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PERFORMANCE EVALUATION OF CARBON FIBER IN DENSE BITUMENIOUS MACADAM

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Abstract — *In this paper, a brief practical review is presented on the the pavement which is compacted with the conventional compaction has been further compacted due to the movement of traffic and which corresponds to the ultimate density which can be attained on the bituminous pavement called as "Refusal density" of the pavement. Addition of polymers is a common method applied for binder modification, although various types of fibers have also been evaluated. It is widely believed that the addition of fibers to asphalt enhances material strength aswellas fatigue characteristics while at the same time adding ductility. Likewise, carbon fibers may also offer excellent potential for binder modification due to their inherent compatibi lity with asphalt cement and superior mechanical properties.*

Secondary compaction has to be studied in detail and it is understood that the 75 blows of the Marshall test does not determine the actual field circumstances. The Marshall design actually in the field will not simulate the field conditions hence there will be a reduction in the air voids at the refusal density. Then due to fineness of the mix, this causes the plastic deformation on the pavement surfaces. Hence an attempt has been made to study the air void content at refusal density. Also the Bulk Density, Air voids (Va), Voids in mineral aggregate (VMA),Voids filled with Bitumen (VFB) of the mix at the refusal density are also studied. For the simulation of the field density in the laboratory a Hugo hammer is used. The usage of the Polymer Modified Bitumen reduces the plastic deformation and other distresses of the pavement.

Keywords—Road network, urban areas, Gis,Conectivity, behavioral model.

I. INTRODUCTION

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.

At present, there are two research orientations to improve pavement performance of asphalt mixture: one is to better asphalt non-deformability at high temperature, via improving aggregate graduation, which is based on asphalt structure type and design procedures; the other is to better asphalt mechanical performance & permanent deformation resistance, and decrease temperature susceptibility, via improving asphalt property and quality. For the past few years, more and more new materials are put into the technology field of bituminous pavement. Thus, the third orientation to improve its performance is formed, that is to add fibers to asphalt, as a specific kind of additives, to holistically better its physical mechanical property.

At the moment, there are mainly three types of fibers applied in pavement project: cellulose fiber, polyester fiber and mineral fiber. Addition of polymers is a common method applied for binder modification, although various types of fibers have also been evaluated. It is widely believed that the addition of fibers to asphalt enhances material strength aswellas fatigue characteristics while at the same time adding ductility. Likewise, carbon fibers may also offer excellent potential for binder modification due to their inherent compatibility with asphalt cement and superior mechanical properties. With new developments inproduction, carbon modified binder has become cost competitive with polymer modified binders. Further, it was expected that carbon fiber- modified asphalt mixtures would increase stiffness and resistance to permanent deformation and, similarly, that the fatigue characteristics of the mixture would improve with the addition of discrete carbon fibers.

Because of the high tensile strength of carbon fibers, cold temperature behaviour of asphalt mixtures was also expected to improve. Finally, carbon fiber modified asphalt could produce a higher quality asphalt mixture for pavements.

II. NEED FOR PRESENT STUDY

Generally we use several kinds of modifications to the bituminous pavements inorder 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.

III. OBJECTIVE AND SCOPE OF THE STUDY

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously gradedfrom 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

IV. LITERATURE REVIEW

M. AREN CLEVEN (2013) investigated the properties of Carbon Fiber Modified Asphalt Mixtures. Preliminary study used to determine the feasibility of modifying the behaviour of a standard AC mixture through the use of pitch-based carbon fibers. This study focused strictly on the ability of mixing and compacting mixtures made with CFMA to achieve statistically significant improvements in the mechanical properties of the mixture.

Carbon fiber modified asphalt mixtures were expected to show increased stiffness and resistance to permanent deformation. Fatigue characteristics of the mixture were expected to improve with the addition of discrete carbon fibers, and because of the high tensile strength of carbon fibers, the cold temperature behaviour of CFMA mixtures was anticipated to improve as well. Carbon fiber modified asphalt was expected to produce a higher quality AC mixture for pavement applications.

The addition of carbon fibers improves the high temperature behaviour of the asphalt binder. If the test temperature does not reach the upper binder grade temperature, the effects of the fibers may be masked by binder behaviour.The low temperature behaviour of CFMA mixtures may be dominated by the binderuntil it begins to fail, at which time the fibers dominate the behaviour.

Fereidoon Moghadas Nejad, Morteza Vadood & Seeyamak Baeetabar (2013) 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. Subsequently, to find out the best set of fiber lengths and dose of usage aimed at fortifying asphalt concrete, Marshall's stability and fatigue property of carbon fiber-reinforced asphalt concrete were investigated. Then, indirect tensile stiffness modulus and fatigue properties under different stresses and permanent deformation of modified and unmodified samples at two different temperatures (35°C and 60°C) were studied.

