**0.807**	**12.727**	**13.534**	**94.037**		**13.593**	**4.200**
		6.25	10.00	1233	725	2.427			13.483			415.000	9.811	4.150
		6.35	10.00	1239	720	2.387			13.261			425.000	10.047	3.950
5.5	66.0	6.10	10.00	1238	735	2.461	**2.461**		13.672			405.000	9.574	3.900
Avg						**2.425**		**1.462**	**14.056**	**15.518**	**90.579**		**9.810**	**4.000**

% of Zycotherm	Weight Of Zycotherm (gm)	Bituminous Content (%)	Weight of Bitumen (gm)	Height(cm)	Diameter	Wt of specimen		Gb	Gt	Vv	Vb	VMA	VFB	Proving ring	Stability	Flow value
						in air	in water									
				6.25	10.00	1227	730	2.468			12.465			560.000	13.238	4.150
0	0	5	60.00	6.30	10.00	1218	732	2.504			12.646			585.000	13.829	4.200
				6.35	10.00	1242	725	2.402	**2.4781**	**0.807**	12.133			580.000	13.712	4.250
Avg								**2.477**			**12.727**	**13.534**	**94.037**		**13.593**	**4.200**
				6.20	10.00	1243	735	2.447			12.345			615.000	14.539	2.700
				6.25	10.00	1217	732	2.507			12.649			670.000	15.839	3.800
0.1	0.06	4.995	59.94	6.30	10.00	1235	737	2.480	**2.4783**	**0.009**	12.512			640.000	15.130	3.250
Avg								**2.478**			**13.034**	**13.043**	**99.933**		**15.169**	**3.250**
				6.25	10.00	1240	730	2.431			12.255			630.000	14.893	6.000
				6.30	10.00	1248	742	2.466			12.432			545.000	12.884	5.900
0.2	0.12	4.990	59.88	6.30	10.00	1244	740	2.468	**2.4785**	**0.948**	12.441			580.000	13.711	4.300
Avg								**2.455**			**12.953**	**13.901**	**93.181**		**13.829**	**5.400**
				6.20	10.00	1239	749	2.529			12.732			560.000	13.238	5.300
				6.15	10.00	1253	735	2.419			12.180			520.000	12.293	5.500
0.3	0.18	4.985	59.82	6.20	10.00	1256	730	2.388	**2.4787**	**1.358**	12.024			530.000	12.529	5.800
Avg								**2.445**			**12.952**	**14.310**	**90.507**		**12.687**	**5.600**
				6.40	10.00	1235	738	2.485			12.500			445.000	10.520	6.200
				6.25	10.00	1244	735	2.444			12.294			425.000	10.047	5.600
0.4	0.24	4.980	59.76	6.30	10.00	1256	732	2.397	**2.4789**	**1.489**	12.057			430.000	10.165	6.400
Avg								**2.442**			**13.003**	**14.492**	**89.728**		**10.244**	**6.000**
				6.25	10.00	1244	740	2.468			12.404			410.000	9.692	7.400
				6.30	10.00	1240	738	2.470			12.413			400.000	9.456	6.500
0.5	0.30	4.975	59.70	6.25	10.00	1237	720	2.393	**2.4791**	**1.416**	12.024			380.000	8.983	5.200
Avg								**2.444**			**13.030**	**14.446**	**90.199**		**9.377**	**6.350**

6. Conclusion

The Marshall Stability value of Fresh mix specimens produced at Binder content 5% (Fig 4.16) by the weight of mineral aggregate has good stability values when compared with Fresh mix specimens and the stability and Marshall Properties of Warm Mix Asphalt specimens prepared at 130°C to 115°C were improved by the addition of Zycotherm at an additive dosage rate of 0.1% (Fig 4.17) by weight of the binder. The optimum binder content for the Fresh mix was found out to be 5% and Warm Mix Asphalt at 130°C to 1150C with 0.1% of Zycotherm was found out to be 4.995%. (Fig 4.18) This concludes that the optimum binder content for Fresh mix and Warm Mix Asphalt are different with varying additive dosage rate, so the Optimum Binder Content should be found out individually for both Fresh mix and Warm Mix Asphalt for varying temperatures and additive dosage rate.

In the present laboratory investigations the Warm Mix Asphalt produced using Zycotherm at 130°C with additive dosage rate of 0.1% showed good results when compared with the Fresh mix. The Warm Mix Asphalt with 0.1% of Zycotherm is recommended to use in practice.

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