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Research Article

Investigating the Performance of Warm Mix Additives

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Abstract

Warm mix asphalt (WMA) is a new technology which helps mixing, laying and compaction of asphalt at temperature lower than hot mix asphalt by the addition of additives. An attempt is done to evaluate the improvements in designing properties of the binder VG30 with and without warm mix additive. As well Marshall Mix design is done on VG30 for DBM II layer with and without warm mix additives i.e. EvothermJ1 and Rediset LQ in reasonable measurements of 0.3%, 0.4% and 0.5% for Evotherm J1 and 0.4%, 0.5%, and 0.6% for Rediset LQ at lower temperature according to the provisions of codal practice, with no settlement with quality. Additionally the performance evaluation of asphalt mixtures are done with respect to moisture damage, fatigue, and rutting cracking via laboratory tests. Further the comparison of two additives is done. The imprint of tests proposes the capable inclination to go for using warm mix additives into the standard of clearing things so that the temperature is cut down to 120°C with no compromise in quality.

Keywords: *WMA (warm mix asphalt), Dense bitumen macadam (DBM), Marshall Mix, Evotherm J1 ,Rediset LQ Chemical, Aggregates, Retained stability, Refusal density, Indirect tensile strength.*

1. Introduction

Warm-mix asphalt innovative technologies permits the creators of bitumen pavement material to decrease the temperatures at which the material is mixed and placed on the road. Reductions of 20° to 30° C are recognized. Such reductions have the obvious benefits of cutting fuel utilization and decreasing the assembly of greenhouse gases. Additionally, engineering advantages includes higher compaction on the road, make possible to haul paving mix for longer distances, and to pave at lower temperatures which leads to extending the paving season. WMA technology includes:

1) Organic like Sasobit, Cecabase RT etc.
2) Chemical like Evotherm J1 and Rediset LQ etc.
3) Foaming like Advera and Aspha-min etc.

2. Literature Review

Warm Mix Bitumen (WMA) is broadly use everywhere throughout the world as a result of its numbers of points of interest when compared with Hot Mix Bitumen (HMA). Literature study associate the work is as shown:

Anand Sampath (2010) studied the comprehensive evaluation result of Sasobit, Evotherm J1 and Rediset TM related to flow number, viscosity, dynamic modulus, tensile strength and dampness.

Graham C. Hurley & Brian D. Prowell(2006) study about the suitability of Evotherm in Warm Mix Asphalt(WMA) technology by performing a laboratory tests under environmental conditions and paving operations and concluded that Evotherm performs to be a feasible tool for decreasing blending and compaction temperatures that can be promptly added to hot mix asphalt.

Lee & Kim, evaluate various WMA products with respect to their fundamental engineering properties and performance-related characteristics. And concluded that Sasobit, Evotherm J1 and Rediset WMX were effective in producing WMA mixtures.

Yi Wang, Jingwen Zhu, Liping Liu, Lijun Sun study about the asphalt rubber mixture(AR) containing Evotherm and the effect of gradation on the high temperature performance and water stability of that mixture. The results indicated that the asphalt aggregate ratio played a critical role in determination of the viability of warm-mix process.

Ambika Behl, Satish Chandra, S. Gangopadhyay `s paper evaluate the effects of three different WMA additives i.e. Sasobit, Rediset WMX and Evotherm on temperature susceptibility of asphalt binders and this was examined by penetration test and viscosity test. Penetration Index (PI), penetration-viscosity numbers (PVN) and Viscosity – Temperature susceptibility (VTS) have been determined to evaluate the results.

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Benjamín Colucci and Freddie Salado in their study they evaluate the additives Evotherm M1, Kaoamin 14, Sasobit and Rediset in WMA. Mixtures with the modified binders were evaluated for compaction, susceptibility to moisture and susceptibility to permanent deformation and various conclusion are drawn.

Zun jhang (2010) research is to evaluate the feasibility of some WMA mixtures which includes Sasobit, Evotherm, and Advera WMA and used it in actual pavement sections to monitor field performance. The laboratory tests are perform to discover the mixture properties and overall performance characteristics. Further to evaluate the effects of WMA with different additives, Mechanistic-Empirical Pavement Design Guide (MEPDG) approach is used by integrating Laboratory test results with other available data.

3. Materials and Methodology

3.1 VG30 (50/70 grade): It is thermoplastic material possess admirable bonding and adhesive properties with aggregates, and also a waterproofing material. It is used to construct intense load carrying asphalt pavements that need to undergo large traffic loads.

