A STUDY ON THE PERFORMANCE OF GLASS FIBRE MODIFIED BITUMEN IN DENSE BITUMEN MACADAM

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Abstract:

Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations of conventional bitumen performance. It is thought that with the help of additives is one of the approaches to improve performance of flexible pavements. Here fibres have been used to improve the performance of asphalt mixtures against permanent deformation and fatigue cracking, Because of their inherent compatibility with asphalt cement and excellent mechanical properties. In the present study, an attempt has been made to study the effects of use of a mineral fibre called Glass fibre is used as an additive in Dense Bituminous Macadam (DBM). An experimental study is carried out on conventional bitumen and fibre modified binder. Using Marshall Procedure, Optimum Fibre Content (OFC) and Optimum Binder Content (OBC) for DBM are found respectively. The modified bitumen at Different percentages are subjected to different performance tests likeDynamic Shear Rheometer (DSR) and Creep Properties to evaluate the effects of fibre addition on mix performance.

Keywords: Dense Bituminous Macadam (DBM), Glass Fibre, Marshall Properties, Dynamic Shear Rheometer (DSR).

1. INTRODUCTION

Some undesirable effects can occur mainly due to high number of vehicles imposing repetitive higher axle loads on roads, environmental condition and construction errors. These usually cause permanent deformation (rutting), fatigue and low temperature cracking, service life of the road pavement is going to be decreased. Fatigue and rutting are the most common distresses in road pavement which result in the shortening of pavement life and increase maintenance cost as well as road user cost. So, it is vital to find out ways to delay the asphalt pavement deterioration and increase its service life. Many studies have been conducted to improve road pavement characteristics which can provide comfortable ride and ensure greater durability and longer service life against climate changes and traffic loading.

A good design of bituminous mix is expected to result in a mix which is adequately

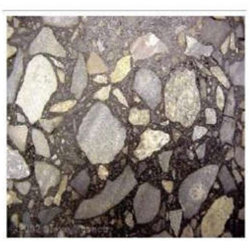
(i) Strong
(ii) durable
(iii) resistive to fatigue and permanent deformation
(iv) Environment friendly
(v) Economical and so on.

Pavement consists of more than one layer of different material supported by a layer called sub grade. Generally pavement is two type flexible pavement and rigid pavement. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. Typical flexible pavement structure consisting of:

- *Surface course*. This is the top layer and the layer that comes in contact with traffic. It may be composed of one or several different HMA sub layers. HMA is a mixture of coarse and fine aggregates and asphalt binder
- *Base course*. This is the layer directly below the HMA layer and generally consists of aggregate (either stabilized or un-stabilized).
- *Sub-base course*. This is the layer (or layers) under the base layer. A sub-base is not always needed.

Hot mix asphalt

HMA is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300°F (roughly 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt, and the asphalt cement at 200 °F (95 °C). Paving and compaction must be performed while the asphalt is sufficiently hot. The most common type of flexible pavement surfacing used in India is a premix bituminous material, commonly called outside as Hot Mix Asphalt (HMA). HMA is a mixture of coarse and fine aggregates and asphalt binder. The aggregates used in the lower layer are to prevent rutting and the aggregates which are used in the top layer are generally selected on the basis of their friction properties and durability.



Dense graded HMA surface Dense-Graded Core sample

2. BITUMINOUS MIX DESIGN

Objective of Bituminous mix design

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through the fine filler that is smaller than 0.075mm.

The objective of the mix design is to produce a bituminous mix by proportioning various components so as to have

1. Sufficient bitumen to ensure a durable pavement
2. Sufficient strength to resist shear deformation under traffic at higher temperature
3. Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic.
4. Sufficient workability to permit easy placement without segregation
5. Sufficient resistance to avoid premature cracking due to repeated bending by traffic
6. Sufficient resistance at low temperature to prevent shrinkage cracks.

Requirements of Bituminous mixes:

- **Stability**

Stability is defined as the resistance of the paving mix to deformation under traffic load. Two examples of failure are (i) shoving - a transverse rigid deformation which occurs at areas subject to severe acceleration and (ii) grooving - longitudinal ridging due to channelization of traffic.

- Durability

Durability is defined as the resistance of the mix against weathering and abrasive actions. Weathering causes hardening due to loss of volatiles in the bitumen. Abrasion is due to wheel loads which causes tensile strains.

