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A LABORATORY STUDY OF BITUMINOUS MIXES WITH AN ADDITION OF ANATURAL FIBRE

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AbstractL: 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.

Keywords: Bituminous Concrete (BC), Stone Matrix Asphalt (SMA), Sisal Fibre, Marshall Properties, Static Indirect Tensile Strength, Static Creep

I. INTRODUCTION

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.

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
- Sufficient workability to permit easy placement without segregation
- Sufficient resistance to avoid premature cracking due to repeated bending by traffic
- Sufficient resistance at low temperature to prevent shrinkage cracks

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 a comparative study is done between BC and SMA with and without using fibre where 60/70 penetration grade bitumen is used as binder.

Different stabilizing additive like fibre such as cellulose fibre, mineral fibre etc., many polymer, plastic, waste material such as carpet fibre, tires, polyester fibre are added to bituminous mix mainly with Stone Matrix Asphalt to prevent excessive draindown of binder. Natural fibre like jute fibre and coconut fibre are also used by many researchers.

Here an attempt has been made in this research work to utilise a naturally available fibre called SISAL FIBRE in bituminous mixture both in Bituminous Concrete (BC) as well as Stone Matrix Asphalt (SMA).

II. LITERATURE REVIEW

The relevant literature on present study was thoroughly reviewed and presented here.

Bradely et al. (2004) studied Utilization of waste fibres in stone matrix asphalt mixtures. They used carpet fibre and polyester fibres and waste tires to improve the strength and stability of mixture compared to cellulose fibre. They found waste tire and carpet fibre are effective in preventing excessive drain down of SMA mixture also found that tensile strength ratio of mixes more than 100% , it means fibre don't weaken the mixture when expose to moisture. Addition of tire and carpet fibre increases toughness of SMA. They found no difference in permanent deformation in SMA mix containing waste fibres as compared to SMA mix containing

cellulose or mineral fibre.
Kamaraj et al. (2004) carried laboratory study using natural rubber powder with 80/100 bitumen in SMA by wet process as well as dense graded bituminous mix with cellulose fibre and stone dust and lime stone as filler and found its suitability as SMA mix through various tests.
Punith et al. (2004) did a comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) .The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep and aging.
Reddy et al. (2004) used Crumb Rubber (CR) OBTAINED from discarded tire with 80/100 penetration grade bitumen in SMA and concluded that it improves fatigue and permanent deformation characteristics, greater resistance to moisture damage than normal mixes.
Ibrahim M.asi(2005) performed different test like Marshall stability test, loss of Marshall stability, tensile strength, loss tensile strength, resilient modulus, fatigue life, rutting resistance were conducted on both SMA and DGM . He concluded that though DGM have high compressive strength and tensile strength; SMA have higher durability, high resilience property, high rutting resistance as compare to DGM. Hence SMA is preferable in hot climate weather.
Muniandy and Huat (2006) used Cellulose oil palm fibre (COPF) and found fibre-modified binder showed improved rheological properties when cellulose fibres were pre blended in PG64-22 binder with fibre proportions of 0.2%,0.4%,0.6%,0.8 %and 1.0% by weight of aggregates. It showed that the PG64-22 binder can be modified and raised to PG70-22 grade. The Cellulose oil palm fibre (COPF) was found to improve the fatigue performance of SMA deign mix. The fatigue life increased to a maximum at a fibre content of about 0.6%, while the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fibre content of 0.6%.
Kumar et al.(2007) studied on 2 type of fibre. Tried to use a fibre in SMA by taking jute fibre which is coated with low viscosity binder and compare the result with a imported cellulose fibre (a cellulose fibre imported from Germany) using 60/70 grade bitumen. and found optimum fibre percentage as 0.3% of the mixture. Jute fibre showed equivalent results to importedpatented fibres as indicated by Marshall Stability Test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fibre showed better result than patented fibre.
Mustafa and Serdal (2007) used waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall test and showed good result.
Chiu and Lu (2007) used asphalt rubber (AR) produced by blending ground tire rubber (GTR) (i) 30% of a coarse GTR with a maximum size of #20 sieve and (ii) 20% of a fine with a maximum size of #30 sieve with an asphalt, as a binder for SMA and found AR-SMA mixtures were not significantly different from conventional SMA in terms of moisture susceptibility and showed better rutting resistance than that of conventional dense graded mixture.
Shaopeng Wu et al. (2007) used basic oxygen slag as aggregate with PG76-22 modified binder and lime stone as filler and chopped polyester fibre in SMA and concluded that experimental SMA is superior than convectional SMA.

