Studies on characterization of SBS polymer modified and neat bituminous mixes using warm mix asphalt for paving application

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Abstract— **Traditionally, asphalt mixtures were produced at high temperatures (between 150 ºC -180 ºC) and therefore referred as the hot mix asphalt (HMA) .recently a new technology named warm mix asphalt (WMA) was developed in Europe that allows HMA to be produced at lower temperature. Over years of research efforts a few WMA technologies were introduced including the foaming method using alpha-min and advera.WMA organic additives such as sasobit and asphalt an and chemical packages such as Evotherm,zycotherm and Cesca base RT were used as per literatures reviews.Benefits were found when lower temperatures were used to produce asphalt mixtures, especially when it comes to energy savings and emission reductions. The asphalt paving industry is constantly exploring technological improvements that will enhance the materials performance, increase construction efficiency conserve resources and advance environmental stewardship, current and impending regulations on emissions and energy conservation are making attractive the reduction in asphalt mix production temperatures Warm mix asphalt (WMA) is a means to this end and several systems have been developed including ,foaming, emulsions,additives,synthetic binders and others.WMA is produced at temperatures 20ºC to 40 ºC lower than that of Hot Mix Asphalt (HMA).The immediate benefit of producing and placing asphalt mixes at lower temperatures is the reduction in energy consumption, greenhouse gas emissions, flumes and odors generated at plant and the paving sites. Furthermore than technical benefits are more sustainable including reduction of short term binder hardening reduction of mixtures tenderness, possible extension of construction season.**

Several properties of asphalt concrete layer affect pavement performance these include mixing and compaction temperatures, optimum bitumen content, temperature susceptibility, fatigue properties, rutting, hardening of asphalt binders and temperature cracking potentials. The addition of polymers to asphalt concrete mixtures enhances the resistance of asphalt concrete to fatigue cracking, rutting, temperature cracking and stripping, with regards to mixing and compaction temperatures, rutting, fatigue and tensile strength properties studies have shown that the addition of polymers to asphalt mixes results in a substantial improvement in these properties.

In present investigation commercial forms of polymer modified bitumen (PMB) of grade (SBS-PMB 40) and neat bitumen of VG 30 grade with and without WMA chemicals of readily blended type was used for characterization .The performance l of PMB mixes was be compared with 80/100 neat bituminous mixes and compaction temperatures for laboratory short term aged SBS-PMB 70 and VG 30 grade with and without warm mix asphalt chemicals, optimum dosage of WMA chemicals, Marshall mix design and Optimum binder content, Moisture and temperature susceptibility, for SBS-PMB 40 and VG 30 grade bitumen with and without chemicals for virgin as well as aged bitumen was evaluated and investigated . Some positive results were obtained when comparison of Marshall Parameters of HMA (VG30) and WMA (PMB-40) are investigated.

Index Terms— **SBS- stereyene-bitudiene-etereyene, WMA,HMA,SBS-PMB-40,VG-30,PMB and temperature.**

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I. INTRODUCTION

One of the latest technologies of the asphalt industries is warm mix asphalt (WMA),which can lower the plant and filed operation temperatures .the temperature reduction is the key idea behind WMA technology, resulting in reduction of production cost energy and most importantly pollutant emissions.

In 1997,the efforts to lower productions temperature of hot mix asphalt(HMA) by between25 and 55ºCwere introduced at German Bitumen Forum (D'angelo etal.2008).it was called warm mix asphalt (WMA) technology that can allow asphalt to flow at lower temperatures For mixing, placing and compaction. A number of WMA technologies have been developed to allow asphalt mixtures to be produced and compacted at a significantly lower temperature. The WMA technology has become popular in recent years because of the economical and environmental advantages in the world (Anderson eta, 2008) Brian and graham (2008) reported an investigation of WMA technologies from European 2002 resulting in first WMA related documentations that included mix design and filed trial data.

Among the polymer modifiers, styrene butadiene styrene (SBS) originally developed the shell chemicals co... Is widely used in the majority of asphalt binder industries and probably the most appropriate polymer for asphalt modification (Lavin 2003), SBS creates a three dimensional network which leads to a durable and long lasting pavements (Kim etal 2003).

The year 2003 NAPA, Federal Highway Administration (FHWA) and national center for asphalt technology (NCAT) convened a meeting to explore the potential of technologies in united states. The same year the three technologies were presented at NAPA convention in San Diego. The presentation at the NAPA convention in san Diego, the world of asphalt 2004, featured a demonstration projects on WMA and since then the major WMA additive companies have carried out several demonstration projects in United States.

Hurley and Powell,(2006) apart from the obvious advantages such as reduced fuel consumptions and reduced emission in the plant there are several other advantages using warm asphalt like longer paving seasons longer hauling distances reduced wear and tear of plants, reduced ageing of binders ,reduced oxidation hardening of binders and thus reduced cracking in pavement ability of opening the site to traffic sooner etc .in addition the workers with a safer working environment lower emissions, with the availability so several proprietary chemicals and processes to produce warm mix asphalt without affecting the properties of the mix. The concept of driving warm mix technologies is reduction in asphalt and compact the mixes at lower temperatures.

