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Performance Of Basalt Fibre Modified Bitumen In Dense Bitumen Macadam

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ABSTRACT

Among the various techniques available for improving the properties of asphalt wearing courses, the addition of fibers has been taking on an increasingly prominent role. Today, the magnitude of what has been produced using these techniques along with the available information collected by monitoring in place behavior has enabled developing a thorough and significant assessment.

Sometime due to a specific reason such as exceeding wheel load or extreme climatic condition by being too hot or cold, the bitumen fails to prevail to certain required attributes such as grade, Dynamic Shear Rheometer (DSR), Indirect Tensile Strength Test, Fatigue Test, Resilient Modulus Test, Moisture Damage Performance Test, Rutting Test etc. Modifiers of asphalt cement are used to overcome this problem and improve the rheological properties of the asphalt cement. There are many modifiers available in the market now a days, but only four are going to be used in this research. Polypropylene, Basalt fibre, cellulose are added to asphalt cement with different percentages and conduct different physical tests. It has been observed that the behaviour of asphalt cement after adding the modifiers differ from percentage to another. Ideal improvement to the rheological properties of asphalt cement. 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 Basalt 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 like Dynamic Shear Rheometer (DSR) and Creep Properties to *evaluate the effects of fibre addition on mix performance.*

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

I. INTRODUCTION

In recent years, along with highway traffic develops, traffic & axle load increasing and traffic channelling have more and more requests to high-grade highway of asphalt pavement. It becomes a significant project for our country to improve quality of bituminous pavement and prolong its service life, so as to increase investment returns.

During the last decades, there has been a rapid increase in traffic volumes, axle loads and tyre pressure of commercial vehicles on highways. This rapid growth leads to a substantial increment in stresses on to the road surface and has resulted in early failure of asphalt pavements much before their expected design life. In order to improve the performance of the asphalt mixes two solutions are available; firstly, increasing the thickness of asphalt layer which will increase the cost of construction and, secondly making a modified asphalt mixture with the help of additives without increasing the thickness of asphalt layer

EVOLUATION OF MIX DESIGN

As per Das et al.(2004); During 1900's, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called *pat test* was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged. The first formal mix design method was Habbard field method, which was originally developed on sand-asphalt mixture. Mixes with large aggregates could not be handled in Hubbard field method.

This was one of the limitations of this procedure. Francis Hveem, a project engineer of California Department of Highways, developed the Hveem stabilometer. Hveem did not have any prior experience on judging the *just right* mix from its colour, and therefore decided to measure various mix parameters to find out the optimum quantity of bitumen. Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpse of Engineers in 1930's and subsequently modified in 1940's and 50's.

OBJECTIVE OF PRESENT INVESTIGATION

Generally we use several kinds of modifications to the bituminous pavements in order to increase the strength and durability of Hot Mix Asphalt. Fibres have been extensively used to increase rheological properties of engineering materials for a long times. The effect of basalt fibre on asphalt binder investigated in this study. In this paper we are going to see how Basalt polymer fibres will show impact on asphalt mixture, fibre improving asphalt behaviour. Previous research papers conveys that by addition or modification of Asphalt mix increases the strength, durability and resistance towards creep, fatigue & rutting condition.

In this investigation we are concentrating about the amount of fibre that is added to the bituminous mix design and which will give the optimum fibre content and as a 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 60/70 penetration grade bitumen is used as binder.

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

- Study of Marshall properties of DBM mixes using lime as filler and different percentages of basalt is added to the weight of bitumen in dry process.
- Study of DBM mix with lime as filler and basalt fibre as stabilizer
- Evaluation of DBM mixes using different test like Static Indirect tensile Strength test, Static Creep test.

II.LITERATURE REVIEW

REVIEW OF LITERATURE

A study was undertaken by Ling Chen You Yushi. The title is Analysis on Asphalt Mixture Performance, Influenced by Basalt Mineral Fibre . They had taken basalt fibre as a stabilising agent in highways. In this article, performance evaluation and impact analysis of bituminous mixture will be done, combining asphalt characteristic with basalt fibre performance. And it will provide a reference on basalt fibre applied in asphalt pavement, via comparing with the performance of polyester fibre reinforced asphalt mixture.

