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CARBON FIBER MODIFIED BITUMEN IN BITUMINIOUS MACADAM

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ABSTRACT: *Asphalt concrete has been used as the basic material for pavement engineering. Hence improving the quality of asphalt concrete for better performance and to last longer has remained an interesting area for researchers. Although various kinds of fibers and polymers have been used widely reinforced in asphalt concrete, fibers due to their exclusive characteristics have attracted much attention. It is realised that the well-distributed fibers create a network in the internal structure of the composite, resulting in asphalt concrete that is more tightened. In the present paper, an approach was developed to mix carbon fibers and bitumen which guarantees the uniform fiber distribution.*

In the present study, an attempt has been made to study the effects of use of a mineral fiber called Carbon fiber is used as an additive in Dense Bituminous Macadam (DBM). An experimental study is carried out on conventional bitumen and fiber modified binder. Using Marshall Procedure, Optimum Fiber Content (OFC) and Optimum Binder Content (OBC) for DBM are found respectively. Detailed laboratory investigations will be carried out by preparing asphalt concrete mixtures by adding carbon fiber with dosages of 0.5%to 2.5% by weight of binder. Volumetric properties of the mixes will be determined and various strength tests such as marshal stability will be conducted.

1.INTRODUCTION

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 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. 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

1.1 Requirements of Bituminous mixes:

1.1.1 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. Stability depends on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen. Sufficient binder must be available to coat all the particles at the same time should offer enough liquid friction. However, the stability decreases when the binder content is high and when the particles are kept apart.

1.1.2 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. Typical examples of failure are
(i) pot-holes, - deterioration of pavements locally and
(ii) Stripping, lost of binder from the aggregates and aggregates are exposed.
Disintegration is minimized by high binder content since they cause the mix to be air and waterproof and the bitumen film is more resistant to hardening.

1.1.3 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. Shrinkage cracks are due to volume change in the binder due to aging. Brittleness is due to repeated bending of the surface due to traffic loads. Higher bitumen content will give better flexibility and less fracture.

1.1.4 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.

1.1.5 Workability:

Workability is the ease with which the mix can be laid and compacted, and formed to the required condition and shape. This depends on the gradation of aggregates, their shape and texture, bitumen content and its type. Angular, flacky, and elongated aggregates workability. On the other hand, rounded aggregates improve workability.

1.1.6 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

1.1.7 Constituents of a mix

- *oarse aggregates*: offer compressive and shear strength and shows good interlocking properties. E.g. Granite
- *Fine aggregates*: Fills the voids in the coarse aggregate and stiffens the binder. E.g. Sand, Rock dust
- *Filler*: Fills the voids, stiffens the binder and offers permeability. E.g. Rock dust, cement, lime, fly ash
- *Binder:* Fills the voids, cause particle adhesion and gluing and offers permeability. E.g. Bitumen, Asphalt, Tar

1.2 SELECTION OF BINDER

Different type of binder like convectional 60/70 or 80/100 penetration grade bitumen and many modified binder like Polymer Modified Bitumen (PMB), Crumb Rubber Modified Bitumen (CRMB), Natural Rubber Modified Bitumen (NRMB) is used by different researcher for their research work . Some researcher also used super pave performance grade binder like PG 76-22 with bituminous mixture like Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA). Here in this research we have used natural polymer Carbon fiber in 60/70 penetration grade bitumen as binder.

1.3 SELECTION OF STABILIZING ADDITIVE

Different stabilizing additive like fiber such as cellulose fiber, mineral fiber etc., many polymer, plastic, waste material such as carpet fiber, tires, polyester fiber are added to bituminous mix mainly with Stone Natural fiber like jute fiber and coconut fiber are also used by many researchers. Here an attempt has been made in this research work to utilise a naturally available fiber called CARBON FIBER in Dense bituminous mixture.

2. 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. Fibers have been extensively used to increase rheological properties of engineering materials for a long times. The effect of Carbon fiber on asphalt binder investigated in this study. In this paper we are going to see how carbon polymer fibers will show impact on asphalt mixture, fiber improving asphalt behaviour. A previous research paper 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 fiber that is added to the bituminous mix design and which will give the optimum fiber content and as a outcome expecting an increase in strength. Dense bituminous concrete Mix is used in our investigation. Fiber 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 on Marshall Properties of DBM mixes using hydrated lime as filler and different percentages of Bitumen content to determine **Optimum Bitumen Content.**

- Study on Marshall Properties of DBM mixes with different percentages of **CARBON** fiber added to the weight of the binder in Dry Process.

3 CHARACTERISTICS OF MATERIAL USED IN BITUMINOUS MIX

3.1 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. Aggregates play a very important role in providing strength to asphalt mixtures. In BC the mineral aggregates content varies from 50-60. According to WSDOT (2000) the Federal Highway Administration, McLean Virginia, has suggested the following characteristics for aggregates used in bituminous mixture. 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.

3.2 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.

3.3 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.**

3.4 FILLER:

Aggregate passing through 0.075 mm IS sieve is called as filler. Here lime is used as filler whose specific gravity is **2.3**.

3.5 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 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. 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 (fibers, 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.

3.6 Stabilizing Additives:

The concept of using fibers to improve the behaviour of materials is not new. The modern developments of fiber reinforcement started in the early 1960s. Fibers have been extensively used to improve rheological properties of engineering materials for a long times. It is well known that modified bitumen considerably increases rheological properties of bitumen used within bituminous pavements suffering from different kinds of distresses like low temperature cracking, rutting, fatigue, etc.

