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A Laboratory Study of Bituminous Mixes Using a Natural Fibre

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***Abstract*: Generally a bituminous mixture is a mixture of coarse aggregate, fine aggregate, filler and binder. A Hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed and compacted at high temperature. HMA can be Dense Graded mixes (DGM) known as Bituminous Concrete (BC) or gap graded known as Stone Matrix Asphalt (SMA). SMA requires stabilizing additives composed of cellulose fibbers, mineral fibres or polymers to prevent drain down of the mix.**

In the present study, an attempt has been made to study the effects of use of a naturally and locally available fibre called SISAL fibre is used as stabilizer in SMA and as an additive in BC. For preparation of the mixes aggregate gradation has been taken as per MORTH specification, binder content has been varied regularly from 4% to 7% and fibre content varied from 0% to maximum 0.5% of total mix. As a part of preliminary study, fly ash has been found to result satisfactory Marshall Properties and hence has been used for mixes in subsequent works. Using Marshall Procedure Optimum Fibre Content (OFC) for both BC and SMA mixes was found to be 0.3%. Similarly Optimum Binder Content (OBC) for BC and SMA were found to be 5% and 5.2% respectively. Then the BC and SMA mixes prepared at OBC and OFC are subjected to different performance tests like Drain down test, Static Indirect Tensile Strength Test and Static Creep Test to evaluate the effects of fibre addition on mix performance. It is concluded that addition of sisal fibre improve the mix properties like Marshall Stability, Drain down characteristics and indirect tensile strength in case of both BC and SMA mixes. Ii is observed that SMA is better than BC in respect of indirect tensile strength and creep characteristics.

***IndexTerms*: Bituminous Mixture, Dense Graded mixes (DGM), Bituminous Concrete (BC), SISAL fibre, Optimum Fibre Content (OFC), Optimum Binder Content (OBC)**

I. INTRODUCTION

A. General

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The present study is related to the mix design considerations.

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. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one. The present research work tries to identify some of the issues involved in this art of bituminous mix design and the direction of current research.

B. 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 0.075

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-

- Sufficient bitumen to ensure a durable pavement
- Sufficient strength to resist shear deformation under traffic at higher temperature
- Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic

C. Objective of Present Investigation

A comparative study has been made in this investigation between Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA) mixes with varying binder contents (4% - 7%) and Fibre contents (0.3% - 0.5%). In the present study 60/70 penetration grade bitumen is used as binder and Sisal fibre is used as stabilizing additive.

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

- Study of Marshall Properties of BC mixes using three different types of fillers without fibre (fly-ash, cement, stone dust)
- Study of BC mixes with fly ash as filler and sisal fibre as stabilizer

- Study of SMA mixes with fly ash as filler and sisal fibre as stabilizer

Evaluation of SMA and BC mixes using different test like Drain down test, Static Indirect tensile Strength test, Static Creep test

II. REVIEW OF LITERATURE

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. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out then passes on these loads to the next layer below. 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.

Brown and Mallick (1994) used viscosity grade binder AC-20 for their research on SMA properties related to mixture design. Mogawer and Stuart (1996) also used AC-20 binder. Putman et al. (2004) used a performance grade binder PG 76-22 to study the SMA properties.

They observed that polymer modified bitumen gives better performance (in terms of deformation) than unmodified bitumen.

Sharma et al. (2004) used natural rubber powder to modify 80/100 penetration grade bitumen. They termed it as Natural Rubber Modified Bitumen (NRMB). Kamaraj et al.(2006) used 60/70 grade bitumen and SBS modified bitumen (PMB-40) in SMA for their investigation. Chiu and Lu (2007) investigated the feasibility of using Asphalt Rubber (AR) as a binder for SMA. They produced this AR by blending ground tire rubber (GTR) with AC-20 asphalt. They termed it as AR-SMA. The performance of AR-SMA was evaluated in terms of moisture susceptibility. It was found that the AR-SMA mixtures were not significantly different from the conventional SMA mixtures in terms of moisture susceptibility. It was also observed that no fibre was needed to prevent drain down when this AR is used in the mix.

It has been reported by Reddy et al. (2006) that the fatigue life, temperature susceptibility and resistance to moisture damage characteristics of the bituminous mixes can be improved by the use of CRMB as compared to other unmodified bitumen.

III. EXPERIMENTAL INVESTIGATIONS

A. *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 fibre), second part deals with the tests carried out on bituminous mixes.

