IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

CHARACTERIZATION OF WARM MIX ASPHALT AT DIFFERENT MIXING AND COMPACTION TEMPERATURES

[1]Santoshakumar H, [2]Nandini Reddy,

[1]PG student, [2] Associates Professor & Head of Department

[1,2] Department of Civil Engineering, Bheema Institute of Technology and Science, Kurnool, Andra Pradesh, India

Abstract: With growing concerns about global warming and rising emissions, the asphalt industry is continuously working to reduce its emissions by lowering the temperatures at which the asphalt mixture is mixed and compacted without compromising the mix's qualities. The industry has access to a number of unique compounds that can assist in lowering the temperatures during mixing and compaction. The qualities of warm mix asphalt and combinations have been examined in studies. In order to properly coat every aggregate at low temperatures with easy workability, a binder with low viscosity must be used, and it must be produced at low heating temperatures. Warm Mix Asphalt is a low viscosity at low temperature binder technology.

I. INTRODUCTION

The majority of paved roads are created of hot mix asphalt (HMA), a mixture of heated aggregate and asphalt binder that is utilized as the principal paving material. In an asphalt factory, the mixers, dryers, and hot bins are the main producers of emissions since they release particulate matter, including dust, smoke, exhaust vapour, and other gaseous pollutants. An asphalt plant's storage silos, truck loading activities, binder storage tanks, conveyers, stock piles, etc. are some additional sources of emissions.

The asphalt industry is continually looking for ways to lower mixing and compaction temperatures of the mixes without significantly compromising the qualities of mixes in order to reduce emissions from asphalt plants. In order to save energy and improve the environment, the asphalt industry has been experimenting with warm and cold asphalt mixtures for decades. But currently, the majority of cold goods fall short of hot mix asphalt in quality.

Higher air voids are typically produced by emulsion binders, which also have longer curing periods and a propensity to only operate with open and coarsely graded mixtures. The volatile compounds in cutback bitumen cause environmental issues as well as extended cure times. While it has been claimed that foamed bitumen only effectively coats fine aggregates and is better suited for recycling applications, it does not require lengthy curing times. Another issue with these approaches is that the energy savings do not outweigh the additional costs. Therefore, it looks that cold mixes won't be able to take the position of hot mixes as the main road covering materials as they haven't reached the same general long-term performance as hot mixes.

Warm Mix Asphalt

The method known as Warm Mix Asphalt (WMA) was first made available in Europe in 1995. The term "warm mix asphalt" refers to techniques that significantly lower the temperatures at which asphalt mixes are mixed and compacted by reducing the viscosity of the asphalt binders. Reduced energy requirements for producing hot mix asphalt, decreased emissions and odors from plants, and improved working conditions at the plant and paving site might all be achieved by lowering mix production and paving temperatures.

By up to 30%, the method can lower production temperatures. Generally speaking, asphalt mixes are created at temperatures of 150 °C or more, primarily depending on the type of binder utilized. At temperatures about 120 oC, WMA mixtures can be made. In the 1990s, WMA technologies such Aspha-min, WAM Foam, and Sasobit were created. In order to research these three WMA technologies, the US National Asphalt Pavement Association (NAPA) arranged a European Scan visit in 2002. In 2003, the National Centre for Asphalt Technology (NCAT) began investigating WMA technology. Later, during the years 2004–2007, new WMA technologies were created in the US, including Evotherm, Rediset WMX, REVIX, LEA (Low Energy Asphalt), and Double Barrel Green.

The first WMA techniques that were created in Europe relied on either waxes or foamed asphalt. The binder is given waxes to make it less viscous and more lubricious. These substances often have melting points lower than those used for standard HMA manufacture. These substances lessen the viscosity of the asphalt binder at temperatures above the melting point. These substances often increase the stiffness of the binder below the melting point. According to recent study, wax additions increase the binder's capacity to lubricate, which increases the mix's workability at lower temperatures. The main method by which many WMA procedures enhance workability and compatibility at lower temperatures may not be viscosity reduction but lubrication.

