Investigation of Rutting Performance of Hot Mix Asphalt And Warm Mix asphalt with and without warm mix asphalt additives

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Abstract

Use of warm mix asphalt (WMA) in pavement industries has been growing rapidly over last decade because it can lower down the construction temperature and subsequently reduces the environment pollution and energy consumption. One of the challenges to WMA(SBS-PMB-40) technology, the uncertainty about performance of WMA mixtures is still unclear. To this end, this study investigated the rutting performance (one of the major distresses) of mixtures with different WMA additives. Rutting performance of WMA mixtures with three different additives Sasobit,Evotherm and Zycotherm were evaluated and compared with the control hot mix asphalt (HMA)(VG-30) mixture through Hamburg wheel track test (HWTT). Rutting tests were conducted fpr both 60^0 C and for Room Temperatures ,Results showed that all WMA mixtures have lower rut depth compared to control HMA mixture. It is also observed that Sasobit samples exhibited better rutting resistance than Evotherm and Zycotherm sample. However, Sasobit WMA sample showed significant enhancement in rutting resistance due to presence of polymer.

Keywords: Rutting resistance,WMA,HMA,Hamburg wheel track test(Hamberg wheel track test

Greater awareness within the past two decades have been created for sustainable development practices in all spheres of human endeavour including the pavement construction industry, Global concerns over the gradual depletion of non-renewable natural resources and increasing damage to the ecosystem from greenhouse gas emissions, generated from human productivity, Within the construction industry, construction and maintenance processes involved with pavement are known to be resource-intensive, sometimes with considerable negative environmental impacts. This place elevated responsibility on industry professionals, to indulge in sustainable construction practices, in order to ensure that the activities of today's generation would not compromise and be detrimental to the ability of tomorrow's generation to prosper unhinged.

Rutting occurs when the asphalt surface becomes consistently deformed and curls up in the direction of the wheel's travel. Rutting occurs mostly due to the repetitive loading cycles of vehicles. The presence of rutting, fatigue cracking, and distresses is indicative of pavement failure. In this research work We used the immersion Hamberg wheel tracking equipment (HWTE) to evaluate the beam specimen and find out how deep the ruts were for both HMA with and without WMA additives and polymer modified bitumen with and without WMA additives. All specimens undergo testing using the immersion wheel tracking apparatus. The research used treated wheels that travel at a speed of 25 cycles per minute.7.2 kg/cm2 was the pressure in the tires. Specimens undergo testing using the immersion wheel tracking apparatus. The research used treated wheels that travel at a speed of 25 cycles per minute.7.2 kg/cm2 was the pressure in the tires.

2.0 Literature review

In perspective of global use, the associated costs for the volume of raw materials used and energy consumption required for asphalt production cost could be astounding. The increasing costs of raw materials and demand for environmentally suitable paving materials in road construction have challenged the asphalt industry to seek and develop alternatives that aid in reduction of production and compaction temperatures of asphalt mixtures without compromising the required performance behavior.

Ali Topal et al (2017) (1) investigated rutting performance of warm mix asphalt in which The conventional properties of the bitumen prepared with organic, chemical, synthetic zeolite and natural zeolite additives, the addition of the additives resulted in a decrease in penetration and increase in softening point value The additives also reduce the viscosity of bitumen. This indicates that all warm mix asphalt additives increase the workability and make relative reductions for mixing and compaction temperatures.

Warm mix asphalt (WMA), pioneered in Europe in the late 1990's [2], is the latest asphalt technology that presents the capability of addressing the practice of environmental sustainability and enhancement of mixture workability without compromising performance.

WMA additives can reduce the viscosity of the binder, allowing mixtures to be produced at a temperature grade of 38°C lower than traditional Hot mix asphalt (HMA) [3], [4], which lead to a number of environmental, operational, and economical benefits.

The implementation of WMA has become more widespread with an increasing number of paving contractors employing these sustainable technologies in construction in order to take advantage of reduced mixing and compaction temperatures, lowered energy usage for production and placement, and reduced emissions. However, one of the challenges to implementation is the uncertainty about how

Research has shown that as mixing temperature are reduced for WMA, the mixes show increased tendencies towards rutting and moisture susceptibility [5], [6]. This was attributed to decreased aging of the binder, possible presence of moisture in the mixture incomplete drying of the aggregates due to lower temperatures.

