LABORATORY INVESTIGATION ON STONE MATRIX ASPHALT USING BANANA FIBER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

BY

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108CE017

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA-769008

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UNDER THE GUIDANCE OF

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ROURKELA

Certificate

This is to certify that the Project Report entitled "**LABORATORY INVESTIGATIONS ON STONE MATRIX ASPHALT USING BANANA FIBRE FOR INDIAN ROADS**" submitted by **Mr.RAVADA SURENDRA DIKSHITH** in partial fulfilment of the requirements for the award of Bachelor Of Technology Degree in Civil Engineering at National Institute Of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma

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Abstract

The technology and usage of the asphalt materials and mixtures is first discovered and mostly used in European countries and North America. The SMA (stone matrix asphalt) mixture is a gap-graded mix which is characterized by high coarse aggregates, high asphalt contents and fiber additives as stabilizers. In this present research, an attempt has been made to study the engineering properties of mixtures of stone matrix asphalt with and without fiber. Here fiber used is a non-conventional natural fiber, namely banana fiber. This research was done to check the suitability of banana fibre as stabilising agent in the mixture by laboratory tests in which a flow parameter and stability were analyzed, as well as the mechanical properties of the mixture. Here for the stone matrix asphalt mix the aggregate gradation is taken based on the MoRTH specification and the binder content is 4%, 4.5%. 5%, 5.5%, 6%, 6.5%, 7% by weight of aggregate and fibre used is 0.3% by weight of aggregate. Here cement is used as filler and binder used is 60/70 grade bitumen.

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Nomenclature:

SMA - Stone Matrix Asphalt or Stone Mastic Asphalt

MoRTH - Ministry of Road Transport and Hghways

Gsb - Bulk specific gravity of aggregates

Gse - Effective specific gravity of aggregates in mix

Ga - Apparent specific gravity of aggregates

Gmm - Theoretical maximum specific gravity of the mix

Gmb - Bulk Specific gravity of the mix

VMA - Voids in mineral aggregates

VA - Air void VFB - Voids filled with bitumen

Wpca - Wt. of wax coated sample in air

Wpcw - Wt. of paraffin coated sample in water

Ws - Wt. of sample in air

Bvs - Bulk volume of sample

CHAPTER 1
INTRODUCTION

1.1 introduction

Stone matrix asphalt (SMA) was developed in Germany in 1960s by Zichner of the Straubag-Bau AG central laboratory, to resist the damage and tear caused by studded tires. As this SMA showed very good resistance to deformation by heavy traffic at high temperatures, its use is continued even after the ban of studded tires.

Stone Matrix Asphalt (SMA) is a gap-graded mixture, which is having a better stone to stone contact and also gives better strength to mixture. . In this research work aggregates are used as per MoRTH specification which is taken from same lot. The samples are made by using aggregate with different gradations, cement as filler and bitumen (60/70) as filler. Here fibres are used as stabilizers. Here fibre helps in decreasing the drain down and also to increase the strength of mix and stability of the SMA mix. The apparatus which test these SMA mix samples is Marshall apparatus. In this experiment comparison of SMA mix with and without fibre is done. Many research works are done mainly by using cellulose fibre, synthetic fibre, polypropylene fibre and polyester fibres. Cellulose fibres are mostly used in SMA made in Europe and USA. The fibres improve the properties of the SMA mix by forming a type of micromesh in the asphalt mix to prevent the drain down of the asphalt so that it will increase the stability and durability of the mixture. Here we tried using banana fibre in place of cellulose fibres, which does same work as that of cellulose fibre. The higher the binder content it makes the mix durable. The fibres or modifier holds the binder in the mixture at high temperature; and prevent drainage during production, transportation and laying.

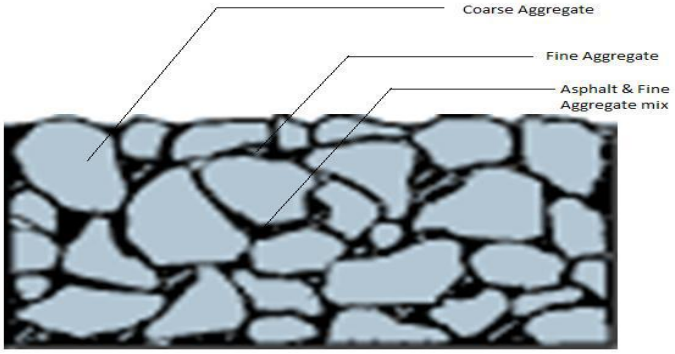


Fig 1. Gap graded mix structure

Stone matrix asphalt (SMA) has been proved as most cost effective than dense graded mixes for high volume roads. Brown (1992) observed that many number of factors will influence the performance of SMA mixtures, as changes in binder source and grade of mix, types of aggregate, environmental conditions, production and methods of construction etc. Good study of these factors would help to determine the long term performance of SMA and provides information so that changes can be made to suit different environmental conditions.

The FHWA SMA Technical Working Group defined SMA as "A gap graded aggregate hot mix asphalt which will maximize the binder content and coarse aggregate fraction and provides a stable stone-on-stone skeleton that is held together by a rich mixture of filler, binder and stabilizing additives".

1.1.1 Advantages of stone mix asphalt over conventional mixes:

The Conventional bituminous pavements have less strength, durability and longevity than SMA. There are several factors for which we can say that SMA is better than many conventional mixes. As mentioned by Bose et al. (2006) SMA provides excellent resistance to rutting due to slow, heavy and high volume traffic, resistance to deformation at high pavement temperatures, it also improves skid resistance, reduces noise when compared to conventional alternative pavement surfaces. SMA also shows improved resistance to fatigue effects and cracking at low temperatures, also increases durability, and reduces permeability

and sensitivity to moisture. According to Brown and Manglorkar (1993) SMA also shows good resistance to plastic deformation under heavy traffic loads with high tyre pressures as well as good low temperature properties. Also SMA has a rough texture which gives good friction properties after the upper surface film of the binder is removed by the traffic. Although the cost of SMA is 20-25 percent more compared to conventional pavements, it can be justified by its increased life span of pavements. Because of all these advantages SMA has been proved to be superior over HMA mixes.

The stabilizing additives like cellulose fibers, mineral fibers and many different types of synthetic polymers, which are used to prevent the drain down of the binder from the mixture, are either costly or not easily available in India. So here we tried using some unconventional fibers (waste fibers) to be used in SMA.

1.1.2 Banana fiber:

Banana plant not only gives delicious fruits but also gives a good textile fiber namely, banana fiber. It is most commonly found in tropical and hot climates. The fibers are obtained once the fruits are harvested and they fall in the group of bast fibres. Almost all the varieties of banana plants have fibre in abundance.