3.7 TYPES OF FIBERS

The fibers can be broadly classified as three types as

- Natural Fibers (e.g. Cellulose, Coconut, Lignin, Sisal, Jute, Banana fiber etc.)
- Synthetic Fibers (e.g. Polypropylene, Polyester, Aramid fibers etc.)
- Mineral Fibers (e.g. Carbon, Basalt, Glass, Steel, Asbestos fibers etc.)

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

2.14.1 Carbon Fiber

arbon fibers are thought to offer advantages over other fiber types for the modification of asphalt binder. Since the fibers are composed of carbon and asphalt is a hydrocarbon, they are thought to be inherently compatible. Because carbon fibers are produced at extremely high temperatures (over 1000°C), fiber melting due to high mixing temperatures is not an issue. The high tensile strength of carbon fibers should increase the tensile strength and related properties of AC mixtures, including resistance to thermal cracking. The stiffening effect showed by the addition of other fibers should also occur in carbon fiber modified mixtures, increasing the fatigue life of pavements. For these reasons it was hypothesized that carbon fibers should be the most compatible, best performing fiber type available for modification of asphalt binder.

Carbon fibers are produced from either polyacrylonitrile (PAN) or pitch precursors. These precursors are processed into carbon fibers in similar ways. First, the liquid precursors are spun into fibers. PAN is already in liquid form and is wet spun, while pitch must first be melted and then spun. To prevent fibers from burning at the high temperatures required for carbonization (>700°C) they are next placed in an oxidizing atmosphere. This process is called stabilization for PAN fibers and infusibilization for pitch-based fibers. The carbonization process follows for both precursor types and is conducted in an inert atmosphere. Once completed fibers are again placed in an inert atmosphere and graphitized at greater than 2500 C resulting in the finished carbon fiber product (Chung 1994). Chung (1994) lists several types of pitch and PAN-based carbon fibers with typical properties. PAN fibers tend to have higher tensile strengths (2760 – 7060 MPa) than pitch-based (1400 – 3900 MPa). Pitch-based have a higher tensile modulus of elasticity (140 – 894 GPa) compared to PAN (228 – 588 GPa).

Fig 3.0 carbon fiber

4. EXPERIMENTAL INVESTIGATIONS

INTRODUCTION:

This chapter describes the experimental works carried out in this present investigation. This chapter is divided into two parts. First part deals with the experiments carried out on the materials (aggregates, filler, bitumen, and fiber), second part deals with the tests carried out on bituminous mixes.

TESTS ON MATERIALS USED

4.1 AGGRETGATES:

SPECIFIC GRAVITY AND WATER ABSORPTION TESTS

These two tests are conducted

i) To measure the strength or quality of the material
ii) To determine the water absorption of aggregates

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values.

The size of the aggregate and whether it has been artificially heated should be indicated. ISI specifies three methods of testing for the determination of the specific gravity of aggregates, according to the size of the aggregates. The three size ranges used are aggregates larger than 10 mm, 40 mm and smaller than 10 mm.
The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68. Though high specific gravity is considered as an indication of high strength, it is not possible to judge the suitability of a sample road aggregate without finding the mechanical properties such as aggregate crushing, impact and abrasion values. Water absorption shall not be more than 0.6 per unit by weight.

Property	**Test Method**	**Test Result**
Aggregate Impact Value (%)	IS : 2386 (P IV)	14.3
Aggregate Crushing Value (%)	IS : 2386 (P IV)	13.02
Flakiness Index (%)	IS : 2386 (P IV)	18.03
Elongation Index (%)	IS : 2386 (P I)	21.5
Water Absorption (%)	IS : 2386 (P III)	0.1

Table 4.1 Physical properties of coarse aggregate

Aggregate Blending

Aggregate gradation is the distribution of particle size as percent of the total weight. Aggregate gradation is one of the most important properties of an aggregate. It affects almost all the important properties of bituminous mix including, stability, durability, stiffness, permeability, workability, fatigue resistance, skid resistance and resistance to moisture damage. Therefore, gradation is a primary consideration in bituminous mix design. Specifications used by most agencies place limits on aggregate gradations that can be used in bituminous mix. Theoretically, it seems reasonable that the best gradation for bituminous mix is the one that gives the densest particle packing. The gradation having maximum density provides increased stability through inters particle contacts and reduced voids in the mineral aggregates. However, there must be sufficient air void space to permit enough bitumen to be penetrated to ensure durability, while still leaving some air space in the mixture to allow secondary compaction and to avoid bleeding, rutting etc.

4.2 Job Mix Formula (JMF)

The steps of the evaluation of an appropriate job mix formula (JMF) are as follows:
1) In accordance with the IRC (requirements for pavement) and with respect to its
experiences with former JMFs, mixing, paving, and selects the aggregates and the filler, with the selected material (aggregates, filler, additives) and on the basis of the feedback from other sites and JMFs, a tentative gradation is chosen.

2) Mixes with the required minimum asphalt content and with three adjacent asphalt contents are prepared.

3) Marshall specimen are prepared at 135/145 • } 5°C and by 75 blows on each side the Marshall tests are running for the evaluation of the air void content which must to 4 % by volume . If the required air void content is not achieved, the following alterations of the tentative mix within the enforceable limits of the specifications are recommended:

• Change content of single sizes of aggregates
• Change filler content

It has to be emphasized that the Marshall-stability and -flow are not an adequate basis for the right choice and evaluation of the DBM Job Mix Formula. On the basis of the mix design results, the JMF will take.