The common practice in asphalt technology is that there is a continuous effort on modifying asphalt binders for changes in properties of modified asphalt under which properties such as fatigue cracking, Marshall Properties, moisture susceptibility, temperature susceptibility along with ageing and field performance using SBS-PMB-40 and VG-30

II. .Literature review:

S.S.Awanti etal 2006,studied influences of modified marshal compaction techniques o engineering properties of polymer modified and neat bituminous concrete mixes and reported about the various laboratory investigations carried out on two types of polymer modified bituminous concrete mixes with SBS copolymer and SBR and neat bituminous concrete mix 80/100 bitumen and studied the effects of adopting modified Marshall compaction technique on engineering properties of optimum binder content and Marshall parameters.marshall test results indicated higher stability, higher flow, higher unit weight lower air voids and lower optimum binder content for all mixes compacted with modified Marshall hammer when compared to standard Marshall compaction. Static ratio,resilent modulus ratio and fatigue life were found to be higher for mixes compacted with modified compaction when compared with standard Marshall compaction. Modified compaction shows permanent deformation as well as deformation rate. The performance of polymer modified bituminous concrete mix with SBS polymer is found to be superior when compared to the other two mixes prepared with polymer modified bituminous mixes prepared with polymer modified bitumen with SBR as well as neat bitumen. The optimum binder content were also reduced by 8 percent,9% and 1.5% for PMB-1,PMB-2and BC mixes compared by modified Marshall compaction when compared to standard Marshall compaction, concluded that this reduction brings substantial economy in PMBC mixes and a marginal economy BC mixes.

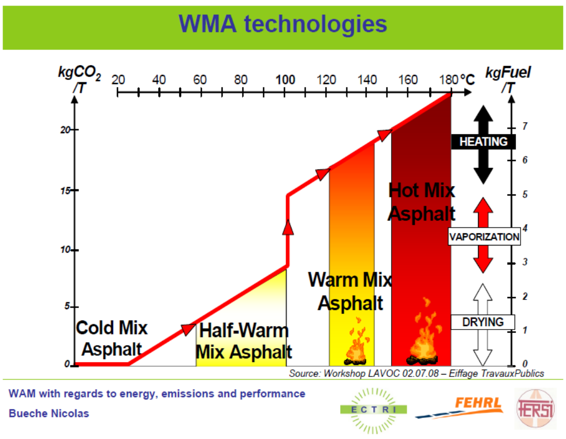
Hakseo Kim and amirkahanian etal 2010 demonstrated in their findings that WMA technology (Aspha-min and sosaobit) can be used to decrease the compaction temperatures of SBS modified asphalt mixtures as compared with HMA mixtures to satisfy the targeted air voids contents. The facts that those WMA mixtures ,especially at lower compactions levels showed lower air voids than that of HMA mixtures at lower temperatures indicates that WMA technologies can help in reducing the compaction effort during the initial stages of constructions. The statistical analysis indicates that WMA mixture regarding all engineering properties (TSR,Rutting etc) tested for their works, which indicated that the use of WMA technologies in SBS modified asphalt mixtures did not adversely affect the mixture properties.

National Centre for Asphalt technology (NCAT)has probably conducted more studies of WMA than any other than any other agencies. The US (Hurley and Prowell,2005a,2005b,2006a,2006b,NCAT 2005).they have demonstrated that aspha-min,Sasobit and Evotherm improve compatibility in the superpave gyratory compactor and reduce air voids by aan average of 0.65,0.87,and 1.5 respectively, over that of the corresponding control mix improved compaction was noted at temperatures as low as 190°F.additio n of aspha-min,sasobit and Evotherm did not affect the resilient modulus of mixes. Decreased aging due to lower mixing and compacting temperatures may have contributed to lower indirect tensile strength of WMA mixes.Apha-min did not increase rutting potential of mixes while sasobit and Evotherm generally decreased the rutting of mixes evaluated. The rutting potential increased with decrease in mixing and compaction temperatures, which may be related to decrease aging of the binder.

Amirkanian,mallick and bergendahl,kirk 2009 button and chowdary etal 2008,hurley and prow ell 2005 have demonstrated the laboratory studies as per the NCAT organizations descriptions that the first to conduct laboratory research on WMA technology around 2005/2006(Hurley and Powell) and produce 3reports on aspha-min,sasobit and evatherm.

It was reported that all these technology improved compatibility in the super pave compactor in temperature as low as 190ºF.The resilient module of the mixes were not affected by implementation of three technologies. Lower mixing and compaction temperatures increase rutting potential due to lessened binder ageing and increase moisture susceptibility due to incomplete drying of aggregates. Lower fuel consumptions and no visible fumes were observed during constructions.

Figure shows the classification of WMA by temperature range.