- Flexibility

Flexibility is a measure of the level of bending strength needed to counteract traffic load and prevent cracking of surface. Fracture is the cracks formed on the surface (hairline-cracks, alligator cracks), main reasons are shrinkage and brittleness of the binder.

- Skid resistance

It is the resistance of the finished pavement against skidding which depends on the surface texture and bitumen content. It is an important factor in high speed traffic. Normally, an open graded coarse surface texture is desirable.

- Desirable properties

From the above discussion, the desirable properties of a bituminous mix can be summarized as follows:

- Stability to meet traffic demand
- Bitumen content to ensure proper binding and water proofing
- Voids to accommodate compaction due to traffic
- Flexibility to meet traffic loads, esp. in cold season
- Sufficient workability for construction
- Economical mix

Glass fibres

The fibres can be broadly classified as three types as

- Natural Fibres (eg: Cellulose, Coconut, Lignin, Sisal, Jute, Banana fibre etc.)
- Synthetic Fibres (eg: Polypropylene, Polyester, Aramid fibres etc.)
- Mineral Fibres (eg: Carbon, Basalt, Glass, Steel, Asbestos fibres etc.)

This paper highlights the erstwhile research works that were carried out in laboratory on asphalt mixes reinforced with Glass fibre as additives to improve the performance.

Represents Glass Fibre

Glass fibres have a high tensile modulus, i.e., about 60 GPA, an elongation of 3-4%, and elastic recovery of 100%. These fibres will not burn, but become soft at 815°C and exhibit decreased stability at Temperatures above 315°C. In addition, glass fibres do not absorb water, but are brittle and sensitive to surface damage. Adding glass fibres into asphalt mixtures enhances material strength and fatigue characteristics as well as improving ductility.

Objectives of the present study

In this investigation we are concentrating about the amount of Glass fibre that is added to the bituminous mix and which will give the optimum fibre content and as an outcome expecting an increase in strength. Dense bituminous concrete Mix is used in our investigation.

Fibre content varies between (0.5% - 2.5%). In the present study VG 30 bitumen is used as binder.

The whole work is carried out in different stages which are explained below.

- Study on Marshall Properties of DBM mixes using hydrated lime as filler with different percentages of Bitumen content to determine Optimum Bitumen Content.
- Study on rheological properties of glass fibre modified bitumen.
- Study on Marshall Properties of DBM mixes with different percentages of Glass fibre to determine Optimum Fibre Content
- Evaluation of Indirect Tensile Test at Optimum Fibre Content.

CHARACTERISTICS OF MATERIAL USED IN BITUMINOUSMIX

Mineral Aggregate:

There are various types of mineral aggregates which can be used in bituminous mixes. The aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines. These are termed as natural aggregates and can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by products such as steel slag, blast furnace slag etc. sometimes used as a component along with other aggregates to enhance the performance characteristics of the mix. Reclaimed bituminous pavement is also an important source of aggregate for bituminous mixes.The aggregates must possess.

- A highly cubic shape and rough texture to resist rutting and movements,
- A hardness which can resist fracturing under heavy traffic loads,
- A high resistance to polishing, and
- A high resistance to abrasion.

Fig:Represents mineral aggregates

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 behavior are temperature susceptibility, visco-elasticity and aging. The behavior of bitumen depends on temperature as well as on the time of loading. It is stiffer at lower temperature and under shorter loading period. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature.

Fig: Represents Bitumen

Mineral fillers

Mineral fillers have a significant impact on the properties of SMA mixtures. Mineral fillers increase the stiffness of the asphalt mortar matrix. According to Mogawer and Stuart (1996) mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures. Mineral fillers also help to reduce the drain down in the mix during construction, which improves the durability of the mix by maintaining the amount of asphalt initially used in the mix. It also helps to maintain adequate amount of voids in the mix.