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Based on the investigation, the addition of fibres to asphalt improves the mechanical properties such as strength, fatigue characteristics, Marshall Stability and electrical conductivity. But fibre properties such as length, distribution and content have a great impact on the performance of asphalt. There are hypotheses and limitations in this area, one of which is to use fibres of high flexibility and remarkable thermal resistance against mixing time with high temperature. The main aim of this research is to find the best fibre length and content for reinforcing asphalt concrete. The evaluation of permanent deformation at different temperatures as well as fatigue properties of asphalt concrete modified with optimum values of fibre length and content is another important objective of this research. Fibres are distributed in all directions in the mixture so as to prevent the production and expansion of cracks due to various reasons whether due to tensile stress induced by applied loads or thermal stresses. To this end, carbon fibres with three levels of length and content were selected.

Rebecca Lynn Fitzgerald(2000) researched on the novel application of carbon fiber for hot mix asphalt reinforcement and carbon-carbon pre-forms. The purpose of the research described in this thesis is to explore two new applications for carbon fibers. The first application involves the addition of carbon fiber to asphalt. Preliminary research indicates that carbon fiber modified asphalt may have beneficial properties ranging from improved mechanical properties to reduced electrical resistance. The enhanced mechanical properties should result in longer lasting, more durable pavements. In addition, carbon fibers are electrically conductive. As an additive to asphalt, they can reduce the electrical resistivity, which may have applications in asphalt stress testing, structural vibration sensing, and eating roads to melt ice and snow.The fibers studied were 2.54cm cut mesophase pitch-based fibers and rolled 5.08cm-7.62cm mesophase pitch-based fibers in random matform. Two different encapsulation methods were investigated: asphalt/water emulsion/carbon fiber and LDPE/carbon fiber.

IV. EXPERIMENTAL INVESTIGATIONS

4.1 Tests on materials used

Binder

Here 60/70 penetration grade bitumen is used as binder for preparation of Mix, whose specific gravity was 1.023. Its 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 δ, 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 4.1 Properties of Binder

Specific gravity and water absorption tests on aggregates

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 4.2 Physical properties of coarse aggregate

V. ANALYSES OF TEST RESULTS AND DISCUSSIONS

Based on volume considered in evaluating specific gravity of an aggregate, some definitionsof specific gravity are proposed.

As per Das A. and Chakroborty P. (2010); the definitionsand other formulae used in calculations hereafter are as follows:

Theoretical Maximum Specific Gravity

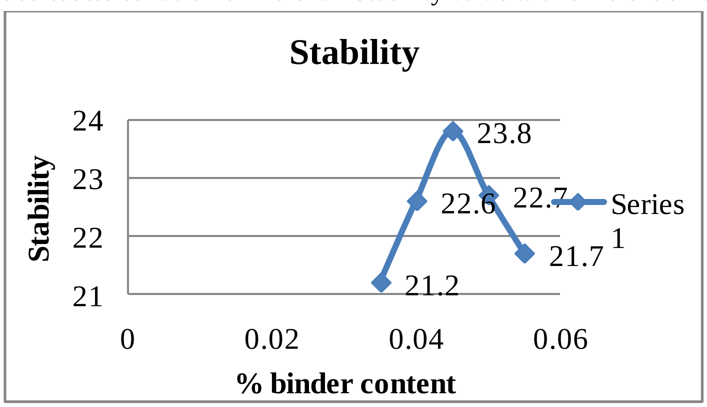
Loose DBM mixtures were prepared to determine their theoretical maximum specific gravity (G_{mm}) values. Test was conducted as per ASTM D 2041.