Extraction on banana fiber:

The extraction methods will vary from place to place and country and country but the most popular and easy ways are found in India.

Characteristics of banana fibre:

Banana fiber is a natural bast fiber and like all other fibers it has its own physical and chemical properties and other characteristics which makes this fiber a fine quality fiber.

1. In appearance it looks almost like bamboo fiber and ramie fiber but it betters in fineness and spinability.

2. The chemical composition includes cellulose, hemicellulose and lignin

3. It is highly strong fiber and has smaller elongation

4. Depending on type of extraction and spinning process it may appear somewhat shiny.

5. It is light weight and has strong moisture absorption quality. It fastly absorbs and releases moisture.

6. It is bio degradeable and has no effect on environment and so it is environment friendly.

7. Average fineness of banana fiber is about 2400 nm.

Fig 2 banana fibre (stabilizer)

1.2 Literature review:

In the year 1980's federal and state highway officials in the United States recognized the need to design stiffer, more rut resistant pavements. As a result, American professionals participated in the European Asphalt Study Tour in 1990, where SMA pavements were investigated. This was the first concerted effort to figure out how to use SMA.

Bradely et.al. (2004) studied on Utilization of waste fibres in stone matrix asphalt mixtures. They used carpet, tire and polyester fibres and other materials to improve the strength and stability of mixture compared to cellulose fibre. They found no difference in moisture susceptibility and permanent deformation in SMA mix containing waste fibres as compared to the SMA mix which contains cellulose or mineral fibre.

Kamaraj C., G. Kumar, G. Sharma, P.K. Jain and K.V. Babu (2004) carried laboratory study by using natural rubber powder with 80/100 bitumen in SMA by wet process and also 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 V.S., Sridhar R., Bose Sunil, Kumar K.K., Veeraragavan A (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.

Muniandy R., Huat, B.B.K. (2006) used Cellulose oil palm fiber (COPF) and found fiber-modified binder showed improved rheological properties when cellulose fibers were preblended in PG64-22 binder with fiber 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 fiber (COPF) was found to improve the diameteral fatigue performance of SMA deign mix. The fatigue life increased to a maximum at a fiber content of about 0.6%, whilst the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fiber content of 0.6%.

Kumar Pawan, Chandra Satish and Bose Sunil (2007) tried to use an indigenous fiber in SMA Mix by taking low viscosity binder coated jute fiber instead of the traditionally used fibers and compared the result with the imported cellulose fiber, using 60/70 grade bitumen and found optimum fiber percentage as 0.3% of the mixture. Jute fiber showed equivalent results to imported patented fibers as indicated by Marshall stability test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fiber showed better result than patented fiber.

Chui-Te Chiu, Li-Cheng Lu, (2007) used asphalt rubber (AR),produced by blending the 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 these mixtures were not significantly different from that of conventional SMA in terms of moisture susceptibility but showed better rutting resistance than that of conventional dense graded mixture.

1.3 Objectives:

- The very main objective of this project is using some non conventional fibres such as banana fiber in place of other conventional fibre and to study the affect on various properties of SMA.
- Preparation of marshall specimens and to get optimum mix content by using marshall apparatus
- To find the suitability of banana fiber for use in SMA
- To compare the engineering properties of SMA samples with other similar type test results

Chapter 2

Experimental overview

2.1 Materials used:

1. Coarse and Fine aggregate
2. Bitumen as binder (60/70)
3. Fibre as stabilizer (Banana fibre)
4. Cement (filler)

Coarse and fine aggregates:

The aggregates are crushed by using jaw crusher to get different sizes of aggregates which vary from 16mm to 75micron. Quality of aggregates are checked through various tests as per MoRTH

2.1.1 Impact value test:

The ratio of the weight of fines formed to the total sample weight in each test shall he expressed as a percentage, the result being recorded to the first decimal place:

Aggregate impact value = (B/A) x 100 where

B=weight of fraction passing 2.36-mm IS Sieve, and

A =weight of oven-dried sample

SL NO	WT. OF OVEN DRIED SAMPLE (gm)	WT. OFAGGREGATE RETAINED TROUGH 2.36mm SIEVE (gm)	WTOF PASSING AGGREGATE (gm)	IMPACT VALUE	AVG. IMPACT VALUE
1	673.5	602.4	71.1	10.56	
2	693.1	619.4	73.7	10.63	11.06
3.	678	605.4	72.6	11.99	

Table 1. tabulation for determining of Impact value

2.1.2 Los Angel's Abrasion Value (IS 2386 -Part1)

The test sample and the abrasive charge will be placed in the Los Angeles abrasion testing machine and the machine is rotated at a speed of about 20 to 33 rev/min. The machine will be rotated for about 500 revolutions. Difference between the original weight and the final weight of the test sample is taken and is expressed as a percentage of the original weight of the test sample. This value shall be reported as the percentage of wear/abrasion value.

Wt. Of oven dried sample (in gm)	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm) B	Abrasion Value
5000	4251	749	14.98

Table 2. showing abrasion value

2.1.3 Flakiness and Elongation Index

Size In mm	Size In mm	Aggregate passing in the gauge in gm.	Flakiness index	Sieve size in mm	Aggregate retained in the elongation gauge in gm	Length of gauge (mm)	Wt of aggregate retained (gm)	Elongation index
63-50	63-50	0	8.4	50-40	1082	81	0	19.9
50-40	50-40	0		40-25	1240	58	350	
40-31.5	40-31.5	82		25-20	1212	40.5	308	
31.25-25	31.25-25	50		20-16	592	32.4	216	
25-20	25-20	174		16-12.5	60	25.06	36	
20-16	20-16	108		12.5-10	6	20.2	0	
16-12.5	16-12.5	0		10-6.3	0	14.2	0	
12.5-10	12.5-10	0						
10-6.3	10-6.3	0						

Table 3. tabulation for determination of flakiness and elongation index

2.1.4 Water Absorption Test:

Water absorption is given by equation: $\frac{W1-W2}{W2} * 100$

Where W1= Weight of saturated dry sample

W2= Weight of material + basket suspended in water

Weight of saturated sample W1(gm)	Weight of material + basket suspended in water W2(gm)	Water absorption(%)
1996	2014	0.90

Table 4. tabulation for determination of water absorption value

- **Specific Gravity Test:**
  Specific gravity of coarse aggregate is determined by $\frac{W1}{W1-(W3-W2)} * 100$

Where W1= Weight of saturated dry sample.