Job Mix Formula (JMF)

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**

Table 4.2 Adopted aggregate Gradation of DBM

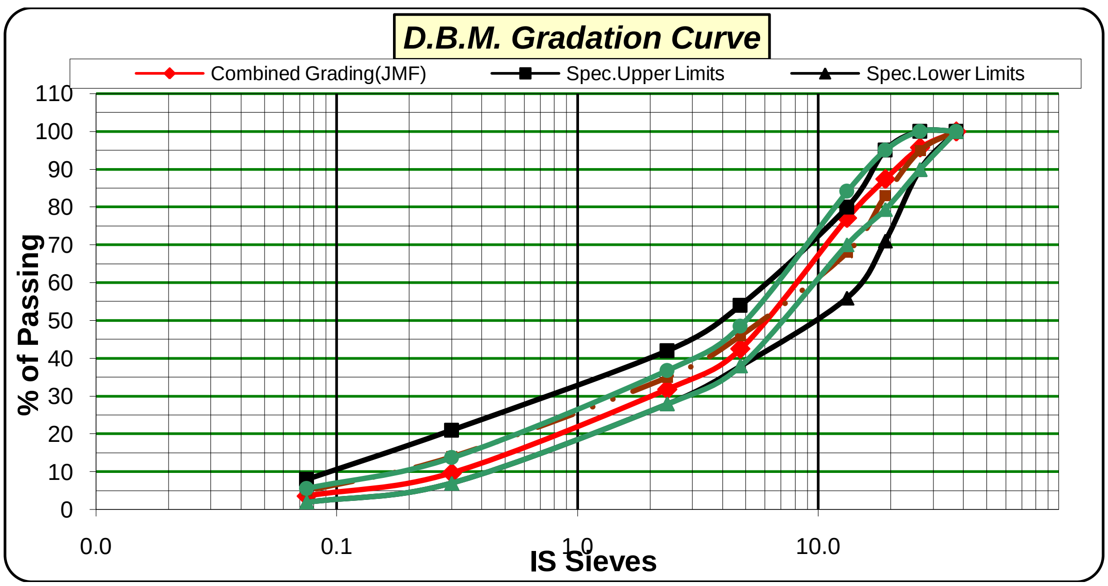


Fig 3.1 DBM Gradation Curve

BINDER

Here 60/70 penetration grade bitumen is used as binder for preparation of Mix, whose specific gravity was 1.023. It's important properties are given:

Rutting Prevention

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, $G^*/\sin\delta$, should be large. When rutting is of greatest concern (during an HMA pavement's early and mid-life), a minimum value for the elastic component of the complex shear modulus is specified. Intuitively, the higher the G^* value, the stiffer the asphalt binder is (able to resist deformation), and the lower the δ value, the greater the elastic portion of G^* is (able to recover its original shape after being deformed by a load).

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). Therefore, the complex shear modulus viscous portion, G*sinδ, should be a minimum. When fatigue cracking is of greatest concern (late in an HMA pavement's life), a maximum value for the viscous component of the complex shear modulus is specified.

Property	Test Method	Value
Penetration at 25°c (mm)	IS : 1203 – 1978	67.7
Softening Point (°C)	IS : 1203 – 1978	48.5
Specific gravity	IS : 1203 – 1978	1.03

Table 4.3 Properties of Binder

4.3 PREPARATION OF MIXES:

The mixes were prepared according to the Marshall procedure specified in **ASTM D1559**. For BC the coarse aggregates, fine aggregates and filler were mixed according to the adopted gradation. First a comparative study is done on BC by taking three different type of BINDER CONTENT. Here Optimum Binder Content (OBC) was found by Marshall Test where binder content is very from 3.5% to 5.5%. Then Optimum Binder Content (OBC) and Optimum fiber Content (OFC) of both BC and SMA was found by Marshall Method where binder content is very from 3.5% to 5.5% and fiber content is vary from 0.5% to 2.5%. The carbon fibers after being cut in to small pieces (15-20 mm) were added directly to the aggregate sample in different proportions. The mineral aggregates with fibers and binders were heated separately to the prescribed mixing temperature. The temperature of the mineral aggregates was maintained at a temperature 10°C higher than the temperature of the binder. Required quantity of binder was added to the pre heated aggregate-fiber mixture and thorough mixing was done manually till the colour and consistency of the mixture appeared to be uniform. The mixing time was maintained within 2-5 minutes. The mixture was then poured in to pre- heated Marshall Moulds and the samples were prepared using a compactive effort of 75 blows on each side. The specimens were kept overnight for cooling to room temperature. Then the samples were extracted and tested at 60°C according to the standard testing procedure.

4.4 TESTS ON MIXES

Presented below are the different tests conducted on the bituminous mixes with variations of binder type and quantity, and fiber concentration in the mix.

MARSHALL TEST

Marshall Mix design is a standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. In India, it is a very popular method of characterization of bituminous mixes. This test has also been used by many researchers to test bituminous mixes. This test method is widely accepted because of its simplicity and low of cost. Considering various advantages of the Marshall method it was decided to use this method to determine the Optimum Binder Content
(OBC) of the mixes and also study various Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voids etc. A figure 3.6 shows the Marshall Apparatus with a loaded Marshall specimen. The Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and optimum fiber contents (OFC). The mix volumetric of the Marshall samples such as unit weight, air voids were calculated by using the procedure reported by Das and Chakroborty (2003).

In the Marshall Test method of mix design three compacted samples are prepared for each binder content. All the compacted specimens are subject to the following tests:
• Bulk Density Determination.
• Stability and Flow Test.
• Density and Voids Analysis.