1. The SMA 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.
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.

Specific Gravity of Aggregates

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 5.1



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

Fig 5.1 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 5.2

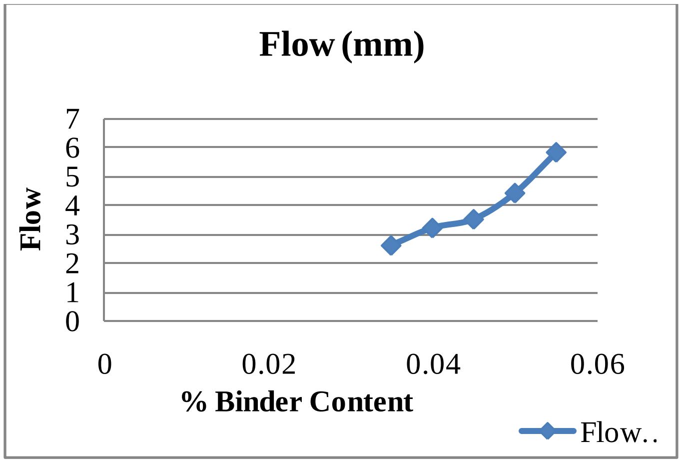


Fig 5.2 Variation of Flow Value of BC with different binder content

Unit weight

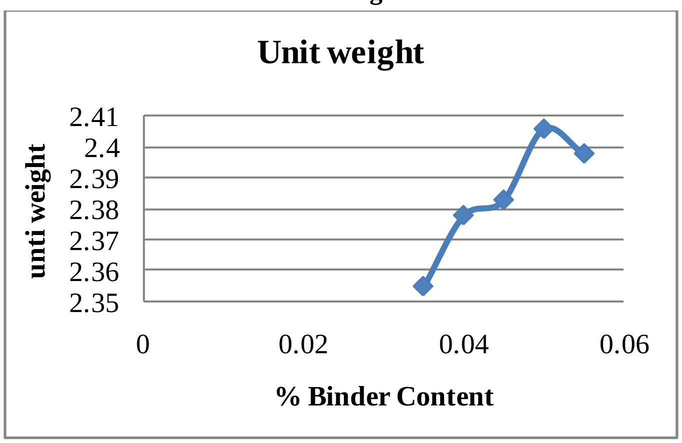


Fig 5.3 Variation of unit weight Value of BC with different binder content

Air Voids (Va) %

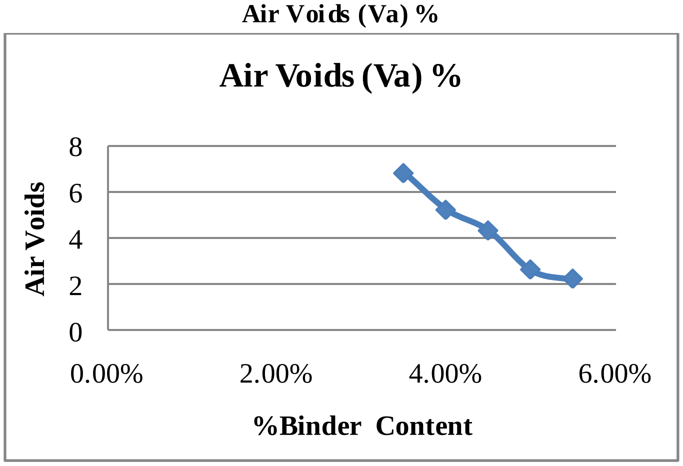


Fig 5.4 Variation of air void of BC with different binder content

VMA (%)

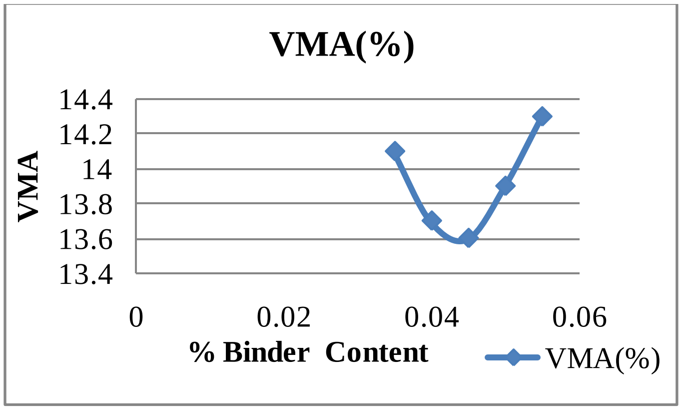


Fig 5.5 Variation of VMA of BC with different binder content

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

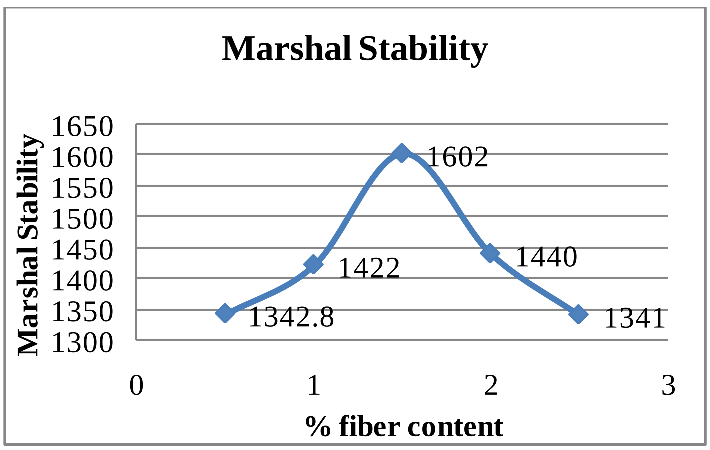


Fig 5.6 Variation of Marshall Stability of DBM With different fiber content

CONCLUSIONS

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

Marshall Stability

It is observed that with increase in binder content the Marshall Stability value increases upto certain binder content value and then decreases, like conventional bituminous mixes. Highest stability value achieved at 1.5% of fiber modified bituminous mix.

Flow value

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

Unit Weight

The unit weight increases with the increase in binder content upto a certain binder content and their after decreases. The maximum Unit weight is for 2% of fiber modified bituminous mix.

Air voids
The amount of air voids decreases with increase in binder content in the mix. It also increases or decreases depending on the fiber content in the mix. The mix is observed to have the lowest air voids content in the higher fiber mix. Highest air voids have obtained at 2.5% of fiber modified 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, 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 highest stability strength .Anything above the optimum fiber content, the mix behaved like a less viscous material.

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