A better understanding of the effects of warm mix additives on the performance of asphalt concrete is a fundamental step towards the effective application of WMA. As part of the structural design processes to optimize field performance of asphalt mixtures, simple performance tests such as Hamburg Wheel Tracking Test (HWTT) has been developed to determine rutting potential. However, the characteristics of the binder component are also important, especially for cases involving binders with modifying agents. Despite the fact that asphalt bitumen make up 4 to 8 % of a pavement mix structure, it provides a level of rigidity, structural bonding, resilience, and absorbance which holds the total pavement mixture together as a solid body [7].

However, with higher traffic densities and effects of environmental exposure, binder flows and dissipates energy with time [8].

As a result, asphalt binder experience a variety of thermomechanical demands; where pavement defects transpire such as rutting at high temperatures due to thermal susceptibility of asphalt [9].

The asphalt contribution to permanent deformation process has traditionally been handled by observing the asphalt binder's consistency based on softening point and penetration tests [10] .

However, with priorities set for environmental conservation and preservation, the integration of polymer modifiers, warm mix additives, and recycling of reclaimed asphalt pavement (RAP) materials into asphalt mixtures have gained popularity [11], [12].

With this in mind, the empirical tests mentioned earlier are insufficient to characterize the rutting resistance behavior of binders. It would be helpful to examine the effects of these modifying agents on the properties of plant produced mixtures. In order to accomplish this task, extraction and recovery of asphalt binder from asphalt concrete were performed. Thus, this research evaluates the rutting resistance of binders modified with different warm mix additive.

3.0 Experimental Investigations

3.1 Materials used

3.1.1 Aggregates

Course aggregates and fine aggregates: The aggregates of different sizes, viz., 20mm, 12mm, 6mm and stone dust was procured from crushers, in Raichur District

3.1.2 Bitumen

The plain VG-30 bitumen and Styrene bitudiene styrene polymer modified bitumen was used in this research work. The VG-30 binder was procured from a local contractor near, Raichur District Karnataka and SBS-PMB-40 was procured from Hindustan Colas Private limited Mangalore District Karnataka

3.1.3 WMA Additives were procured, Sasobit, from :KPL international limited New Delhi, Evotherm :Ingevity india, Zycotherm: Zydex Hyderabad India

3.1.3 Mix design

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.

3.1.4 Determination of Optimum Bitumen Content (OBC)

In this work, the OBC for SBS-PMB-40 combinations was determined to be the binder content with 4% air spaces. To verify that all of the OBC-obtained attributes fall within the specified parameters, we compared them to the specification values.

Graphs were plotted with values of binder content against the values of

Unit weight gm/cc,Marshall stability kN,Air Voids,Flow Value,Volumetric Mineral Aggregates (VMA)

Voids Filled with bitumen (VFB)

We averaged binder content that corresponded to maximum unit weight, Marshall stability, and 4% Air Voids to get optimal binder content from these graphs. In accordance with IRC:SP:53-2015 for PMBC while MoRT&H for BC, design values of marshall stability, flow, percentage of air voids, and marshall quotient were verified at OBC utilizing graphs corresponding to OBC. Mix was compacted utilizing marshall compaction method.

3.1.5 Calculation of Rut Depth

In order to determine the deformation and rutting depth, we use the numerical integration method for the temperature levels corresponding to their different frequencies during the exploitation term of the road. The integral step in the calculation

4.0 Results and Discussions

Table 5.1 Gradation of Aggregates for Bituminous Concrete Mix Of Grade-2

IS sieve (mm)		% passing			Obtained gradation	Desired Gradient
	20mm A	12.5mm B	6mm C	Dust D		Percent by wt. passing the IS Sieve (grading
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

Blend proportion = 0.23A+0.30B+0.16C+0.31D

Tests on Materials:

The basic tests were performed and the results are tabulated as shown in table 3.2

Table 5.2 Tests on Aggregates

SL. No	Tests conducted	Test Results	Specifications as per MORTH5th Revision	IS Codes
1	Aggregate Impact Test	12.24%	Max 27%	IS-2386 Part IV
2	Aggregate Crushing Value	20.09%	-	IS-2386 Part IV
3	Los Angeles Abrasion Value	28.30%	Max 35%	IS-2386 Part IV
4	Combined Flakiness and Elongation Index	17.48%	Max 35%	IS-2386 Part I
5	Water Absorption Test	0.50%	Max 2%	IS-2386 Part III
6	Specific Gravity Test			IS-2386 Part III
(a)	20 mm down	2.68	2.5 to 3.2	
(b)	12 mm down	2.69		
(c)	6 mm down	2.71		
(d)	Stone Dust	2.72		