3.2 Warm Mix Additive

- ***Evotherm J1****:* Evotherm J1 is chemical additive of WMA produced by MeadWestvaco Asphalt Innovations, U.S., and France. This is a low viscosity liquid, warm blend added substance that provide various benefits over hot mix asphalt (HMA) by reducing the blending and compaction temperatures of mix, and with addition to this it helps in improving the dampness resistance of asphalts. Evotherm J1 also aids to reduce the harmful emission of gases and odours at plant as well as at working site.
- ***Rediset LQ***: It is a chemical warm mix additive offers an easy-to-use liquid product that simplifies managing and metering at the plant. It produced by Akozo Nobel Company. It offers Good workability and compaction even at reduced temperatures. Furthermore it provide active adhesion that permits coating of incompletely dried aggregates, prevents stripping and improves moisture resistance.

4. Methodology

In this study Marshall Mix Design is use for Dense Bituminous Macadam (DBM II) mix which is designed for 26.5 mm nominal size of aggregate. The VG30 grade of bitumen is obtained from IRB Plant Gujarat. Evotherm J1 additive is collected from MeadWestvaco Asphalt Innovations, U.S. And from Akozo Nobel Company, Mumbai, Rediset LQ is collected. The aggregates are obtained from IRB plant, Pij chokadi, Nadiyad, Gujarat.

Firstly, laboratory test are done to evaluate the physical properties of aggregate which are carry out as per the MoRTH specification section 500 clause 505 for DBM grade II. Similarly, the Bitumen tests for VG30 with & without WMA additives (Evotherm J1 & Rediset LQ) are carry out which are as per IS standard and all results satisfied the IS specification.

Secondly, in order to obtain the Optimum bitumen content (OBC) Marshall Mix design for DBM Grade II is worked out which comes to be 4.62% and further at this OBC, samples are prepared at temperature 110°C, 120°C, 130°C and at different dose of

- Evotherm J1 i.e. 0.3%, 0.4%, 0.5% of weight of binder and
- Rediset LQ i.e.0.4%, 0.5%, and 0.6%of weight of binder.

From this the Optimum dosage of Evotherm J1 and Rediset LQ with Optimum temperature are evaluated. Furthermore, the Performance evaluation of DBM Grade II design consist of Retained stability, Refusal Density Test and Indirect Tensile strength(ITS) are conducted on warm mix sample.

A. Laboratory investigations

Table 1: Physical properties of Aggregate

Physical Properties for Coarse Aggregate for Dense Bituminous Macadam Grade II (As per MoRTH Table : 500-8)				
Sr.no	Property	Test	Specification	Result
1	Cleanliness	Grain size analysis	Max 5% passing 75 micron IS-Sieve	Pass.26.5-Ret.22 mm 0.33% Pass.2.5 - Ret.14 0.45% Pass.14 - Ret. 8 0.79 %
2	Practical Shape	Flakiness & Elongation n Indices	35 % Max	27.79%
3	Strength	Aggregate e impact value	27 % Max	12.36%
4	Resistance to Abrasion	Los angles abrasion test	30 % Max	18.20%
5	Water absorption n value	Water absorption n test	2 % Max	0.98%

Gradation of aggregate meeting MoRTH section 508

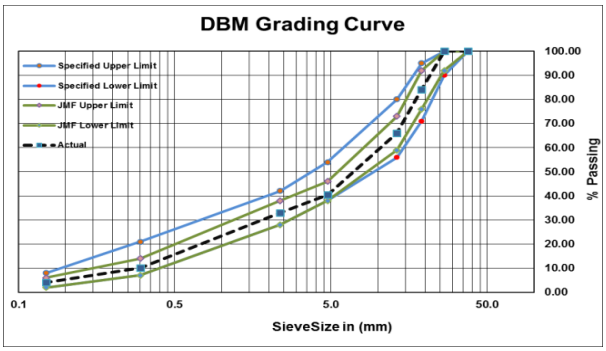

Fig. 1: Gradation of aggregate chart

It is clear from the above graph that the limits are within the Upper and Lower limits satisfying JMF & MoRTH specifications for 26.5 mm nominal size of aggregate.

