A Comparative Laboratory Studies on the Behaviour of Dense Bituminous Macadam (Grading II) Mix Prepared Using Different Binder and Mineral Fillers

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Abstract: *The bituminous mix design aims to determine the proportion of coarse aggregate, fine aggregate, mineral filler and bitumen to produce a mix which is workable, strong, durable and economical bituminous materials are extensively used for roadway construction, because of their excellent binding characteristics and water proofing properties and relatively low cost. Dense Bituminous Macadam is strong enough to handle years of vehicular traffic and is relatively easy to maintain. Bituminous paving is also fully recyclable, though recycled products may not be as strong as raw materials. Bituminous materials consist of bitumen which is a black or dark coloured semi solid or viscous substance. Design of Dense Bituminous Macadam mix (Grade-II) prepared using VG-30 & PMB-40 was carried out as per MORT&H and IRC SP-53:2010 specifications. Using Marshall Method of mix design, the OBC for DBM Mix was determined. At optimum bitumen content, Marshall Stability test was conducted to determine the Marshall properties of DBM, Indirect Tensile Strength test (ITS) and Tensile Strength Ratio (TSR) and Fatigue behaviour are evaluated on Marshall specimens prepared using Stone Dust (2%) and Ground Granulated Blast Furnace Slag (2%) as mineral filler at optimum bitumen content. the laboratory test carried out, it can be concluded that the DBM mix prepared using PMB-40 with GGBS (2%) as mineral filler is superior when compared to that of mix prepared using VG-30 with Stone Dust (2%) and GGBS (2%) as mineral fillers and mix prepared using PMB-40 with Stone Dust (2%) as mineral fillers.*

Keywords: Marshall Properties, ITS, TSR, GGBS, Stone Dust, VG-30, PMB-40, CRMB-55.

1. INTRODUCTION

Dense bituminous macadam is the layer of binder course, it is strong enough to handle the vehicle traffic and is relatively easy to repair or refinish. It provides the smoother and good ride than cement surfaces, which helps to reduce sound pollution around highways and other busy roads. Bituminous paving is also fully recyclable, through recycled products may not be as strong as raw materials. Flexible pavements with bituminous black tops are widely used in India. The intensity of high traffic in terms of commercial vehicles, heavy loaded trucks and significant variations in daily and seasonal temperature of the pavement has been responsible for early develops the distresses in bituminous pavement like rutting, cracking, bleeding, shoving and potholing. The problems for pavements in India, is very high and very low pavement temperature conditions in some parts of the country. Under the conditions of these, bituminous surfacing fines to become soft in summer and brittle in winter.

1.1 PAVING BITUMEN

Paving bitumen is a product that is mostly obtained from crude petroleum through a series of refining steps. Bitumen can also be used in other forms, such as in emulsified form in emulsions. With reference to paving mixes, bitumen is commonly referred to as binder, since its basic purpose is to “bind” the aggregate particles together. In general, binders are semi-solid or solid at room temperature and liquid at high temperature. Different “grades” of binders are produced by changing the source (of crude petroleum) as well as the refining conditions to meet different paving demands, mainly arising from differences in environmental and traffic conditions. Bitumen Binders are classified into different “grades of Bitumen” with the help of characterization tests. The properties of binders are affected significantly by the temperature and time of loading.

1.2 Modified Bitumen

The properties of bitumen and bituminous mixes can be modified with the incorporation of certain additives or blend of additives. And these additives are called "Modifiers" and the bitumen which are blended with the modifiers are known as "Modified Bitumen". Use of modified bitumen in the top layers of the flexible pavement is expected to significantly improve the life of the surfacing and extend the time of the next renewal of the surfacing. Full-scale performance studies on overlay carried out by the various research institutions, Indian Institutes of Technology under the agency of Ministry of Road Transport and Highways, Central Road Research Institute, Highways Research Station, Chennai, Rubber Board, Kerala, Gujarat Engineering Research Institute, and various state Public Works Departments showed that the use of Modified Bitumen in construction or maintenance of bituminous roads significantly enhance the pavement performance and is cost effective.