Awanti etal 2006 in his research on fatigue behavior of polymer modified and neat bituminous mixes using modified Marshall specimens, from their experimental work and subsequent material used,characteriszed the neat and polymer modified bituminous binder and specifically concluded that softening point and viscosity values found to be higher by 16 and 98% for PMB-SBS when compared to neat bitumen. Elastic recovery showed higher flexibility and higher deformation resistance of pmb compared to pmb-sbr mixing and compaction temperatures for pmb binders were 150-170°C respectively, for neat bitumen these values were 150-138°C respectively. Fatigue lives have been decreased for PMBC-1-ML-M and BG-ML-M mixes. The reduction in fatigue lives with increase in air voids for BG-ML-M -M at higher stress level is of much higher magnitude when compared to PMBC-1-ML-M mixes. the fatigue life of PMBC-1-ML-M mix was 1.82 times higher when compared to BG-ML-M.modified Marshall compaction increased the resistance to permanent deformation when compared to standard Marshall compaction. The performance of PMBC1 mix showed superior results when compared to BC mix at all temperatures. Moisture susceptibility found to be reduced by using modified Marshall compaction to standard Marshall Compaction, due to improved comp active efforts, which resulted in lower moisture penetration and that led to higher TSR and MRR .polymer modified and neat bituminous mixes prepared using middle limits gradation showed lowest moisture susceptibility when compared to upper and lower gradation limits.

Economic analysis was made considering flexible pavements with PMBC surfacing provided higher serviceability levels, lower user costs such as vehicle operation cost, time cost and accident cost when compared to flexible pavement with BC surfacing. In view of this the flexible pavements with PMBC surfacing was treated as the most cost effective.

Veeraragavan etal(2008) reported and carried out laboratory investigations on polymer modified bituminous mixes with EVA and determined retained stability values for neat and PMB mixes. the tests were carried out as ASTM D 1075-96,from their results it was concluded that the retained stability values is increased by 15% with additional 12% bitumen modifier, which shows the reaction in moisture susceptibility of paving mixes by incorporation of polymers.

Soon-jae lee and serji n amirkhanian etal 2006 while characterizing short term aging of asphalt binders using gel permeation chromatography and selected super pave binders tests studied both the rolling thin film oven test (RTFOT) and short term oven ageing (STOA) methods to represent the ageing of asphalt binders during plant mixing, transportation and paving. they conducted as a experimental program me and the material was desu ignited as control bindes,three SBS-modified binders of PG 76-22 as SM binder and three rubber modified binders.loose asphalt mixes were obtained from six paving fields series of gel permeation chromatography (GPC),rotational viscosity(Rv) and dynamic shear (DSR) tests were conducted. From the results obtained they concluded that based on increase in LMS ratios from GPC test the RTFOT method was found to have less effect on binders than the STOA methods for asphalt mixtures in the laboratory. Laboratory ageing methods indicated a good correlation with each other but the ageing effect among the binders which were short term aged in field varied widely. The longer ageing time in RTFOT was found to lead to an increase in high temperature viscosity and in the high failure temperature of asphalt binders, the only exception being rubber modified binders, in which the rubber in asphalt binders. The GPS test for the crumb rubber modified binders in which the rubber in asphalt was removed using a syringe filter was effective in evaluating the ageing effect of rubber modified binders for different RTFOT aging times.

III. Objectives of the Present Investigation :

To determine mixing and compaction temperatures for styrene-butadiene-styrene(SBS) polymer modified bitumen 70 grade(SBC-PMB 70) and neat bitumen of VG 30 Grade with and without warm mix asphalt (WMA) chemicals.

To determine mixing and compaction temperatures for laboratory short term aged SBS-PMB70 and VG30 Grade with and without warm mix asphalt chemicals.

To evaluate optimum dosage of WMA chemicals for SBS-PMB70 and VG30 Grade for virgin as well as aged bitumen.

To carryout Marshall Mix design and to determine optimum bitumen content for SBS-PMB70 and VG30 Grade bitumen with and without WMA chemicals for virgin as well as aged bitumen.

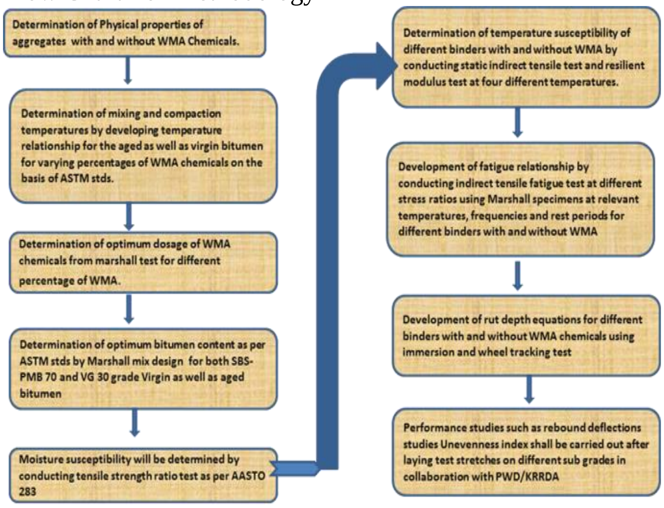
To investigate moisture and temperature susceptibility of SBS-PMB70 and VG30 Grade bitumen with and without WMA chemicals for virgin as well as aged bitumen.