NihatMorova (2013) investigated the usability of basalt fibre in hot mix asphalt concrete. The best results in terms of better stability values were obtained for 5% bitumen content (OBC) and 0.50% basalt fibre addition. Wang et al. (2013) tested the basalt fibre reinforced asphalt mixes using the direct tension test and fatigue test. The effect of basalt fibre was also analyzed using numerical simulations of direct tension and fatigue tests based on the finite-element method. The direct tension test and fatigue test results showed that the tensile strength and fatigue life of mix was significantly improved by adding basalt fibres.

III. EXPERIMENTAL INVESTIGATIONS

MATERIALS USED IN THE PRESENT INVESTIGATION

Coarse Aggregates

Coarse aggregates consisted of stone chips collected from a local source, up to 4.75 mm IS sieve size. Its specific gravity was found as **2.75**. Standard tests were conducted to determine their physical properties.

Fine Aggregates

Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found as **2.6.**

FILLER

Aggregate passing through 0.075 mm IS sieve is called as filler. Here lime is used as filler whose specific gravity is . First a comparative study is done on BC where all these three types of fillers is used but later on only fly ash is used as filler where a comparative study is done on DBM as well as SMA with or without using fibre.

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, viscous-elasticity and aging. The behaviour 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 viscous-elastic material as 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.

Bitumen along with different additives (fibres, polymers etc). Act as a stabilizer for bituminous Mix. Polymer modified bitumen can also be used as a stabilizer with or without additives in the mixture. Different types of bitumen have been used by various researchers to the mixture properties. Penetration grade bitumen such as 60/70.

Stabilizing Additives

Stabilizing additives are used in the mixture to increase the strength and reduce the chances of permanent deformation. Fibres commonly used now-a days are polypropylene, polyester, mineral and cellulose.

The main stabilizing additives used in mixes can be classified in to different groups

- Fibres' (Cellulose Fibres, Mineral Fibres, Chemical Fibres)
- Polymer
- Powder and flour like materials (Silicic acid, Special Filler)
- Plastics (Polymer Powders or Pellets)

Natural fibre:-Natural fibre classified into 3 categories depending upon the part of plant from

Where it is extracted

- Stem fibre (jute, banana etc.)

- Leaf fibre (sisal, pineapple)

- Fruit fibre (cotton, coir, oil palm)

Basalt Fibre

Basalt fibre is produced from a volcanic rock formed from the quick cooling of basaltic lava, which is typically exposed at the surface of the land.

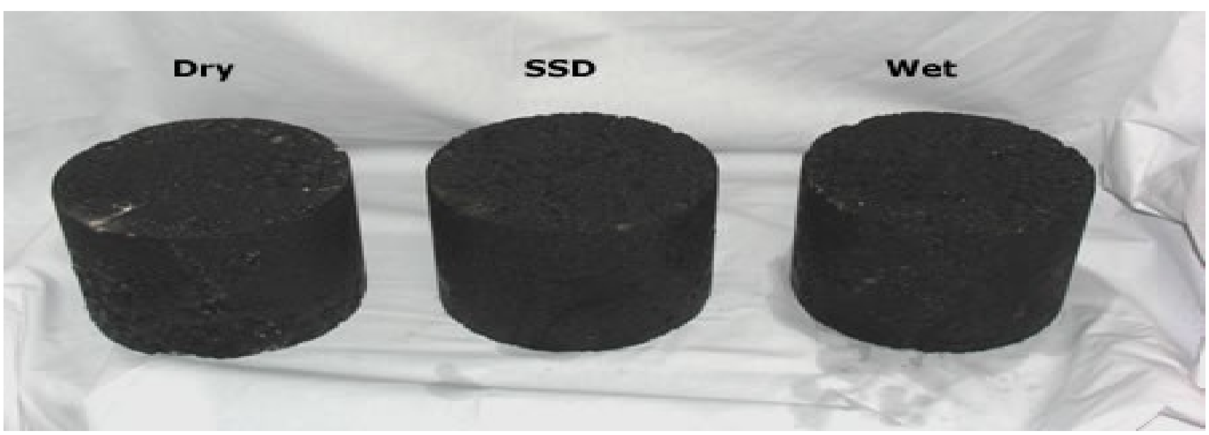
Currently, basalt fibre is utilized in a variety of industries such as automotive construction, aerospace, textiles and etc.