Xue et al. (2008) used municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler and Basic Oxygen Furnace (BOF) Slag as part of coarse aggregate with polyester fibre of 6.35 mm in length obtained from recycled raw materials, PG76-22 binder in the SMA mix and performed Marshall and super pave method of design and found it’s suitability for use in the SMA mix.
C.S Bindu , Beena K.S. (2010) used shredded waste plastic as stabilizing agent in stone matrix asphalt mixture and compare its property with SMA without stabilizing agent. Marshall Test, compressive strength test, tensile strength test, tri axial test were performed with varying percentage of bitumen (6-8%) and different percentage of plastic (6-12%) by wt. of mix.

Jony Hassanet.al.(2010) studied effect of using waste glass power as mineral filler on Marshall property of SMA by comparing with SMA where lime stone, ordinary Portland cement was taken as filler with varying content (4-7%) . Optimum glass power content was found 7%. By using glass power as filler in SMA its stability increases up to 13%, flow value decreases up to 39%, density also decreases as compare to SMA contains lime stone and cement filler.

III. OBJECTIVE OF STUDY

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, objectives of which are;
- To study of Marshall Properties of BC mixes using three different types of fillers withoutfibre(fly-ash, cement, stone dust)
- To study of BC mixeswith fly ash as filler and sisal fibre as stabilizer
- To study of SMA mixeswith 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.

IV. MATERIALS AND METHODS

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 1Adopted 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

Table 3 Physical Properties of Aggregates

Property	Test Method	Test Result
Aggregate Impact Value (%)	IS: 2386 (P IV)	14.3
Aggregate Crushing Value (%)	IS: 2386 (P IV)	13.02
Los Angels Abrasion Value (%)	IS: 2386 (P IV)	18
Flakiness Index (%)	IS: 2386 (P I)	18.83
Elongation Index (%)	IS: 2386 (P I)	21.5
Water Absorption (%)	IS: 2386 (P III)	0.1

Filler: Aggregate passing through 0.075 mm IS sieve is called as filler. Here cement, fly ash and Stone dust are used as filler whose specific gravity are 3.0, 2.2, 2.7 respectively.
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 BC as well as SMA with or without using fibre.
Binder: Here 60/70 penetration grade bitumen is used as binder for preparation of Mix, whose specific gravity was 1.01. Its important properties are given in table 4.

Table 4 Properties of Binder

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

Fibre: Here sisal fibre is used as additive whose length is about 900 mm. and diameter varied from 0.2 to 0.6 mm. The sisal fibres were cleaned and cut in to small pieces of 15-25 mm in length to ensure proper mixing with the aggregates and binder during the process of mixing.
TESTS ON MIXES:
Presented below are the different tests conducted on the bituminous mixes with variations of binder type and quantity, and fibre 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.
Drain down test: There are several methods to evaluate the drain-down characteristics of bituminous mixtures. The drain down method suggested by MORTH (2001) was adopted in this study. The drainage baskets fabricated locally according to the specifications given by MORTH (2001) is shown in Figure 3.3. The loose un-compacted mixes were then transferred to the drainage baskets and kept in a pre-heated oven maintained at 150°C for three hours. Pre-weighed plates were kept below the drainage baskets to collect the drained out binder drippings. From the drain down test the binder drainage has been calculated from the equation :-
Drain down equation is

$$d = W2 - W1/1200 + X$$

Where
$W1$ = initial mass of the plate
$W2$ = final mass of the plate and drained binder
X = initial mass of fibres in the mix
For a particular binder three mixes were prepared at its optimum binder content and the drain down was reported as an average of the three. Figure 3.3 shows the drainage of 60/70 bitumen.
Indirect Tensile Strength Test: Indirect tensile test is used to determine the indirect tensile strength (ITS) of bituminous mixes. In this test, a compressive load is applied on a cylindrical specimen (Marshall Sample) along a vertical diametrical plane through two curved strips the radius of curvature of which is same as that of the specimen. A uniform tensile stress is developed perpendicular to the direction of applied load and along the same vertical plane causing the specimen to fail by splitting. This test is also otherwise known as splitting test. This test can be carried out both under static and dynamic (repeated) conditions. The static test provides information about the tensile strength,

modulus of elasticity and Poisson's ratio of bituminous mixes.
Static Indirect Tensile Test: The static indirect tensile strength test has been used to evaluate the effect of moisture on bituminous mixtures.
Static Creep Test: For Static Creep test sample were prepared at their OBC and OFC. The test consists of two stages. In first stage a vertical load of 6 KN is applied for 30 min. The deformation was registered during these 0, 10, 20, 30 min using a dial gauge graduated in units of 0.002 mm and it was able to register a maximum deflection of 5 mm. Secondly, the load was removed and its deformation had been registered during next 10 min interval of time i.e. 40, 50, 60min. Here throughout the test temperature is maintained 40°C.