Fig: Hydrated Lime Filler

RHEOLOGICAL PROPERTIES

Rheology involves the study and evaluation of the flow and permanent deformation of time-and temperature-dependent materials, such as bitumen, that are stressed through the application of a force. The fundamental rheological properties of bituminous materials including bitumen are normally measured using a dynamic shear rheometer (DSR), from low to high temperatures. DSR is a powerful tool to measure elastic, viscoelastic and viscous properties of binders over a wide range of temperatures and frequencies, provided the tests are conducted in the linear viscoelastic region. Therefore, the study of bitumen rheology is crucial since it's reflects the overall performance of a flexible pavement. However, it is well known that the DSR also has limitations, where the measurements are exposed to compliance (testing) errors particularly at low temperatures and/or high frequencies.

Laboratory preparation of glass fibre modified bitumen

In order to accommodate adequate fibre distribution within the bitumen, the mixing process considered very important stage in the procedure. Since the cellulose fibre is water loving and susceptible to moisture, forming a uniform fibre distribution is an obstacle within the bitumen composition. Fibre with moisture tends not to disperse and gathers as a ball within the bitumen therefore prevents enhancement of the bitumen- fibre- matrix. In order to avoid this problem, the fibre was kept in an oven for one-hour at 100 C and then added to the mixture to encourage uniform dispersion. An apparatus was developed to assure adequate distribution of Glass fibre within the bitumen.

Fibres can be blended to the mix in two ways, one is wet mixing and the other is dry mixing. In wet mixing process, specific amount of fibres are added separately to asphalt and then added to aggregates.

- Percentage Of Fibres : 0.5, 1.0, 1.5, 2.0, 2.5
- Mixing Temperature : 140-145
- Time Stirred: 30 min.

Fig :represents mixing of fibres with bitumen

Tests on bitumen

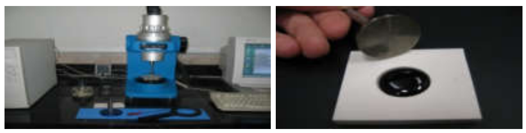
Dynamic Shear Rheometer

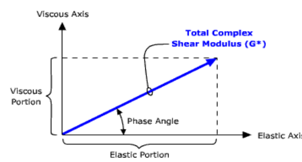
The dynamic shear rheometer (DSR) is used to characterize the viscous and elastic behavior of asphalt binders at medium to high temperatures. This characterization is used in the Super pave PG asphalt binder specification. As with other Super pave binder tests, the actual temperatures anticipated in the area where the asphalt binder will be placed determine the test temperatures usedAsphalt binders are Visco elastic.

The larger the phase angle (δ), the more viscous the material. Phase angle (δ) limiting values are:

Purely elastic material: δ = 0 degrees

Purely viscous material: δ = 90 degrees





Represents Complex modulus and Phase angle

Rutting Prevention

Complex shear modulus is specified. Intuitively, the higher t In order to resist rutting, an asphalt binder should be stiff (it should not deform too much) and it should be elastic (it should be able to return to its original shape after load deformation). Therefore, the complex shear modulus elastic portion, G*/sinδ, should be large.

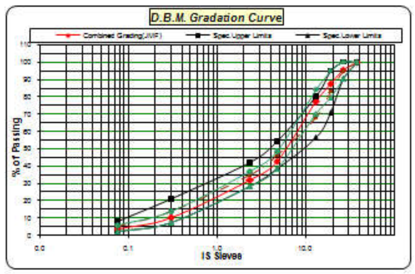
Fatigue Cracking Prevention

In order to resist fatigue cracking, an asphalt binder should be elastic (able to dissipate energy by rebounding and not cracking) but not too stiff (excessively stiff substances will crack rather than deform-then-rebound)

Creep Test

The MSCR test is used to evaluate the creep compliance and elastic recovery of asphalt binders Using the Dynamic Shear Rheometer (DSR). This test will be performed at two consecutive control stress levels (0.1 kPa and 3.2 kPa) by applying a haversine load for 1 second followed by a 9-second rest period, as per AASHTO TP 70 (AASHTO, 2010). During each cycle, the asphalt binder reaches a peak strain and then recovers before the shear stress is applied again. The percentage of elastic recovery (ER) for each cycle is obtained by dividing the difference between the peak strain and the final strain by the peak strain. Ten creep-recovery cycles are used at the shear stress level of 0.1 kPa and the average elastic recovery is determined. Immediately after ten cycles are completed at this shear stress level, the testing continues with an additional ten creep-recovery cycles at a shear stress level of 3.2 kPa