Basalt fibre is a high-performance fibre made of basalt rocks that are melted at approximately 1, 500°C and manufactured into continuous fibres. It has captured the interest of the research community because of its good performance in terms of strength, its suitability for large range of temperatures, and its durability.

In the recent decade, the basalt fibres have been used in asphalt concrete as a strengthening additive. Compared with the other two prevalent strengthening additives of asphalt concrete, polyester 1fiber and lignin fibre, basalt fibre has higher tensile strength and elastic modulus and a lower elongation rate, as shown in Table 1. Research also shows that the absorption rate of basalt fibre is very high, which allows it to avoid the bleeding and ravelling problems of asphalt concrete pavement under high temperatures. Basalt fibre retains 95% of its strength under 600°C

Mineral fibres are two kinds of GBF® basalt fibre, manufactured by Zhejiang GBF Basalt Fibre Co., LTD. (GBF). One is the fibre with surface bulked & decentralized processing; the other is the fibre without surface processing, as picture 2-1, 2-2. Purely natural volcanic rock is the only raw material for this basalt fibre, and rapidly drawn into continuous fibres at temperature as high as 1450～1500°C. It is a kind of inorganic fibres. Two brands of polyester fibres used in civil project are chosen in this test.

IV.RESULTS AND DISCUSSIONS



Shows the Dry, Surface dry. & wet sample of Marshall

1. 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

Bulk specific gravity, Apparent specific gravity & Water Absorption

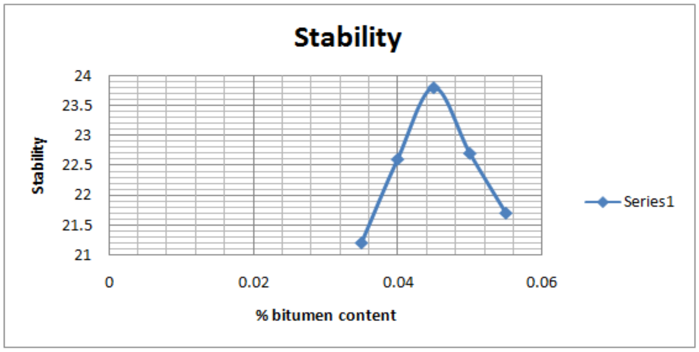
SIZE	BULK SP. Gravity (G sb)	Apparent Specific gravity (G sa)	Water Absorption (%)
40MM	2.656	2.664	0.1
20MM	2.654	2.661	0.1
10MM	2.656	2.663	0.1

RHEOLOGICAL PROPERTIES OF BINDER

Property Tested	Test Method	Results Obtained	Requirement as per IS-73
Penetration (100 gram, 5 seconds at 250C) (1/10th of mm)	IS 1203-1978	49 mm	50-70
Softening Point 0C (Ring & Ball Apparatus)	IS 1205-1978	53°C	Min 47