V. RESULTS AND DISCUSSIONS

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 1.

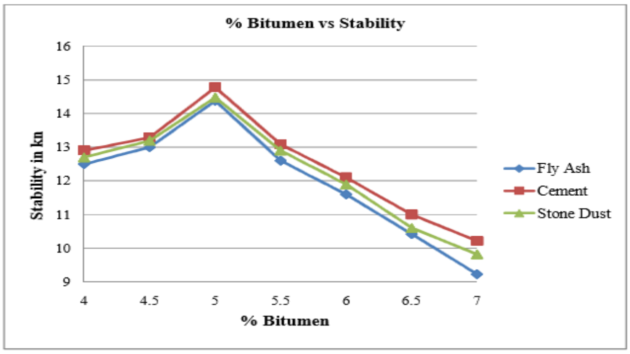

Fig 1 Variation of Marshall Stability of BC with different binder content

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 2.

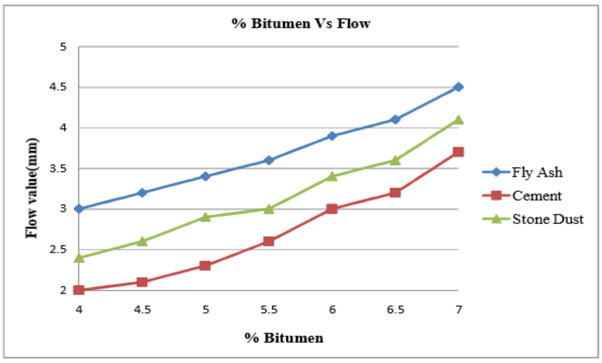

Fig 2 Variation of Flow Value of BC with different binder content (With different type of filler)

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

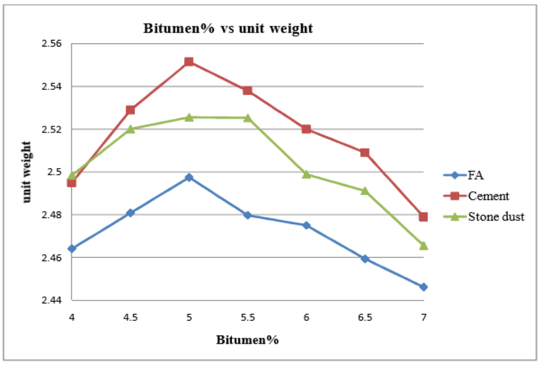

Fig 3 Variation of unit weight Value of BC with different binder content (With different type of filler)

Air Void: It is observed that with increase binder content air void decreases. Variation of air voidwith different binder content is given fig 4.

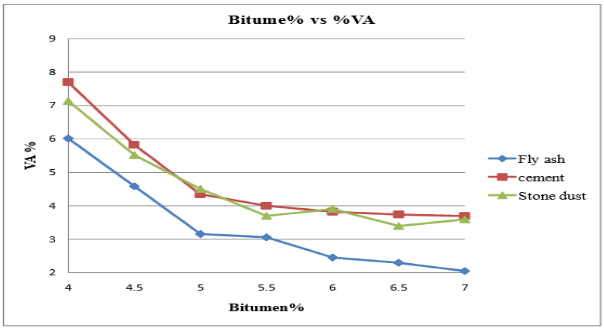

Fig 5 Variation of air void of BC with different binder content (With different type of filler)

EFFECT OF FIBRE ON BC:

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 6.

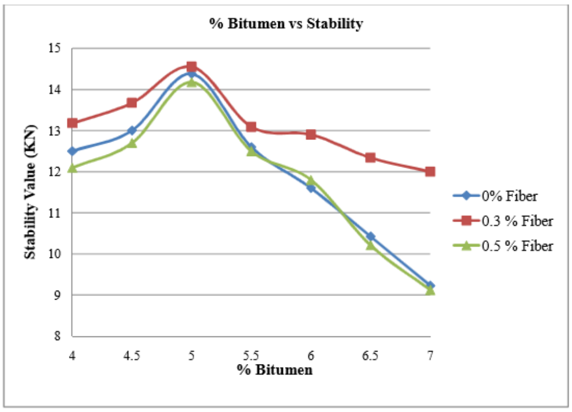

Fig 6 Variation of Marshall Stability of BC with different binder content (With different fibre content)

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 fibre content is shown in fig 7.

