INFLUENCE OF STEEL FIBRES ON LABORATORY PEFORMANCE STUDIES OF DENSE BITUMINOUS MACADAM (GRADING II) USING VG-30 & PMB-40 AS BINDERS

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Abstract: *Bitumen has been widely used in India for the construction of flexible pavements for more than a century. Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations in bitumen binder performance. The Modification of bitumen is one of the alternate solutions to improve the deficiencies of conventional bitumen. Use of modified bitumen and fillers improve the performance of bituminous mix in terms of Marshall Properties, Tensile Strength and Fatigue life. it is observed that modified binder stiffens the mixes to reduce the thermal cracking and rutting Many studies over the years has shown the uses of various fibres yields adequate strength and improves the overall characteristics of the binder used. The objective of the present study is to analyse the effect of steel fibres when added with binders (VG-30 and PMB 40) by carrying out experimental investigations such as Marshall Test, indirect tensile test, tensile strength ratio on Dense Bituminous Macadam mixes. Dense Bituminous Macadam mix with PMB 40 as binder and stone dust as filler with steel fibre showed higher overall strength and improved characteristics of the binder.*

Keywords: Marshall Properties, ITS, TSR, Steel fibre, Stone Dust, VG-30, PMB-40.

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 also provides a smoother and quieter ride than cement surfaces, which helps to reduce noise 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 surfacing are widely used in India. The high traffic intensity in terms of commercial vehicles, overloading of trucks and significant variations in daily and seasonal temperature of the pavement have been responsible for early development of distress like rutting, cracking, bleeding, shoving and potholing of bituminous surfacing. A factor, which causes concern in India, is very high and very low pavement temperature conditions in some parts of the country. Under these conditions the bituminous surfacing tends 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 semisolid or solid at room temperature and liquid at a relatively 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. Binders are classified into different “grades” (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. These additives are called "Modifiers" and the bitumen premixed with these modifiers is known as "Modified Bitumen". Use of modified bitumen in the top layers of the pavement is expected to significantly enhance the life of the surfacing and extend the time of the next renewal. 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 revealed that the use of Modified Bitumen in construction or maintenance of bituminous roads significantly improve the pavement performance and is cost effective.

1.3 Tensile and Compressive stresses in pavement

Fatigue cracking and permanent deformation is considered as most serious distresses associated with flexible pavements. These distresses reduce the service life of the pavement and increase the maintenance cost. To reduce the pavement distresses there are different solutions such as adopting new mix design or by using additives to bitumen. The fatigue cracking caused by traffic on the bituminous layer is a very common occurrence and must be given a careful consideration in pavement design and 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

2. OBJECTIVE OF THE PRESENT STUDY

1. To determine the properties of the aggregates and binders VG-30 and PMB-40
2. To design dense bituminous macadam mixes (Grading II) using VG-30 and PMB-40 as binders by Marshall Mix design method using stone dust as filler
3. To design the dense bituminous macadam mixes (Grading II) VG-30 and PMB-40 by adding steel fibres in varying proportions (1%,2%,3%,4%) of total weight of aggregates and to determine the Marshall properties.
4. To determine the Indirect tensile strength (ITS) and Moisture susceptibility of Dense Bituminous Macadam mix of VG-30 and PMB-40 as binders at optimum percentage of steel fibres.

3. LITERATURE REVIEW

Aniruddh et al, In the study, In india use of bitumen content since many years ago. Although these mixture proved as successful as a pavement material, they were not design in any proper mix design method. As a knowledge regarding paving material expanded, need for more economical, functional and safer design criteria should require to find out optimum bitumen content in semi dense bitumen macadam. To satisfy the mix design specification, numbers of method have been developed. The present paper aims to highlight addition of steel fibres in it. The performance of DBM with steel fibres (2%,2.5%,3%,3.5%,4%,4.5%,5%,5.5% & 6% with 18 mm and 11 mm length was studied by conducting Marshall Stability Test for Stability of Bituminous Mixes The results have been noticed that the considerable improvement in stability of dense bitumen macadam was at an optimum percentage of added steel fibre for bitumen concrete at 3 % of 18 mm long steel fibre. Therefore these fibres at optimum content has been recommended for making improvements in DBM mix.