Tests on Materials Used Aggregates

For preparation of Bituminous mixes (BC, SMA) aggregates as per MORTH grading as given in Table 1 and Table 2 respectively, a particular type of binder and fibre in required quantities were mixes as per Marshall Procedure.

Table 1: Adopted aggregate Gradation for BC (MORTH)

Sieve size (mm)	Percentage passing
26.5	100
19	95
9.5	70
4.75	50
2.36	35
0.30	12
0.075	5

Table 2: Adopted aggregate Gradation for SMA (MORTH)

Sieve size (mm)	Percentage passing
16	100
13.2	94
9.5	62
4.75	34
2.36	24
1.18	21
0.6	18
0.3	16

0.15	12
0.075	10

B. 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.

Figures 1 and 2 show the Marshall sample and 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 fibre 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). For constraint of time each and every test on all types of mixes cannot be completed. Hence it was decided to carry out the next set of experiments such as drain down test, static indirect tensile test and moisture susceptibility tests on the mixes prepared at their OBC and OFC

Fig 1 Marshall Sample

Fig 2 Marshall Test In Progress

IV. ANALYSIS OF TEST RESULTS AND DISCUSSIONS

A. *Introduction*

In this chapter Result and Observation of test carried out in previous chapter is presented, analyzed and discuss. This chapter is divided into five sections. First section is deals with parameter used for analysis. Second section deals with calculation of Optimum binder Content (OBC) of BC where cement, fly ash, stone dust is used as filler. Third section deals with calculation of Optimum binder Content (OBC) and Optimum Fibre content (OFC), Marshall Properties of BC with or without using fibre. Fourth section deals with calculation of Optimum binder Content (OBC) and Optimum Fibre content (OFC), Marshall Properties of SMA with or without using fibre. Fifth section deals with result of Drain down test and Static Indirect Tensile Stress and static Creep test.

B. Effect of Different Type of Filler on BC

Variation of Marshall Properties of bituminous concrete (BC) with different type of filler is explained below.

1. Marshall Stability

It is observed that stability value increases with increase 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.

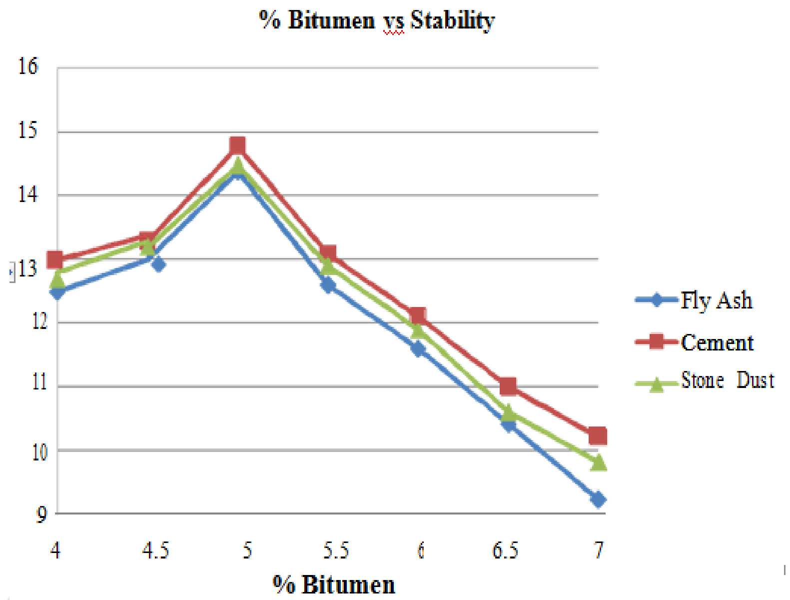

Fig1. Variation of Marshall Stability of BC with different binder content

Table 1 Maximum Marshall Stability values and their corresponding binder content

BC with filler type	Max. Stability (KN)	Corresponding Binder Content (%)
Cement	14.78	5
Stone dust	14.48	5
Fly ash	14.38	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 filler is shown in fig 2