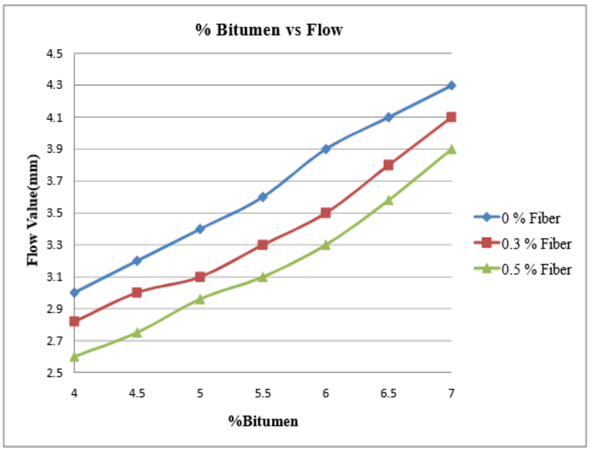

Fig 7 Variation of Flow value of BC with different binder content (With different fibre content)

Unit weight: It is observed that unit weight increases with increase binder content up to certain binder content; then decreases.

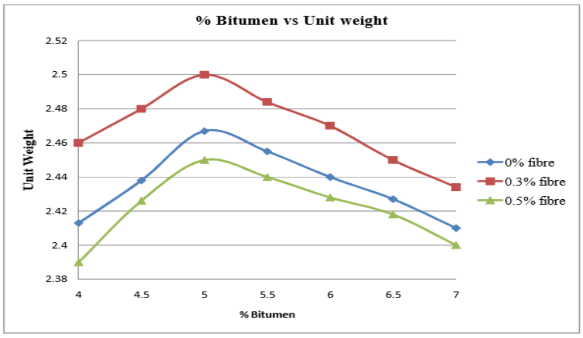

Fig 8 Variation of unit weight of BC with different binder content(With different fibre content)

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 9. MORTH recommended it should be lies between 3 to 6%.

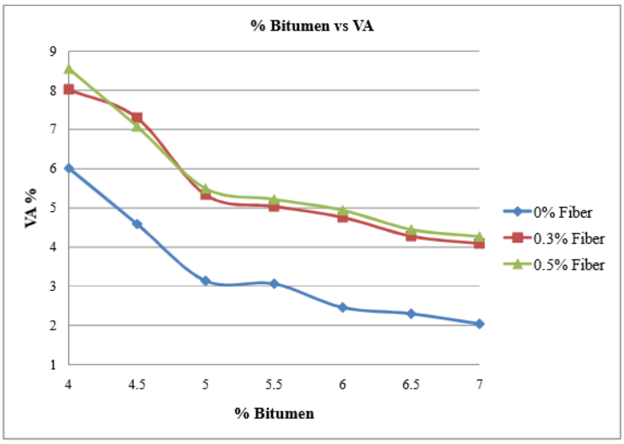

Fig 9 Variation of Air Void of BC with different binder content (With different fibre content)

EFFECT OF FIBRE ON SMA:Here result of variation of Marshall Properties with different binder content where fibre content is taken as 0%, 0.3%, and 0.5% is explained below.

Marshall Stability:

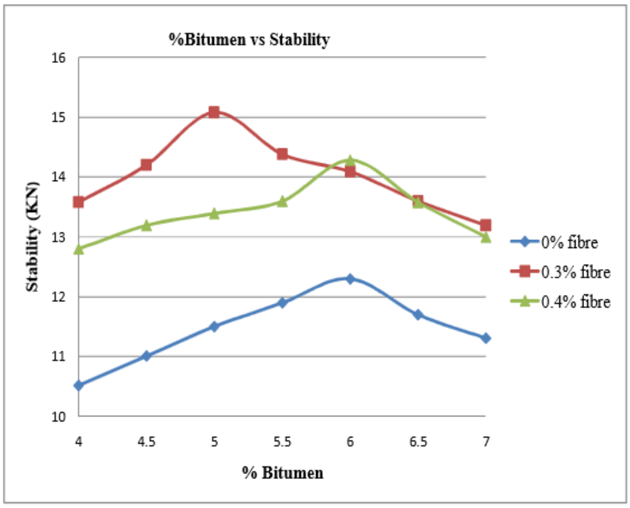

Fig 10 Variation of Stability Value of SMA with different binder content (With different fibre content)

Flow value:

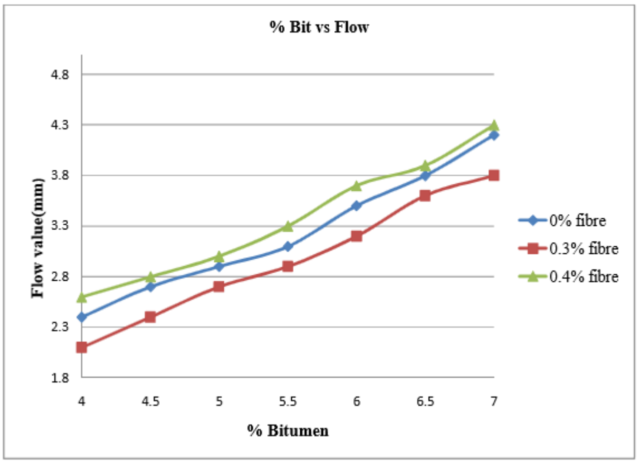

Fig 11 Variation of Flow Value of SMA with different binder content (With different fibre content)

Unit Weight:

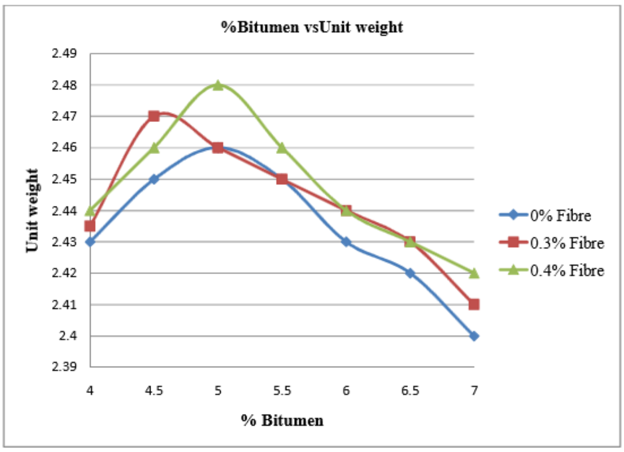

Fig 12 Variation of Unit Weight Value of SMA with different binder content (With different fibre content)

Air Void:

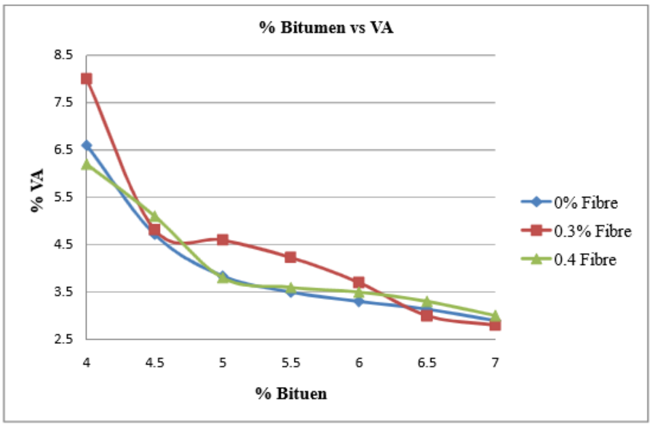

Fig 13 Variation of Unit Weight Value of SMA with different binder content (With different fibre content)

Static Creep Test:

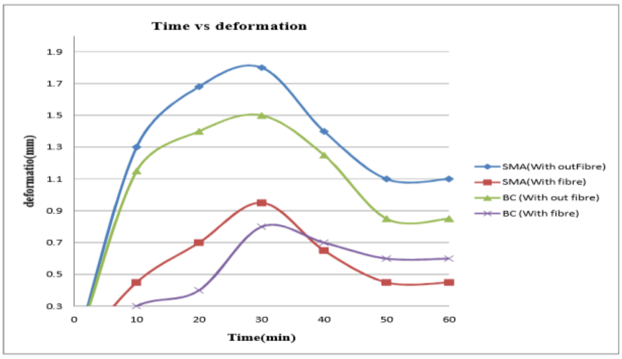

Fig 4.21 Deformation of SMA and BC (with and without fibre)

VI. CONCLUSIONS

From the present study the following conclusions are drawn:

1. As BC made from all the three type filler satisfies requirements for bituminous mix, 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.
2. In present studyfor BC Optimum Binder Content is 5%, Optimum Fibre Content is found as 0.3%
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.
4. By addition of fibre flow value also decreases as compare to mix without fibre, but addition of 0.5% fibre again flow value increases.
5. For SMA, OBC is 5.2% and OFC is 0.3%..
6. 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 lead to maximum drain down.
7. By addition of 0.3%fibre to SMA Stability value increases significantly and further addition to it, stability decreases.
8. By addition of 0.3%fibre to SMA flow value decreases and further addition of fibre flow value increases.
9. Main advantage of using fibre is that air void in mix decreases.
10. At OFC, drain down of binder decreases.

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