Ahmed Nayeem et al, In this study, 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.

Malik Shoeb Ahmad et al (2017) In this study, this paper presents the use of waste polythene carry bags in flexible pavement construction. Reclaimed plastic waste derived from low density polyethylene (LDPE/PW) carry bags from kitchen waste and plastic bottles have been used as additive in flexible pavements. Purposes of using above materials are to utilize environmentally unacceptable waste material and to develop a better material mix to resist increased traffic load and pressure resulted in cracks in the pavement surface. In the present study the plastic waste was cleaned and cut into a size such that it passes through 2-3mmsieve using shredding machine. In this study Dense Bituminous Macadam (DBM) mix has been prepared by using plain bitumen as a control specimen and bitumen mixed with low density polyethylene (LDPE/PW) in different proportions such as 2, 4, 6, 8, 10 and 12%by weight. The Marshall Stability tests were conducted on control and modified DBM mixes. It has been observed that the plastic waste modified bitumen mix show better binding property, stability, density and more resistant to water. Hence, the present technology will not only strengthen the road construction but also increases the road life as well as will help to improve the environment.

B Gopi Raju et al, In the present study, an attempt has been made to study the effects of use of a naturally and locally available fiber called COIR fiber is used as stabilizer in SMA For preparation of the mixes aggregate gradation has been taken as per MORTH Specification, binder content has been varied from 5% to 7%. Fiber content varied from SMA 0.2 %, 0.3% and 0.4%and the fiber length varied from 10 and 15mm. Different performance tests conducted on SMA Mix are Marshall Stability test, drain down test, Indirect Tensile test, Moisture Susceptibility, Repeated Load test with rest period.

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 (%)	18.27	Max 27%
Los Angeles Abrasion Value (%)	28.76	Max 35%
Flakiness and Elongation Indices Combined (%)	27.42	Max 35%
Water Absorption (%)	0.4	Max 2%
Specific Gravity		-----
Coarse Aggregate	2.72	
Fine Aggregate	2.70	
Mineral Filler		
Stone Dust	2.70	

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. The test results are shown in the Table 2 and 3 respectively.

Table -2: Test results of Bitumen VG-30

Tests on Bitumen	Results	Requirement as per IS 73- 2016 Specifications
Penetration at 25^{0}C	66	Min 45
Softening point , ^{0}C	51	Min 47
Flash point , ^{0}C	232	Min 220
Fire point , ^{0}C	256	Min 240
Ductility @27^{0}C, cm	79	Min 40
Specific Gravity	1.01	-

Table -3: Test results of Bitumen PMB-40

Tests on Bitumen	Results	Requirement as per SP:53-2010
Penetration at 25^{0}C	44	30-50
Softening point , ^{0}C	68	Min 60
Flash point , ^{0}C	240	Min 220
Fire point , ^{0}C	260	Min 240
Ductility @27^{0}C, cm	84	Min 40
Specific Gravity	1.04	-

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 4.

Table -4: 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 Steel Filler

Low-carbon steel, also known as mild steel is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Low-carbon steel contains approximately 0.05–0.25% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form surface hardness can be increased through carburizing. One of the innovative technique of improvement in bitumen concrete surface practiced all over the world is addition of steel fibres in it. The Dense Bituminous concrete Mixes are added with 11mm steel fibres.

Table 5: Properties of crimped steel fibres

Property	Specifications
Density	7850 Kg/m^3
Tensile strength	1150 Mpa
Modulus of elasticity	2x10^5 Mpa
Poisson's ratio	0.28
Length	11 mm
Diameter	0.15 mm
Aspect ratio	73

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.