W2=Weight of dry basket

W3=Weight of basket+ material in water

Weight of dry basket W2(gm)	Weight of basket+material in water W3 (gm)	Weight of saturated dry sample W1(gm)	Specific gravity
886	1275	2000	2.76

2.2 Selection of binder:

Many researchers have used many types of binders one being, conventional 60/70 Penetration grade bitumen and many other modified binders such as Polymer Modified Binder (PMB), Crumb Rubber Modified Binder (CRMB), Natural Rubber Modified Binder (NRMB) etc. in stone matrix asphalt(SMA) mixes. In this research work we used 60/70 bitumen as binder.

2.3 Selection of stabilizing additive:

Because SMA is a gap graded mix it has more air void content and high concentration of binder. So to prevent drain down of the binder stabilizing additives are added to the mixture. in order to solve this drain down problem many fibers such as cellulose fibers, mineral fibers etc., and many polymers, plastics in pellet or powder form, waste materials such as carpet fiber, tires, polyester fiber, natural fiber such as jute fiber have been tried by various investigators in SMA mixes. Here we used banana fiber , a natural fiber as a stabilizing agent.

Many research works are carried before to check the influence of fibre in stone matrix asphalt (SMA) mix. Chui-Te Chiu and Li-Cheng Lu (2006) done a laboratory study on stone matrix asphalt (SMA) by using ground tire rubber. Asi Ibrahim M (2003) used mineral fibre of 0.3 percentage in Laboratory comparison study for the use of stone matrix asphalt in hot weather conditions. Also (Bradley J. Putman and Serji N.Amirkhanian, 2004) both done research on Utilization of waste fibers in SMA mixtures. (Huaxin Chen, Qinwu Xu) done a laboratory study on fibres in stabilizing and reinforcing asphalt binder.

As per MoRTH specification usually 0.3%-0.5% fibre is used in SMA mixtures. In this research study, we used 0.3% fibre by weight of aggregate.

2.4 Filler:

Filler is used in stone matrix asphalt (SMA) mix for better binding of materials. Materials like cement, fly ash ,Rock dust, slag dust, hydrated lime, hydraulic cement, mineral filler etc are used as filler in SMA mix. We can also use the fine aggregate below 75micron as filler, but here in this we use cement as filler which makes a better bond with aggregate, fibre and bitumen

2.4.1 Specific Gravity of filler: The specific gravity of the filler material was determined by Le Chatlier Apparatus. Specific gravity was given by:

Table 5. specific gravity of filler

Sample No	Air temp (oC)	Weight of the cement (gm)	Initial reading of the flask (ml)	Final reading of the flask (ml)	Volume of cement particles (cc)	Specific gravity (gm/cc)	Avg Specific gravity (gm/cc)
1	25	60	0.5	19.5	19	3.15	3.13
2	25	60	0.7	20	19.3	3.11	

2.5 Experimental procedure:

The experiment is performed as follows

2.5.1. Sieve analysis Sieve analysis is performed and aggregates of appropriate sizes are collected and stored in place with sizes as per MoRTH specification. Here weight of one sample is 1200 gms. The distribution of samples are taken as per table above in

Table 6. gradation table for sample with fibre

Sieve size (mm)	%age retained	4%	4.50%	5.00%	5.50%	6.00%	7.00%
		0%	0%	0%	0%	0%	0%
		1148.4	1142.4	1136.4	1130.4	1124.4	1112.4
13.2	5%	57.42	57.12	56.82	56.62	56.22	55.62
9.5	33%	378.972	376.992	375.012	373.032	371.052	376.092
4.75	29.5%	338.778	337.008	335.238	333.468	331.698	328.158
2.36	8%	91.872	91.392	90.912	90.432	89.952	88.992
1.8	3.50%	40.194	39.984	39.774	39.564	39.354	38.934
0.6	2.50%	28.71	28.56	28.41	28.26	28.11	27.81
0.3	2.50%	28.71	28.56	28.41	28.26	28.11	27.81
0.15	4%	45.396	45.696	45.456	45,216	44.976	44.496
0.075	1.50%	17.226	17.136	17.046	16.956	16.866	16.686
Filler	10.50%	120.582	119.952	119.322	118.692	118.062	116.802
Binder		48	54	60	66	72	84
Fiber (gm)		3.6	3.6	3.6	3.6	3.6	3.6

Table 7. gradation table for sample without fibre

Sieve size (mm)	%age retained	4%	4.50%	5.00%	5.50%	6.60%	7.00%
		1152	1146	1140	1134	1128	1116
13.2	5%	57.6	57.3	57	56.7	56.4	55.8
9.5	33%	380.16	378.18	376.2	374.22	372.24	368.28
4.75	29.5%	339.84	338.07	336.3	332.53	332.76	329.22
2.36	8%	92.16	91.68	91.2	90.72	90.24	89.28
1.18	3.50%	40.32	40.11	39.9	39.69	39.48	39.06
0.6	2.50%	28.8	28.65	28.5	28.35	28.2	27.9
0.3	2.50%	28.8	28.65	28.5	28.35	28.2	27.9
0.15	4%	46.08	45.84	45.6	45.36	45.12	44.64
0.075	1.50%	17.28	17.19	17.1	17.01	16.92	16.74
Filler	10.50%	120.96	120.33	119.7	119.07	118.44	117.18
Binder		48	54	60	66	72	84

2.5.2 Preparation of sample:

For sample preparation some steps are given below:

Weighing of sample

Here 6 samples with binder content 4%, 4.5%, 5%, 5.5%, 6%, 6.5% and 7% of each were prepared. So at first weight of all sample were taken as per table 1. Fibre of 0.3% is taken in each of 3 samples.

Heating

After weighing of aggregates is done, aggregates of all gradation are mixed with each other to get one sample of weight 1200gms. All samples are kept in oven at a temperature of 130 centigrade for 24hrs to make sure that fibre is not burnt. care should be taken that sample is not over heated.

Heating of bitumen

60/70 grade bitumen was heated in high temperature get liquefied so that it will mix with all the aggregates and fibre very easily.

2.5.3 Mixing of components

All components like aggregate, cement, bitumen and fibre are mixed thoroughly to make a homogeneous mix sample.

Fig 3. Heating of components

Putting in mould

For preparation the samples the mixture which is prepared is kept in moulds. A standard mould is a cylindrical mould made of iron which has a diameter of 100 mm. The mould is also heated before use to make sure that mixture may not become cold before hammering.