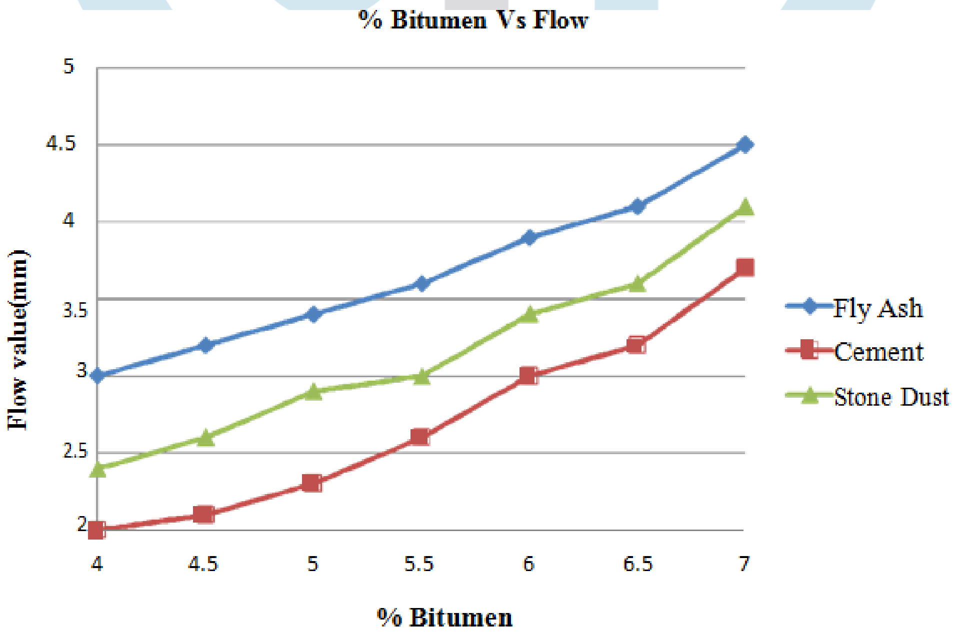

Fig 2 Variation of Flow Value of BC with different binder content

3. 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 3

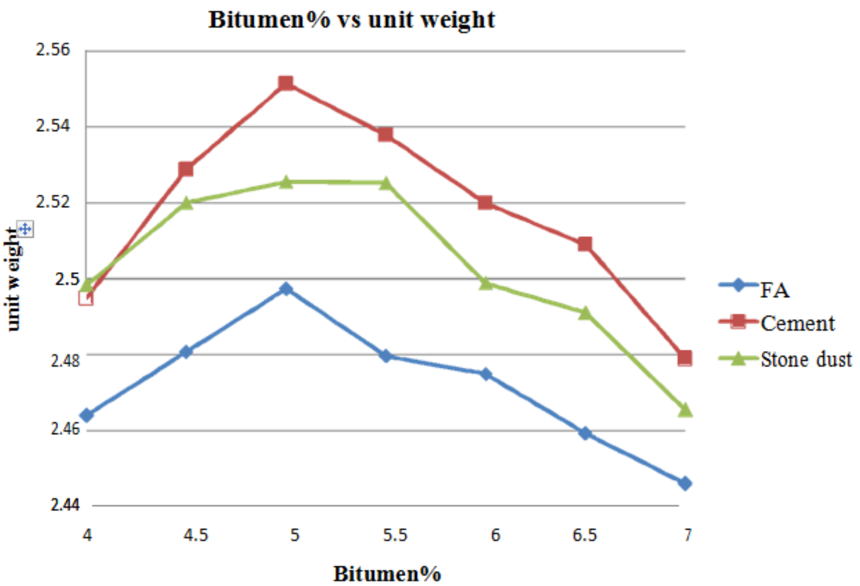

Fig 3 Variation of unit weight Value of BC with different binder content

Table 2 Maximum unit weight values and their corresponding binder content

BC with filler type	Max. Unit weight	Corresponding Binder Content (%)
Cement	2.54	5
Stone dust	2.52	5
Fly ash	2.49	5

4. Air Void

It is observed that with increase binder content air void decreases. Variation of air void with different binder content is given fig 4. MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4.5% of air void given below table

