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Use of Different Types of Additives in DBM (Dense Bitumen Macadam)

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Abstract

India has a road network of over 4,865,000 kilometers, the second largest in the world. The road transport carries close to 85% of passenger traffic and 70% of freight transport. The properties of bitumen and bituminous mixes can be made better to meet requirements of any pavement with the incorporation of certain additives or a blend of additives. Bituminous mixes can be prepared and used in a pavement section for a bituminous binder course using different types of additives such as Polymers, Crumb Rubber and waste materials like discarded tube tyres, plastic bottles and rice husk ash. Modified bituminous mixes are expected to give higher life of surfacing depending upon degree of modification and type of additives used. The present study aims at developing bituminous mixes for the Dense Bituminous Macadam (DBM) Grade 1 incorporating the plastic wastes, waste tyre tubes and rice husk ash as partial replacement of the bitumen content. Also the study focuses on the DBM Grade 1 mixes with different blends by using Crumb Rubber Modified Bitumen (CRMB) and Polymer Modified Bitumen (PMB). In this study, the Stability-Flow analysis for the various DBM Grade 1 mixtures with modified binders and with different percentage replacement of bitumen with plastic wastes, waste tyre tubes and rice husk ash are reported. It is found that of the three materials used, replacement of OBC by 10% discarded tyre tube has the highest stability value. The optimum content of CRMB and PMB for use in DBM Grade 1 mix is 5%. Also the bituminous mixes of DBM Grade 1 with 5% PMB having 40% stone dust shows the maximum stability value and the bituminous mixes of DBM Grade 1 with 5% CRMB having 44% stone dust shows the maximum stability value.

Keywords

Polymer crumb rubber, plastic bags, poly-ethylene, tyre rubber, glass powder and waste plastic, stability value and flow characteristics.

I. Introduction

The quality of roads dictates the economy of a country and hence the quality of our life's. Roads are vital for the transport of the goods and passengers. In India, road transport carries approximately 85% of passenger traffic and 70% of freight transport. But the construction of highways involves huge amount of the investment and mainly sixty percent of the highway project cost is associated with the pavement construction. Pavement is a durable surfacing of a road, airstrip, or similar area and the primary function is to transmit loads to the sub-base and underlying soil sub-grade. Around ninety percent of the Indian Highways have a covered surface with bituminous layers which are constructed and maintained by using naturally available road aggregates and bitumen, a petroleum product, which being mixed at high temperatures to produce hot mix asphalt. Mix design for the different layers of the pavement can have a major impact on the performance, cost and sustainability of the bituminous surfaces.

II. Dense Bituminous Macadam Mix

Dense bituminous macadam is mainly used as binder course for roads having much higher number of heavy commercial vehicles. In DBM mix there is a wide scope of varying the gradation to obtain the good mix without affecting the durability of pavement. Achieving adequate compaction of bituminous mixes is crucial to the performance of flexible pavement. Normally Marshall Mix design method is adopted for mix design of Dense Graded Bituminous Macadam, (DBM). DBM is also intended for use as road base material.

3. Materials

The following section covers the description of the coarse aggregate, fine aggregate, bitumen and additives used in the study.

Fine Aggregates

Fine aggregates for DBM consists of crushed or naturally occurring mineral material or a combination of the two, passing the 2.36mm Indian standard sieve and retained on the 75 micron Indian standard sieve. Aggregates should be clean, hard, durable, and free from dust, dry and soft or friable matter, organic or other deleterious matter.

Coarse Aggregates

The coarse aggregates for the DBM mix consists of crushed rock, crushed gravel or other hard material retained on the 2.36mm sieve. Aggregates should be clean, hard, and durable, of cubical shape, free from dust and soft or friable material, organic or other deleterious matter. Where the Contractor's selected source of aggregates have poor affinity for bitumen, as a condition for the permission of that source, the bitumen shall be treated with an approved anti -stripping agent, as per the engineering's recommendations, without additional payment.

Bitumen

The bitumen for the DBM is a paving bitumen of penetration Grade complying with Indian Standard Specifications for "Paving Bitumen" IS: 73, and of the penetration specified by MOSRT & H Specifications for Road and Bridge Works (Fourth Revision) Re-print March 2007 for Dense Bituminous Macadam.