Compaction

After putting the aggregate mixture in mould hammering was performed. A standard hammer was used for hammering. Usually hammering was performed by giving 50 or 75 blows to each side of the specimen. In this research each sample was given 50 blows each on both the faces of the specimen . For hammering, first of all, the mould was attached to a fixed arrangement to make sure that the mould is not disturbed or staggered during hammering. A piece of paper of size of the mould was put in mould over fitting to make sure that the

mixture is not glued to fitting. oiling was also done in inner faces of mould and bottom of hammer to serve the above purpose.

Fig 4. Cylindrical hammer

2.5.4 Finalizing the sample

After hammering is done the sample was taken out of mould.and named according to sample's binder content and sample number are glued to sample to recognize it later on. Later the sample was left in open space to cool down to room temperature. In figure given below a samle is shown.

Fig 5. A typical mould

2.6 EXPERIMENTS PERFORMED

After the sample is prepared it was supposed to undergo Marshall Test. The test was performed as per ASTM D 6927 – 06. This test gives the results of flow value and stability number of the specimen. Before that dry weight of all samples is taken and recorded. Weight of sample in water is also noted. Because the sample has voids and to prevent the water from entering into the voids the specimen was coated with wax fully around the sample. Wax was heated upto liquification and after that the sample is immersed in wax by holding it through a thread holding the sample. Once the sample was dipped fully in wax it is made to cool so that wax is glued to specimen properly.

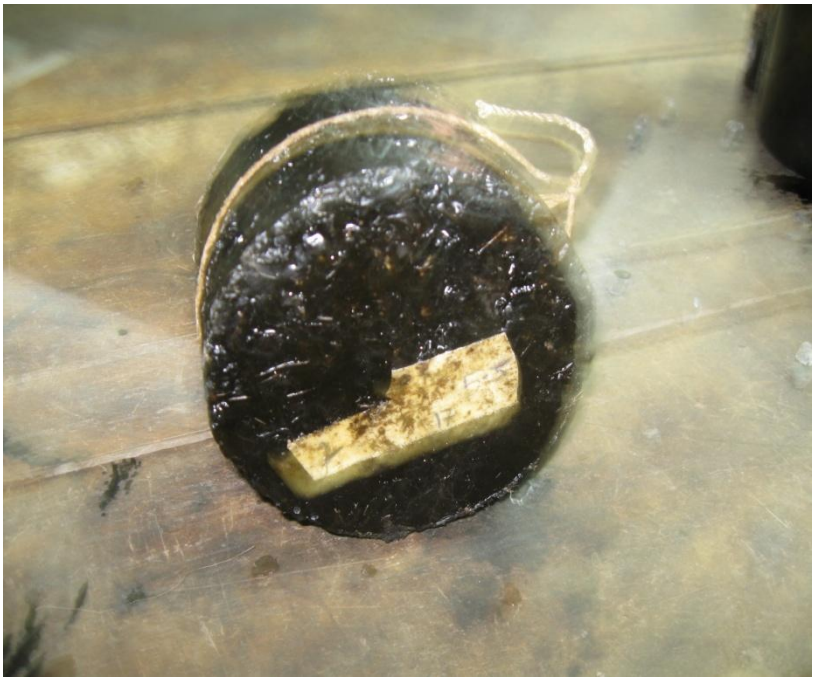


Fig 6. Sample after coated with wax

The above figure shows a wax coated sample. After wax coating is done, the weight of waxed sample is taken. Now weight of sample in water is also taken. After weighing, the sample is kept in water bath before testing up to a maximum of 30 minutes. In water bath temperature of 600 C is maintained throughout the 30 minutes time. overheating is avoided to make sure that wax will not melt and eventually comes out. Maximum of 6 samples can be put in Water bath at a time. Water bath is shown in figures as below:

Fig 7. Waterbath

Once the sample is heated up to 600 C for 30 minutes it is ready for Marshall Test.

2.6.1 Marshall Test

The method of testing of Marshall Test is given in ASTM D 6927-06. The various parts of Marshall Apparatus which is used for testing is as follows:

Breaking Head:

The testing head consists of upper and lower cylindrical segments of cast gray or ductile iron, cast steel, or annealed steel tubing. The lower segment was mounted on a base having two perpendicular guide rods or posts (12.5 mm in diameter) extending upwards. Guide sleeves in the upper segment direct the two segments together without appreciable binding or loose motion on the guide rods.

Compression Loading Machine

The compression loading machine may consist of a screw jack mounted in a testing frame and is designed to load at a uniform vertical movement of 50.8 mm/min.

Load Measuring Device

A calibrated 20 kN ring dynamometer with a dial indicator to measure ring deflection for applied loads is situated. The 20 kN ring has a minimum sensitivity of about 50 N . The dial indicator is graduated in increments of 0.0025 mm or finer. The ring dynamometer is attached to the testing frame and an adapter is provided so as to transmit load to the breaking head. Usually this is called as a proving ring.

Flowmeter

For measurement of flow a dial gauge is used. By using dial gauge we can get the initial and final values during test and their difference is taken as flow value for the sample.

Fig 8. marshall test apparatus

2.6.2 Test procedure

The guide rods and inside surfaces of the test head segments before conducting the test are cleaned thoroughly. Guide rods are lubricated so that the upper test head segment slides freely over them. Excess water from the inside of the testing head segments is wiped. A specimen from the Water bath is removed and placed in the lower segment of the testing head. The upper segment of the testing head on the specimen is placed, and the complete assembly is paced in position in the loading machine. The dial gauge is placed in position over one of the guide rods. The elapsed time from removal of the test specimens from the water bath to the final load determination should not exceed 30 s. Readings of dial gauge and proving ring are recorded. In this case 36 divisions of proving ring were equal to 100 kg.

2.6.3 Drain down test:

Drain down test is done on stone matrix asphalt (SMA) mixes to evaluate the drain down percent of the binder which is used in the mix. It is observed from the drainage test conducted on SMA mixes that there is no drain down of binder in case of all the mixes with fiber. Mixes 60/70 bitumen yield better results with addition of fiber.

2.6.4 Static indirect tensile test

Static indirect tensile tests are carried out to determine tensile strength of the SMA mixes with and without fibres at their OBC and OFC. It is also observed from the results that adding of fiber improves the tensile strength of the mixture. The effect of temperature on tensile strength of these SMA mixes is also being observed using this method as the same is time taking in case of repeated load test. The result values shows that with increase in test temperature the value of tensile strength decreases.

The tensile strength of the specimen was calculated by using the formula given in ASTM D 6931 (2007) .