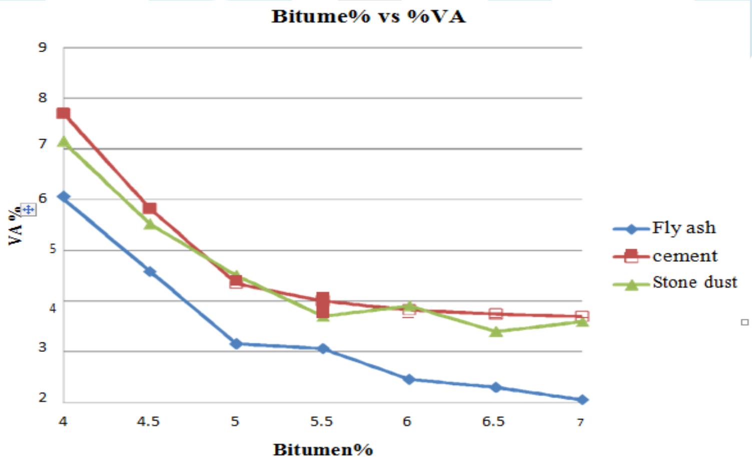

Fig 4. Variation of air void of BC with different binder content

Table 3 binder content corresponding to 4.5% of air void

BC with filler type	Air void (%)	Corresponding Binder Content (%)
Cement	4.5	5
Stone dust	4.5	5
Fly ash	4.5	4.8

5. 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 is shown in Fig 5

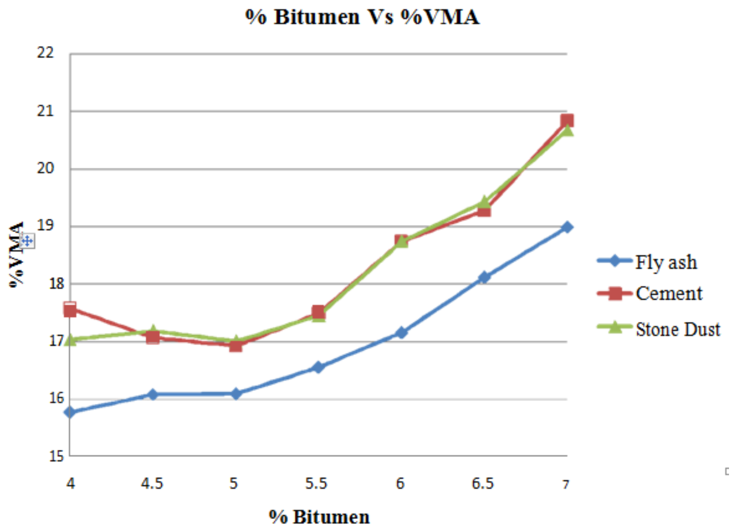

Fig 5 Variation of VMA of BC with different binder content

6. Void filled with Bitumen (VFB)

VFB increases with increase binder content. Variation of VFB with different binder content is shown in Fig 6

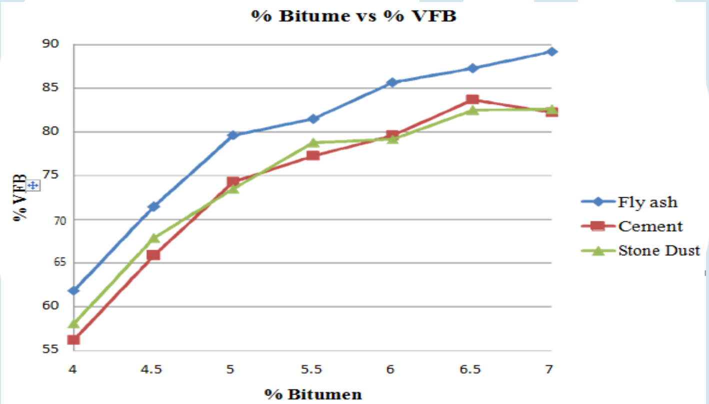

Fig 6 Variation of VFB of BC with different binder content

C. Optimum Binder Content

Optimum Binder Content is found out by taking average value of following three bitumen content found from above graph i.e. 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 OBC of BC with different type of filler is given table 4

Table 4 OBC of BC with different type of filler

BC With filler type	OBC (%)
Cement	5
Stone dust	5
Fly ash	4.8

From above result it has been observed that BC mixes with all three type 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 fly ash has been selected as filler material for further investigation considering its wide availability, low cost price and environment protection.

1. EFFECT OF FIBRE ON BC

For preparation of mix binder content vary from 4 to 7% and fibre content vary from 0.3% to 0.5%. Here OBC, OFC and other Marshall properties is calculated by Marshall Method.

Marshall Stability

It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases. Also stability value increases with increase fibre content and further addition of fibre it decreases. Variation of Marshall Stability value with different binder content with different fibre is given fig 7.