Marshall Stability

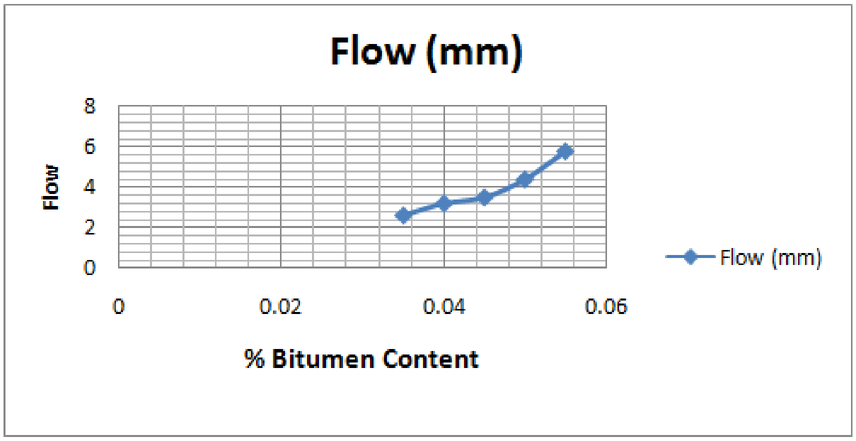
It is observed that stability value increases with increase in binder content up to certain binder content; then stability value decreases. Variation of Marshall Stability value with different binder content with different filler is given fig



Variation of Marshall Stability of DBM with different binder content

Flow Value

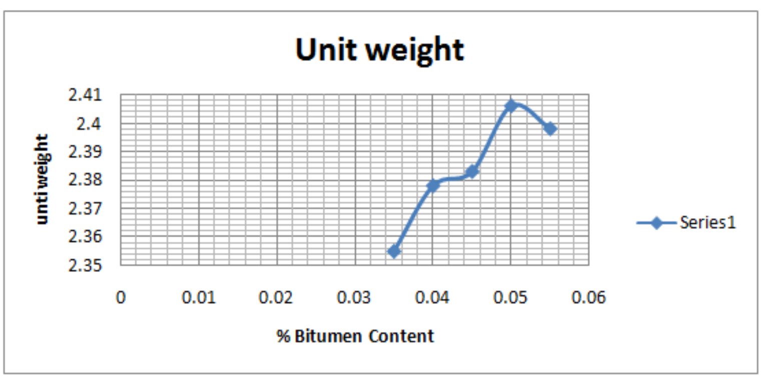
It is observed that with increase binder content flow value increases. For BC flow value should be within 2 to 4 mm. Variation of flow value with different binder content of BC with different filler is shown in fig



Variation of Flow Value of BC with different binder content

Unit Weight

It is observed that unit weight increases with increase binder content up to certain binder content; then decreases. Variation of unit weight value with different binder content with different filler is given fig



Variation of unit weight Value of BC with different binder content

Air Voids

It is observed that with increase binder content air void decreases. Variation of air void with different binder content. MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4% of air void given below

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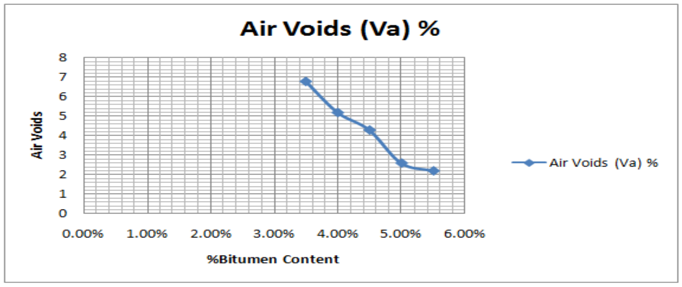
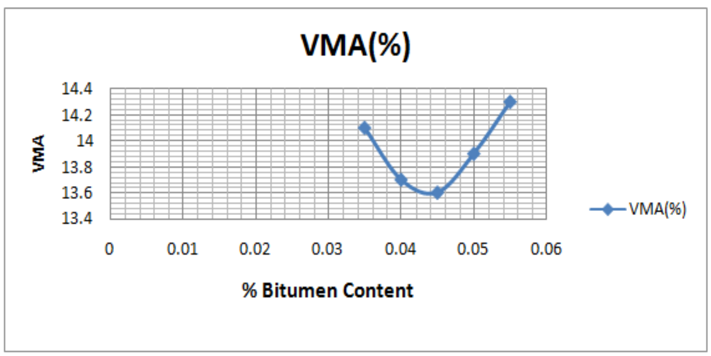