1.3 Tensile and Compressive stresses in pavement

The distresses that arrives in flexible pavement are fatigue cracking and permanent deformations. These distresses reduce the service life of the bituminous pavement and increase the maintenance cost on an

average. To reduce the pavement distresses there are solutions such as opting new mix design or by using additives with bitumen. The traffic causing fatigue cracks on the bituminous layer is a very common distress and must be taken into consideration in pavement design and the appropriate selection of materials to prevent premature cracking of bituminous pavements. Therefore there is a need to carryout studies to evaluate the performance of the bituminous mixes with modified binders and to obtain information on the long term benefits over conventional binders

1.4 Advantages of Mineral Filler

- Stiffen the Bituminous Mix.
- Alter the moisture resistance of the bituminous mix.
- Affect the ageing characteristics of bituminous mix.
- Affect the workability and compaction characteristics of bituminous mix

2. OBJECTIVE OF THE PRESENT STUDY

- To determine the Optimum bitumen content for Dense Bituminous Macadam mix prepared using Viscosity Grade (VG-30) and Modified Bitumen (PMB- 40) as binders with Stone Dust (2%) and GGBS (2%) as mineral fillers by Marshall Method.
- To compare the Marshall Properties of Dense Bituminous Macadam mix prepared using Viscosity Grade (VG-30) and Modified Bitumen (PMB- 40) as binders at optimum bitumen content by varying mineral fillers with Stone Dust (2%) and GGBS (2%).
- To conduct Indirect Tensile strength Test and to determine Tensile strength Ratio of Dense Bituminous Macadam mix prepared using Viscosity Grade (VG-30) and Modified Bitumen (PMB- 40) as binders at optimum bitumen content by varying mineral fillers with Stone Dust (2%) and GGBS (2%).

3. LITERATURE REVIEW

Durga Priyanka B et al (2014) this paper says that, the prices of the crude oil are increasing in recent years resulted in an increase in the prices of bitumen binder as crude oil is origin for bitumen & in other hand the fly ash, waste material from the power generating plants causing severe disposal problems. The main purpose of this project is to study the possibility of changing the mineral filler with fly ash in bituminous paving mixes where in general cement, stone dust are used. Fly ash from the plant Dr.NTTPS, Vijayawada, AP has used in the experimental work. Coarse aggregates of downsizes 40mm, 20mm, 10mm, 6mm obtained from the crusher units nearby Ibrahimpatnam are used. For comparison, stone dust and fly ash is used to prepare the mix. Marshall Stability test is used to determine the properties like stability, flow value, % air voids, voids in mineral aggregate(VMA), voids filled with bitumen(VFB) for a Dense Bituminous Macadam(DBM) mix of Grading II. The experimental work is carried out by using specifications from MORTH (Ministry of road transports & highways, specifications for road & bridge works, 5th revision).By replacing the stone dust with fly ash at the levels 4%, 8%, 12% the results are compared. The variance in the properties, optimum bitumen content and fly ash contents are evaluated. It is observed that the mixes with fly ash as filler do not differ much in properties when compared with the mix and satisfy the desired criteria specified. Hence, it has been recommended to utilize fly ash as mineral filler with availability, not only reduces the cost of execution, but also partly solve disposal problems of fly ash from the palnts.