Table 5.3 Tests on Binders

Sl.no	Tests conducted	Test Results SBS-PMB-40	Specifications ns for SBS-PMB-40Binder	IS Codes
1	Penetration Test at 25°C, 0.1mm	54	Min 45	IS-1203
2	Softening Point (°C), min	55	Min 47	IS-1205
3	Ductility Test (cm) at 25°C	100	Min 40	IS-1208
4	Elastic Recovery Test (%) at 15°C	77	Min	IS-1208
5	Flash Point (°C)	290	Min 220	IRC SP 53 2002
6	Fire Point (°C)	350	-	IS-1209
7	Specific Gravity	1.04	0.97 - 1.02	IS-1202

Table 3.7 Mix Design Values for BC Grade-02 Mix

Marshall parameters obtained for Mix Design	For VG-30 neat		For SBS-PMB-40 Neat	
Marshall Parameters	Values Obtained	MoRTH Specification	Values Obtained	IRC-SP-53
Maximum Stability,in Kg	1296	Min 900	1452	Min 1200
Maximum Bulk Density g/cc	2.28	Max	3.28	
Air Voids Vv %	4.64	3 to 6	4.20	3 to 5
Flow Value mm	3.18	2 to 4	3.28	2.5 to 4
VFB	68.2	65 to 75	68.78	65 to 75
VMA	15.2	-	15.2	--
Obtimum Bitumen Content	figure 3.2 From Graph for Optimum Bitumen Content of **5.70**% for VG 30 is obtained		figure 3.1 From Graph for Optimum Bitumen Content of **5.58%** SBS-PMB-40 Neat is obtained	

Table 3.8 RUTTING ANALYSIS OF VG-30-NEATAND WITH WMA ADDITIVES

Height of the Mould	Width	Length	Wt in air	wt in water
50mm	100mm	600mm	7098 gms	3062gms Density =2.37
NO OF CYCLES	RUTT DEPTH(mm) For VG-30-NEAT	RUTT DEPTH(mm) For VG-30-+3% Sasobit	RUTT DEPTH(mm) For VG-30-+0.75% Evotherm	RUTT DEPTH(mm) For VG-30-+0.3% Zycotherm
0	0	0	0.000	0.000
100	3.51	1.84	1.840	1.840
200	1.13	2.92	2.040	2.040
300	1.23	4.67	1.512	1.512
400	1.48	6.06	2.402	2.402
500	1.56	5.91	2.527	2.527
600	1.93	1.94	1.517	1.517
700	2.39	2.28	1.917	1.917
800	2.76	2.41	2.098	2.098
900	3.02	2.72	2.337	2.337
1000	3.34	2.94	2.503	2.503
1500	3.73	3.14	2.765	2.765
2000	3.88	3.32	3.313	3.313
2500	4.03	3.52	3.463	3.463
3000	4.15	3.64	3.582	3.582
3500	4.47	3.84	3.760	3.760

4000	4.72	4.02	3.933	3.933
4500	5.00	4.31	4.140	4.140
5000	5.18	4.54	4.207	4.207
5500	5.57	4.8	4.323	4.323
6000	5.89	5.05	4.655	4.655
6500	6.21	5.18	5.522	5.522
7000	6.59	5.74	5.590	5.590
7500	6.83	5.84	5.815	5.815
8000	7.30	6.06	6.063	6.063
8500	7.75	6.36	6.253	6.253
9000	8.44	7.52	6.417	6.417
9500	8.71	7.72	7.013	7.013
10000	9.09	8.03	8.14	8.39