Additives

In the present study additives used were Plastic waste, Rice husk Ash, CRMB (crumb rubber modified bitumen)

Methodology

This stage in divided into three sections: - Testing of aggregates, testing of bitumen, testing of DBM with additive and without

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Testing of Aggregates

Sieve analysis test was used to determine the aggregate sizes from a sample taken from quarry. Through this sieve test, the proportion of coarse aggregates, fines aggregate and filler was determined and ensuring the aggregate were well blended within the gradation limit as specified in MORTH for DBM Grade 1. The sieve analysis test results are presented in Table 1. The MORTH gradations of dense bituminous macadam are shown in table 2. The blending selected for the gradation of dense bituminous macadam DBM-Grade 1 is shown in table 3. The combined gradation of the sample taken is shown in table 4. Aggregates were tested for the various specified properties and the obtained test results were compared with the allowable values as per the MORTH specifications as shown in Table 5.

Table 1 Sieve Analysis Results

Sieve Size	Percentage Passing 40mm	Percentage Passing 20mm	Percentage Passing 10mm	Percentage Passing Stone Dust
45	100	100	100	100
37.5	95.6	100	100	100
26.5	70.5	100	100	100
13.2	2.14	2.8	57.87	100
4.75	0	0	2	98
2.36	0	0	0.14	88.6
0.300	0	0	0.01	10
0.075	0	0	0	0

Table 2 Gradations for Dense Bituminous Macadam

EXISTING MORTHS GRADATION FOR DENSE BITUMENOUS MACCADAM		
Grading	1	2
Thickness	80-100 mm	50-75 mm
Nominal Aggregate Size	40mm	25 mm
Sieve, mm		
45	100	
37.5	95-100	100
26.5	63-93	90-100
19		71-95
13.2	55-75	56-80
9.5		
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen Content, %	Min.4	Min. 4.5

Table 3Percentage of Aggregate Size Taken

Calculated Blending for DBM grading no-1				
40 mm	**20 mm**	**10mm**	**Stones dust**	**Total**
16	16	29	39	100

Table 4 Combined Gradation of the Sample Taken

Required sieve	%age passing 40mm	%age passing 20mm	%age passing 10mm	%age passing stone dust	Combined gradation	LIMIT AS PER MORTH	Required sieve
45	16	16	29	39	100	100	100
37.5	15.296	16	29	39	99.296	95	100
26.5	9.28	16	29	39	91.28	63	93
13.2	0.3424	0.448	16.782	39	56.5727	55	75
4.75	0	0	0.58	38.22	38.8	38	54
2.36	0	0	0.0406	34.632	34.6726	28	42
0.300	0	0	0.0029	7.9	7.9029	7	21
0.075	0	0	0	0	0	2	8

Table 5 Test Results of the Ingredient Aggregates.

Property	Results	Specifications
Aggregate Impact Value, %	19	Maximum 27
Abrasion value%	27	Maximum 35
Flakiness and Elongation Indices, %, (Combined)	29	Maximum 30
Water Absorption, %	1.5	Maximum 2
Specific Gravity	2.665	

Testing of Bitumen

Sample of bitumen were tested for penetration test, viscosity test and softening point test. The penetration and viscosity test was to obtain consistency of bitumen at some specified temperature and designate grade of asphalt while softening point test is to obtain temperature for bitumen melt. The test results of different bitumen tests are shown in table 6.

Table 6 Test results of Ingredient Bitumen Sample.

TEST RESULTS FOR INGREDIENT BITUMEN		
Property	Test Results	Specified Limits as per BIS : 73-1992
Penetration at 25ºC/100 gm /5 sec, mm	65	60-70
Softening Point, ºC	51.7	40-55
Ductility, cm	75	> 75
Specific Gravity, at 27ºC	1.01	>0.99
Viscosity at 60ºC, Poise	1032	1000±200
135ºC, CSt	265	>150