The aggregates are heated to a temperature of 165° to 175°C the compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 90°C to 145°C. The bitumen is heated to a temperature of 121°C to 138°C and the required amount of first trial of bitumen is added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with 75 blows. The sample is taken out of the mould after 24 hours using sample extractor. The bulk density of the sample is usually determined by weighting the sample in air and in water. It may be necessary to coat samples with paraffin before determining density. In conducting the stability test, the specimen is immersed in a bath of water at a temperature of 60° for a period of 30 minutes. It is then placed in the Marshall Stability testing machine and loaded at a constant rate of deformation of 5 mm per minute until failure. The total maximum in kg (that causes failure of the specimen) is taken as Marshall Stability. The stability value so obtained is corrected for volume. The total amount of deformation is units of 0.25 mm that occurs at maximum load is recorded as Flow Value. The total time between removing the specimen from the bath and completion of the test should not exceed 30 seconds.

Density and Voids Analysis

This study compared the difference in air voids, voids in mineral aggregate (VMA), and Voids in coarse aggregate. The critical air voids level at which stone matrix asphalt mixtures are considered to become permeable was also determined for the gradations used in this study. Before mix properties are discussed in detail, the Technician is required to understand that paving mix properties are most affected by volume and not weight; however, production and testing of asphalt mixture is by weight. Much of what determines long term pavement performance of the asphalt mixture, such as Air Voids, VMA and VCA, are based on volume not weight.

Specific Gravity

The density of the compacted mix is the unit weight of the mixture (the weight of a specific volume of asphalt mixture). Density is important because proper density in the finished product is essential for lasting pavement performance. Mix properties are required to be measured in volumetric terms as well as weight. Density allows us to convert from units of weight to volume. There were two types of specific gravity:

1. Bulk Specific Gravity of Compacted Mixture (Gmb).
2. Theoretical Maximum Specific Gravity (Gmm).

Air Voids (Va)

Air voids are small air spaces or pockets of air that occur between the coated aggregate particles in the final compacted asphalt mixture. A (4 %) of air voids is necessary in all Dense bitumen mixes to prevent the pavement from flushing, shoving, and rutting. Air voids may be increased or decreased by lowering or raising the binder content. They may also be increased or decreased by controlling the amount of material passing the 0.075 mm sieve in the asphalt mixture. The more fines added to the asphalt mixture generally the lower the air voids. Finally, the air voids changed by varying the aggregate gradation in the asphalt mixture. The durability of an asphalt pavement is a function of the air void content. Too high an air void content provides passageways through the asphalt mixture for the entrance of damaging air and water. Too low an air void content, on the other hand, may lead to flushing, a condition where excess binder squeezes out of the asphalt mixture to the surface. Density and air void content are directly related. The higher the density, the lower the percentage of air voids in the asphalt mixture. Specifications require pavement densities that produce the proper amount of air voids in the pavement

Voids in Mineral Aggregate (VMA)

Voids in the mineral aggregate (VMA) are the void spaces that exist between the aggregate particles in the compacted paving asphalt mixture, including the space filled with the binder. VMA represents the space that is available to accommodate the effective volume of binder (i.e., all of the binder except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the asphalt mixture. The more VMA in the dry aggregate, the more space is available for the binder. Since a thick binder film on the aggregate particles results in a more durable asphalt mixture, specific minimum requirements for VMA are recommended and specified as a function of the aggregate size.. Minimum VMA values are required so that a durable binder film thickness may be achieved. Increasing the density of the asphalt mixture by changing the gradation of the aggregate may result in minimum VMA values with thin films of binder and a dry looking, low durability asphalt mixture. Therefore, economizing in binder content by lowering VMA is actually counterproductive and detrimental to pavement quality. Low VMA mixes are also very sensitive to slight changes in binder. If binder content varies even slightly during production, the air voids may fill with binder resulting in a pavement that flushes and ruts. VMA is most affected by the filler fractions which pass the 0.075 mm sieve. The reason was these particles tend to be absorbed by the binder film. Because they take up volume, there is a tendency to bulk (extend) the binder resulting in a lower VMA

Marshall Stability Testing Machine

4.4 METHODOLOGY

Method of fiber addition

Several methods of blending carbon fibers and asphalt binder were attempted. The goal was to find a method that would uniformly disperse fibers throughout the binder. Small trial blends were made with approximately 150 grams of asphalt binder and 0.5 percent fiber by weight. After each trial mix was completed, the hot, modified binder was poured onto a square paper and allowed to cool. As the asphalt flows outward, fiber clumps appeared as lumps in the binder, easily identified by visual inspection, this is known as the *Balling effect*. This method was abandoned after additional trials with longer mixing times were also unsuccessful in producing a mixture free of clumping.

After many trails the wet mix process is forgone and the dry mix process is taken into consideration and the mix is prepared.

Volumetric properties

Theoretical Maximum Specific Gravity

Loose DBM mixtures were prepared to determine their theoretical maximum specific gravity (G_{mm}) values. Test was conducted as per ASTM D 2041.

1. The DBM mixture was prepared using oven-dry aggregates, and placed in a pan and the particles of mix were separated by hand, taking care to avoid fracturing the aggregate, so that the fine aggregate portion were not larger than about 6 mm. The sample was cooled to room temperature.
2. The sample was placed directly into a cylindrical container and net mass (mass of sample only) weighed and was designated as A.
3. Sufficient water was added at a temperature of approximately 25°C to cover the sample completely. The cover was placed on the container.
4. The container was placed with the sample and water, and agitation was started immediately to remove entrapped air by gradually increasing the vacuum pressure (by vacuum pump) for 2 min until the residual pressure manometer read 3.7 ± 0.3kPa, vacuum and agitation was continued for 15 ± 2 min.

Fig 3.3 rice apparatus

5. The vacuum pressure was gradually released using the bleeder valve and the weighing in water was done. For determining the weight in water, the container and contents were suspended in water for 10 ± 1 min, and then the mass was determined. The mass of the container and sample under water was designated as C.