Other benefits of using warm asphalt include the ability to open construction sites to traffic sooner, longer paving seasons, longer hauling distances, reduced wear and tear on plants, reduced aging of binders, reduced oxidative hardening of binders and thus reduced cracking in the pavements. These benefits are in addition to the obvious ones, such as reduced fuel consumption and reduced emissions in the plant. Warm asphalt paving also offers workers a cleaner, safer working environment with less emissions. Warm asphalt may now be created without compromising the mix's qualities because to the availability of many proprietary compounds and production techniques. Warm mix technologies work by reducing the viscosity of the asphalt binder, which enables the asphalt to reach the proper viscosity to coat the particles and compact the mixes at lower temperatures

II. SCOPE AND OBJECTIVES OF THE STUDY

This study's goal is to find out how a warm mix chemical addition can be utilized to lower the hot mix's mixing and compaction temperatures in comparison to the standard mix. More research is needed to determine how the properties and performance traits of the mixes are impacted by lower mixing and compaction temperatures. The purpose of the lab tests was to

.

a) Determine the Marshall properties of Hot Mix Asphalt of BC-2 mixes.
b) Determine the Marshall properties of Warm Mix Asphalt of BC-2 mixes under different mixing and compaction temperatures.
c) Determine the Indirect Tensile Strength of Hot Mix Asphalt and Warm Mix Asphalt of BC-2 mixes.

III. MATERIALS USED IN THIS STUDY

The coarse aggregate is gathered Narsareddy Plant Near Tuntapur Village Beside M-sand Quarry Raichur. Stone dust from crusher run is used as filler. To ascertain the physical qualities, the aggregates are investigated in a lab setting using the prescribed test procedures. The results are shown in table: PROPERTIES OF AGGREGATES

Table 1: Properties of Aggregates

Properties Tested	**Test results on Aggregates**	**MoRTH Specifications clause table 500-16**	**Test conduction as per**
Aggregate impact value	26%	30%max	IS 2386(Part 4)
Specific Gravity of Coarse aggregate & Fine Aggregate	2.66 & 2.70	2.5-3	IS 2386(Part 2)
Elongation and Flakiness index	22.2%	35%max	IS 2386(Part 1)
Water Absorption	0.25%	2%max	IS 2386(Part 3)

The investigation used a bitumen sample of VG-30 grade from M/s Tiki Tar Industries (India) Ltd. in Mumbai. Table 3.2 displays the outcomes of the experiments performed on VG-30 neat bitumen. By mixing M/s Zydex industries' Zycotherm additive with VG 30 grade bitumen, warm mix asphalt is created. By weight of the binder, the addition added to VG 30 bitumen is 0.1%. Table3.3 presents the findings for the warm mix binder.

Table 2: Properties of VG-30

Sl.no	**Characteristics**	**Results**	**Requirement as per IS 73 2013**	**BIS specifications**
1	Specific gravity	1.02	0.97-1.02	IS 1202-1978
2	Softening point	54 ° C	45-55°C(min)	IS1205-1978
3	Ductility test	100cm	75cm(min)	IS 1208-1978
4	Penetration test	67mm	45 (min.)	IS1203-1978

Table 3: Properties of Warm Mix bitumen

SI. NO	**Properties**	**Results Obtained**
1	Penetration@25°C	68
2	Softening Point(R&B)°C	49
3	Ductility at 27°C,(cm)	100+
4	Specific Gravity	1.01

IV . MIX DESIGN

Marshall Test is conducted to find out optimum bitumen emulsion content and optimum bitumen content. The mix design procedure for warm mix and hot mix is explained below. The Percentage of material used in marshal Mix design is Coarse Aggregates (21%), Fine aggregates (38%), Filler (39%) & cement (2%)

A. Marshall properties with varying mixing and compaction temperature

In the current research, the Marshall Asphalt warm mix qualities specimens with varying temperature for compaction and mixing are opted. The different temperatures for compaction and mixing adopted for warm mix asphalt are as indicated in Table 4

Table 4 Mixing and Compacting Temperatures for WMA

For mixing temperature(°C)	Compacting temperature(°C) is
110	80
	90
	100
120	80
	90
	100
130	80
	90
	100

B. Marshal Mix Design of Hot Mix Prepared Using VG-30 Bitumen

ASTM-D 1559-82 was followed for conducting the Marshall tests. The average of the binder content corresponding to the highest levels of stability, unit weight, flow at 3 mm, and air void content (4%), has been determined to be the optimal binder. Plotting graphs with bitumen content on the X-axis and subsequent values on the Y-axis allows for the determination of OBC.