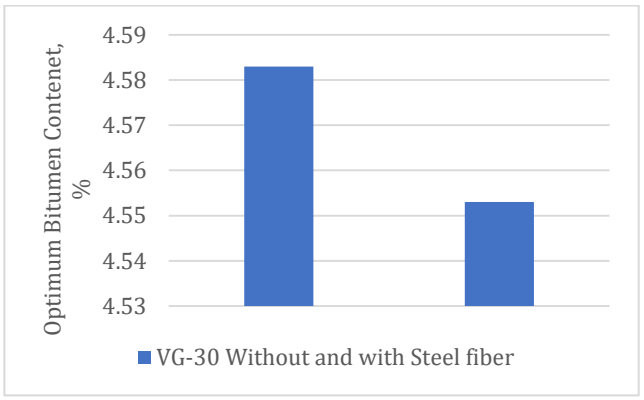
Marshall Test were conducted on Dense Bituminous Macadam Mix prepared using viscosity Grade (VG-30) and Modified Bitumen (PMB- 40) with steel fibres and stone dust as mineral filler, to determine the optimum bitumen content, Marshall Stability, Flow, bulk density, total air voids, voids in mineral aggregates and voids filled with bitumen. The test results are in shown Table 6 and 7 respectively.

Table 6: Results of Marshall Properties of Binder VG-30.

Sl No.	Marshall Properties	Test Results of VG-30 without steel fiber	Test Results of VG-30 with steel fiber	Requirements as per Table-500-10 of MORT&H (V Revision)
1	Optimum Bitumen Content, %	4.583	4.553	4.50 (Min.)
2	Marshall Stability, kN	12.93	13.94	9.00 (Min.)
3	Flow, mm	3.2	3.1	2.5 - 4.0
4	Air voids(Vv), %	4.60	3.85	3.0 - 5.0
5	Voids filled with Bitumen (VFB), %	70.85	74.71	65-75

Table -7: Results of Marshall Properties of Binder PMB-40

Sl No.	Marshall Properties	Test Results of PMB-40 without steel fiber	Test Results of PMB-40 with Steel fiber	Requirements as per Table-500-10 of MORT&H (V Revision)
1	Optimum Bitumen Content, %	4.636	4.593	4.50 (Min.)
2	Marshall Stability, kN	14.15	15.49	9.00 (Min.)
3	Flow, mm	3.2	3.00	2.5 - 4.0
4	Air voids(Vv), %	4.602	4.364	3.0 - 5.0
5	Voids filled with Bitumen (VFB), %	73.91	74.96	65-75



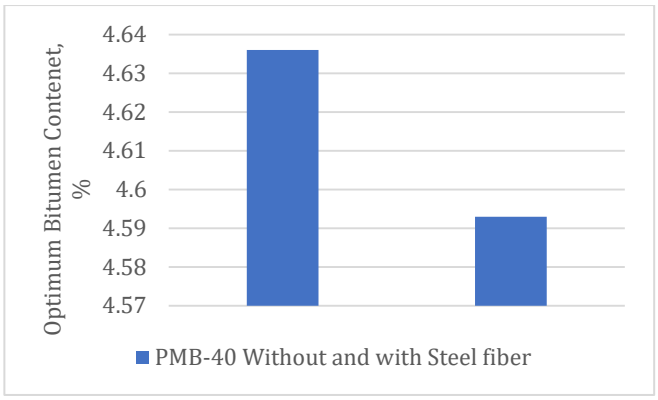
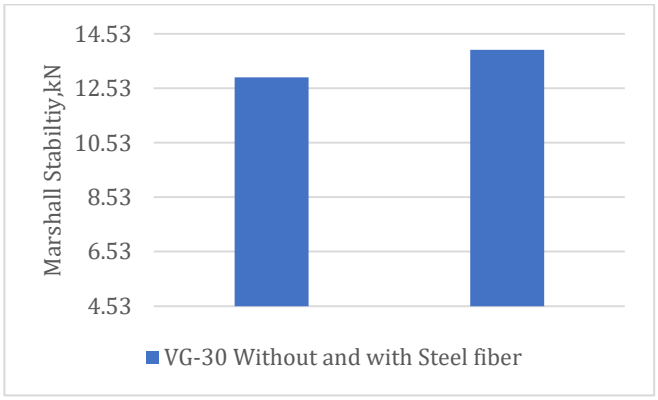