To develop fatigue relations for SBS-PMB70 and VG30 Grade bitumen with and without WMA chemicals for virgin as well as aged bitumen.

To develop rut depth relations for SBS-PMB70 and VG30 Grade bitumen with and without WMA chemicals for virgin as well as aged bitumen.

IV. Materials and Methodology

Flow Chart For Methodology



Physical properties of aggregates SBS-PMB70 and VG30 Grade for virgin as well as aged bitumen are to be determined with and without WMA chemicals.

Mixing and compaction temperatures shall be determined by developing viscosity temperature relationships for aged as well as virgin bitumen for SBS-PMB70 and VG30 Grade bitumen for varying percentages of WMA chemicals. On the basis of viscosity values as per ASTM standards mixing and compaction temperatures will be determined.

Optimum dosage of WNA chemical shall be determined from the test results of maximum stability and air voids from marshal test results for different percentages of WMA chemical.

Marshall mix design shall be carried out on bituminous concrete specifications prepared using SBS-PMB70 and VG30 Grade for virgin as well as aged bitumen are to be determined with and without WMA chemicals. Optimum bitumen content will be determined as per the procedure laid in ASTM standards.

Temperature susceptibility of different binders with and without WMA will be determined by conducting statics indirect tensile test and resilient modulus test at different temperatures.

Fatigue relationship will be developed by conducting indirect tensile fatigue tests at different stress ratios using Marshall specimens at relevant temperatures, frequencies and rest periods etc for different binders with and without WMA

Rut depth equations shall be developed for different binders with and without WMA chemicals using immersion wheel tracking test conducted on beam specimens at 40 degrees C temperatures..

Performance studies such as rebound deflection studies, unevenness index, shall be carried out after laying test stretches on different sub grades in collaboration with PWD/KRRDA.

Materials

Aggregates of 20mm down,12.5mm down,6.0mm down and 75 micron down passing dust.

VG-30 grade and PMB-40 grade bitumen mix.

SBS-PMB-40 zycotherm chemical used in Warm Mix Asphalt.

Marshall stability testing machine.

V. Results and Discussions:

Investigation for characterization of SBS polymer modified bitumen and neat bituminous mixes using WMA technology were conducted and following positive results were obtained during the tests.

Results of Physical Properties of Aggregates used.

Content	Aggregates used,mm				Average values	Required as per Morth
	20	12.5	6.0	Dust		
Specific gravity	2.74	2.65	2.85	2.65	2.72	2.65
Water absorption	1.42	1.65	1.42		1.52	1.5%
Aggregate impact value	11.29				11.29	>10%
Loss angeles abration test	18.24	33.28	43.54		32.28	<35%

Results of Physical Properties analysis values of VG-30 bitumen mix

Physical properties	Average values obtained	Required values as per morth
Penetration test	66.33 mm	60-70 mm
Softening point test	47 degree centigrade	➢ 40 degree centigrade
Specific gravity test	1.14	1
Fire and flash point		
Fire point	210 degree centigrade	200 degree centigrade
Flash point	240 degree centigrade	220 degree centigrade

Results of Physical Properties analysis values of SBS-PMB_40 bitumen mix.

Physical properties	Average values obtained
Penetration test	47.66 mm
Softening point test	57 degree centigrade
Specific gravity test	1.04

Gradation for Aggregate

IS sieve (mm)	% passing				Obtained gradation	Desired Gradient
	20mm A	12.5 mm B	6mm C	Dust D		Percent by wt. passing the IS Sieve (grading II
26.5	100	100	100	100	100	100
19	43.78	100	100	100	87.06	79-100
13.2	2.62	98	100	100	77	59-79
9.5	0.65	59.69	100	100	65.05	52-72
4.75	0.17	4.31	88.65	100	46.51	35-55
2.36	0.15	0.4	24.92	95.93	33.88	28-44
1.18	0.14	0.27	5.98	77.83	25.19	20-34
0.6	0.13	0.26	1.58	60.54	19.12	15-27
0.3	0.12	0.24	0.78	33.08	10.47	10-20
0.15	0.1	0.23	0.65	18.34	5.88	5-13
0.075	0.08	0.2	0.46	6.14	2.05	2-8

Mixing and compaction temperatures,density and voids analysis for VG-30 grade bitumen mix

s.no	sample	mix. Temp	Comp Temp	Mean height	Weight of sample (gm)		Bulk Density (Gb)	Theoretical Density (Gt)	Vv in %	Vb in %	VMA in %	VFBmix in %
					Air	Water						
1	VG 30 plain	140	130	6.4	1185	730	2.55	2.57	1.11	13.46	14.58	83.8
2	VG 30	140	130	6.5	1260	750	2.46	2.57	4.28	13	17.28	75.23
3	VG 30	120	110	6.26	1280	780	2.53	2.57	1.55	14.6	16.14	90.45