- Values of Marshall Stability
- Values of flow
- Unit weight or Bulk Density (Gb)
- Percentage of total mix air voids (Vv)
- Percentage of bitumen-filled voids (VFB)

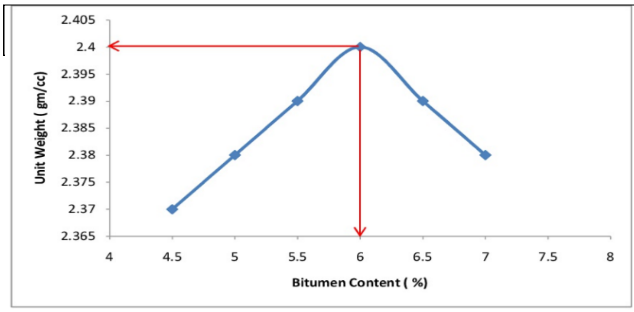
The average value of the following bitumen contents discovered from the graphs of the test results is used to determine the OBC for the mix design

- Maximum stability corresponds to bitumen content.
- Maximum unit weight for bitumen content
- Bitumen content matching the median of the design flow limitations (3 mm)
- Bitumen content that is equal to the median of the allowed percentage of air voids in the whole mix (4%).

The volumetric properties of the bituminous mixes are assessed, together with the maximum theoretical specific gravity and bulk specific gravity of the mixtures. Table 3.6 lists the Marshall characteristics for a mix made using neat bitumen VG 30. In Fig. 1 to 4, the connections between the Marshall attributes are shown.

Table 5 Marshall Properties of B.C-2 Hot mix Prepared using VG-30 binder

Bitumen content (%)	Unit Weight (Gb) (gm/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Marshall stability (Kg)	Flow(mm)
4.5	2.37	6.7	10.5	17.2	60.9	2678	2.4
5.0	2.38	5.6	11.6	17.3	67.6	2951	2.7
5.5	2.39	4.6	12.9	17.5	73.7	3048	2.9
6.0	2.40	3.6	14.1	17.7	79.7	2835	3.2
6.5	2.39	3.2	15.2	18.4	82.6	2487	3.6



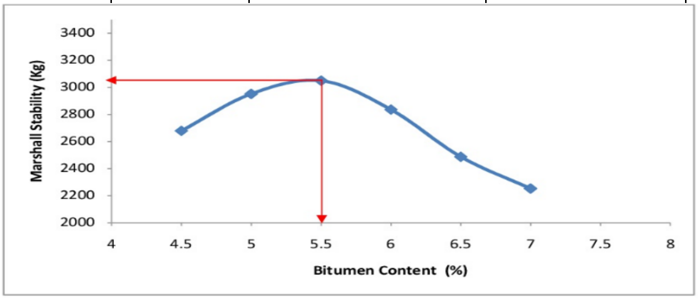
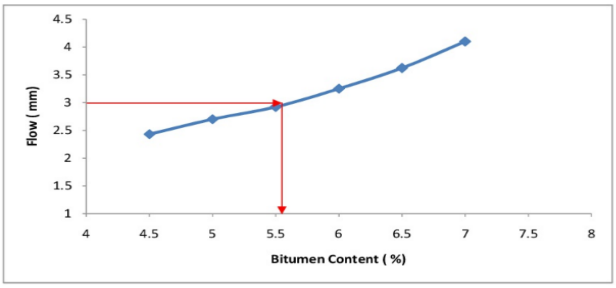


Fig . 1 Unit Weight v/s Bitumen content **Fig . 2 Marshal Stability v/s Bitumen content**



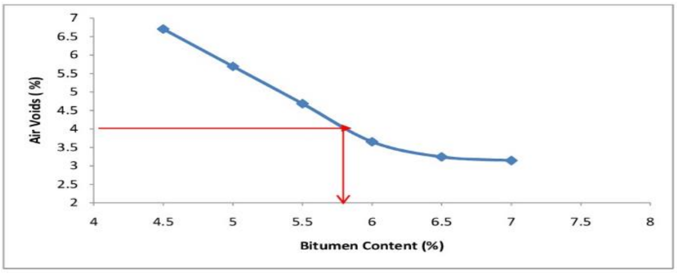


Fig . 3 Flow v/s Bitumen content **Fig . 4 Air Voids v/s Bitumen content**

Marshall Properties at Optimum Binder Content

The Marshall properties obtained for hot mix at optimum binder content is presented in Table 6