Malik Shoeb Ahmad et al (2014) in this study, this paper presents the addition of waste polythene carry bags in flexible pavement construction. The low density polyethylene (LDPE/PW) carry bags gives out the plastic waste from kitchen household waste and plastic bottles of liquids are used as additive in flexible pavements. Purposes of using these materials are to environmentally unacceptable waste material and to make the better material mix to resist heavy traffic load and pressure results the cracks in the pavement surface. In the study the plastic waste was cleaned from dust and cut into a sizes passes through 2-3mmsieve with shredding machine. In this study, DBM mix are prepared by using plain bitumen as a control specimen and bitumen blended with low density polyethylene in different proportions such as 2, 4, 6, 8, 10 and 12% by weight. The Marshall Stability tests were conducted on modified DBM mixes. It has been observed that the plastic waste modifies the bituminous mix showing better binding property, stability, density and more resistant to water. Hence, the present technology will strengthen the road construction and increases the road life as well as will help to improve the environment.

Anup Singh and Sandeep Goyal (2017) in this paper, the quest for new and competent road surface points to the needs for improvement of road surface. This would accomplishment by improving the strength of road surface with the addition of some foreign material in its composition. The improvement in concrete surface practiced all over the world is addition of fibers in it. This technique could also be adopted in bituminous surface but due to high mixing temperature of Bituminous mixes only steel fiber could withstand with it and the length of the steel fiber is 18 mm and 11 mm and the fiber is used in the different percentages and proportions i.e., 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, 5%, 5.5% and 6%. Therefore these fibers content has been recommended for making improvements in parameter of Bituminous Mixes.

4. MATERIALS USED

4.1 Aggregates

The aggregates shall consist of crushed rock and shall be clean, hard, durable, and free from dust or friable matter, organic or other deleterious substances. Aggregates offer good compressive strength along with, they provide good interlocking facility with sufficient permeability. Coarse aggregate of 26.5 mm to 2.36 mm, fine aggregates of 2.36 mm to 75 micron were used and fillers passing 75 microns sieve. The test results are presented in Table 1.

Table -1: Test results of aggregates

Aggregate Test	Test Result	Requirement as per Table: 500-8 MoRT&H (V Revision) 2013 Specifications
Aggregate Impact Value (%)	25.28	Max 27%
Los Angeles Abrasion Value (%)	29.84	Max 35%
Flakiness and Elongation Indices Combined (%)	31.46	Max 35%
Water Absorption (%)	0.5	Max 2%
Specific Gravity		-----
Coarse Aggregate	2.72	
Fine Aggregate	2.70	
Mineral Filler		
Stone Dust	2.74	
Ground Granulated Blast Furnace Slag	2.86	

4.2 Bitumen Binder

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix. The characteristics of bitumen which affects the bituminous mixture behaviour are temperature susceptibility, visco- elasticity and aging. The behaviour of bitumen depends on temperature as well as on the time of loading. It exhibits both viscous as well as elastic properties at the normal pavement temperature. Though at low temperature it behaves like an elastic material and at high temperatures its behaviour is like a viscous fluid and the test results are shown in the Table 2.

Table -2: Test results of Bitumen VG-30 & PMB-40

Tests on Bitumen	Results of PMB-40	Results of VG-30	Requirement as per Table-1 IS 73- 2013 & SP 53-2010 Specifications
Penetration at 25^{0}C	44	67	60/70
Softening point , ^{0}C	69	48	Min 47
Flash point , ^{0}C	240	232	Min 220
Fire point , ^{0}C	260	256	Min 240
Ductility @27^{0}C, cm	84	79	Min 40
Specific Gravity	1.04	1.01	---

4.3 Gradation of Aggregate

The aggregate gradation (Grading-II) was adopted for Dense Bituminous Macadam mix as per MORT&H (V Revision) Specifications presented in Table 3.