The maximum specific gravity of the sample was calculated as follows:

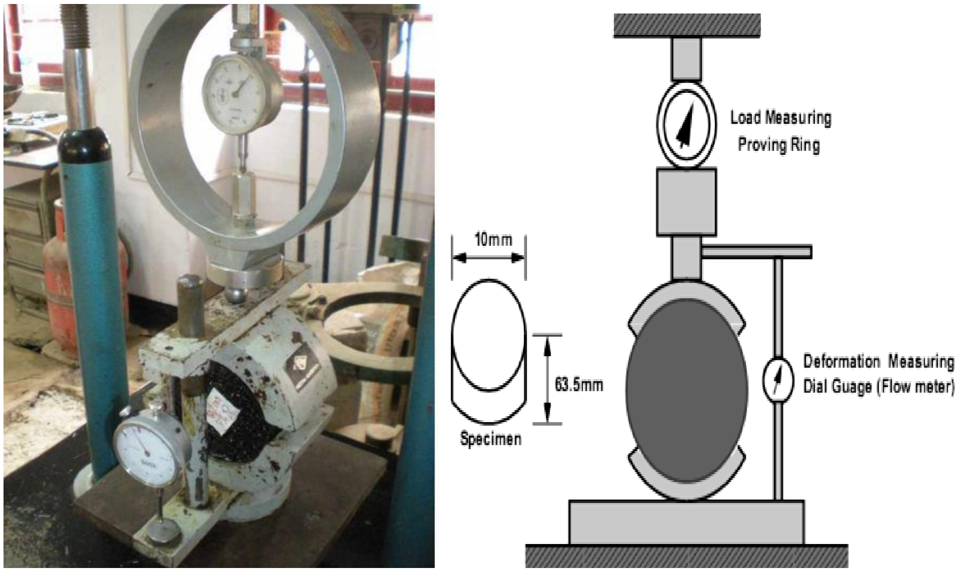
Gmm=(A)/[A-(C-B)]

where:

G_{mm} = Maximum specific gravity of the mixture,
A = Mass of dry sample in air, g,
B = Mass of bowl under water, g, and
C = Mass of bowl and sample under water, g.

Marshall Stability Test

Marshall Stability test was conducted on cylindrical DBM specimens to find out their stability and flow values. The principal features of the method were a density-voids analysis and a stability-flow test of compacted specimen. The specimen was kept in thermostatically controlled water bath maintained at 60 $\pm 1^0$C for 30 to 40 minutes. Then it was placed in Marshall Test head and tested to determine Marshall Stability value which was a measure of strength of the mixture. It was the maximum resistance in kilo Newton, which it would develop at 60^0C when tested in the standard Marshall equipment. The flow value was the total deformation in units of mm, occurring in the specimen between no load and maximum load during the test. The test specimens were prepared with varying bitumen content in 0.5 per cent increments over a range that gives a well-defined maximum value for specimen density and stability.



Marshall Stability Testing Machine

Optimum Bitumen Content

Graphs were plotted for bitumen content against bulk density, air voids, VMA, VFB, Marshall Stability and Flow. The Optimum Binder Content (OBC) for DBM mixtures is usually selected to produce the specified air voids. The binder content, corresponding to the specified air voids (4%) was found from the plots and is considered as OBC for DBM Mix. All these values are compared with the specification values to check whether they were in specified limits.

5.RESULT ANALYSIS

5.1 Aggregate Properties

Particle shape, strength tests, specific gravity and water absorption tests have been conducted and data is as follows:

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

Table 5.1 Physical Properties of Coarse aggregate

5.2 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

Table 5.2 Specific Gravity of Aggregates

5.3 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	62.78mm	50-70
Softening Point 0C (Ring & Ball Apparatus)	IS 1205-1978	49.82°C	Min 47

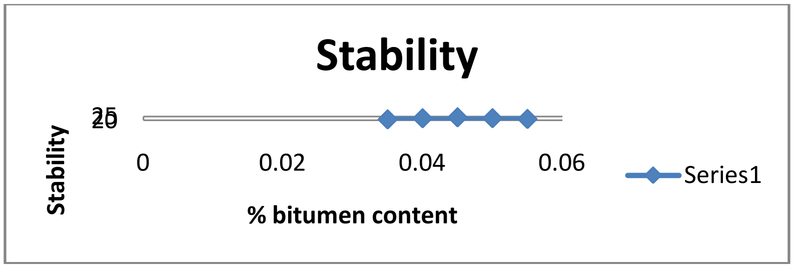
Table 5.3 physical properties of binder

5.4 EFFECT OF BINDER PERCENTAGE ON DBM

Variation of Marshall Properties of Dense bituminous Macadam (DBM) with different percentages of bitumen content is explained below.

Marshall Stability

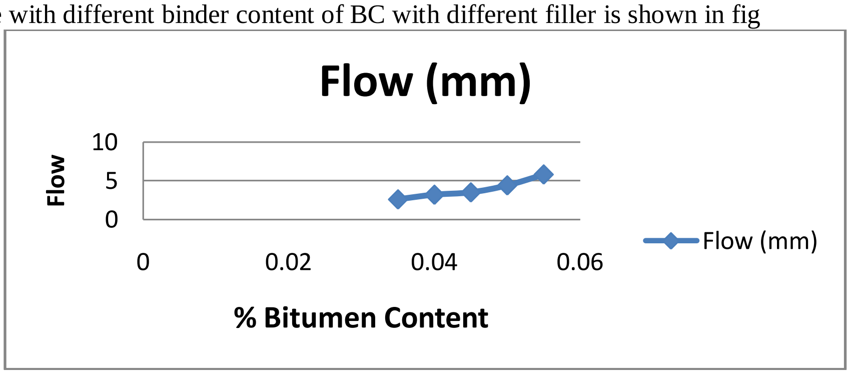
It is observed that stability value increases with increase in binder content up to certain binder content; then stability value decreases. Variation of Marshall Stability value with different binder content with different filler is given fig 4.2.