Table 6 Marshall Properties at Optimum Binder Content for HMA BC-2mix

Sl.No	**Marshall Properties**	**Result of HMA BC-2 Mix**	**Requirement as per M oRT&H V Revision**
		VG-30 Grade Bitumen	
1	Optimum Bitumen Content,(%)	5.7	5.4
2	Stability,(Kg)	2896	9 Minimum
3	Flow,(mm)	3.7	3 Minimum
4	Bulk Density,(gm/cc)	2.35	----
5	Air Voids (Vv), (%)	4.8	4 Minimum
6	VMA, (%)	18.4	16 minimum
7	VFB, (%)	73.6	65-75

C. Marshall Mix Design of Warm Mix Prepared Using VG 30 Bitumen

ASTM-D 1559-82 was followed for conducting the Marshall tests. The average of the binder content corresponding to the highest levels of stability, unit weight, flow at 3 mm, and air void content (4%), has been determined to be the optimal binder. Plotting graphs with bitumen content on the X-axis and subsequent values on the Y-axis allows for the determination of OBC.

- Values of Marshall Stability
- Values of flow
- Unit weight or Bulk Density (Gb)
- Percentage of total mix air voids (Vv)
- Percentage of bitumen-filled voids (VFB)

The Marshall properties obtained for Warm mix prepared using neat bitumen VG 30 is presented in Table 7. The relationships between Marshall properties are presented in Fig. 5 to 8

Table 7 Marshall Properties of Warm Mix Asphalt BC-2

Bitumen content (%)	Gb, (gm/cc)	Gt, (gm/cc)	Vv, (%)	Vb, (%)	VMA, (%)	VFB, (%)	Marshal stability, (Kg)	Flow (mm)
4	2.41	2.56	5.8	9.5	15.3	62.1	2514	2.7
4.5	2.42	2.54	4.7	10.7	15.5	69.3	2780	2.9
5.0	2.43	2.52	3.6	12.0	15.7	76.4	2670	3.1
5.5	2.42	2.50	3.3	13.5	16.5	79.9	2571	3.6