Figure -1: OBC for VG-30 & PMB-40 without and with Steel fiber



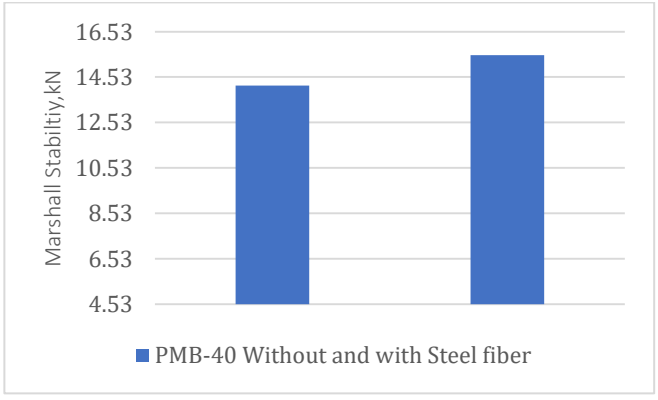


Figure -2: Marshall Stability for VG-30 & PMB-40 without and with Steel fiber

5.2 Indirect Tensile Strength

Indirect Tensile Strength test is conducted on Dense Bituminous Macadam mix (Grading-II) prepared using stone dust as mineral filler with steel fibres 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 8.

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

Mix Type	Binder	Indirect Tensile Strength, N/mm²	
		Stone dust	Stone dust with steel fibre
Dense Bituminous Macadam	VG-30	0.778	1.076
	PMB-40	0.895	1.269

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 9 with graph of Figure-3.

Table -9: ITS for binders VG-30 & PMB-40 with fillers.

Mix Type	Indirect Tensile Strength, N/mm²		TSR, %	Requirements as per Table 500-38 MORT&H (V Revision) Specifications
	Unconditioned at 25°C	Conditioned at 60°C		
VG-30+SD	0.778	0.673	86.54	Min 80%
VG-30+SD+SF	1.076	0.962	89.41	
PMB-40+SD	0.895	0.790	88.33	
PMB-40+SD+SF	1.269	1.169	92.06	

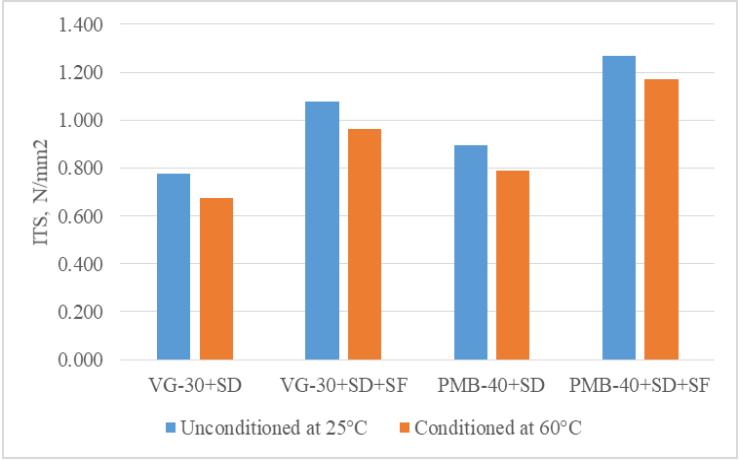


Figure -3: ITS for binders VG-30 & PMB-40 with fillers.

6. CONCLUSONS

1. Marshall properties for Dense Bituminous Macadam mix prepared at OBC using VG-30 and PMB-40 as binders, Stone dust as filler with steel fibres has shown considerable improvement in Marshall Properties.
2. The Dense Bituminous Macadam mix prepared at OBC using VG-30 and PMB-40 as binders, Stone dust as filler with steel fibres is performing better in terms of Indirect Tensile Strength and Tensile strength Ratio at optimum bitumen content.
3. It is concluded that, the Dense Bituminous Macadam mix prepared at OBC using PMB-40 as binder, Stone dust as filler with steel fibres is superior in terms of overall laboratory performance.

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BIOGRAPHIES

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