Mixing and compaction temperatures, density and voids analysis for SBS-PMB-40 grade bitumen mix.

s.no	sample	mix. Temp	Comp Temp	Mean height	Weight of sample (gm)		Bulk Density (Gb)	Theoretical Density (Gt)	Vv in %	Vb in %	VMA in %	VFBmix in %
					Air	Water						
1	PMB-40	180	170	6.13	1235	730	2.42	2.54	4.72	11.6	16.6	71.4
2	PMB-40	150	130	6.53	1255	760	2.51	2.54	1.18	13.74	14.3	91.7
3	PMB-40	140	130	6.46	1230	730	2.43	2.54	4.33	14.09	18.3	76.4

Analysis of bitumen content,density and voids for VG-30 bitumen.

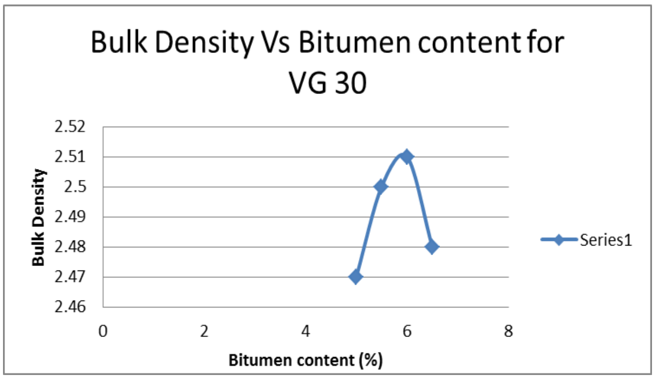
Sample No.	Bitumen content %	Height of sample in mm		Mean height		Weight of sample (gm)		Bulk Density (Gb)	Theoretical Density (Gt)	Vb in %	VMA in %	VFBmix in %
		h1	h2	h3		Air	Water					
1	5	6	6.1	6.1	6.1	1100	660	2.48	2.6	11.27	15.88	70.95
	5	6.2	6.3	6.5	6.33	1205	725	2.49	2.6	11.31	15.54	72.74
	5	6.7	6.5	6.4	6.53	1220	730	2.47	2.6	11.22	16.04	69.91
								2.48			**15.82**	**71.2**
2	5.5	6	6.2	6.1	6.2	1227	740	2.5	2.59	12.05	15.97	78.27
	5.5	6.3	6.2	6.3	6.3	1150	695	2.51	2.59	10.75	13.78	76.81
	5.5	6.4	6.6	6.6	6.5	1220	735	2.51	2.59	12.5	15.97	78.27
								2.5			**15.24**	**77.78**
3	6	6.2	6.3	6.3	6.3	1265	760	2.5	2.57	13.63	16.35	83.1
	6	6.1	6.3	6.3	6.23	1250	755	2.51	2.57	13.63	15.96	85.4
	6	6.4	6.5	6.5	6.45	1260	665	2.52	2.57	13.74	15.68	87.62
								2.51			**15.99**	**85.37**
4	6.5	6.3	6.4	6.4	6.4	1275	775	2.51	2.56	14.59	16.54	88.6
	6.5	6.3	6.2	6.3	6.27	1250	745	2.24	2.5	14.77	17	86.38
	6.5	6.4	6.3	6.2	6.3	1240	750	2.5	2.56	14.77	17.07	86.52
								2.503			**16.87**	**87.16**

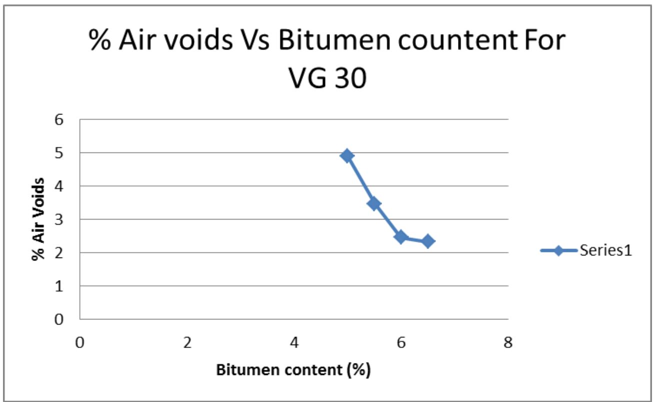
Bitumen content,Density and voids Analysis for SBS-PMB- 40 Grade Bitumen