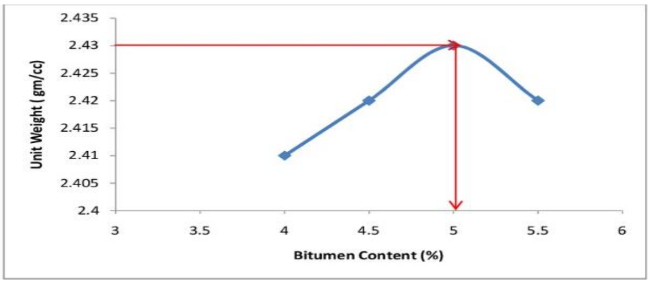


Fig. 5 Unit Weight v/s Bitumen content

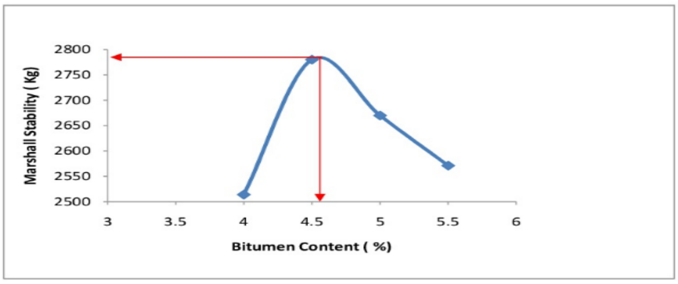


Fig .6 Marshall Stability v/s Bitumen content

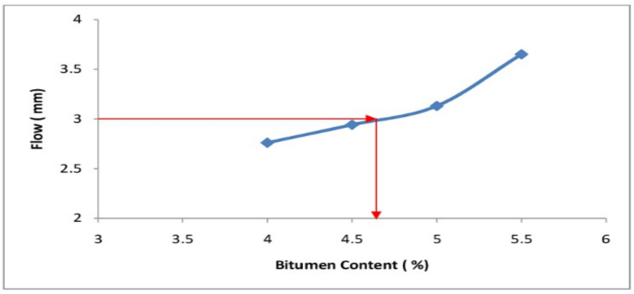


Fig. 7 Flow v/s Bitumen content

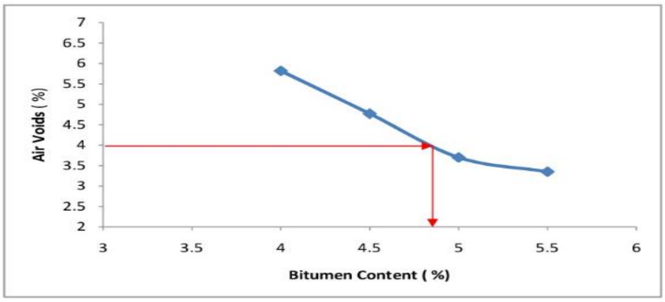


Fig. 8 Air Voids v/s Bitumen content

Marshall properties at optimum bitumen content for WMA BC-2 mix

Marshall properties obtained for the WMA (BC-2)mix at optimum binder content is presented in Table 8.

Table 8 Marshall Properties at Optimum Binder Content for WMA (BC-2) mix

Sl.No	Marshall Properties	Result of WMA BC-2 Mix	Requirement as per MoRT&H V Revision
1	Optimum Bitumen Content,(%)	4.7	----
2	Stability,(Kg)	2738	9 minimum
3	Flow,(mm)	3.0	3 minimum
4	Bulk Density,(gm/cc)	2.42	----
5	Air Voids (Vv), (%)	4.2	4 minimum
6	VMA, (%)	15.6	12 minimum
7	VFB, (%)	72.8	65-75

V Static Indirect tensile Strength Test

The ASTM: D-4123-1995 static indirect tensile test was used to examine how paving mixes behaved under various temperature conditions. By applying a single compressive force that acts parallel to and along the vertical diametrical plane to Marshall Specimens, the split tensile strength of bituminous mixes was ascertained. The specimen fails by splitting along the vertical diameter due to the development of a nearly uniform tensile stress normal to the direction of the applied force and along the same vertical plane. The specimen's indirect tensile strength was determined

The load at failure was noted, and using the relation provided in equation 1, the indirect tensile strength was calculated.

$$\sigma x = \frac{2 \times P}{(\pi \times d \times t)} \text{ Mpa}$$

Where,

σ_x = Tensile stress along the horizontal, Mpa

P = Applicable Load in,N.

d = Dimensions of the sample , mm.

t =Thickness of sample, mm.

The ratio of the strength retained after conditioning by accelerated moisture and freeze-thaw to the initial strength of the control specimens is used to express the numerical index of resistance of bituminous mixture to the harmful effects of water sensitivity value. This formula is used to compute the tensile strength ratio (TSR):

Tensile strength ratio (TSR) = (S2/S1) Retained tensile strength, % =100*(S2/S1) Where,

S2=average strength of the conditioned subset of specimens, Kpa
S1=average strength of the control or unconditioned subset of specimens, KPa

VI. ANALYSIS OF TEST RESULTS

Warm mix Samples are created at different mixing temperatures of 110, 120 and 130°C and at different compacting temperatures of 80, 90 and 100°C. Static Indirect tests for tensile strength were carried out at a constant temperature 25^0C. Repeated load tests were performed at a temperature of 250°C, a frequency of 1Hz, and stress levels of 20% with respect to IDT strength.

A. Marshal Properties of WMA BC-2 at varying Mixing and Compaction Temperature

Table .9 Marshall Properties of WMA BC-2 at Different mixing and Compacting temperatures

Bitumen content (%)	Mixing temp °C	Compaction temp °C	Wt in Air (gm)	Wt. in Water (gm)	Gb (gm/cc)	Gt (gm/cc)	v (%)	Vb (%)	VMA (%)	VFB ,(%)	Marshall Stability (Kg)	F
4.7	110	80	1251	726	2.38	2.53	5.8	11.2	17.0	65.8	2039	
		90	1252	728	2.38	2.53	5.5	11.2	16.7	66.8	2273	
		100	1255	734	2.41	2.53	4.7	11.3	16.1	70.2	2333	
	120	80	1258	736	2.40	2.53	4.7	11.3	16.0	70.5	2428	
		90	1260	738	2.41	2.53	4.5	11.3	15.9	71.1	2438	
		100	1261	740	2.42	2.53	4.3	11.4	15.7	72.3	2768	
	13	80	1261	734	2.41	2.53	4.51	11.3	15.8	71.3	2677	
		90	1261	740	2.42	2.53	4.33	11.3	15.7	72.4	2780	
		100	1262	743	2.43	2.53	3.88	11.4	15.1	74.6	3083	