Variation of Marshall Stability of BC with different binder content

Flow Value

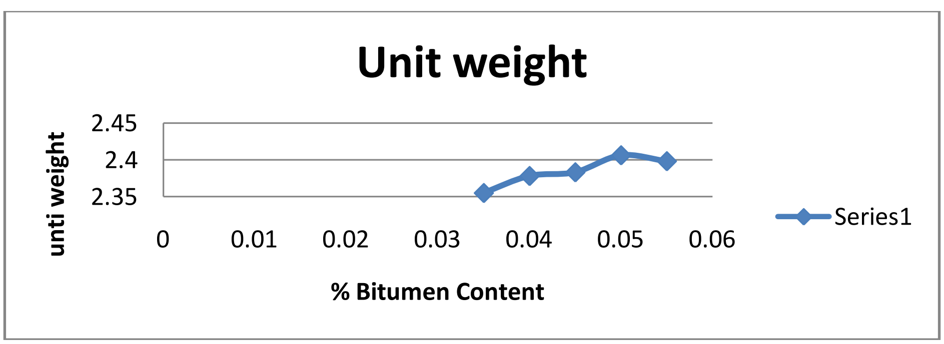
It is observed that with increase binder content flow value increases. For BC flow value should be within 2 to 4 mm. Variation of flow value with different binder content of BC with different filler is shown in fig



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

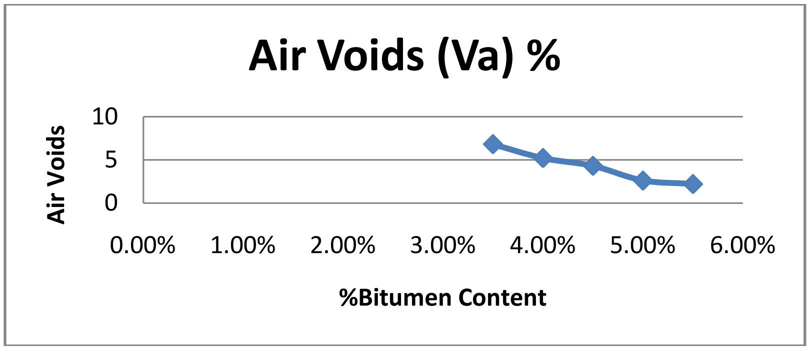


Variation of unit weight Value of BC with different binder content

Air Voids

It is observed that with increase binder content air void decreases. Variation of air void with different binder content.

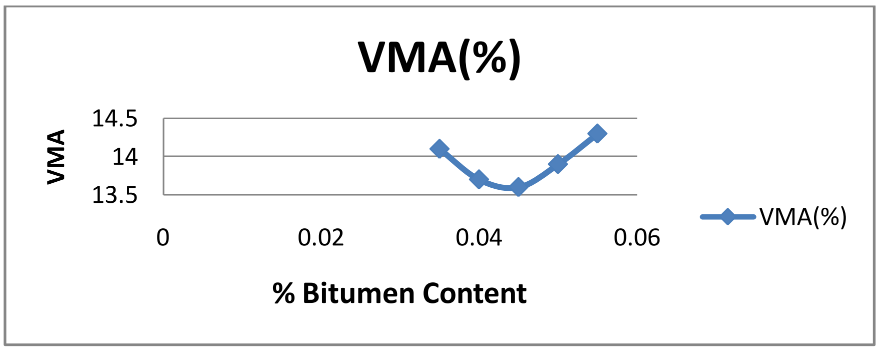
MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4% of air void given below



Variation of air void of BC with different binder content

Voids in Mineral Aggregate (VMA)

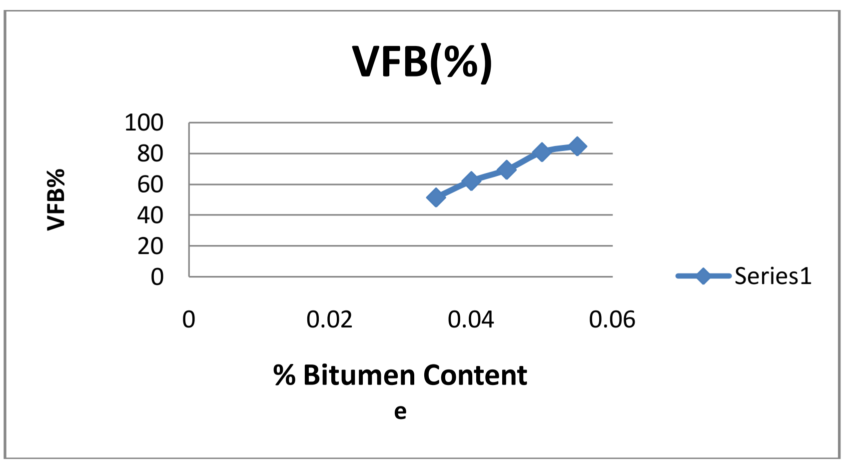
It is observed that first it decreases and then it increases at sharp rate. Variation of VMA with different binder content.



Variation of VMA of BC 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

OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following three bitumen

Content found from above graph i.e.

I. Bitumen content corresponds to maximum stability
II. Bitumen content correspond to maximum unit weight
III. Bitumen content corresponding to the median of designed limits of percentage air voids in total mix.