Variation of air void of BC with different binder content

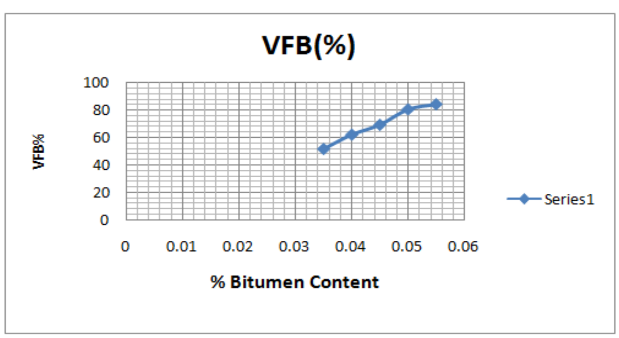
Voids in Mineral Aggregate (VMA)

It is observed that first it decreases and then it increases at sharp rate. Variation of VMA with different binder content



Void filled with Bitumen (VFB)

VFB increases with increase binder content. Variation of VFB with different binder content is shown in Fig

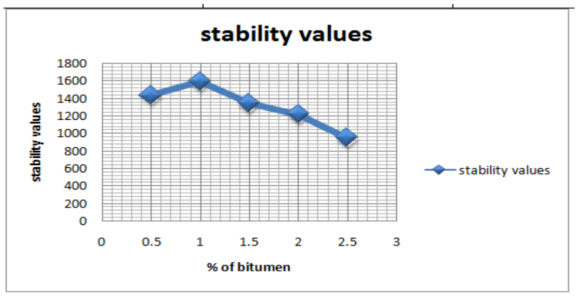


Variation of VFB of BC with different binder content

2. MARSHAL STABILTY

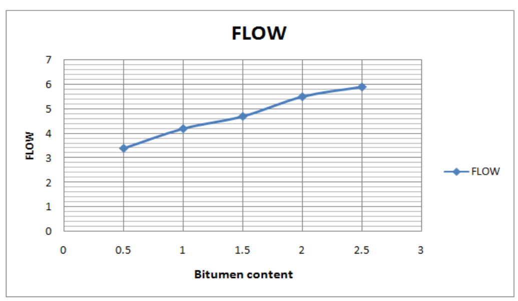
percentage of fiber	stability values	Flow
0.5	1436.4	7.2
1	1593	6.7
1.5	1341	5.9
2	1214	4.8
2.5	945	4.5

Stability values and Flow values



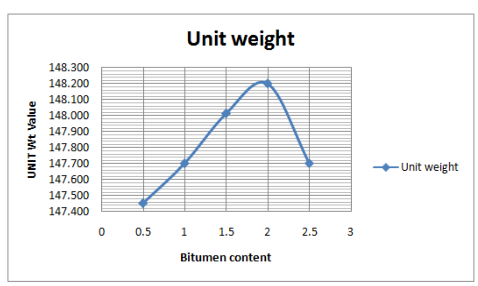
Variation of Marshall Stability of BC with different fibre content

FLOW VALUE



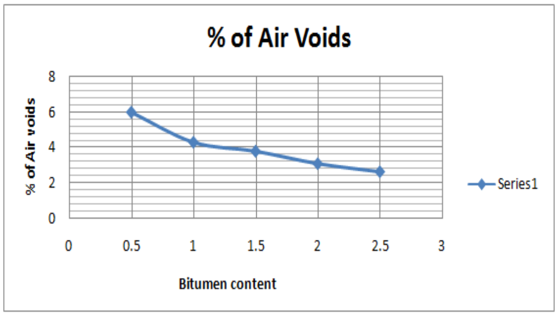
UNIT WEIGHT

percentage	Unit weight
0.5	147.451
1	147.701
1.5	148.013
2	148.200
2.5	147.701



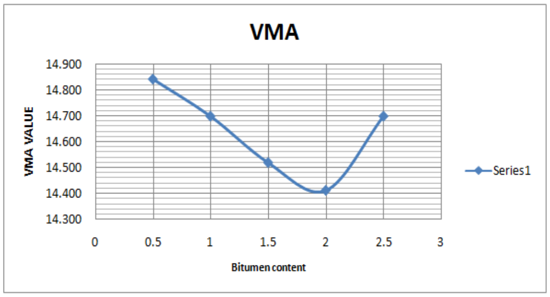
AIR VOID:

percentage	Gmm	Gmb (mean density value)	% of Air Voids
0.5	2.514	2.363	6.00636436
1	2.473	2.367	4.286291953
1.5	2.465	2.372	3.772819473
2	2.45	2.375	3.06122449
2.5	2.43	2.367	2.592592593



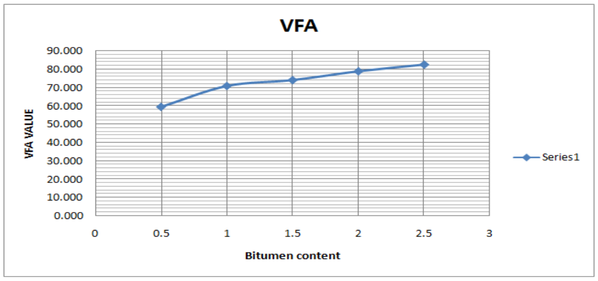
VMA:

percentage	Gmb (mean density value)	Gsb	Ps	VMA
0.5	2.363	2.65	95.5	14.843
1	2.367	2.65	95.5	14.699
1.5	2.372	2.65	95.5	14.518
2	2.375	2.65	95.5	14.41038
2.5	2.367	2.65	95.5	14.699



VFA:

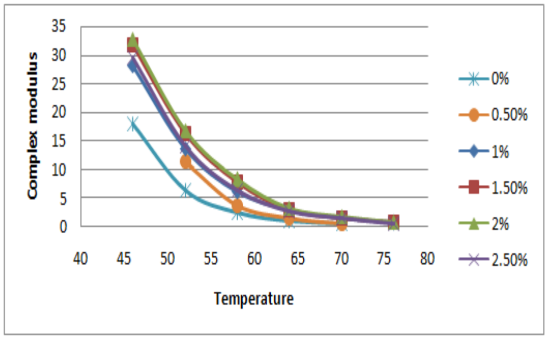
percentage	VFA
0.5	59.53356
1	70.83893
1.5	74.01369
2	78.75681
2.5	82.36173

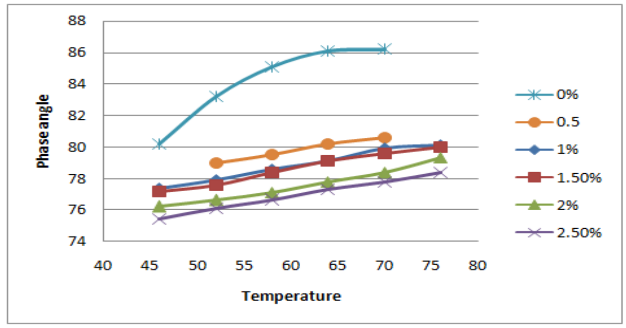


Dynamic Shear Rheometer

Figure shows the variation of Complex Modulus with temperature, in general the Complex modulus of plain bitumen is less when compared to modified bitumen.