Table 2: Physical properties of VG 30, VG30+%Evotherm J1, VG30 +%Rediset LQ

Characteristics of tests:	VG-30	VG-30 + 0.3 % Evotherm J1	VG-30 + 0.4 % Evotherm J1	VG-30 + 0.5 % Evotherm J1	VG30+0.4 % Rediset LQ	VG30+0.5% Rediset LQ	VG30+0.6 % Rediset LQ	Min. Limit	Code
Penetration (mm)	53.33	48	45	44	34	42	43	50/70	IS 1203
Softening point (C°)	52.5	54	55	54	52	51	50	47	IS 1205
Ductility (cm)	94	85	82	85.5	92	90	86	40	IS 1208
Absolute Viscosity at 60 (C°)	4640	3500	3340	2810	4570	3960	3230	2400	IS 1206 (part 2)
Kinematic Viscosity at 135°C(cst)	652	580	545	460	596	555	557	350	

Table 3: Summary of test results for VG 30 + 0.3%Evotherm J1 & VG30+0.4% Rediset LQ for DBM Mix Design Grading II

	0.3% Evotherm J1			**0.4% Rediset LQ**		
TEMP. °C	110	120	130	110	120	130
CDM,gm/cc	2.555	2.564	2.559	2.545	2.549	2.552
Air Voids %	3.72	3.41	3.56	4.3	3.79	3.53
VMA , %	14	13.35	13.49	13.62	13.84	13.05
VFB , %	72.72	73.9	71.76	70.94	70.48	72.76
Stability, kg	13.18	15.58	12.9	14.1	13.89	14.8
Flow, mm	3	2.2	2.4	3.43	3.3	2.93

B. Marshall Mix design for optimum binder content (OBC) using VG30

For deciding the Optimum Bitumen Content, 6 specimens are arranged of bitumen substance at 4, 4.2, 4.4, 4.6, 4.8 and 5.0% of degree blend weight at blending temperature 160° C according to the system and prerequisites of MoRTH segment 508. The volumetric properties obtained are as shown in table 3.

Table 4: Properties of Marshall Mix Design for DBM Grade II as per MoRTH.

% Bit. By Weight of Mix	Bulk Sp. Gr. (Gmb)	Stability (KN)	Voids in Mineral Agg. VMA (%)	Voids Filled with Bitumen VFB (%)	Flow (mm)	Air Voids VA (%)
4.00	2.49	10.75	15.29	48.84	2.17	7.82
4.20	2.50	12.03	14.85	56.77	2.47	6.42
4.40	2.52	13.16	14.56	63.05	2.93	5.38
4.60	2.53	13.30	14.45	68.22	3.43	4.59
4.80	2.52	13.72	14.87	72.15	3.80	4.14
5.00	2.52	12.46	15.36	74.41	4.40	3.93

Parameters	Binder Content %
Stability (KN)	4.62
Bulk Sp. Gravity	4.60
VA %	4.63
VFB %	4.64
Avg.	4.62

Optimum bitumen content: 4.62%

C. Marshall Mix Design for VG30 (4.62 % OBC) plus (% EvothermJ1& %Rediset LQ) for optimum dosage and optimum temperature

Marshall Mix Design for VG30+% EvothermJ1

- Different dosage of Evotherm J1 are taken i.e. 0.3%, 0.4%, and 0.5% of Evotherm J1.
- Graphs of all properties of each mix are plotted for different properties and concluded that 0.3% Evotherm J1 fulfils the criteria's set down in codal MoRTH procurement at 120°C,and leads into a huge change in flow values, stability, and unit weight which directly improving the compaction and increasing the workability conditions.

Marshall Mix Design for VG30+%Rediset LQ

- Different dosage of Rediset LQ are taken i.e. 0.4%, 0.5%, and 0.6% of Rediset LQ.
- Graphs of all properties of each mix are plotted for different properties and concluded that 0.4% Rediset LQ fulfils the criteria's set down in codal MoRTH procurement at 130°C,and leads into a change in flow values and stability.

D. Comparison study of warm mix additives

Table 5: Comparison of the warm mix additives

Property		0.3%Evotherm J1 at 120°C	0.4% Rediset LQ at 130°C	Specification as per Morth
Stability (kn)	Max.	15.58	14.8	Min. 9
Flow(mm)	Min.	2.2	2.93	2-4

Air voids (%)	Min.	3.41	3.53	3-5
Vfb (%)	Max.	73.9	72.76	65-75
Vma (%)	Low	13.35	13.05	Min.12
Comapcted density	Max.	2.564	2.552	-

E. Retained Stability

It is conducted on the Marshall samples to the find out the resistance of mix towards the water damage. The stability of mix is determined after placing the samples in water bath at 60°C for half an hour and 24 hours. Table 6 shows the summary of Retained Marshall Stability test results.