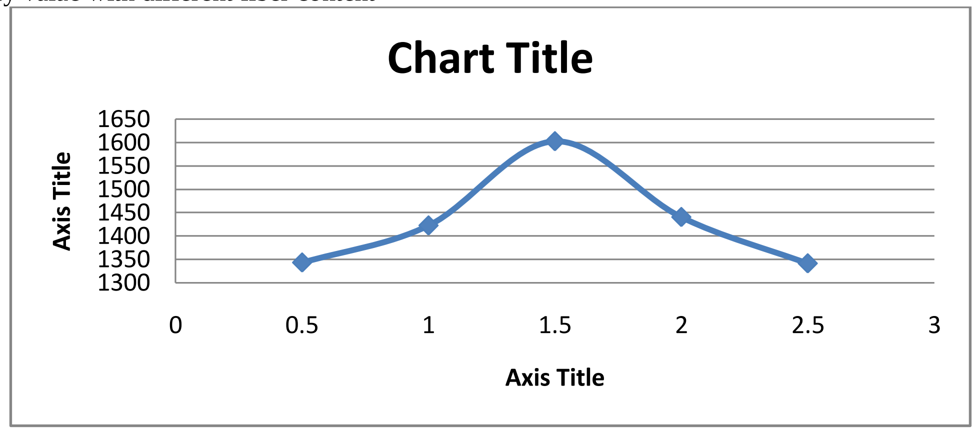
From above result it has been observed that BC mixes with all three types of filler produce satisfactory result as suggested as in MORTH. Here mixes with cement filler gives higher stability and other improved characteristics followed by stone dust filler and then fly ash filler. Here **LIME** has been selected as filler material for further investigation considering its wide availability, low cost price and environment protection.

4.5 EFFECT OF FIBER ON DBM

For preparation of mix, binder content at 4.5% and fiber content vary from 0.5% to 2.5%. Here OFC and other Marshall properties are calculated by Marshall Method.

4.5.1 MARSHAL STABILTY

It is observed that stability value increases with increase fiber content and further addition of fiber it decreases. Variation of Marshall Stability value with different fiber content



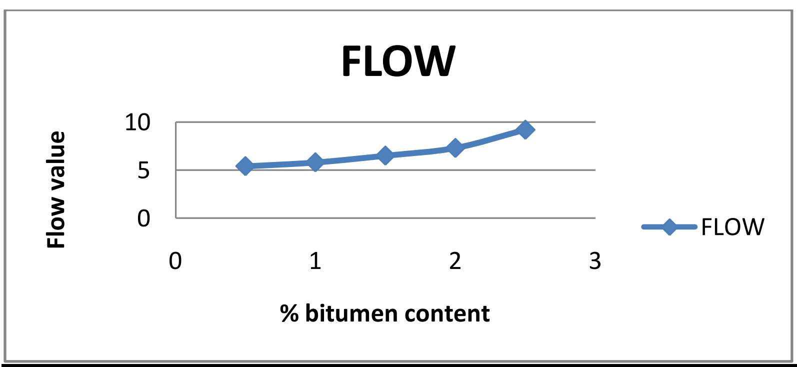
Variation of Marshall Stability of DBM With different fiber content

4.5.2 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 fiber content is shown in fig

percentage	FLOW
0.5	5.4
1	5.8
1.5	6.5
2	7.3
2.5	9.2

Flow value for different fiber content



Variation of Flow value of DBM with different fiber content

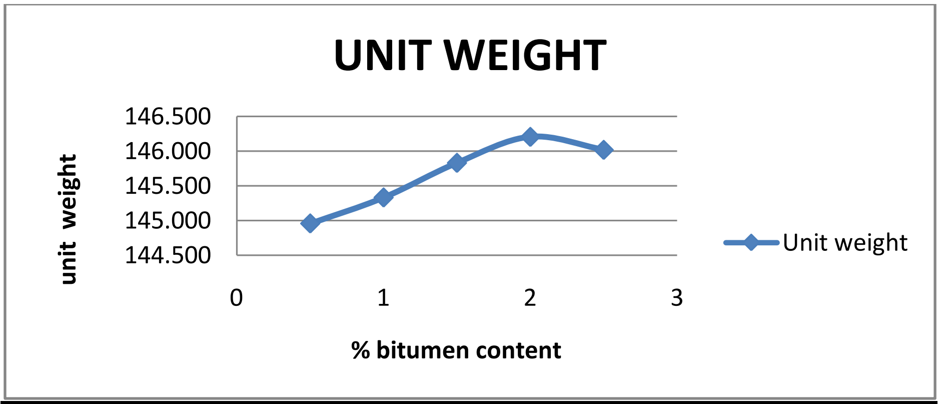
UNIT WEIGHT

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 fiber is given fig

percentage	Unit weight
0.5	**144.955**
1	**145.330**

1.5	**145.829**
2	**146.203**
2.5	**146.016**

unit weight for different fiber content



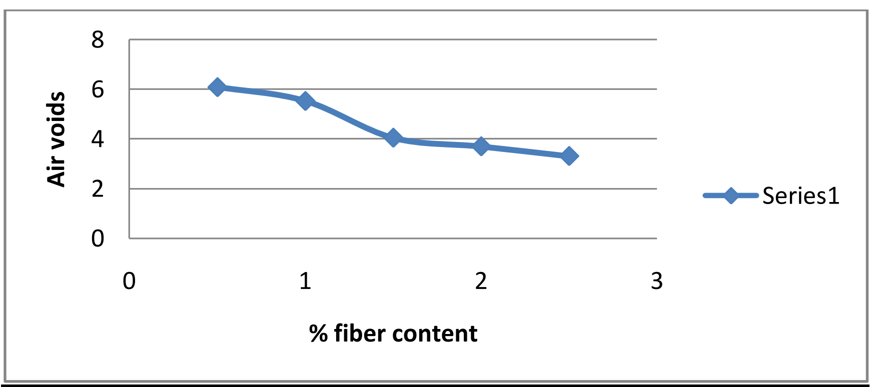
Variation of unit weight of DBM With different fiber content

