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Performance Evaluation of Flexible Pavements with Modified Bitumen Binders

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Abstract: ***In India majority of roads are being constructed by flexible pavements. But the performance of the pavement largely depends on quality and type of materials used, Construction methodology adopted, temperature, climatic conditions etc. Because of these variations in the mentioned parameters, pavements undergo distress/ failure. The different types of failure in flexible pavement are Rutting, Shovelling, Edge breaks, Cracks, Slippage etc. Rutting is a common phenomenon which occurs in flexible pavement surface due to overloading of vehicles and repeated application of wheel load. Rutting is defined as channelized depression in the pavement surface along wheel path due to heavy repetitive traffic load. Design of bituminous paving mixes greatly effects the performance of pavements. In the present laboratory research work, conventional bitumen is used in wearing/ surface course and Modified Bitumen is used in binder course of the layer. Pavement layers are constructed/casted in an Indigenously designed, developed and fabricated equipment called Roller Compactor cum Rut Analyzer (RCRA) and Rutting test was performed. The overall objective is to compare the Marshall properties of the conventional and Modified Bituminous mix and to study the rutting performance of these bituminous mixes. Results shows that bituminous mixes prepared with Modified Bitumen/Binders has a very high Marshall Strength and offers greater resistance to rutting***

Keywords: Modified Bitumen, Bituminous Concrete (BC), Dense Bituminous Macadam (DBM), Marshall Stability, Roller Compactor cum Rut Analyzer (RCRA), Crumb Rubber Modified Bitumen (CRMB)

I. INTRODUCTION

Bituminous pavement is extensively used in India for the construction of both rural and urban roads. Overloading of axles and increased traffic volume in excess of permissible limits and higher tyre pressure, have caused widespread problems with the performance of the pavement. The mix design is to produce a bituminous mix by proportioning various components so as to have sufficient bitumen to ensure a durable pavement, strength to resist shear deformation under traffic at higher temperature, sufficient air voids in compacted bitumen to avoid flushing and bleeding under traffic load and sufficient workability to provide easy placement without segregation. The Marshall Stability and flow test provides the performance prediction measure for the Bituminous mixes. It is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The stability is derived mainly from internal friction and cohesion. Cohesion is the binding force of binder material while internal friction is the interlocking and frictional resistance of aggregates. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous mix with good stability and flow. It is a common practice in India to use the Modified Bitumen in the wearing course and conventional bitumen in the binder course of pavement layers. But due repeated application of heavy wheel loads, temperature difference between the top and bottom of pavement layers, climatic conditions severely affects performance of pavement .So, in the present laboratory research work, an attempt is made to study the performance of bituminous mixes by using Crumb Rubber Modified Bitumen (CRMB-55) as a Modified bitumen in the Binder course of pavement layers. The Rutting test is carried out on wearing course of bituminous layer (BC Gr-II with VG-30) and by adopting Binder course layer namely DBM Gr-II prepared with two different types of binders namely VG-30, CRMB-55.

II. OBJECTIVES OF THE RESEARCH WORK

A. To conduct the basic tests on Aggregates, Bitumen and Modified Bitumen (CRMB-55) in the laboratory as per the relevant IS/ MoRTH standards to ascertain its suitability for the use in research work.
B. Based on the obtained Job Mix Formula (JMF) for different bituminous mixes, conduct Marshall stability test on bituminous mixes with VG-30 and CRMB-55.
C. To Conduct the rutting test on casted specimens of bituminous mixes at different temperatures in the laboratory using Roller Compactor cum Rut analyser (RCRA).
D. Comparison of results of Marshall stability and rutting values for the bituminous mixes prepared with VG-30 and CRMB-55.

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III. LITERATURE REVIEW

Prasad [1] Studied the importance to add the shredded waste plastic bottles to bituminous concrete (BC) mix and to evaluate the various mix properties like Marshall Stability, flow, bulk density, voids in the mix and VFB in 2012. Also the effect of soaking conditions of the mix was investigated. Indirect tensile strength was investigated for OBC and 8% plastic coated on aggregates which had yielded the highest marshal stability.

The optimum plastic content for 60/70 and 80/100 grade bitumen was 8%. For both 60/70 and 80/100 grade bitumen with plastic content 8%, the maximum stability was achieved in 80/100 grade bitumen. Hence there is an increase in stability with the addition of PET (polyethylene terephthalate) plastic in asphalt mix by incorporating dry process this can be used in highway construction for better stability for the appropriate traffic.