Aggregate Blending for Dense Bituminous Macadam [Hot Bins]									
(Spec. Limits As per MORT & H,Table-500-10,Grading-2)									
Aggregate Size (mm)	Description	% Passing I.S. Sieves							
	I.S Sieve Size (mm)	37.5	26.5	19.0	13.20	4.75	2.36	0.30	0.075
Bin -4 (33 - 20mm)	Individual Gradations	100	46.00	0.31	0.12	0	0	0	0
Bin -3 (20 - 10mm)		100	100	78	29.03	0.83	0.61	0.47	0.35
Bin -2 (10 - 4.75mm)		100	100	100	100	5.18	1.08	0.67	1
Bin -1(4.75 - 0mm)		100	100	100	100	95	72.35	20.10	6.00
Filler (Lime)		100	100	100	100	100	100	100	90.00
	% Feed								
Bin -4 (33 - 20mm)	8	8	3.68	0.02	0	0	0	0	0
Bin -3 (20 - 10mm)	21	21	21	16.34	6.10	0.17	0	0	0
Bin -2 (10 - 4.75mm)	28	28	28	28	28.00	1.45	0	0	0
Bin -1(4.75 - 0mm)	42	42	42	42	42	39.90	30.39	8.44	2.52
Filler (Lime)	1	1	1	1	1	1	1	1	0.90
Combined Grading (JMF)		100	95.68	87.36	77.11	42.52	31.82	9.73	3.63
Spec. Upper Limits		100	100	95	80	54	42	21	8
Spec. Lower Limits		100	90	71	56	38	28	7	2
Mid Limits		100	95	83	68	46	35	14	5
Permissible variation by Wt. of total mix in %age		+/-8	+/-8	+/-8	+/-7	+/-6	+/-5	+/-4	+/-2
JMF Upper Limit		100	100	95	84	49	37	14	6
JMF Lower Limit		100	90	79	70	38	28	7	2



Marshall Moulds Using Glass Fibres

3. RESULTS AND ANALYSIS

Aggregate properties

Sl.No	Property	Name of the Test	Test Result	Specification Limit (MORT&H)	Test Method
1	Particle Shape	Combined Flakiness & Elongation Indices of Aggregate	21.75%	Max. 35%	IS:2386 Part-1
2	Strength	Aggregate Impact Value	21.4%	Max. 27%	IS:2386 Part-4

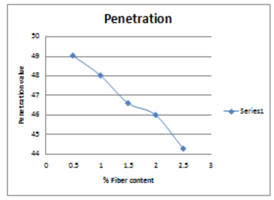
Specific gravity of aggregates

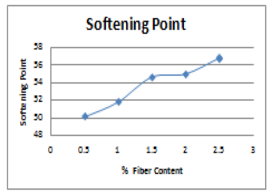
SIZE	BULK SP. Gravity (G sb)	Apparent Specific gravity (G sa)	Water Absorption (%)
40MM	2.656	2.664	0.1
20MM	2.654	2.661	0.1
10MM	2.656	2.663	0.1

Rheological Properties

Properties of binder

Fiber	Glass	
Percentage	penetration	softening
0.5	49	50.1
1	48	51.8
1.5	46.6	54.65
2	46	55
2.5	44.3	56.8

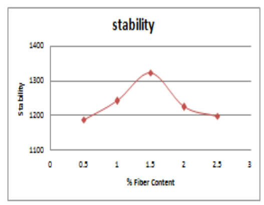




EFFECT OF FIBRE ON DBM :

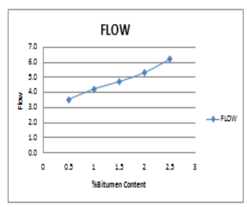
Marshall Stability

bitumen content	Stability(KN)
0.5	1188
1	1242
1.5	1323
2	1224
2.5	1197



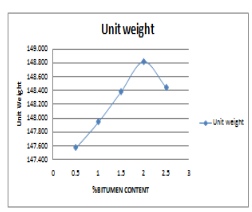
Flow Value

bitumen content	FLOW (mm)
0.5	3.5
1	4.2
1.5	4.7
2	5.3
2.5	6.2



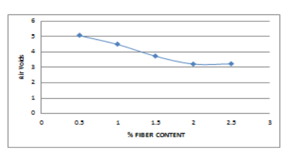
Unit weight

bitumen content	Unit weight(
0.5	147.570
1	147.950
1.5	148.380
2	148.824
2.5	148.450