(A)Relationship between Complex Modulus with temperature (B) Relationship between Phase angle with temperature for bitumen

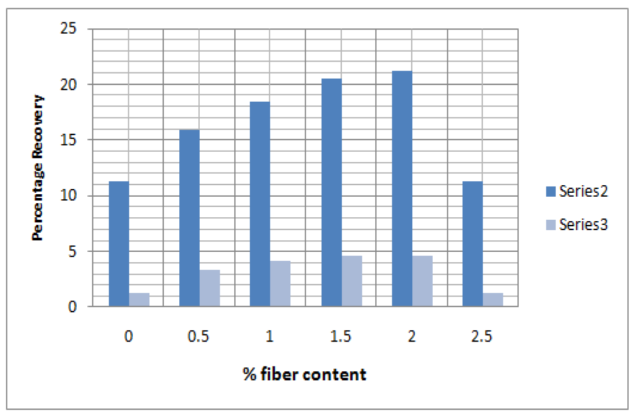




Creep Test

Creep tests (application of constant stress for a defined period of time) allow an alternative means of determining the zero shear viscosity. When combined with recovery testing (removal of the stress) these tests enable the amount of elasticity in the sample to be measured because a material will with elasticity will recoil and attempt to recover its original shape

Source	True Grade Temperature	Temperature @64^{0}C Creep parameters @ 100Pa Stress Creep Recovery (%)	Creep Parameters @ 3200Pa Stress Creep Recovery (%)
VG30	69.2	11.34	1.32
VG30+ Basalt 0.5%	76.5	15.92	3.32
VG30+ Basalt 1.0%	77.4	18.48	4.14
VG30+ Basalt 1.5%	78.5	20.56	4.65
VG30+ Basalt 2.0%	79.4	21.24	4.62
VG30+ Basalt 2.5%	69.2	11.34	1.32



V. CONCLUSIONS

General

The primary purpose of this report was to develop information about the addition of basalt fibre in wet process in different percentages. This study was intended to provide information that would validate the recipes to use in DBM and provide data to indicate why these recipes are successful. This study looked at the effect of bitumen content and amount of fibre to it.

Based on the results and discussions of experimental investigations carried out on different DBM mixes the following conclusions are drawn.

MARSHALL PROPERTIES

Marshall Stability

It is observed that with increase in binder content the Marshall Stability value increases up to certain binder content and then decreases, like conventional bituminous mixes. It is also found from the variations that the stability value varies with the type of percentage of fibre used in the mix.

FLOW VALUE

The value of flow increases with increasing in fibre content, to bitumen content of 4.5%. The maximum flow value obtained at 2.5% of fibre content.

UNIT WEIGHT

The unit weight increases with the increase in binder content up to a certain binder content and their after decreases.

AIR VOIDS

The amount of air voids decreases with increase in binder content in the mix. It also increases or decreases depending on the fibre content in the mix. The mix is observed to have the lowest air voids content in the higher fiber mix.

OPTIMUM BITUMEN CONTENT

The optimum bitumen (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 FIBER CONTENT

The optimum fibre content is based on the marshal stability test itself which gives the 1% of basalt modified bituminous mix gives the highest stability strength.

From the results of usaged samples indicated that the addition of 0.5% to 2.5% BASALT fibre modified binders caused an increase in G^* value. As a result of the rheological changes, the mechanical properties of un aged 1% BASALT fibre modified binders show improvement, as indicated by increased complex modulus and decreased phase angle.

From MSCR tests, it is observed that, plain bitumen shows higher non recoverable compliance when compared to modified bitumen. The MSCR test showed that BASALT caused a significant increase in binder elastic recovery, reducing permanent deformation and thus improving rut resistance. A comparison of the two stress levels showed that BASALT fibre modified binders were stress sensitive, showing less recovery at 3200 Pa for each binder but more improvement as BASALT content increased.

Higher the non recoverable compliance can possibly increase the magnitude of rutting in the actual service

The optimum fibre content is based on rheological properties and marshal stability test, shows that 1 % BASALT fibre is the optimum fibre content which gives better results

SCOPE FOR FUTURE WORK

As I have got 1% of basalt fibre as optimum fibre content that gives the higher stability value, Creep recovery and strength to the mix, by conducting various advanced experiments like Dynamic Shear Rheometer (DSR), CREEP, & Indirect Tensile Strength Test (IDT).There is a scope of conducting more advanced tests like Fatigue Test, Resilient Modulus Test, Moisture Damage Performance Test, Rutting Test etc.

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