Sharma D K[2] Investigated the use of plastic/polymer as modifiers in 2009. The waste plastic/polymer was added on the aggregate before mixing Optimum Binder Content (OBC) in dry process at 150-160^{0}C temperature. This type of mixing increases the bonding between aggregates coated with plastic/polymer which increases the strength of the bituminous concrete mixes. Stability values and indirect tensile strength values were observed to be more in polymer modified bitumen than in conventional bitumen. Rutting values were also higher in polymer modified bitumen mixes than in conventional mixes

Justo[3], Reported the possible use of the processed plastic bags as an additive in bituminous concrete mixes at the Centre for Transportation Engineering of Bangalore University in 2002.The properties of the modified bitumen were compared with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 % by weight.

Therefore the life of the pavement surfacing course using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen.

Sheeb[4] Concluded that the modified mixture has a higher stability and VMA (Void in Mix Aggregate) percentage compared to the non-modified mixtures in 2007.

This, in returns, would positively influence the rutting resistance of these mixtures. The air void contents of the modified mixtures are not far from that of the non-modified one. Air void proportion around 4% is not enough to room for the expansion of asphalt binder to prevent bleeding or flushing that would reduce the skid resistance of the pavement and increase rutting susceptibility. In summary, using the poly-ethylene in asphalt mixtures reduces pavement deformation; increase fatigue resistance and provide better adhesion between the asphalt and the aggregates

Tayde[5] Intended to find the effective ways to reutilize the hard plastic waste particles as bitumen modifier for flexible pavements. The use of recycled waste plastic in pavement asphalt represents a valuable reuse for such materials. The use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improves the longevity and pavement performance with marginal saving in bitumen usage. The process is environment friendly. The use of waste plastics in the construction of roads and laminated roofing also help to consume large quantity of waste plastics.

Darshna B Joshi [6] conducted tests on finding out of Optimum binder content by Marshall mix design for DBM. Bituminous mix design is done to find out the properties of coarse aggregate, filler and binder materials and also mix should be workable, strong, durable and economical. Aggregate gradation and mix design requirements are primary concern in a asphalt mix. Various volumetric parameter and Marshall Stability is different for different mixes. Material tests should be done to make sure that all material satisfies the Indian Standards /MoRTH.

IV. METHODOLOGY

The following methodology is adopted in the present research work:

1) The methodology includes conducting the Basic tests on the materials used in the research work such as aggregate, bitumen, modified bitumen binders as per the relevant IS/MoRTH Codal standards
2) Preparing the Marshall specimens and conducting Marshall Stability test
3) Preparing the specimens for Rutting and conducting rutting test by Roller Compactor cum Rut analyser (RCRA) at different temperatures with VG-30 and Modified Bitumen (CRMB-55).

V. LABORATORY TEST RESULTS

The laboratory investigation/tests were carried out on different materials used in the research work and the obtained results are as follows:

Table 1
Tests on Aggregates

Sr No	Properties of aggregate	Obtained Test Results	Method adopted	Permissible Limit as Per IS/ MoRTH	Results
1	Cleanliness	3	IS 2386-Part-I	Max, 5% passing 0.075 mm sieve	Satisfactory
2	Specific Gravity	---	IS 2386 Part-III	2.5-3.0	Satisfactory
	Coarse Aggregate	2.70			
	Fine Aggregate	2.64			
3	Water absorption, %, max	0.25	IS 2386 Part-III	2	Satisfactory
4	Impact Value, %, max	16.32	IS 2386 Part-IV	27	Satisfactory
5	Abrasion Value, %, max	14.30	IS 2386 Part-IV	35	Satisfactory
6	Flakiness and Elongation Index, %, max	11.35	IS 2386 Part-I	35	Satisfactory
7	Plasticity Index, (Fine Aggregate)	2.5	IS 2720 Part-V	Max, 4 passing 0.075 mm sieve	Satisfactory