Retained stability (%)

$$=\frac{\text{Stability after 24 hrs in water bath at 60°C}}{\text{Stability after 30 mins in water bath at 60°C}} X100$$

Table 6: Retained Marshall Stability Test Results

Retained stability KN	VG30	VG30+0.3% Evotherm J1	VG30+0.4% Rediset LQ
Marshall Stability at 60°C for 30 min	16.24	13.62	14.78
Marshall Stability at 60°C for 24 hrs	14.32	15.23	12.74
Retained Stability,%	88.17%	89..2%	86.4%

F. Refusal Density

It is a simply procedures for ascertaining the air Voids level when the mix has achieved its maximum density under Marshall Compaction (or any other type of compaction). For refusal density testing the Marshall Specimens have been made with the modified aggregate grading at the design Asphalt content, giving different compactive efforts ranging from 100 to 500 blows and the Air voids of the mixes have been determined from G_{mm} and G_{mb} values(table 7).

Table 7: Refusal Density Test Results

	No.of blows on each side	100	200	300	400	500	600
	%bit.by wt. Of mix sample	4.62	4.62	4.62	4.62	4.62	4.62
Evotherm J1	Temp.	120° C	120° C	120° C	120° C	120° C	-
	% Air voids (VA)	3.37	3.30	3.18	3.12	3.06	3.10
Rediset LQ	Temp.	130° C	130° C	130° C	130° C	130° C	130° C
	% Air voids (VA)	4.88	4.03	3.63	3.14	3.17	

G. Indirect Tensile Strength (ITS) & Tensile Strength Ratio (TSR)

ITS tests were performed on Marshall Samples of conventional bituminous mixes and Warm bituminous mixes at 25°C. The ITS test was performed by loading a Marshall specimen with a single compressive load, that acts parallel to and along vertical diametrical plane. This loading configuration develops a uniform tensile stress perpendicular to the direction of the applied load and along the vertical diameter. The load at which the specimen fails is taken as the indirect tensile strength (also referred as the dry indirect tensile strength) of the bituminous mix.

The tensile strength ratio of the bituminous mixes is used to determine the moisture susceptibility of the mixes. The ratio of the wet to dry indirect tensile strength is recorded as Tensile Strength Ratio (TSR) of the bituminous mix.

Table 8*:* Indirect Tensile Strength & Tensile Strength Ratio for DBM Grade II mix

Sr. No	Grade of Bitumen	Indirect Tensile Strength, kg/cm² at 25°C		Tensile Strength Ratio, % (S2/S1)	Requirement as per MoRTH Specification
		Unconditioned S1(dry)	Conditioned S2(wet)		
1	VG 30	12.87	10.49	81.5	Min 80%
2	0.3% EVOTHERM J1	13.45	11.05	82.15	
4	0.4%REDISET LQ	14.99	13.35	89.05	

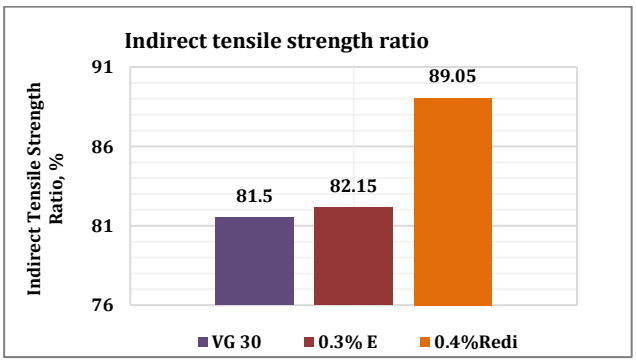

Fig 2: Indirect Tensile Strength Ratio

Conclusions

From the different examinations completed in the laboratory taking after, conclusions are drawn:

1) Physical properties of aggregates are fulfilling the IS codes.
2) Aggregate gradation chart plot in figure1, shows that the obtained gradation line falls above the lower limit line which means that the selected

Aggregate proportion are more towards fine aggregate line.