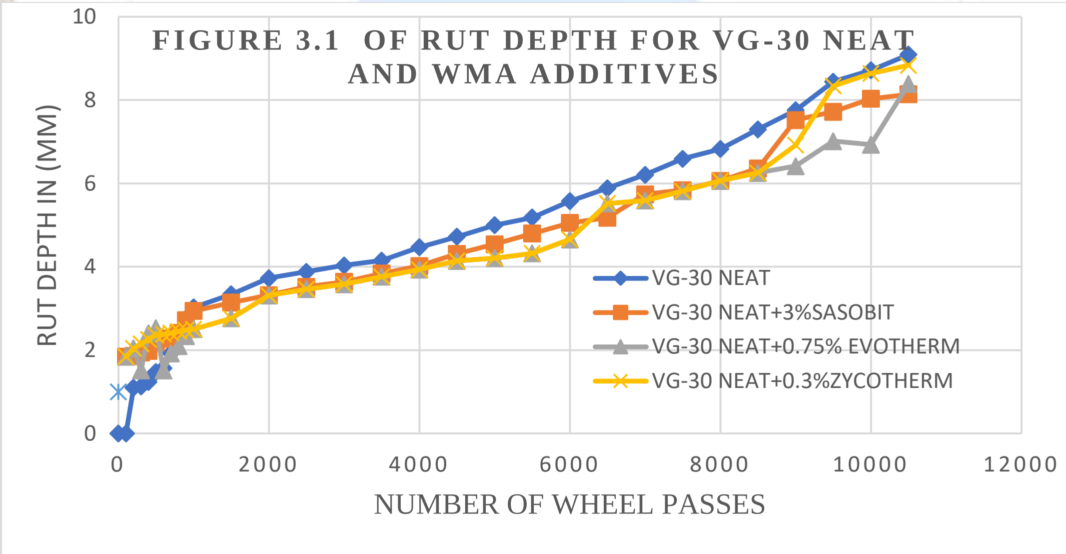


Table 3.2 RUTTING TEST RESULTS FOR VG-30 AND ADDITIVES at 60 Degree Tempt

NO OF CYCLES	RUTT DEPTH IN mm			
	VG 30 NEAT	VG 30 NEAT+3% Sasobit	VG 30 NEAT+0.75% Evotherm	VG 30 NEAT+0.3% Zycotherm
0	0.00	0	0.0	0
50	2.06	2.39	1.8	2.18
100	5.32	4.71	5.7	5.31
200	6.51	6.04	6.7	6.43
300	7.84	7.48	7.9	7.64
400	8.75	8.42	9.3	8.65
500	9.57	9.14	9.7	9.45
1000	11.33	10.72	11.7	10.82
1500	13.32	10.79	12.5	11.83