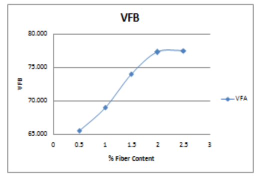
Air Voids

bitumen content	% of Air Voids
0.5	5.09
1	4.51
1.5	3.72
2	3.19
2.5	3.21

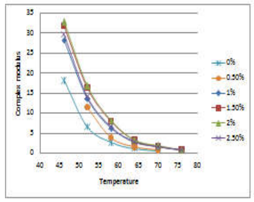


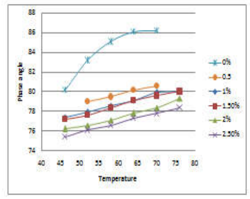
Void Filled With Bitumen (VFB)

Bitumen Content	VFB (%)
0.5	65.400
1	69.000
1.5	73.950
2	77.260
2.5	77.470



Dynamic Shear Rheometer

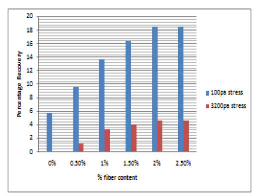




Glass	True Grade Temperature(c)
0.50%	67.7
1%	70.3
1.50%	72.6
2%	72.5
2.50%	70.4

Multi Shear Creep Recovery Test:

		Temperature @64°C	
		Creep parameters @ 100Pa Stress	Creep Parameters @ 3200Pa Stress
Source	True Grade Temperature	Creep Recovery (%)	Creep Recovery (%)
VG30	64.36	5.74	0.18
VG30+ Glass 0.5%	68.2	9.53	1.32
VG30+ Glass 1.0%	73.4	13.65	3.32
VG30+ Glass 1.5%	74.3	16.36	4.14
VG30+ Glass 2.0%	75.06	18.48	4.65
VG30+ Glass 2.5%	73.08	18.5	4.62



4. CONCLUSIONS

The following conclusions were drawn from the above results obtained from tests conducted on Dense Bituminous Macadam Mix.

Optimum bitumen content

- The optimum bitumen content (OBC) of DBM mix based on the marshal test results since, all Marshall Parameters are satisfying the requirement of MORTH specifications, the Optimum Binder Content is fixed as 4.5%.

Optimum fibre content

- The dynamic shear rheometer was used to characterize the rheological properties of the modified and unmodified Binders.

The modified bitumen has higher complex modulus than plain bitumen which means that it is more stable. This means that using Glass Fibre with plain bitumen increases the binder elasticity at high temperatures and improves the flexibility at low temperatures there by lessening both rutting and fatigue cracking.

In this study all the samples were tested in strain mode at a constant strain of 12%, and by considering the True Grade temperature at 1.5% is 72.6 and for 2% it is 72.5 which shows there is no much difference in temperature on addition of glass fibres more than 1.5%.

A comparison of two stress levels showed that Glass fibre modified binders were stress sensitive, showing less recovery at 3200 Pa for each binder but more improvement as glass content increased. From Multi Shear Creep Recovery test, Elastic recovery increases with increase in percentage of modified binders. Hence higher value of elastic recovery indicates more flexibility to the binder and will increase the life of pavement at low temperature.

From Marshall Properties it is seen that, 4% of Air voids is obtained at 1.5% Glass fibre content and the stability value is also maximum at this percentage

From the above conclusions on , i.e. DSR and Marshall Properties it was observed that 1.5% Glass fibre is the optimum fibre content which gives better results.

Future Scope

Many properties of DBM mix such as Marshall Properties, Dynamic shear Rheometer characteristics, Creep characteristics have been studied in this investigation.

Only VG 30 Viscosity grade bitumen is used, some other grades of bitumen like VG 20 VG 40 can be further investigated

Some of the properties such as fatigue properties, moisture susceptibility characteristics, resistance to rutting can be further investigated.

Some other synthetic and natural fibres can be investigated and compared.

Fillers like cement, fly ash and other industrial wastes also can be investigated

Glass fibre used in this study is a low cost material; therefore a cost-benefit analysis can be made to know its effect on cost of construction.

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