3) The properties of VG30 grade and VG30 +% WMA additives is investigated like penetration test, viscosity test, softening test, specific gravity and Ductility fulfilling the criteria as laid down in codal provisions for bituminous surface.
4) For VG 30 Marshall Mix Design DBM Grade II, the optimum binder content comes out to be 4.62% satisfying the permissible limits as per the MoRTH section 508.
5) The corroborative test of Marshall Mix design utilizing VG 30 as 4.62% by weight of bitumen with 0.3 %, 0.4 % and 0.5% Evotherm J1 as warm mix added substance demonstrates that VG 30 with 0.3 % Evotherm J1 fulfils the criteria's set down in codal MoRTH procurement at 120°C, likewise for Rediset LQ 0.4% at 130°C fulfils the criteria and leads into a huge change in flow values, stability, and unit weight which directly improving the compaction and increasing the workability conditions.
6) The experimental test has been proved that the increase in the compactive energy shows an increase in the bulk density and decrease in the air voids level. 500 blows are obtained as the **refusal density** for Evotherm J1 and 400 blows is for Rediset LQ. A refusal density result with reference to air voids ascertains the mix to have attained maximum density. Comparing the threshold lower level of air voids (3 percent), it can be referred that the mix is not prone to rutting from the consideration of secondary compaction of traffic.
7) For **retained stability** test under normal and wet conditions, it is observed that the retained stability increases with addition of Warm mix additives and there observe more increase in the stability in case of Evotherm J1 compare with the Rediset LQ which signifies the effect of additive on resistance to moisture induced damage. This test measures the stripping resistance of a bituminous mixture.
8) Warm mix asphalt had better **TSR** (Tensile strength ratio) value as compare to the neat VG30 asphalt mix.VG 30 mixes containing the warm asphalt additives had significantly higher TSR values than control mixes. Rediset LQ have higher ratio as compare to Evotherm J1.Warm asphalt mixes showed better resistance to moisture induced damage.

References

Anand Sampath(2010), Comprehensive evaluation of four warm asphalt mixture regarding viscosity, tensile strength, moisture sensitivity, dynamic modulus and flow number University of lowa.

Brian D Prowell, Graham C. Hurley, Everett crews l(2007) Field Performance of Warm-Mix Asphalt Transportation Research Record Journal of the Transportation Research Board (Impact Factor: 0.44). 01/2007; 1998(1):96-102. DOI: 10.3141/1998-12

Devendra K. Patel, Prof. C. B. Mishra, Prof. A. A. Amin (2014), Evaluation of Rediset as Warm Mix Adhesion Promoter with CRMB 60 in Mix Design International Journal of Engineering Research and Technology Vol. 3 (03), 2014, ISSN 2278 – 0181

IS: 1202- 1978, Methods for testing tar and bituminous materials: determination of specific gravity.

IS: 1203- 1978, Methods for testing tar and bituminous materials: determination of penetration.

IS: 1205- 1978, Methods for testing tar and bituminous materials: determination softening point.

IS: 1206- 1978, Methods for testing tar and bituminous materials: determination of viscosity

IS: 2386 (Part 1) - 1963, Methods of test for Aggregates for concrete: Particle size and shape.

IS: 2386 (Part 3) - 1963, Methods of test for Aggregates for concrete: specific gravity, density, voids, absorption and bulking.

IS: 2386 (Part 4) - 1963, Methods of test for Aggregates for concrete: Impact value and Abrasion value.

IS: 15462- 2004, Polymer and Rubber Modified Bitumen-Specification.

IS: SP 53- 2002, Guidelines on the use of Polymer Modified Binder Specifications.

MeadWestvaco (2003), Evotherm warm mix asphalt-The next-generation sustainable paving solution. (www. majeskaassociates.com/ images/ Evotherm.pdf)

Ministry of Road Transport and Highways (MORTH), Government of India for Road and Bridge works, section 508, Design of Bituminous Concrete.

Rohith N., J.Ranjitha (2013) A Study on Marshall Stability Properties of Warm Mix Asphalt Using Zycotherm A Chemical Additive, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 7, July – 2013.

Prithvi Singh Kandhal (2010) Warm Mix Bitumen Technologies: an overview Journal of Indian Road Congress

Yu Kuang (2012) Evaluation of Evotherm as a WMA technology compaction and anti-strip additive M.tech thesis, Iowa State University, Ames, Iowa.

Zun Jhang (2010) Effects of Warm Mix Asphalt Additives on Bitumen Mixture Characteristics and Pavement performance Civil Engineering Theses, Student Research, University of Nebraska-Lincoln.