Testing Of DBM Grade 1 Mix Design Without Any Additive

To calculate the optimum binder content (OBC), Marshall Samples were prepared by varying percentage of 60/70 binder without any addition of any modifier. Stability-Flow analysis and Volumetric analysis was carried out for the prepared Marshall Core samples with varying bitumen content from 3.5% to 5.5%. The test values obtained are plotted graphically. From the graphs plotted from Fig 1 to 6, the optimum binder content was found to be 4.5 percent by wt. of aggregates using stability flow values. The outputs of stability and flow values are as in table no 7 and fig 1 to 6:-

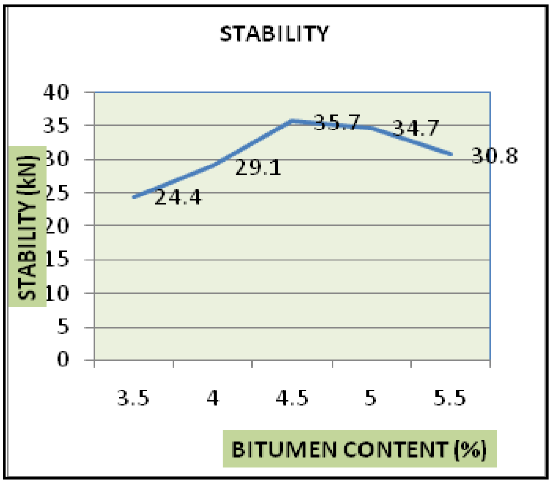

Fig. 1 : Variation of Stability Value to the Variation in Bitumen Content

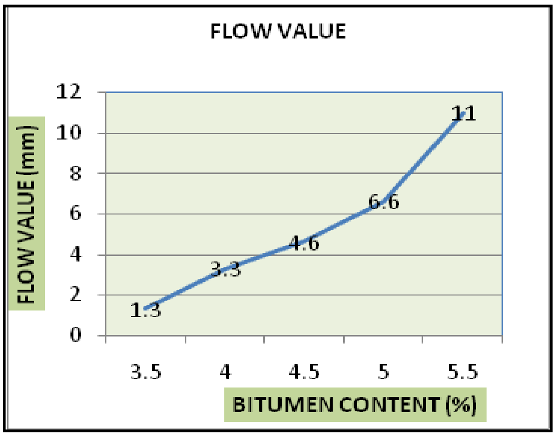

Fig.2 : Variation of Flow Value to the Variation in Bitumen Content

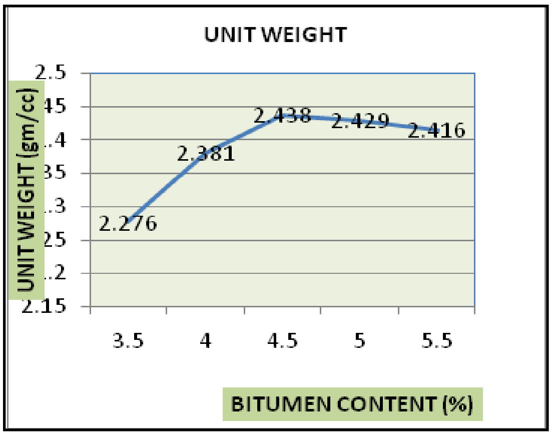

Fig.3 : Variation of Unit Weight to the Variation in Bitumen Content

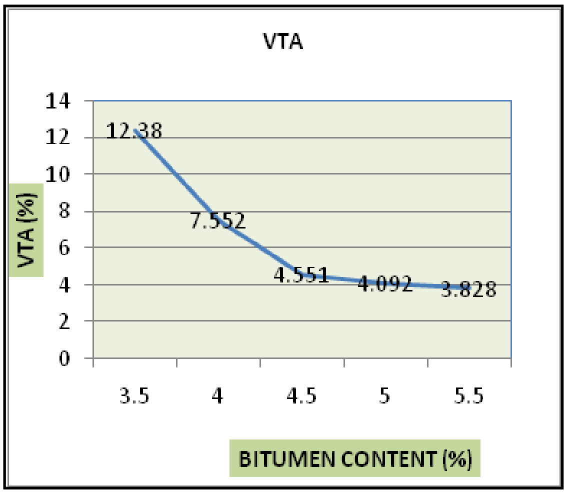

Fig. 4 : Variation of VTA to the Variation in Bitumen Content

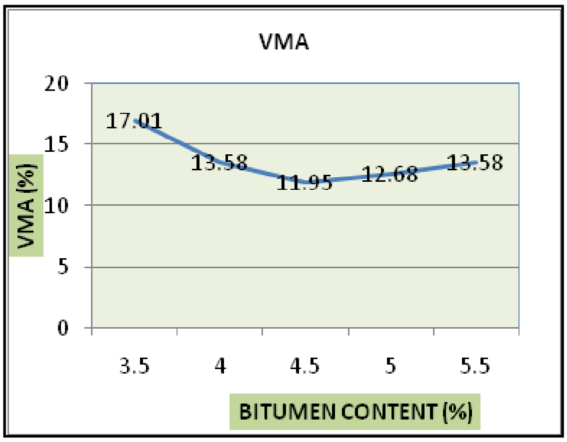

Fig. 5 : Variation of VMA to the Variation in Bitumen Content

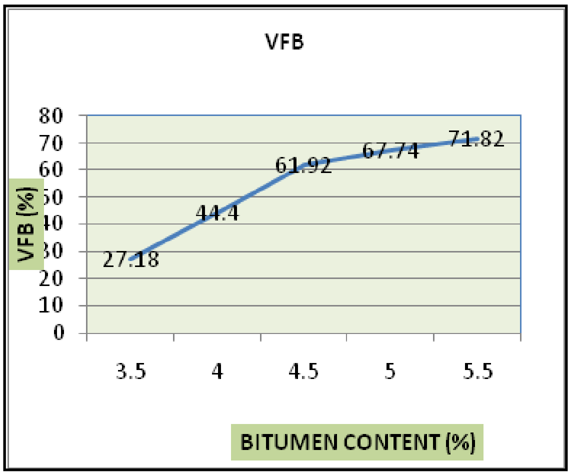

Fig. 6 : Variation of VFB to the Variation in Bitumen Content

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Table 7 : Marshall Properties of Specimens without Additives

Bitumen Content (%)	Unit weight (gm/cc)	Stability (KN)	Flow Value (mm)	Air Void VTA (%)	Voids in mineral aggregates VMA (%)	Voids Filled with Bitumen VFB (%)
3.5	2.276	24.4	1.3	12.38	17.01	27.18
4.0	2.381	29.10	3.3	7.552	13.58	44.4
4.5	2.438	35.70	4.6	4.551	11.95	61.92