AIR VOID

It is observed that with increase binder content air void decreases. Variation of air void content with different fiber content is given fig 4.8. MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4.5% of air void given below table

carbon			
percentage	**Gmm**	**Gmb (mean density value)**	**% of Air Voids**
0.5	**2.4734**	**2.323**	**6.080698633**
1	**2.4651**	**2.329**	**5.52222398**
1.5	**2.4532**	**2.354**	**4.043698027**
2	**2.4329**	**2.343**	**3.696240602**
2.5	**2.4200**	**2.34**	**3.305785124**

%Air voids for different fiber content



Variation of Air Void of DBM With different fiber content

Void in Mineral Aggregate (VMA)

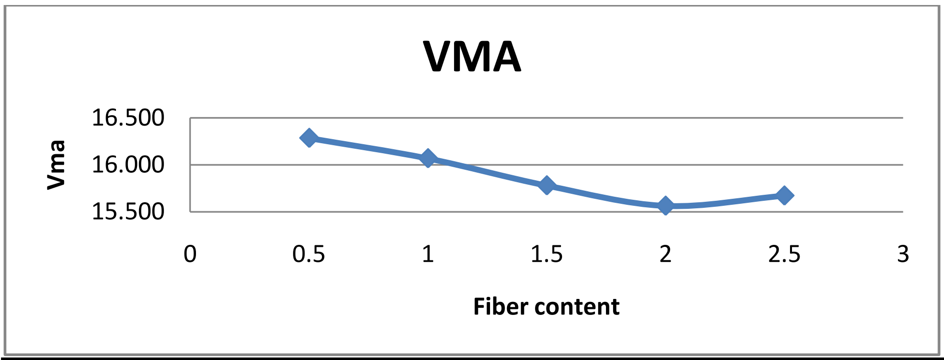
It is observed that first it decreases and then it increases at sharp rate. Variation of VMA

With different binder content with different fiber content is shown in Fig 4.12.

percentage	**Gmb (mean density**	Gsb	Ps	VMA

	value)			
0.5	**2.323**	2.65	95.5	16.284
1	**2.329**			16.068
1.5	**2.337**			15.780
2	**2.343**			15.56358
2.5	**2.340**			15.672

VMA for different fiber content



Variation of VMA of DBM With different fiber content

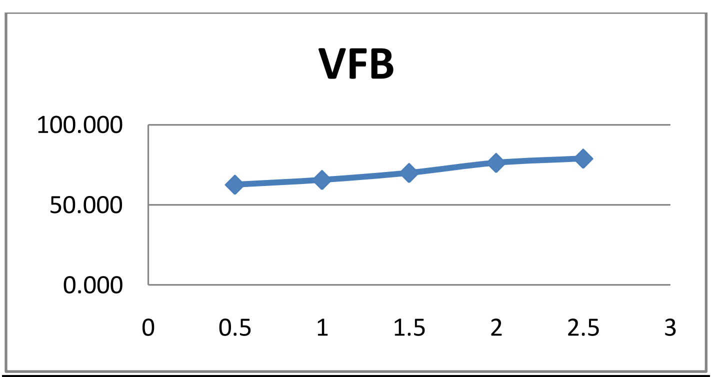
4.5.6 Void Filled With Bitumen (VFB)

It is observed that first it increases at sharp rate. Variation of VFB with different binder

Content with different fiber content is shown in Fig

percentage	VFB
0.5	62.659
1	65.632
1.5	69.983
2	76.251
2.5	78.906

%VFB for different fiber content



Variation of VFB of DBM With different fiber content

OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following three bitumen Content found from above graph i.e.

I. Bitumen content correspond to maximum stability

II. Bitumen content correspond to maximum unit weight
III. Bitumen content corresponding to the median of designed limits of percentage air voids in total mix.

From the looking into the above graphs the *optimum binder content* is taken as **4.5%.**

OPTIMUM FIBER

The fiber content corresponding to 4% Air voids is designated as Optimum fiber Content and in the present case it is **1.45%.** From the Marshall data of 4.5% bitumen content, it was observed that the Air voids fallen to 3.1%, any increasing in fiber content further decreases this value, which is not desirable.

6.CONCLUSION

The primary purpose of this report was to develop information about the addition of carbon fiber in dry 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 fiber to it.

The use of carbon fiber showed consistency of results in the present study. It was observed that the addition of fiber favourably affects the properties of bituminous mixtures by increasing its stability and voids and decreasing the flow value. As such, it can be said that carbon fiber has the potential to improve structural resistance to distress occurring in road pavement due to traffic loads.

Compared to the control mixture, the fiber content of **1.5**% by weight of total mix resulted in highest performance in terms of stability; however, some mechanical properties of the same mix may be compromised when the fiber content exceeds **1.5**% level.

Since the length of the fiber is a critical factor affecting the performance of carbon fiber modified asphalt mixtures it must be ensured that individual fibers keep their linear configuration intact after the mixing process. To achieve these improvements, proper attention must be paid to ensure that the fibers are uniformly dispersed in the mixture.

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, and the Optimum Binder Content is fixed as **4.5%.**

OPTIMUM FIBER CONTENT

The optimum fiber content is based on the marshal stability test itself which gives the **1.5%** of carbon modified bituminous mix gives the high

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