$St=2000*p/D*t*\prod$

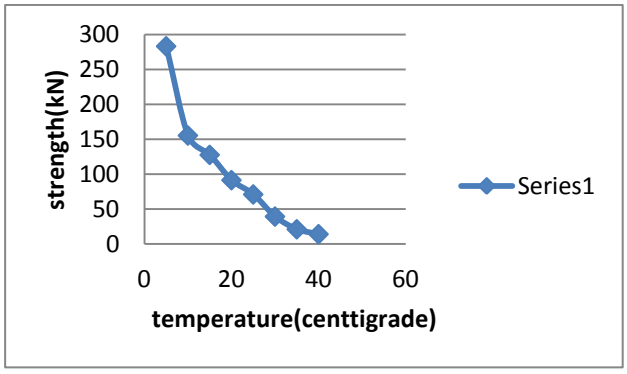
where

S_t = Indirect Tensile Strength, kPa
P = Maximum Load, N
t = Specimen height before testing, mm
D = Specimen Diameter, mm

The test temperature was varied from 5 centigrade to 40 C at an increment of 5 degree Celsius. In this test three Marshall samples were tested at a particular temperature and the tensile strength was reported as the average of the three test results. Figures shows SMA sample with CRMB 60 binder after static indirect tensile testing at temperatures 10°C and 30°C respectively.

Fig 9. Static indirect tensile test

Fig 10. graph showing strength vs temperature (for fiber)



h	temp	load(KN)	avg load	p(N)	St(kN)
6.1	40		50	1486	14.01
6					
5.9	35		75	2229	21.02
6.2					
6	30		140	4160.8	39.245
6.1					
6	25		253	7519.16	70.93
5.9					
6.2	20		326	9688.7	91.4
6					
6.1	15		455	13522.6	127.57
6					
6.1	10		554	16464.8	155.36
6.2					
5.8	5		1015	30017.2	283.181
6					

Table 8. table showing load and temperature for static indirect test

CHAPTER 3

ANALYSIS

3.1 PARAMETERS USED :

Based on volume considered in calculating specific gravity of an aggregate, some definitions of specific gravity are proposed here below. The definitions and other formulae used in calculations hereafter are as follows:

3.1.1. Bulk specific gravity (Gsb) of aggregates

Gsb= Magg/$volume\ of\ (aggregate\ mass + air\ void\ in\ aggregate + absor\ )$
Where Magg is the mass of aggregate.

3.1.2. Effective specific gravity (Gse) of aggregates in mix

Gse = Magg/$volume\ of\ (aggregate\ mass + air\ void\ in\ aggregate)$
Gse = (Mmix –Mb) / (Mmix/Gmm – Mb/Gb)
Where Mb is the mass of bitumen used in mix
Gb is the specific gravity of bitumen

3.1.3. Apparent specific gravity (Ga) of aggregates

Ga = Magg/$Volume\ of\ aggregate\ mass$

3.1.4. Theoretical maximum specific gravity (Gmm) of the mix

Gmm = Mmix/$volume\ of\ (mix - air\ vods)$

3.1.5. Bulk specific gravity (Gmb) of the mix

Gmb = Mmix/$bulk\ volume\ of\ t\ \ e\ mix$

3.1.6. Voids in mineral aggregates (VMA)

VMA = [(Mmix/Gmb− Mmix/PsGsb)/Mmix/Gmb]∗100

Where Ps is the percent of aggregate present, by total mass of the mix (that is, Magg = Ps * Mmix)

So VMA =(1−Gmb/Gsb∗ Ps) ∗100

3.1.7. Air voids (VA)

VA = [1−Gmb/Gmm] ∗100

3.1.8. Voids filled with bitumen (VFB)

VFB =[$VMA-VA/VMA$] *100

3.2 Observations and Tabulations

3.2.1. Weights of samples

After the sample is prepared its dry weight, weight after coating of wax and weight in water is taken. By these values the bulk volume of the sample is evaluated and after that Gmb is calculated by formula given above. For calculation of bulk volume, volume of paraffin is deducted from total volume. Specific gravity of wax is taken as 0.9 g/cc and for water, as 1 g/cc for calculation. Data obtained in this case is tabulated below:

Here

Wpca = wt. of wax coated sample in air.

Wpcw = wt. of paraffin coated sample in water.

Ws = wt. of sample in air

Bvs = bulk volume of sample

Gmb = bulk specific gravity of the mix For every percentage average specific gravity is calculated.

Table 9. marshall parameters of samples without fibers:

Binder %	BULK V	Gmb	Gsb	avg VMA	VMA	Gmm	VA	avg VA	VFB
4	483.666	2.51	2.786	13.39	13.51	2.62	4.19	4.066667	69.89884
	475.444	2.53			12.82		3.43		
	469.4444	2.54			13.85		4.58		
4.5	478.5556	2.53	2.785	13.24	13.24	2.6	2.69	2.816667	78.72608
	478.5556	2.52			13.58		3.07		
	476.7778	2.53			12.9		2.69		
5	482.7778	2.52	2.785	14.01	14.03	2.587	2.59	2.46	82.46614
	479.8889	2.52			14.03		2.59		
	481.6667	2.53			13.96		2.2		
5.5	481.2222	2.57	2.786	14.29	12.82	2.57	1.56	1.79	86.03744
	478.3333	2.53			14.18		3.5		
	491.2222	2.48			15.87		0.31		
6	477.889	2.52	2.786	15.2	14.97	2.55	1.17	1.43	90.44756
	479	2.51			15.32		1.56		
	477.7778	2.51			15.31		1.56		
7	482	2.49	2.786	16.74	16.88	2.52	1.19	1.02333	93.93762
	485	2.4962			16.67		0.94		
	479.62	2.4963			16.67		0.94		

3.3 Marshall test values:

From marshall test values are recorded and tabulated as follows. Here stability is in KN and flow value in mm

Table 10. flow and stability values for samples without fibers:

Binder %	WSA	Wpcsa	Wpcsw	Stability n	Flow	Stability (kn)	avg Flow
4	1205	1217	720	242	2.1	7.18858004	2.13
	1204	1218	727	213	1.9	6.327138631	
	1202	1216	731	262	2.4	7.782677564	
4.5	1198	1211	718	268	2.5	7.960906822	2.36
	1197	1210	717	282	2	8.376775088	
	1200	1211	722	266	2.6	7.901497069	
5	1205	1216	721	254	3.4	7.545038555	2.83
	1199	1209	718	275	2.9	8.168840955	
	1205	1217	722	260	2.2	7.723267812	
5.5	1205	1203	724	297	5	8.822348231	3.7
	1199	1205	720	245	3	7.277694669	
	1205	1203	714	239	3.1	7.099465412	
6	1195	1205	716	229	4.5	6.80241665	4.03
	1196	1205	716	235	3.9	6.980645907	
	1197	1208	718	234	3.7	6.950941031	
7	1188	1197	705	227	4.8	6.743006897	5.3
	1195	1204	709	232	5.8	6.891531278	
	1187	1196	704	202	5.3	6.000384992	