5.0	2.429	34.70	6.6	4.092	12.68	67.74
5.5	2.416	30.80	11.0	3.828	13.58	71.82

Testing of DBM Grade 1 Mix Design With Plastic Waste

The waste plastic bottles were used in the bituminous mixes of DBM Grade 1 and stability flow characteristics of the mix was carried out using Marshall Method of bituminous mix design. The optimum binder content (OBC) of 4.5% was replaced with 8%, 12% and 16% of plastic content to determine the Stability and Flow characteristics of the modified mix. The outputs are shown in table 8.

Table 8 : Test Outputs for Stability and Flow by Varying Plastic Content.

Replacement of OBC with plastic%	Height of sample (mm)	Corrected stability (KN)	Flow (mm)
8	100	26.864	3.9
12	101	31.32	9.3
16	100	22.816	6.4

Testing of DBM Grade 1 Mix Design With Rice Husk Ash

Bituminous mix design for DBM grade 1 by Marshal method was carried out by replacing the optimum binder content with varying percentages of 6%, 10% and 14% rice husk ash to determine the Stability-Flow characteristics of the modified mix. The outputs are as shown in table 9.

Table 9 : Test Outputs for Stability and Flow by Varying Rice Husk Content.

Replacement of OBC with Rice husk%	Height of sample (mm)	Corrected stability (KN)	Flow (mm)
6	100	40.48	7.3
10	99	31.92	4.3
14	100	28.30	4.3

TESTING OF DBM GRADE 1 MIX DESIGN WITH CRMB (CRUMB RUBBER MODIFIED BITUMEN)

Test outputs of the CRMB sample are. From the test outputs, sample was identified as CRMB 60. The mix design of DBM grade 1 was carried out with CRMB by making various trial samples with varying CRMB content starting from 3.5% and the optimum content of CRMB was calculated as shown in table 10.