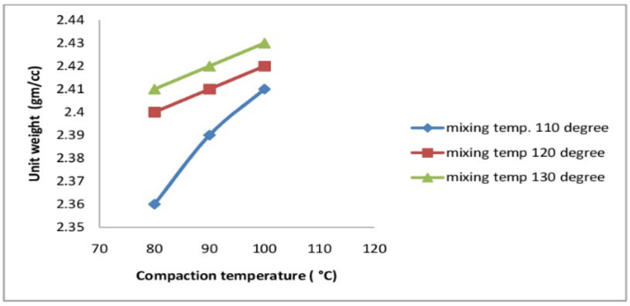


Fig .9 Unit Weight Vs Compaction Temperature

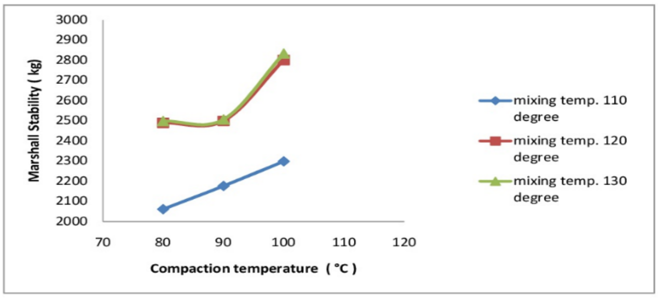


Fig. 10 Marshal Stability Vs Compaction Temperature

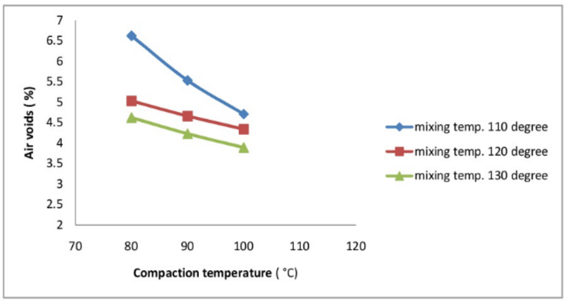


Fig .11 Air Voids Vs Compaction Temperature

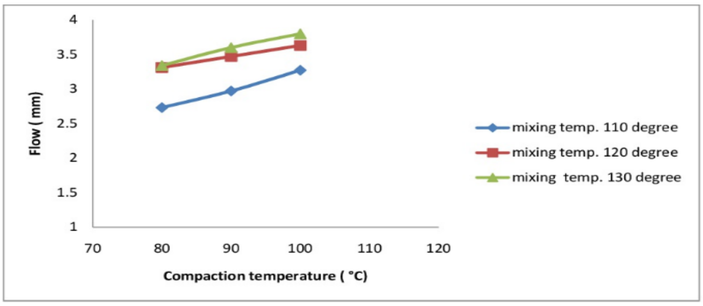


Fig.12 Flow Vs Compaction Temperature

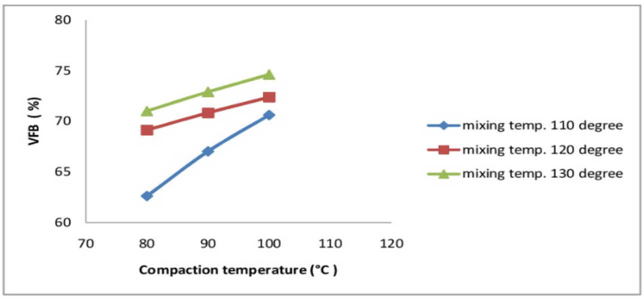


Fig .13 VFB Vs Compaction Temperature

B. Indirect Tensile Strength of WMA BC-2 at varying Mixing and Compaction Temperature

The indirect tensile strength at 25^{0}C temperature for specimens of hot mix asphalt and warm mix asphalt BC-2 mixes at different mixing and compacting temperatures are shown in Table 10, 11 and 12 for unconditioned and conditioned specimens respectively. The tensile strength ratio of hot mix asphalt and warm mix asphalt mixes are presented in Table 10 and 14. The Tensile Strength Ratio v/s Compaction Temperature for different mixing temperatures of warm mix asphalt and hot mix asphalt.