Table 11. flow and stability values for samples with fibers

binder	Wpca	Ws	Wpcw	flow	stability	avg flow	avg stability
4	1196	1213	715	3.6	216		
4	1194	1205	713	4.6	232	4.133	231.66
4	1198	1208	716	4.2	247		
4.5	1194	1208	710	3.5	275		
4.5	1200	1210	719	2.1	290	2.8133	276.33
4.5	1196	1209	716	2.9	264		
5	1195	1210	705	4.3	330		
5	1197	1212	712	5.5	329	4.8666	333.33
5	1196	1210	708	4.8	341		
5.5	1197	1211	714	5.1	202		
5.5	1194	1207	716	7.9	192	5.5	210.66
5.5	1193	1203	710	3.5	238		
6	1195	1201	713	6.5	282		
6	1191	1200	712	4.5	226	5	264.66
6	1193	1199	715	4	286		
7	1188	1196	704	6.2	235	5.2	260.5
7	1192	1200	702	4.2	286		

3.4 Calculations ans results:

We will evaluate the values of Gmm, Gsb, Gmb, VA, VMB, and VFB. For these calculations above formulae are used. All the values of the weights in table are in gms and all values of volumes are in cc.

Table 12. values of different parameters (densities and void parameters for fiber):

binder	bk vol	g mb	Gmm	Gsb	VA	avgVA	VMA	avgVMA	VFB	avg VFB
4	479.11	2.53			3.42		13.1		73.89	
4	482	2.51	2.62	2.795	4.19	3.933	13.78	13.55	69.95	71.24
4	480.88	2.51			4.19		13.78		69.95	
4.5	476.66	2.53			2.62		13.55		80.66	
4.5	479.88	2.52	2.589	2.795	3	2.75	13.36	13.48	77.54	79.67
4.5	478.33	2.53			2.6		13.55		80.81	
5	488.33	2.52			2.2		15.67		85.97	
5	483.33	2.5	2.578	2.794	3	2.7	15.67	15.56	80.4	82.02
5	486.44	2.49			3.1		15.34		79.7	
5.5	481.44	2.52			1.59		14.73		88.52	
5.5	476.55	2.53	2.56	2.793	1.19	1.83	14.39	14.82	84.5	85.144
5.5	481.88	2.49			2.73		15.75		82.412	
6	481.88	2.49			1.96		16.34		88	
6	478	2.51	2.54	2.798	1.29	1.5	15.67	15.89	91.76	90.4
6	477.33	2.51			1.29		15.67		91.76	
7	483.11	2.47			1.47		17.76		91.7	
7	489.11	2.45	2.5	2.793	2.01		18.42	18.09	90.4	91.05

3.5 GRAPHS OBTAINED:

3.5.1 Stability vs bitumen content

A graph between values of stability and bitumen content are plotted against bitumen in x-axis and stability in y-axis. Here stability is in Kn.

Table 13. binder vs stability(for fibre)

binder	stability		
4	216	6.420816	
4	232	6.896432	6.886683
4	247	7.3428	
4.5	275	8.1746	
4.5	290	8.62054	8.214268
4.5	264	7.847664	
5	330	9.80958	
5	329	9.779854	9.908
5	341	10.13657	
5.5	202	6.011	
5.5	192	5.713	8
5.5	238	7.074	
6	282	8.38	
6	226	6.71	7.8
6	286	8.5	
7	235	7	
7	286	8.5	6

Table 14. stability value for sample with and without fibre:

binder content(fibre)	4	4.5	5	5.5	6	7
without fibre	6.65	8.079	7.8	7.73	6.91	6.54
fiber	6.886	8.214	9.9	8	7.6	6

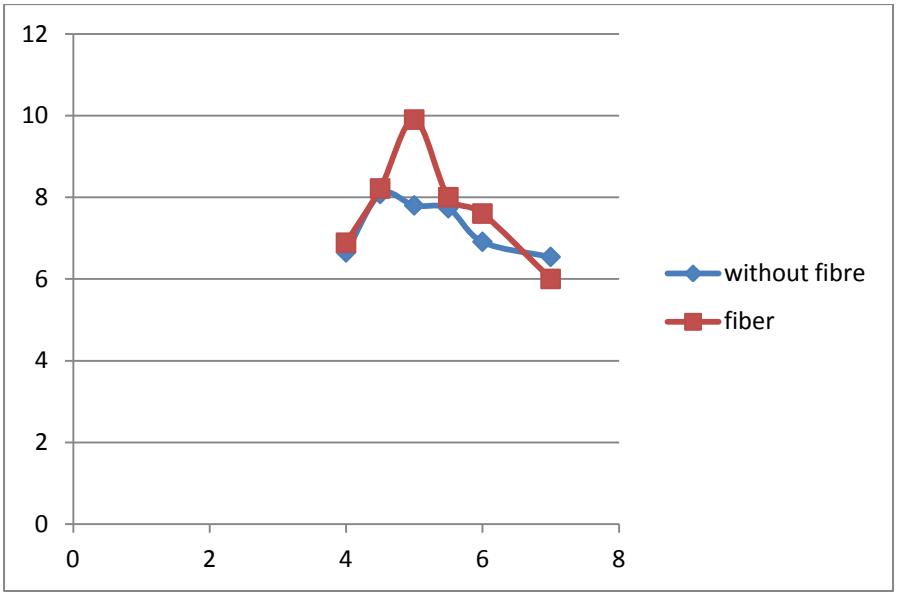


Fig 11. comparison of stability value for samples with and without fibre vs binder content