Table -3: Gradation of aggregates of DBM mix (Grade II)

Grading	2		
Nominal Aggregate Size	26.5mm		
Layer Thickness	50-75 mm		
IS Sieve Size mm	Cumulative % weight of total aggregate passing		
	Upper Limit	Lower Limit	Mid Limit
37.5	100	100	100
26.5	100	90	95
19	95	71	83
13.2	80	56	68
4.75	54	38	47
2.36	42	28	36
0.3	21	7	15
0.075	8	2	2

4.4 Mineral Filler

Mineral filler consists of very fine, inert mineral matter that is added to the dense bituminous mix, to increase the density and enhance strength of the mixture. The Mineral filler shall be free from organic impurities. The Mineral fillers may be cement, ground granulated blast furnace slag, stone dust, fly ash or hydrated lime. The Mineral filler material used in the present study is stone dust and GGBS. Mineral Filler content of about 2% by weight of total aggregates is added in the preparation of dense bituminous mix. The specific gravity test and grading of Mineral Fillers conducted in the lab and results are presented in Table 4.

Table -4: Specific Gravity of Mineral Filler

Filler	Specific Gravity
Stone Dust	2.70
GGBS	2.86

5 ANALYSIS OF THE DATA

5.1 Binder optimization by Marshall Method

To determine the optimum bitumen content for four different percentage of bitumen content are 3.5%, 4.0%, 4.5% and 5.0% respectively by weight of aggregate. The optimum bitumen content is determined by the ability of a mix to satisfy the mechanical properties and volumetric properties. The data obtained from Marshall Stability-Flow test are used to plot the Marshall Properties versus Bitumen Content, from these plots optimum bitumen contents are determined corresponding to Maximum Stability, Maximum Bulk density and 3-5% air voids in total mix. The optimum bitumen content of the mix is the numerical average of the three values of Maximum Stability, Maximum Bulk density and 3-5% air voids in total mix.

Marshall Test were conducted on Dense Bituminous Macadam Mix prepared using viscosity Grade (VG-30) and Modified Bitumen (PMB- 40) with ground granulated blast furnace slag (2%) and stone dust (2%) as mineral fillers, to determine the optimum bitumen content, Marshall Stability, Flow, bulk density, total air voids, voids

in mineral aggregates and voids filled with bitumen. and the test results are in Table 5 and Table 6.

Table -5: Results of Marshall Properties of Binder VG-30.

Sl No.	Marshall Properties	Test Results of VG-30 with stone Dust	Test Results of VG-30 with GGBS	Requirements as per Table-500-10 of MORT&H (V Revision)
1	Optimum Bitumen Content, %	4.5	4.46	4.50 (Min.)
2	Marshall Stability, kg	1352	1368	9.00 (Min.)
3	Flow, mm	2.9	3	2.5 - 4.0
4	Air voids(Vv), %	3.02	3.85	3.0 - 5.0
5	Voids filled with Bitumen (VFB), %	74.93	72.56	65-75

Table -6: Results of Marshall Properties of Binder PMB-40

Sl No.	Marshall Properties	Test Results of PMB-40 with stone Dust	Test Results of PMB-40 with GGBS	Requirements as per Table-500-10 of MORT&H (V Revision)
1	Optimum Bitumen Content, %	4.52	4.51	4.50 (Min.)
2	Marshall Stability, kg	1550	1610	9.00 (Min.)
3	Flow, mm	2.94	3.02	2.5 - 4.0
4	Air voids(Vv), %	4.1	4	3.0 - 5.0
5	Voids filled with Bitumen (VFB), %	74.08	72.34	65-75

The comparative graphs are plotted for Marshall Properties of Dense Bituminous Macadam (Grading II)Mix prepared using VG-30 & PMB- 40 with 2% Ground Granulated Blast Furnace Slag & 2% Stone Dust as mineral fillers are shown below in the Figures 1, 2, 3 & 4.