Table 10 : Test Outputs for Stability and Flow by Varying CRMB Content.

Replacement of OBC with CRMB%	Height of sample (mm)	Stability	Flow (mm)
3.5	100	21.1	3.2
4	100	22.4	3.8
4.5	99	21.6	4.0
5	100	25.2	4.2
5.5	99	22.9	5.8

Discussions of Results

Effect of Plastic Waste on the Stability & Flow Analysis of DBM Grade 1 Mix

Table 8 shows the variation of stability and flow of DBM mix with percentage replacement of OBC with plastic content. It is observed from the data obtained that on replacing OBC with 8%, 12% and 16% waste plastic, the stability value is reduced. The stability value decreased by 24.76% with 8% plastic waste, 12.26% with 12% plastic waste and 36.10% with 16% plastic waste. However, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied only for the mix with 8% plastic waste.

Effect of Rice Husk Ash on the Stability & Flow Analysis of DBM Grade 1 Mix

The Optimum binder content calculated for the DBM grade 1 was replaced with the 6%, 10% and 14% Rice Husk ash. Table 9explains the variation of stability and flow of DBM mix with percentage replacement of OBC by varying percentages of rice husk ash as stated above. With this replacement, the stability value increased by 13.38% with 6% Rice Husk ash, however, the stability value decreased by 10.58% with 10% rice husk ash and by 20.72% with 14% rice husk ash replacement. However, all the three mixes have higher stability value than the minimum specified stability value as per MS2 and MORTH specifications. But the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied for the mix with 10% Rice Husk ash and 14% Rice Husk ash. It is observed that replacement of OBC by 10% discarded tyre tube has the highest stability value.

Effect of Use of CRMB on the Stability & Flow Analysis of DBM Grade 1 Mix

Different percentage viz. 3.5%, 4%, 4.5%, 5% and 5.5% of CRMB was used to calculate the optimum CRMB content for the DBM GRADE-1. Table 10explains the variation of flow and stability level for different percentages of CRMB content. It is observed that the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied for the entire range of mixes having 3.5%, 4%, 4.5%, 5% and 5.5% CRMB. On analysis it was found that the optimum CRMB content comes out to be 5%.

Conclusions and Scope for Future Study

Conclusions

The major conclusions drawn from the study carried out on stability flow analysis of DBM (GRADE 1) by using different additives are as under:

- The flow criteria for DBM grade 1 is satisfied only if the Bitumen is replaced by 8% plastic waste, although the stability values lie within the specific range for all replacement levels.
- It is observed from the data obtained that on replacing OBC with 8%, 12% and 16% waste plastic, the stability value decreased. The stability value decreased by 24.76% with 8% plastic waste, 12.26% with 12% plastic waste and 36.10% with 16% plastic waste
- The flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied only for the mix with 8% plastic waste.
- The stability value increased by 13.38% with 6% Rice Husk ash, however, the stability value decreased by 10.58% with 10% rice husk ash and by 20.72% with 14% rice husk ash replacement.
- Although the stability value increased for 6% replacement of OBC by rice husk ash and reduced for 10% and 14% replacement levels, but the 6% replacement level only does not satisfy the flow criteria. It indicates that 10 to 15% replacement level of rice husk ash is suited for creating a stable and flow able DBM mix of grade 1. Higher limit of rice husk ash replacement needs further investigations.
- It is observed that the flow criteria of 3 to 6 mm for DBM grade 1 *[MS2 and MORTH]* was satisfied for the entire range of mixes having 3.5%, 4%, 4.5%, 5% and 5.5% CRMB. On analysis it was found that the optimum CRMB content comes out to be 5%.
- Of the three materials used, replacement of OBC by 6% discarded Rice Husk has the highest stability value.

Scope for Further Work

A trial section of a pavement, with DBM Grade 1 layer, can be prepared and investigated by using the optimum percentage replacement values of various additives obtained in the work. This trial section can be evaluated for the performance characteristics both in terms of structural evaluation as well as functional evaluation of the pavement. We can also use the other type of natural and artificial additives for further study.

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