Table 5 Maximum Marshall Stability values and their corresponding binder content

Fibre content (%) >		0		0.3		0.5
BC with binder	Max. Stability (KN)	Binder Content (%)	Max. Stability (KN)	Binder Content (%)	Max. Stability (KN)	Binder Content (%)
60/70	14.38	5	14.55	5	14.1	5

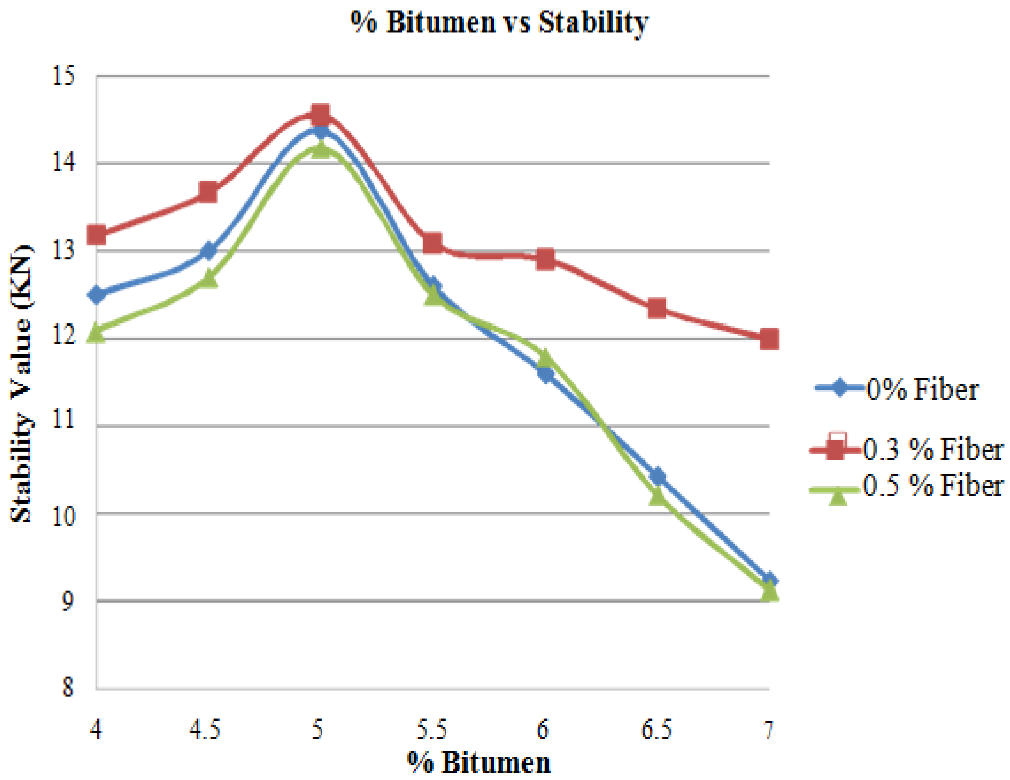

Fig 7 Variation of Marshall Stability of BC with different binder content

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 fibre content is shown in fig 8