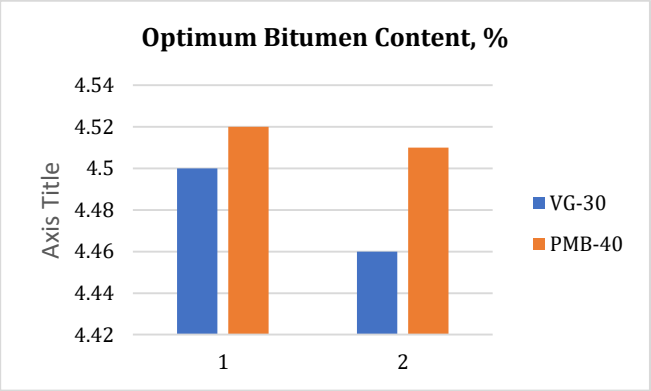

Figure -1: OBC for VG-30 & PMB-40 with Mineral Fillers

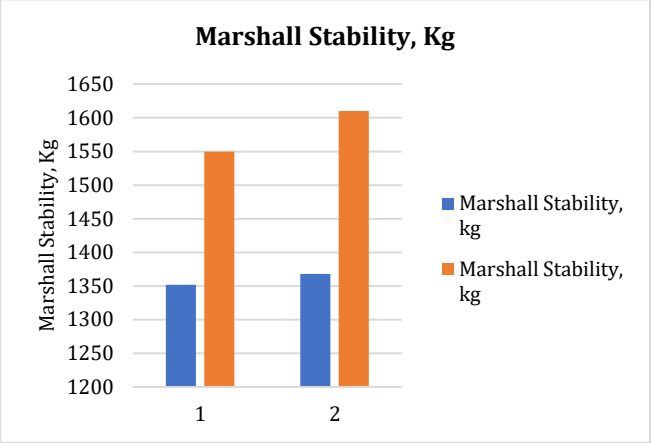

Figure -2: Marshall Stability for VG-30 & PMB-40 with Mineral Fillers

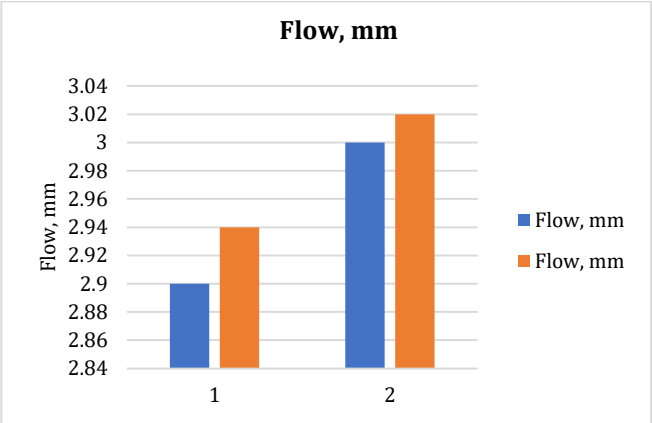

Figure -3: Flow Value for VG-30 & PMB-40 with Mineral Fillers

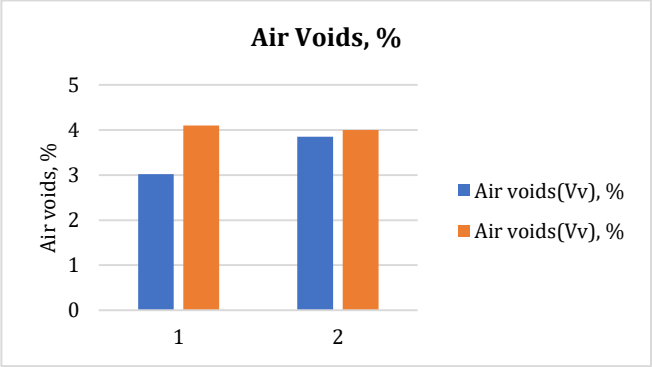

Figure -4: Air Voids, % for VG-30 & PMB-40 with Mineral Fillers

5.2 Indirect Tensile Strength

Indirect Tensile Strength test is conducted on Dense Bituminous Macadam mix (Grading-II) prepared using stone dust (2%) and GGBS (2%) as mineral filler at optimum bitumen content of binders VG- 30 and PMB- 40. Specimens are conditioned at 25°C in water bath for duration of 2 hours. The test results are presented in Table 7.