Table 2
Tests on Bitumen and Modified Bitumen

Sr No	Name of the test	Obtained Test Results		Method adopted	Permissible Values as per IS/ MoRTH	Remarks
		VG 30	CRMB 55			
1	Specific Gravity, min	1.00	1.12	IS:1203-1978	--	---
2	Penetration test at 25 ^{0} C, 0.1 mm, 100g, (mm), min	64.3	58.0	IS:1203-1978	45	Satisfactory
3	Softening point, (R&B) ^{o}C, min	48	68.0	IS:1203-1978	47	Satisfactory
4	Flash and Fire point, ^{o}C, min	278 & 300	278 & 300	IS:1203-1978	220	Satisfactory
5	Ductility, ^{o}C, min at 27^{0}C, min, cm	86..0	64.0	IS:1208-1978	75	Satisfactory

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TABLE 3
Obtained job Mix Formula (JMF) and Optimum Binder Content (OBC)

Sr No	Type of Bituminous Mix	Bitumen/ Modified Bitumen used	Percentages of Aggregate to be used as per Job Mix Formula (JMF)			OBC obtained based on Marshall Stability Test (%)
			Material A (26.5 mm down)	Material B (13.2 mm down)	Material C (4,75 mm down)	
1	BC Gr-II	VG-30	15	22	63	5.60
2	DBM Gr-II	VG-30	5	30	65	5.10
		CRMB-55	5	30	65	



Fig 1: Marshall Stability Apparatus



Fig 2: Roller Compactor um Rut Analyzer (RCRA)

TABLE 4
OBTAINED RESULTS OF MARSHALL STABILITY TEST

Sr No	Marshall Property	BC Gr-II with VG-30	DBM Gr-II	
			VG-30	CRMB-55
1	Optimum Binder Content (OBC), %	5.60	5.10	5.10
2	Marshall Stability, kg	2490	1190	1845
3	Flow Value, mm	3.57	3.85	4.10
4	Bulk Density, gm/cc	2.32	2.36	2.37
5	Volume of Voids, %	3.73	3.05	5.10
6	Voids in Mineral aggregate , VMA, %	15.99	18.50	16.5
7	Voids filled with Bitumen, VFB, %	72.43	73.0	61.4

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TABLE 5
RUTTING TEST RESULTS FOR PAVEMENT LAYERS, USING BC GR-II WITH VG-30 AS WEARING COURSE AND DBM GR-II AS BINDER COURSE WITH VG-30 AND CRMB -55 AT DIFFERENT TEMPERATURES.

Sr No	Rut Depth (mm)	Number of passes required in Roller Compactor Cum Rut Analyzer at different temperature ranges					
		VG-30			CRMB-55		
		30 ^{0}C	50 ^{0}C	70 ^{0}C	30 ^{0}C	50 ^{0}C	70 ^{0}C
1	0	0	0	0	0	0	0
2	2	6456	5459	4902	8402	6234	5324
3	4	11322	10458	7952	13567	12130	9010
4	6	15598	15006	12005	18965	16876	11680
5	8	18659	17956	11551	21780	18950	14236
6	10	21322	20300	13658	23988	21304	15900
7	12	22869	21986	14520	26015	22988	16301
8	14	24005	22568	15569	28590	24975	18900
9	16	27120	24355	16520	31450	26840	22364
10	18	28004	25010	17589	34679	28865	24678
11	20	29100	25542	19602	36414	31935	29098

VI. DISCUSSIONS

A. The basic properties on aggregates, bitumen and modified binders are carried out in the laboratory and the materials satisfies the requirements as per the relevant IS / MoRTH standards.

B. The optimum binder Content (OBC) for BC Gr-II with VG-30 is found to be 5.6%, DBM Gr-II with VG-30 is 5.1% and DBM Gr-II with CRMB-55 is 5.1% respectively.

C. The stability value of Binder course (DBM Gr-II) with CRMB-55 shows 55% higher value than with VG-30.

D. The Wearing course (BC Gr-II) with VG-30 at 30^0 C shows, 14% and 48% higher resistance to rutting at 50^0 C and 70^{0}C respectively.

E. The Modified Bitumen (CRMB-55) shows 25%, 25%, 32% higher resistance to rutting at 30^{0}C, 50^{0}C, and 70^{0}C respectively, when compared at same temperatures with VG 30.

VII. CONCLUSIONS

From the present research work, it can be concluded that:

1) The modified binders shows a higher Marshall stability value when compared with VG-30 bitumen.