Figure 3.2COMPARISION OF RUT DEPTH FOR VG30 NEAT WITH AND WITHOUT WMA ADDITIVES AT 60 DEGREE TEMPERATURE

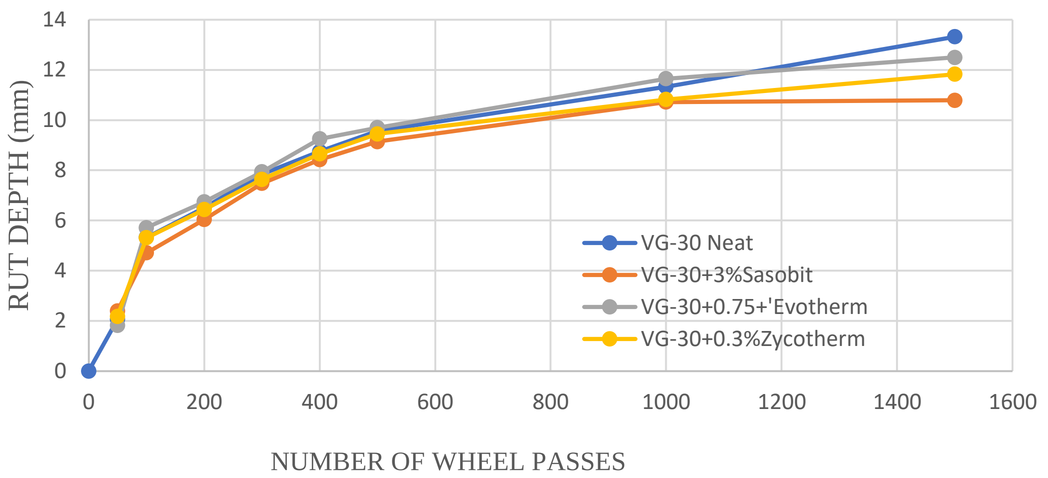


Table 3.3 RUTTING ANALYSIS OF SBS-PMB-40 NEATAND WITH WMA ADDITIVES				
Height of the Mould	Width	Length	Wt in air	wt in water
50mm	100mm	600mm	7098 gms	3062gms
Density =2.37				
NO OF CYCLES	RUTT DEPTH(mm) For SBS-PMB=40 NEAT	RUTT DEPTH(mm) For SBS-PMB-40 NEAT-+3% Sasobit	RUTT DEPTH(mm) For SBS-PMB=40 NEAT-+0.75% Evotherm	RUTT DEPTH(mm) For SBS-PMB=40 NEAT-+0.3% Zycotherm
0	0	Rut Depth(mm)	0.00	0
100	2.90	0	2.90	2.90
200	0.33	2.90	0.33	0.33
300	0.96	0.33	0.97	0.97
400	1.33	0.97	1.27	1.27
500	1.52	1.27	1.37	1.37
600	1.58	1.52	1.50	1.50
700	1.69	1.62	1.63	1.63
800	1.86	1.70	1.77	1.77
900	1.90	1.85	1.91	1.91
1000	2.00	1.90	1.97	1.97
1500	2.04	2.00	2.06	2.06
2000	2.24	2.04	2.34	2.34
2500	2.56	2.22	2.58	2.58
3000	2.55	2.50	2.64	2.64
3500	2.75	2.53	2.83	2.83

4000	3.03	2.73	3.12	3.12
4500	3.13	3.00	3.33	3.33
5000	3.26	3.13	3.43	3.43
5500	3.82	3.25	3.80	3.80
6000	3.84	3.74	3.94	3.94
6500	3.77	3.79	4.09	4.09
7000	4.23	3.85	4.30	4.30
7500	4.41	4.18	4.62	4.62
8000	4.75	4.34	4.71	4.71
8500	4.90	4.66	4.90	4.90
9000	6.01	4.79	5.32	5.32
9500	6.26	5.13	5.54	5.54
10000	7.00	5.29	6.15	5.84

Figure 3.3COMPARISION OF RUT DEPTH FOR VG30 NEAT WITH AND WITHOUT WMA ADDITIVES AT 60 DEGREE TEMPERATURE

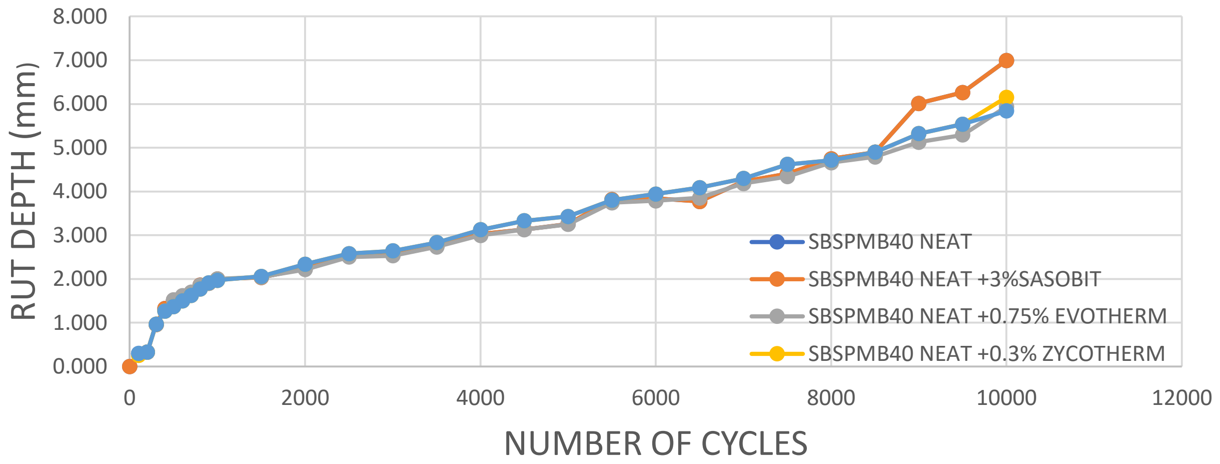
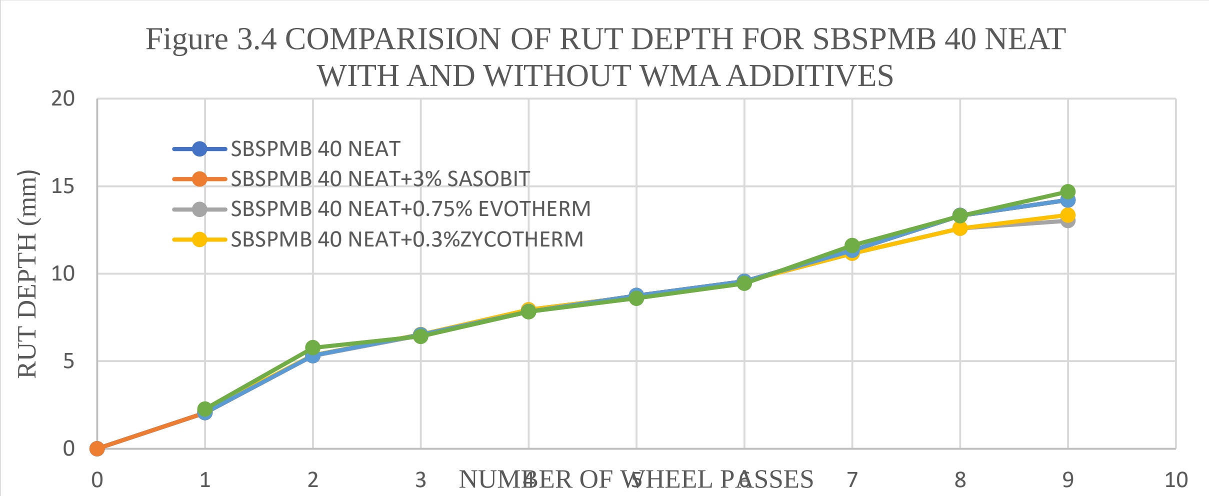