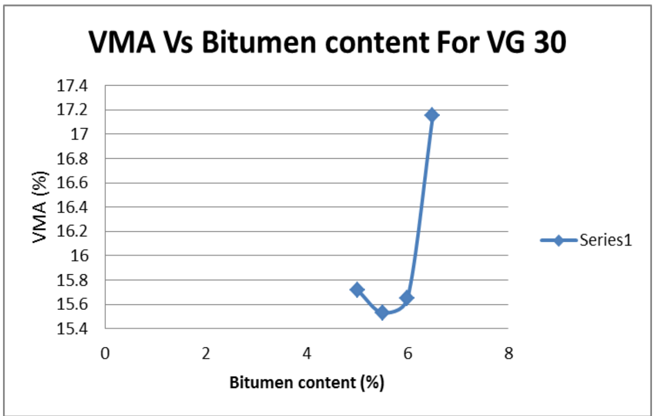
Sample No.	Bitumen content %	Height of sample in mm			Mean height	Weight of sample (gm)		Bulk Density (Gb)	Theoretical Density (Gt)	Vv in %	Vb	VMA in %	VFBmix in %
		h1	h2	h3		Air	Water				in %		
1	5	6.4	6.6	6.5	6.5	1100	660	2.47	2.58	4.26	11.22	15.48	72.48
	5	6.6	6.7	6.6	6.63	1095	655	2.46	2.58	4.65	11.18	15.83	70.62
	5	6.5	6.6	6.6	6.57	1100	660	2.46	2.58	4.65	11.18	15.83	70.62
								2.46		**4.52**		**15.71**	**71.24**
2	5.5	6.6	6.5	6.6	6.67	1235	745	2.49	2.56	2.73	12.45	15.18	82.015
	5.5	6.7	6.6	6.6	6.63	1225	740	2.5	2.56	2.34	12.5	14.84	84.23
	5.5	6.6	6.7	6.5	6.6	1230	745	2.51	2.56	1.95	12.55	14.5	86.55
								2.5		**2.34**		**14.84**	**84.26**
3	6	6.3	6.2	6.2	6.23	1260	765	2.51	2.54	1.18	13.69	14.87	92.06
	6	6.3	6.3	6.4	6.33	1230	745	2.51	2.54	1.18	13.69	14.87	92.1
	6	6.5	6.6	6.3	6.47	1225	740	2.51	2.54	1.17	13.69	14.86	92.12
								2.51		**1.17**		**14.86**	**92.09**
4	6.5	6.3	6.3	6.2	6.27	1120	675	2.49	2.52	1.16	14.71	15.87	92.66
	6.5	6.2	6.3	6.5	6.33	1225	735	2.48	2.52	1.39	14.65	16.04	91.33
	6.5	6.2	6.4	6.5	6.36	1220	730	2.479	2.52	1.58	14.65	16.23	90.23

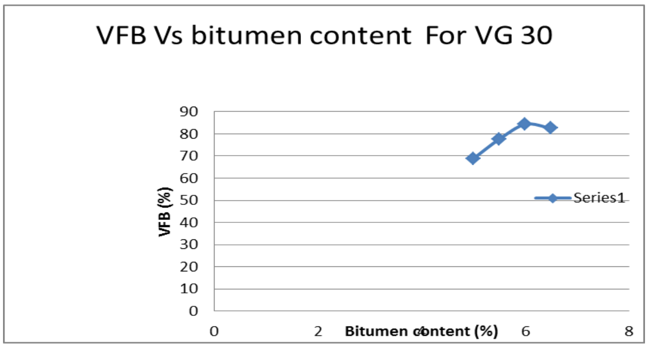
STABILITY TEST ON VG 30 GRADE BITUMEN

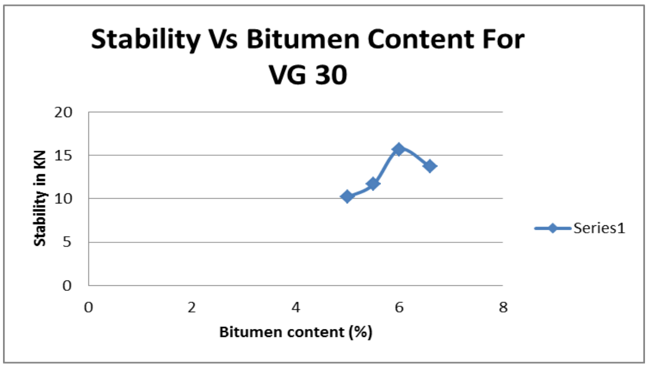
Sl. No	Bitumen Content	Mean Height	Flow dial reading	Flow value (mm)	Proving ring reading	Correction factor	Corrected stability (KN)
1	5%	6.6	310	3.1	165	1	10.14
	5%	6.5	330	3.3	170	1	10.45
	5%	6.53	320	3.2	163	0.96	9.62
				3.2			10.07
2	5.50%	6.36	350	3.5	230	1.04	14.71
	5.50%	6.33	340	3.4	250	1	15.37
	5.50%	6.46	370	3.7	190	1.04	12.15
				3.5			14.07
3	6%	6.5	360	3.6	265	1	16.29
	6%	6.66	375	3.75	250	0.93	14.29
	6%	6.7	390	3.9	270	0.96	15.94
				3.7			15.5
4	6.50%	6.33	400	4	280	1.04	17.9
	6.50%	6.4	390	3.9	260	1.09	17.49
	6.50%	6.5	420	4.2	250	1	15.37
				4.02			16.92