2) The use of modified binders (CRMB-55) in the binder course layer of pavement shows a high resistance to rutting when compared with VG-30. The percentage of higher resistance is upto 48%.

3) Modified Binders can also be used in Binder course of pavement. The use of modified bitumen makes the structural layer of pavement to have more stability and greater resistance to rutting.

4) The temperature significantly affects the rutting in pavement. The pavement undergoes higher rutting with increase in temperature.

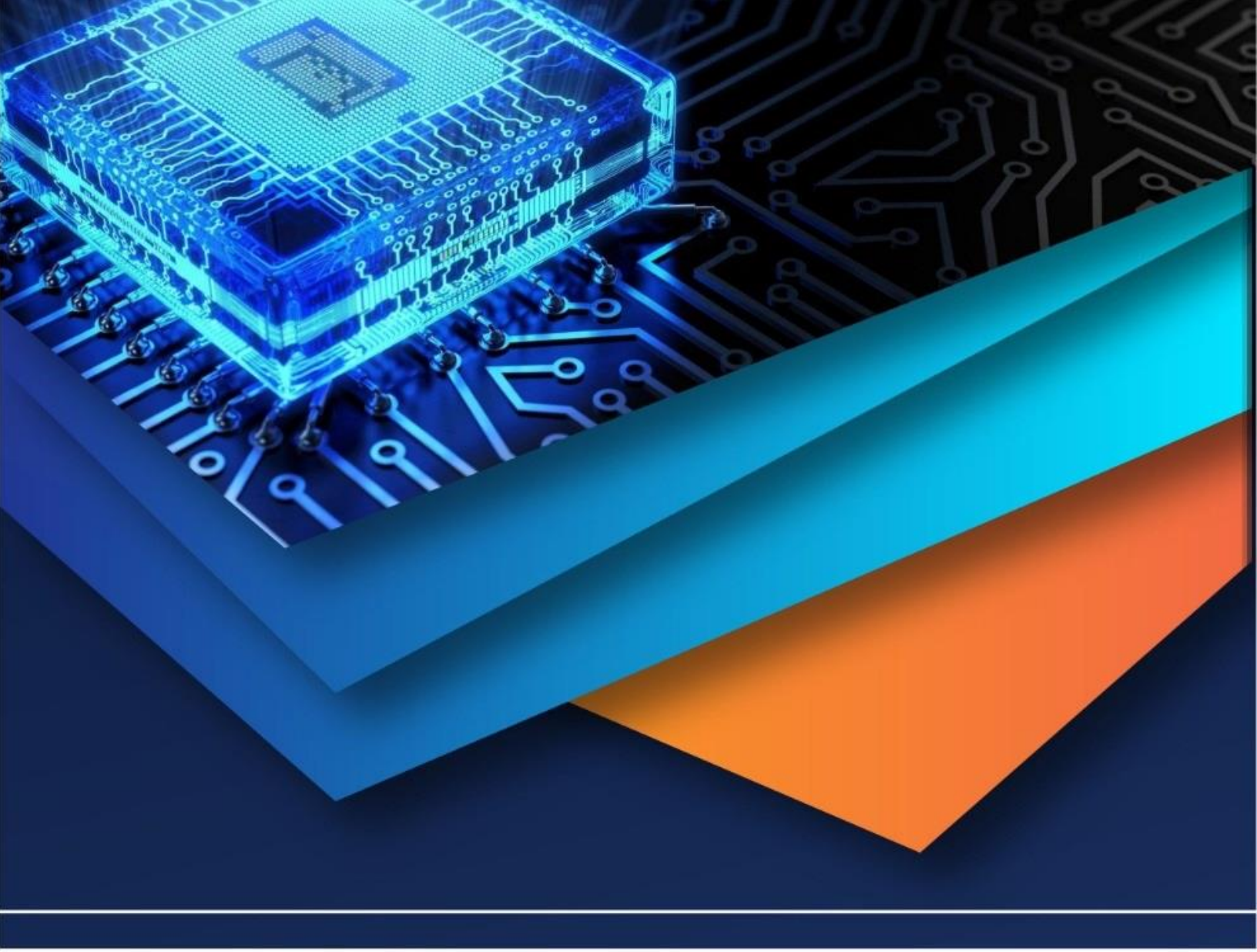
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