Table 10 Tensile strength ratio of HMA

Temperature (℃)	Unconditioned Tensile strength (M Pa)	Conditioned Tensile strength (M Pa)	TSR	Retained Tens il e Strength (%)
25	1.31	1.087	0.83	83

Table.11 Unconditioned Indirect Tensile Strength of WMA BC-2 at Different Mixing and Compacting Temperature

Bitumen content(%)	Mixing temp(°C)	Compaction temp (°C)	Gb (gm/cc)	Gt (gm/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Stability (Kg)	Tensile strength (MPa)
4.7	110	80	2.39	2.53	5.4	11.2	16.7	67.2	2262	2.06
		90	2.4	2.53	5.1	11.2	16.4	68.7	2351	2.14
		100	2.4	2.53	4.7	11.3	16	70.4	2387	2.17
	120	80	2.4	2.53	4.6	11.3	15.9	70.9	2639	2.4
		90	2.41	2.53	4.5	11.3	15.9	71.1	2700	2.45
		100	2.42	2.53	3.9	11.4	15.3	74.2	2739	2.49
	130	80	2.41	2.53	4.7	11.3	16	70.5	2627	2.39
		90	2.43	2.53	3.8	11.4	15.3	74.6	2675	2.43
		100	2.43	2.53	3.5	11.5	15	76.2	2830	2.57

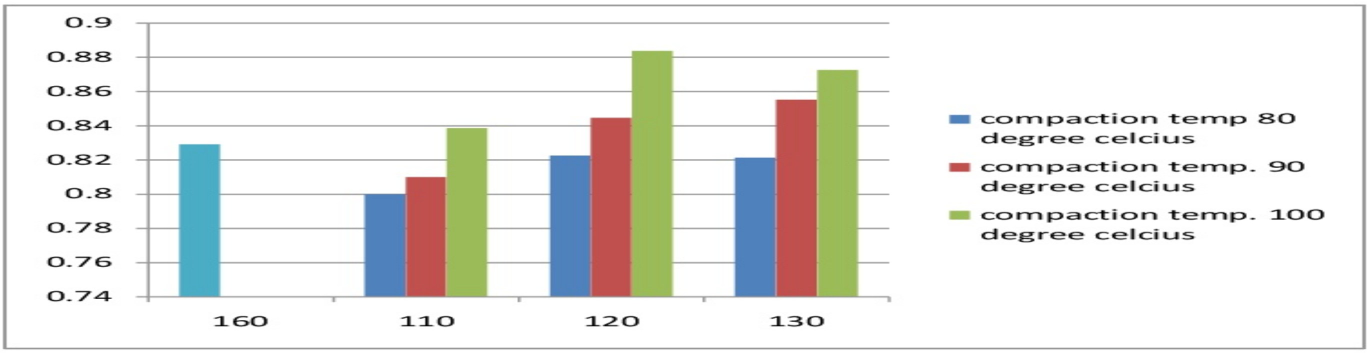
Table ,12 Conditioned Indirect Tensile Strength of Warm Mix Asphalt BC-2 at different Mixing and Compaction Temperatures.

Bitumen content(%)	Mixing temp.(°C)	Compaction temp.(°C)	Gb (gm/cc)	Gt (gm/cc)	Vv (%)	Vb(%)	VMA (%)	VFB(%)	Stability (Kg)	Tensile strength (MPa)
4.7	110	80	2.39	2.53	5.2	11.2	16.5	68	1800	1.64
		90	2.4	2.53	5.1	11.2	16.4	68.7	1890	1.72
		100	2.41	2.53	4.6	11.3	15.9	71	1950	1.77
	120	80	2.41	2.53	4.6	11.3	15.9	71	2202	2
		90	2.42	2.53	4.3	11.3	15.7	72.3	2310	2.1
		100	2.43	2.53	4	11.4	15.4	73.8	2430	2.21
	130	80	2.41	2.53	4.3	11.3	15.7	72.3	2161	1.96
		90	2.43	2.53	4	11.4	15.4	73.9	2249	2.04
		100	2.44	2.53	3.6	11.4	15.1	75.7	2450	2.23