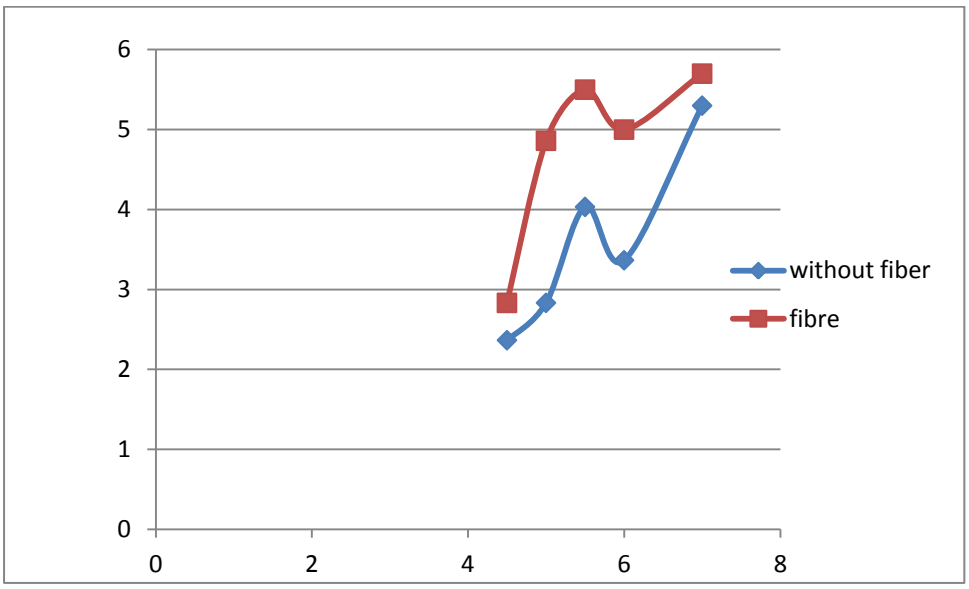
3.5.2 Flow value vs bitumen content:

Graph between flow values in mm and bitumen content in bitumen in %ge are plotted against each other as bitumen in x-axis and Flow in y-axis.

Table 15. flow values of samples with and without fibre:

			flow value			
binder content	4	4.5	5	5.5	6	7
without fiber	2.933	2.366	2.8333	4.0333	3.366	5.3
fibre	4.133	2.8333	4.8606	5.5	5	5.7

Fig 12. comparison of flow values for samples with and without fiber



3.5.3 VMA vs. bitumen content

Graph between VMA values in %ge and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and VMA in y-axis.

Table 16. VMA vs binder content (for fiber):

binder fiber	VMA	avgVMA
4	13.67	
4	13.3	13.6
4	13.6	
4.5	13.55	
4.5	13.36	13.48
4.5	13.55	
5	15.67	
5	15.67	15.56
5	15.34	
5.5	14.73	
5.5	14.39	14.82
5.5	15.75	
6	16.34	
6	15.67	15.89
6	15.67	
7	17.76	
7	18.42	18.09

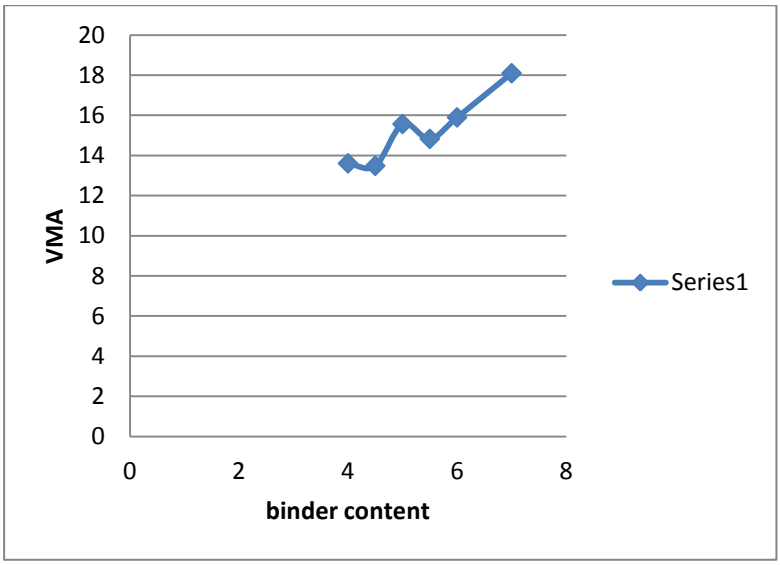


Fig 13. graph between VMA and binder content

3.5.4 VFB vs. bitumen content

Values of VFB values in percentage and bitumen content in bitumen in pecentage are plotted against bitumen in x-axis and VFB in y-axis.

Table 17 VFB vs binder content:

binder	VFB	
4	73.89	
4	69.95	71.24
4	69.95	
4.5	80.66	
4.5	77.54	79.67
4.5	80.81	
5	85.97	
5	80.4	82.02
5	79.7	
5.5	88.52	
5.5	84.5	85.144
5.5	82.412	
6	88	
6	91.76	90.4
6	91.76	
7	91.7	
7	90.4	91.05