Table 3.4 RUTTING TEST RESULTS FOR SBS-PMB-40 AND ADDITIVES at 60 Degree Tempt				
NO OF CYCLES	RUTT DEPTH IN mm			
	SBS-PMB-40	SBS-PMB-40 +3% Sasobit	SBS-PMB-40 +0.75% Evotherm	SBS-PMB-40 +0.3% Zycotherm
0	0	0	0	0
50	2.06	2.16	2.16	2.27
100	5.320	5.31	5.350	5.770
200	6.510	6.48	6.530	6.420
300	7.840	7.94	7.940	7.830
400	8.750	8.71	8.710	8.600
500	9.570	9.56	9.560	9.450
1000	11.330	11.17	11.170	11.610
1500	13.320	12.59	12.590	13.310
2000	14.215	13.035	13.348	14.688



Discussions

- Under room temperature conditions, the rut depths of VG-30 neat with and without WMA additives mix are 9.09 mm, 8.14mm, 8.39mm, and 8.84mm, respectively.
- At 60^{0}C temperature, the rut depths for VG-30 neat with and without WMA additives are 13.32, 10.79, 12.50, and 11.83 mm.
- The results of the rutting analysis show that at room temperature, the rut depth of SBS-PMB-40 neat with and without WMA additives mix is 6.99 mm, for SBS-PMB-40 +3% Sasobit it is 5.94 mm, for SBS-PMB-40 +0.75% Evotherm it is 6.15 mm, and for SBS-PMB-40 +0.3% zycotherm it is 5.84 mm.
- At 60^{0}C, the rut depths for SBS-PMB-40 neat with and without WMA additives are 14.21, 13.23, 13.34, and 14.68 mm, respectively.
- Comparison of Rut dept for VG-30 and SBS-PMB-40 with and without WMA additives

Parameters	Rut depth in mm@room temperature	Rut depth in mm@ 60^{0}C
VG-30 neat	9.09	13.32
VG-30 +3%\Sasobit	8.03	10.79
VG-30 +0.75%Evotherm	8.14	12.5
VG-30 +0.3%Zycotherm	8.39	11.83
SBS-PMB-40 neat	7.00	14.215
SBS-PMB-40 +3%\Sasobit	5.29	13.035
SBS-PMB-40 +0.75%Evotherm	6.15	13.348

SBS-PMB-40 +0.3%Zycotherm	5.84	14.688

6.0 Conclusions

- Based on the results of the rutting investigation, we know that VG 30 neat bituminous concrete of grade-2 conventional and SBS-PMB-40 mix with and without WMA additions have different rut depths.
- Addition of Sasobit, Evotherm, and zycotherm, three WMA additives, the rut depth comes down compared to the normal conventional mix for both VG-30 and SBS-PMB-40 Mixes .
- Incorporating WMA additives into pavement improves its resistance to repeated wheel loads and reduces rutting in both VG-30 and SBS-PMB-40 Mixes.
- The rut depth comparisons between aged WMA and HMA under room and 60^0c temperatures conditions revealed that WMA rut resistance is inferior to HMA with and without additives
- The rut depth for WMA is greater than the HMA for Sasobit percentages. Despite this result, the WMA mixtures show a good performance for both Sasobit percentage.
- Rutting resistance performance for the WMA mixture competes with the HMA mixture, indicating that the WMA mixture has good resistance to rutting.
- In all test findings, 3% content of Sasobit performed better than 0.75% content of Evotherm and 0.3% content of zycotherm,

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