Table 13 Tensile Strength Ratio of Warm Mix Asphalt at Different Mixing and Compacting Temperatures

Mixing temp.(°C)	Compaction temp.(°C)	Average Unconditioned Tensile Strength, (MPa)	Average Conditioned Tensile Strength,(MPa)	TSR	Retained Tensile Strength,(%)
110	80	2.06	1.64	0.8	80
	90	2.14	1.72	0.81	81
	100	2.17	1.77	0.82	84
120	80	2.4	2.0	0.83	82
	90	2.45	2.1	0.86	84
	100	2.49	2.21	0.88	88
130	80	2.39	1.96	0.82	82
	90	2.43	2.04	0.84	85
	100	2.57	2.23	0.87	87

Fig. 14 Tensile Strength Ratio v/s Compaction Temperature for different mixing temperatures of warm mix asphalt and hot mix asphalt



VII. DISCUSSIONS AND CONCLUSIONS

A. Marshall Properties

(a) The Optimum Binder content for WMA is 17.54% lesser than the HMA (BC-2).
(b) Marshall Stability of HMA is 5.45% higher than WMA.
(c) Marshall Flow of HMA is 18% greater than the WMA.
(d) Bulk Density of HMA is 2.89% lesser than the WMA.
(e) Air voids of HMA is 12.9% higher than WMA.
(f) Voids filled with mineral aggregates of H M A i s 15.2% higher than WMA.
(g) Voids filled with bitumen of HMA is 1% higher than WMA.
(h) Even though the stability of WMA is 5.4% lower than HMA, WMA gives more advantages like, mix can be used at lower temperature due to the presence of its additives in the bitumen easily workable at lower temperature.
(i) WMA gives higher bulk density and less air voids at low binder content because of the presence of the additives.

B. Influence of Mixing and Compaction Temperature

It is inferred from the above results that, WMA gives more stability, density and VFB at 120 and 130°C mixing temperature compacted at 100°C temperature.

C. Indirect Tensile Strength Test

From the above results it shows that the tensile strength ratio of WMA at 120°C mixing temperature is 0.05% and 0.01% greater than 110°C and 130°C compacted at 100°C respectively. The tensile strength ratio of WMA at 120°C is 0.06% higher compared to the HMA

REFERENCE

1. *D'Angelo*, "Warm Mix Asphalt : European Practices", American Trade Initiatives, Washington DC,U.S department of Transportation2008.
2. *Dr. Adriana vargas*," Physical and Structural Characterization of Sustainable asphalt Pavement sections at the NCAT test track", NCAT report2013.
3. *Hainian Wang*, "Effect of warm mixture asphalt (WMA) additives on high failure temperature properties for crumb rubber modified (CRM) binders", Research Institute of Highway Ministry of Transport , Beijing, China2012.
4. IS73:2006,"Paving Bitumen Specification",Indian Standards.
5. *Juris Smirnovs*, "analysis of possibilities for use of warm mix asphalt", 3rd International Conference Civil Engineering proceedings 2011.
6. *Liantong Mo*, "Laboratory investigation of compaction characteristics and performance of warm mix asphalt containing chemical additive" State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, Wuhan, China 2012.
7. *Martins Zaumanis*,"Warm mix asphalt investigation", Danish Road Institute 2010.
8. NCHRP report 691,"Mix Design Practices for Warm Mix Asphalt",TRB 2011.
9. NCHRP report 673,"A Manual for Design of Hot Mix Asphalt with Commentary",TRB 2011.

10. *Prithvi Singh Kandhal*,"Warm Mix Asphalt Technologies: An Overview", journal of Indian Road Congress (IRC) 2010.
11. *S.K. Khanna and C.E.G. Justo*, " Highway Engineering", 8th edition Nemchand & *Brothers* Publications, Roorkee 2001.
12. *Shu Wei Gohand Zhanping*,"Mechanical properties of porous asphalt pavement materials with warm mix asphalt and RAP",journals of ASCE2012.
13. Specifications Of Road and Bridge works Ministry Of Road Transport and Highway (MoRT&H), Govt of India, Fourth Edition 2001.
14. *Tejas hgandhi*,"Effects of warm asphalt additives on asphalt binder and mixture properties", Clemson University 2008.
15. *Zydex*,"Laboratory Protocol-Warm Mix Asphalt With Zycotherm", 2012