Table -7: ITS for binders VG-30 & PMB-40 with fillers.

Mix Type	Binder	Indirect Tensile Strength, N/mm2	
		Stone dust 2%	GGBS 2%
Dense Bituminous Macadam	VG- 30	0.83	0.95
	PMB- 40	0.84	0.96
	CRMB- 55	0.83	0.99

5.3 Moisture susceptibility test: tensile strength ratio

Moisture damage in bituminous mixes refers to the loss of serviceability due to the percent of moisture. The extent of moisture damage is called the moisture susceptibility. The Indirect Tensile Strength test is a performance test which is often used to evaluate the moisture susceptibility of a bituminous mixes. Tensile Strength Ratio (TSR) is a measure of water sensitivity or to say moisture susceptibility. Tensile Strength Ratio is expressed as the percentage of ratio of average indirect tensile strength of the conditioned specimen to the average indirect tensile strength of the unconditioned specimens and the results are shown in table 8 with graph of figure-5.

Table -8: ITS for binders VG-30 & PMB-40 with fillers.

Binder	Filler	Indirect Tensile Strength N/mm2		TSR %
		Unconditioned at 25°C	Conditioned at 60°C	
VG-30	Stone Dust 2%	0.83	0.74	88.97
	GGBS 2%	0.95	0.81	85.90
PMB-	Stone Dust 2%	0.84	0.77	91.55
	GGBS 2%	0.96	0.87	90.68
CRMB-	Stone Dust 2%	0.83	0.75	90.00
	GGBS 2%	0.99	0.88	88.69

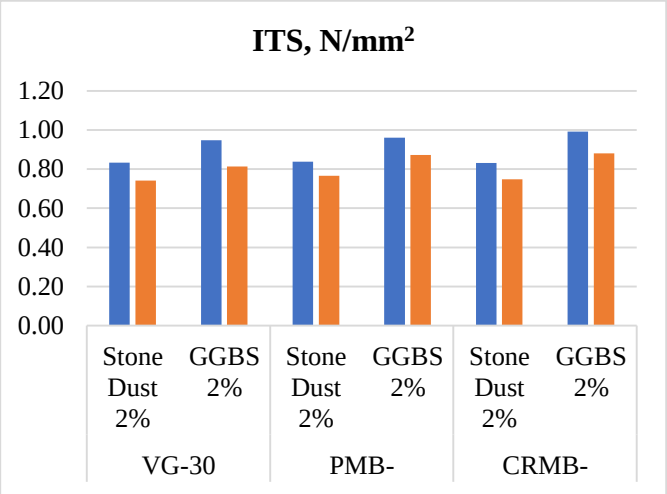

Figure -5: ITS for binders VG-30 & PMB-40 with fillers.

6. CONCLUSONS

- Dense bituminous macadam mix prepared using VG-30 and PMB-40 as binder with mineral filler as stone dust (2%) and GGBS (2%) is satisfying the requirements as per MORTH (V Revision) specification and as per IRC SP 53-2010 respectively.
- Marshall Properties of Dense bituminous macadam mix prepared using PMB-40 at optimum bitumen content (OBC) with GGBS (2%) is superior in terms of Marshall Properties when compared to mix prepared using stone dust (2%) and binder VG-30 with GGBS (2%) & Stone dust (2%).
- The Indirect Tensile Strength and Tensile Strength Ratio for Dense bituminous macadam mix prepared using VG-30 at OBC with GGBS (2%) is performing better when compared to the mix, prepared using stone dust (2%).
- The Indirect Tensile Strength and Tensile Strength Ratio for Dense bituminous macadam mix prepared using PMB-40 at OBC with GGBS (2 %) is performing better when compared to the mix, prepared using stone dust (2%) and binder VG-30 with GGBS (2%) & Stone dust (2%).

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