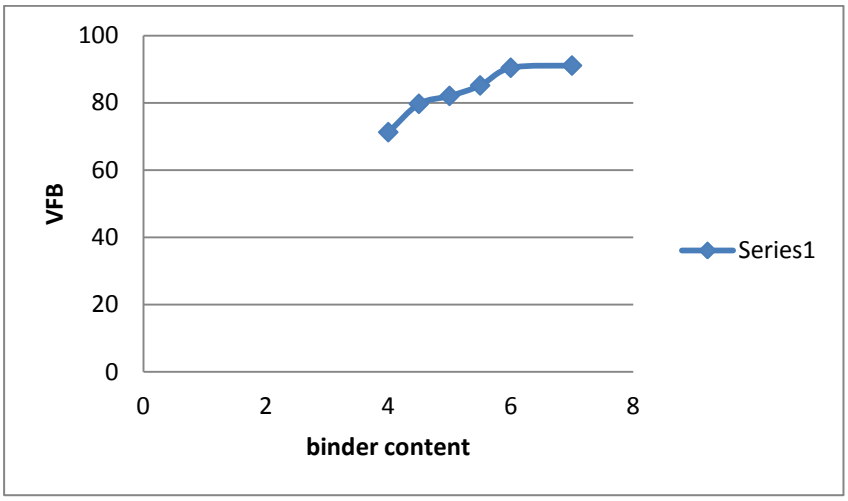


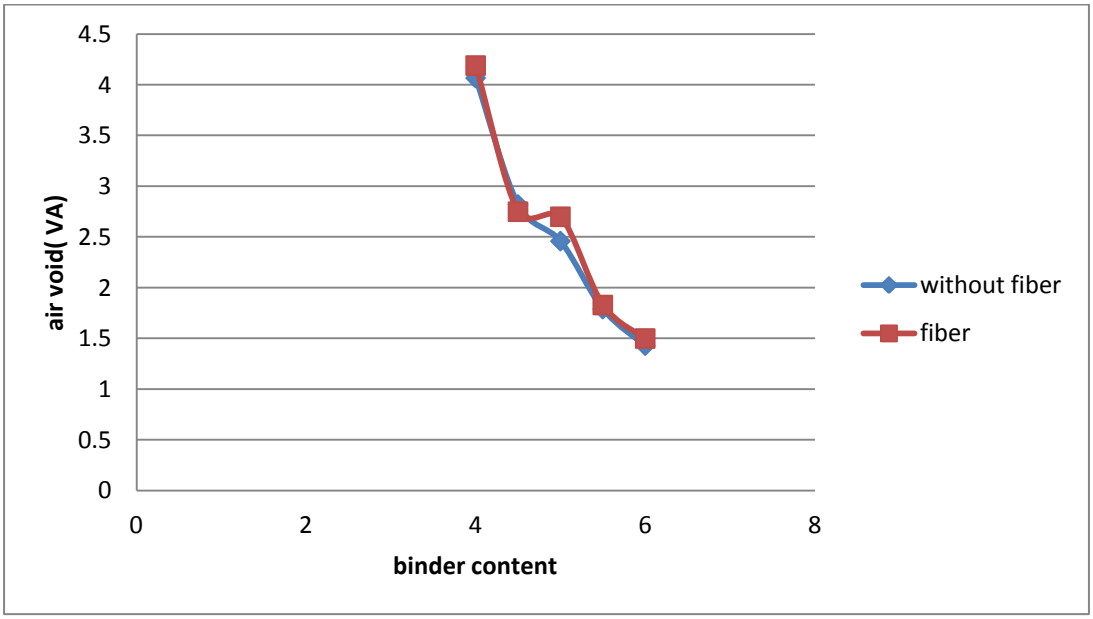
Fig 14. graph showing VFB vs binder content (fibre)

3.5.5 Va vs bitumen content:

Table 18. showing Va and average Va for samples with fiber:

	VA	avgVA
4	3.42	
4	4.19	3.933
4	4.19	
4.5	2.62	
4.5	3	2.75
4.5	2.6	
5	2.2	
5	3	2.7
5	3.1	
5.5	1.59	
5.5	1.19	1.83
5.5	2.73	
6	1.96	
6	1.29	1.5
6	1.29	
7	1.47	1.74
7	2.01	

Fig 15. comparison of air void (Va) vs binder for samples with and without fibre:



CHAPTER 4

RESULTS AND CONCLUSIONS

1. The SMA samples were prepared using varying bitumen content of 4%, 4.5%, 5%, 5.5%, 6%, and 7%. This was done to find out the effect of increasing bitumen content on the stability value. This plot also helps us to find the Optimum binder content for this mix. The plot below indicates that the stability value increases initially with increase in bitumen content but then decreases gradually. This can be attributed to the fact that with initial increase in bitumen content, the aggregate bitumen bond gradually gets stronger, but with further increase in the bitumen content, the applied load is transmitted as hydrostatic pressure, keeping the fraction across the contact points of aggregates immobilized. This makes the mix weak against plastic deformation and the stability falls.

   The same principle applies to mix with fibers, but this mix shows higher stability value at the same binder content than the mix without fibers. This can be attributed to the fact that , the fibers in the mixes act as stabilizers which not only fills up the voids in the sample but also reduces the drain down significantly, thus holding up the binder in the mix. The addition of fibers also provides homogeneity to the mix.

2. Flow is the deformation undergone by the specimen at the maximum load where failure occurs. The flow value increases with the increase in the bitumen content both the mixes with and without fibers .The increase is slow initially, but later the rate increases with the increase in the bitumen content.The flow value of mixes with fibers is more than that without fibers initially, This may be due to the reason that , at lower bitumen content the fibers fills up the voids effectively contributing to the homogeneity and thus providing the stability required to resist any deformation under load . But as the bitumen content increases the this homogeneity is lost , due to which the binder property dominates which makes the fibers to form lumps , reducing stability and increasing deformation under load .
3. The VMA value, for a given aggregate should theoretically remain constant. However, in this case, it is sometimes observed that, at low bitumen content, VMA slowly decreases with the increase in bitumen content, then remains constant over a range, and finally increases at high bitumen content. The initial fall in VMA value is due to the re-orientation of the aggregates in the presence of bitumen. At very high bitumen content, due to a thicker bitumen film, the aggregates slightly moves apart resulting in an increase in VMA.

   The VMA values are quite similar in both the mix with and without fiber , but at larger bitumen content of 6%, VMA of mix with fiber is slight more , which can be attributed to the fact that at more bitumen content the fibers will form lump thus causing the further movement of aggregates apart increasing the VMA .

4. The Air Voids (VA) decreases with increase in the bitumen content because with increase in bitumen content it goes on filling the air voids progressively.

The VA of mix with fiber is much less than that without fiber. This is because the fiber already filled up some portion of air voids (VA) which further decreases as the bitumen goes on filling the air voids with increase in bitumen content.At 6% binder the VA values for sample with fiber are quite more than that without fiber which may be due to improper mixing .

5. The Voids Filled Bitumen (VFB) is expressed basically as a fraction of VMA. . The VFB of a mix generally increases with the increase in the bitumen content. Here in our result too, we can clearly observe that VFB increases since increase in bitumen content causes more and more bitumen to fill the voids present in the mix as well as that inside the aggregates causing the overall increase in the bitumen inside the voids or VFB.

6. The draindown remains to be one of the most important problems associated with SMA due to its high bitumen content .To counter this fibers as stabilizers are generally used . Here the draindown tests was carried out to compare the draindown characteristics of samples with and without fibers at OBC .

   It was found out that with the use of fibers no drain down was obtained. Hence we can easily observe that use of fibers significantly reduce the drain down in a SMA Mix.

7. The result of the indirect tensile test clearly indicates that the indirect tensile strength of the SMA sample decreases considerably with increase in temperature. At low temperature the tensile strength is very high but it reduces significantly with increase in temperature. This may be attribute to the fact that at lower temperature the binder becomes very stiff thus increasing the binding ability considerably, but at higher temperature the bitumen softens, loosens its binding ability , thus attributing to the loss of its tensile strength .The results are very high in case of 5^0C and very less for 40^0C

   From the graph of stability vs. bitumen we learnt that optimum binder content for samples prepared by use of banana fibre is found to be 4.15 %.

8. Here maximum stability obtained is 10.1 kN. When compared to other fibres it is a bit higher. So because of this banana fibre can be used in case of general heavy traffic requirements and it would be suitable for severe traffic situations also.
   From graph of flow value and binder content we can see that flow value increases with binder content.

9. From graph of stability vs binder with and without fibre we can see that the stability gets increases for almost all binder contents after using banana fiber.

References:

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4. Chui-Te Chiu, Li-Cheng Lu,"A Laboratory study on stone matrix asphalt using ground rubber", Construction and Building Materials, Volume 21, Issue 5, May 2007, Pages 1027-1033.