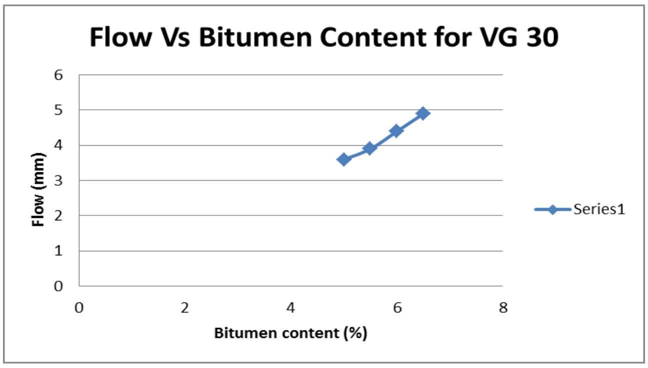




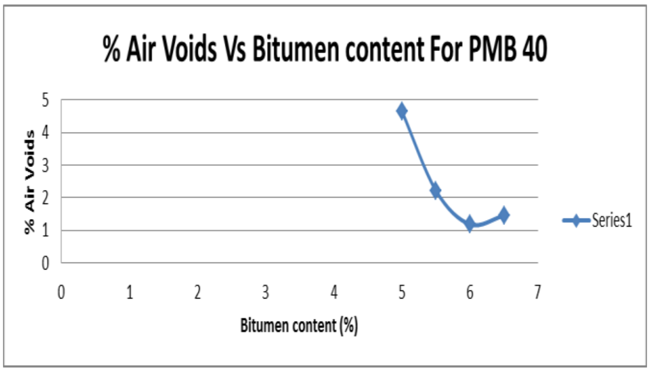


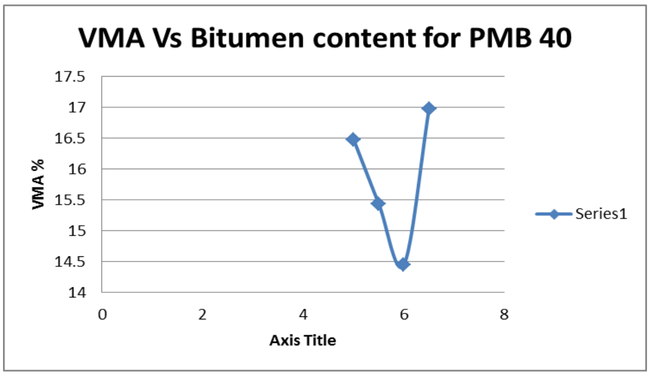


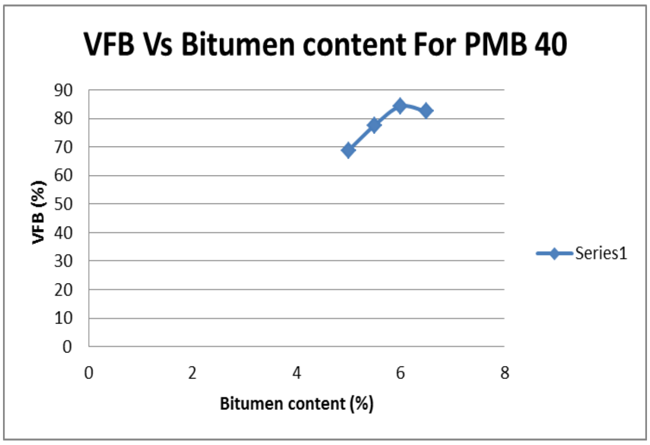


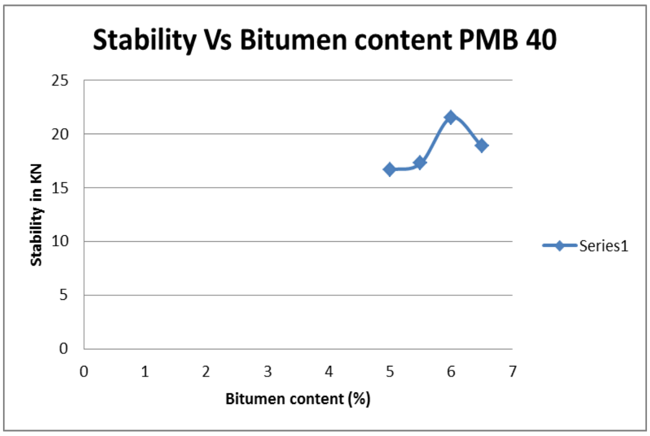


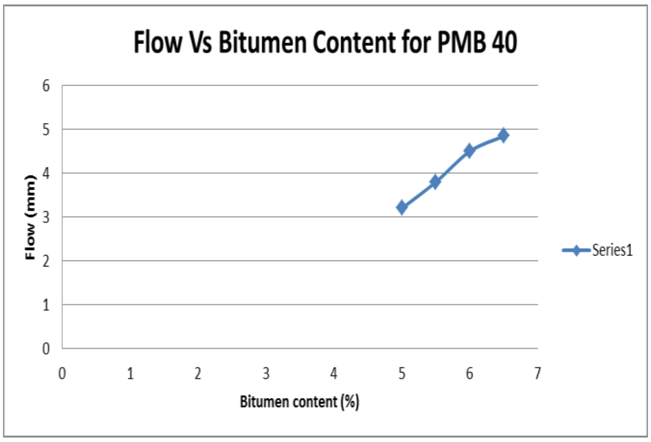
STABILITY TEST ZycoTherm added GRADE BITUMEN











Determination of Tensile Strength Ratio

Preparation is same as the Marshall specimens; they are prepared with 30 blows on each side (voids ratio should be in between 6% to 8%). Here two specimens are prepared for soaked and two for un-soaked for both the grade bitumenVG30 and PMB40 without warm mix asphalt.

Another four specimens are prepared for soaked and un-soaked for both the grade bitumen using warm mix asphalt chemical.

The soaked specimen are kept in a thermostatic container at 60˚c for 24 hours, After 24 hours they are kept at room temperature for 30 minutes, Then these specimens are kept at 25˚c for a hour and checked for Marshall stability value.

Then TSR is calculated as,

TSR=(soaked/un-soaked)*100

Tensile strength ratio for 30 blows at optimum binder content for VG30 grade bitumen.

SI.no	Specimen	Average ht. (mm)	Proving ring reading	Failure load (KN)	Average failure load (KN)	TSR
Soaked						
1	VG30 plain	65.7	185	10.786	9.49	VG30 plain TSR= 92.3%
2	VG30 plain	65.5	140	8.196		
3	VG30 with WMA	66.2	156	9.008	9.085	
4	VG30 with WMA	66	158	9.163		
Unsoaked						
1	VG30 plain	65.2	170	11.217	10.27	VG30 with WMA TSR= 94.02
2	VG30 plain	65.7	160	9.328		
3	VG30 with WMA	65.7	163	9.503	9.662	
4	VG30 with WMA	65.9	169	9.822		

Tensile strength ratio for 30 blows at optimum binder content for PMB40 grade bitumen.

SI.no	Specimen	Average ht. (mm)	Proving ring reading	Failure load (KN)	Average failure load (KN)	TSR