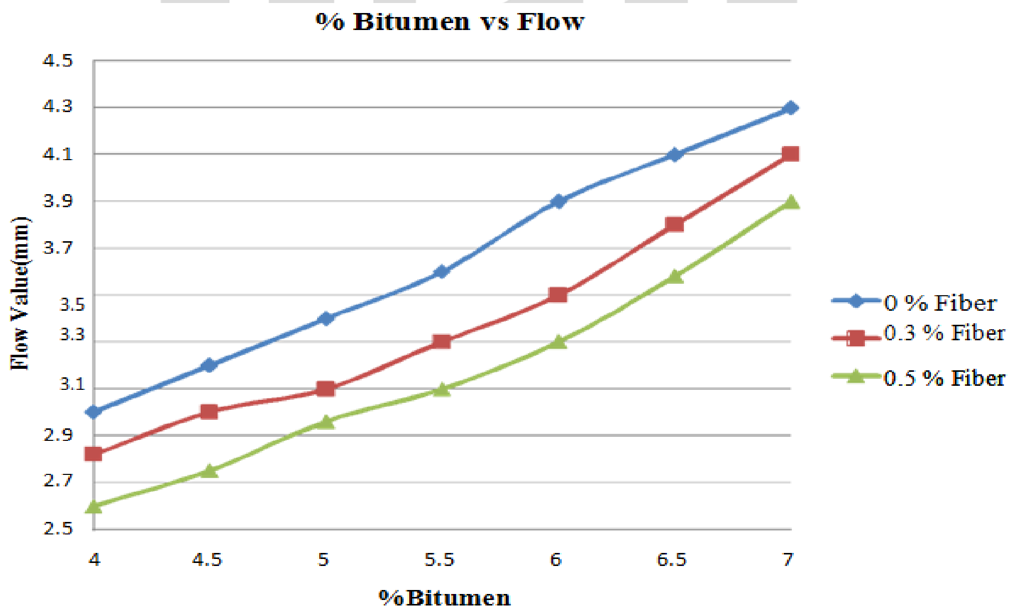

Fig 8 Variation of Flow value of BC with different binder content

3. 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 fibre is given fig 9

Table 6 Maximum unit weight values and their corresponding binder content

Fibre content (%) >		0		0.3		0.5
BC with binder	Max. Unit wt.	Binder Content (%)	Max. Unit wt.	Binder Content (%)	Max. Unit wt.	Binder Content (%)
60/70	2.49	5	2.45	5	2.45	5

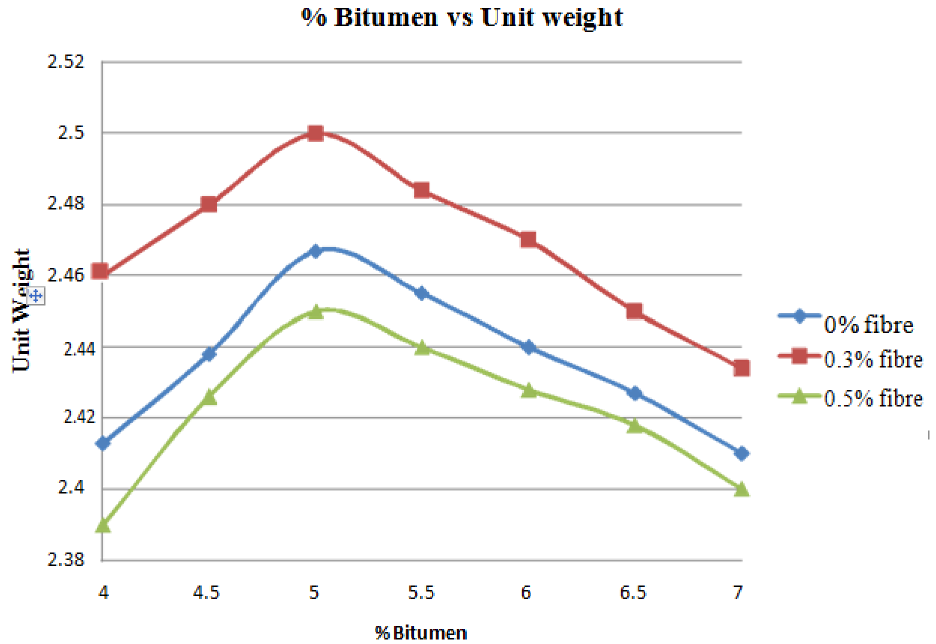

Fig 9 Variation of unit weight of BC with different binder content

4. Air Void

It is observed that with increase binder content air void decreases. Variation of air void content with different fibre content is given fig MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4.5% of air void given below table 8

Table 8 binder content corresponding to 4.5% of air void

BC with fibre content (%)	Air void (%)	Corresponding Binder Content (%)
0	4.5	5
0.3	4.5	6
0.5	4.5	6.5