Soaked						
1	PMB40 plain	66.2	198	11.434	11. 645	PMB40 plain TSR=92. 9%
2	PMB40 plain	66.4	202	11.856		
3	PMB40 with WMA	65.9	208	12.088	13. 114	
4	PMB40 with WMA	66	215	12.52		
Unsoaked						
1	PMB40 plain	66.1	210	12.253	12. 528	PMB40 with WMA TSR=93. 82%
2	PMB40 plain	66.2	219	12.803		
3	PMB40 with WMA	66.3	222	13.004	13. 114	
4	PMB40 with WMA	66.2	229	13.224		

ANALYSIS OF RESULTS OF SBS-PMB-40 MIX

PROPERTY	SPECIFICATIONS	RESULTS	STATUS
MARSHALL STABILITY	340kg minimum	22.14 KN	OK
FLOW	8-16	14	OK
VFB	75-85	79	OK
VMA	None Required	18.6	--

ANALYSIS OF RESULTS HMA

PROPERTY	SPECIFICATIO NS	RESULTS	STATUS
MARSHALL STABILITY	340kg minimum	2775	OK
FLOW	8-16	14	OK
VFB	70-80	79	OK
VMA	None Required	18.6	--

ANALYSIS OF RESULTS

The various results obtained are as shown in table 4.1

Marshall parameters at optimum binder content

Sl.No	Parameters	Results	
		VG 30	PMB 40
1	OBC%	5.75	5.7
2	Stability (KN)	13	18.8
3	Flow (mm)	4	4
4	Unit Weight (gm/cc)	2.507	2.505
5	Percentage Air Voids (Vv%)	3	1.8
6	VMA%	15.6	15.2

VI. CONCLUSION

The temperature required for mixing and compaction of bitumen with WMA(warm mix asphalt) chemicals is reduced as compared to the bitumen without WMA about 40˚c

Optimum binder content is determined as 5.75% of Marshall mix design

Stability of bitumen with WMA is same as compared to bitumen without WMA at higher temperature

The tensile strength ratio of VG30 grade bitumen is greater than that of PMB40 grade bitumen

Static indirect tensile strength of VG30 grade bitumen is lesser than that of PMB40 grade bitumen

Fuel consumption for heating the bitumen with WMA is reduced as compared to without WMA chemical

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