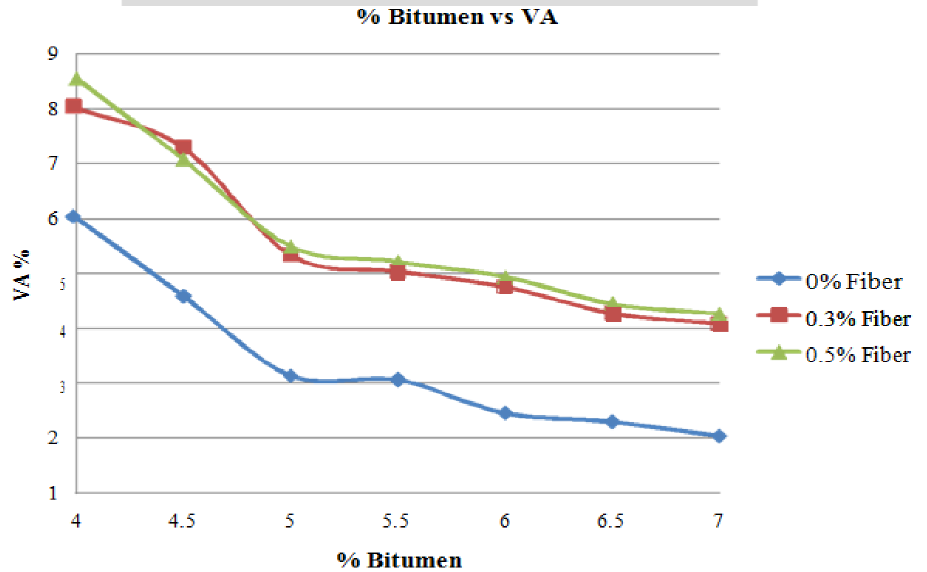

Fig 10 Variation of Air Void of BC with different binder content

5. 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 fibre content is shown in Fig 10

V. CONCLUSTIONS

A. General

Based on the results and discussion of experimental investigation carried out on mixes i.e. SMA and BC following conclusion are drawn. BC with different type of filler

As per MORTH Specification mix design requirements of bituminous mix is given in table 1

Table 1 MORTH Specification mix design requirements of bituminous mix

Property	Value
Marshall stability (KN at 60°C)	>9KN
Flow Value (mm)	2-4
Air Void (%)	3-6
VFB (%)	65-75
OBC (%)	5-6

As BC made of from all the three type filler satisfy above requirements we can use them as filler.

Although BC with cement as filler gives maximum stability, as it is costly we can also use fly ash and stone dust as filler material. Use of fly ash is helpful in minimise industrial waste.

BC With different Fibre content

Here OBC is 5%, OFC is found as 0.3%

- By addition of fibre up to 0.3% Marshall Stability value increases and further addition of fibre it decreases. But addition of fibre stability value not increased as high as SMA.
- By addition of fibre flow value also decreases as compare to mix without fibre, but addition of 0.5% fibre again flow value increases.

SMA With different Fibre content

Requirements of SMA according to IRCSP-79-2008 IS given in table

Table 2 IRCSP79-2008 Specification mix design requirements of SMA

Property	Value
Void (%)	4
Binder Requirement (%)	5.8 min
VMA (%)	17
OFC (%)	SHOULD NOT EXCEED 0.3%

Here OBC is 5.2% and OFC is 0.3%.

It is found that for SMA without fibre has binder requirement 5.8%, By addition of sisal fibre 0.3% to SMA this value is decreases to 5.2%. and further addition of fibre it increases up to 6 which leads to maximum drain down.

- By addition of 0.3%fibre to SMA Stability value increases significantly and further addition to it, stability decreases.
- By addition of 0.3%fibre to SMA flow value decreases and further addition of fibre flow value increases. Main advantage of using fibre is that air void in mix decreases. Drain down of binder decreases.MIX at their OBC and OFC

Different test like Drain down test, Indirect Tensile Strength (ITS), Static creep test is done on MIX at their OBC, OFC and its conclusion is given below.

- Drain down of SMA is more than BC without fibre. At their OFC drain down of binder is decreases.
- From Indirect Tensile Strength it is concluded that Tensile Strength of SMA is more than BC.
- From Static Creep Test it is concluded that by addition of fibre to BC and SMA mixes deformation reduced. MORTH recommended that permanent deformation should not be more than 0.5 mm. SMA sample with fibre shows deformation about 0.45mm which is good.

Concluding Remarks

Here two type of mix i.e. SMA and BC is prepared where 60/70 penetration grade bitumen is used as binder. Also a naturally available fibre called sisal fibre is used with varying concentration (0 to 0.5%). OBC and OFC is found out by Marshall Method of mix design. Generally by adding 0.3% of fibre properties of Mix is improved. From different test like Drain down test, Indirect Tensile Strength and static creep test it is concluded that SMA with using sisal fibre gives very good result and can be used in flexible pavement.

FUTURE SCOPE

Many properties of SMA and BC mixes such as Marshall Properties, drain down characteristics, tensile strength characteristics have been studied in this investigation. Only 60/70 penetration grade bitumen and a modified natural fibre called sisal fibre have been tried in this investigation. However, some of the properties such as fatigue properties, moisture susceptibility characteristics, resistance to rutting and dynamic creep behaviour can further be investigated. Some other synthetic and natural fibres and other type of binder can also be tried in mixes and compared. Sisal 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. Moreover, to ensure the success of this new material, experimental stretches may be constructed and periodic performances monitored.

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