LABORATORY INVESTIGATIONS ON STONE MATRIX ASPHALT USING SISAL FIBRE FOR INDIAN ROADS

A project submitted in partial fulfillment of the requirements for the degree of

Bachelor of technology

In

Civil Engineering.

By

Narayan Panda (10601031)

DEPARTMENT OF CIVIL ENGINEERING

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Certificate

This is to certify that the Project Report entitled "**LABORATORY INVESTIGATIONS ON STONE MATRIX ASPHALT USING SISAL FIBRE FOR INDIAN ROADS**" submitted by **Mr. NARAYAN PANDA** in partial fulfillment 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.

Date:

Prof. Simantini Behera

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NARAYAN PANDA

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ABSTRACT

The technology of asphalt materials and mixtures is discovered and mostly used in Europe and North America. The SMA (stone matrix asphalt) mixture is a gap-graded mix. In this present study comparison of strength of pavement wearing coat made with SMA mix with fibre and without fibre was done. This research was done to evaluate the viability of sisal fibres as stabilising agent in the mixture by laboratory tests in which a flow parameter was analyzed, as well as the mechanical properties of the mixture. For the SMA mix the aggregate gradation was taken as per the MoRTH specification and the binder content was 4%, 4.5%. 5%, 5.5%, 6%, 6.5%, 7% by weight of aggregate and fibre used was 0.3% by weight of aggregate. Here we used cement as filler and 60/70 grade bitumen as binder.

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Nomenclature

SMA	- Stone Matrix Asphalt or Stone Mastic Asphalt
MoRTH	- Ministry of Road Transport and Hghways
G_{sb}	- Bulk specific gravity of aggregates
G_{se}	- Effective specific gravity of aggregates in mix
G_a	- Apparent specific gravity of aggregates
G_{mm}	- Theoretical maximum specific gravity of the mix
G_{mb}	- Bulk Specific gravity of the mix
VMA	- Voids in mineral aggregates
VA	- Air void
VFB	- Voids filled with bitumen
W_{pca}	- Wt. of wax coated sample in air
W_{pcw}	- Wt. of paraffin coated sample in water
W_s	- Wt. of sample in air
B_{vs}	- Bulk volume of sample

Chapter 1

INTRODUCTION

INTRODUCTION:

Stone Matrix Asphalt (SMA) is a gap-graded mixture, have a better stone to stone contact which gives better strength to the mixture.

In this research work aggregate used as per the MoRTH specification which was taken from a same lot. The samples are made with aggregate with different gradation, filler(cement) and binder(bitumen 60/70). Fibres are used as stabilizer. Fibres are used to decrease the drain down and to increase the strength and stability of the SMA mix. The test of the SMA mix samples are done in Marshall apparatus. Here the comparison of SMA mix with and without fibre was done.

All the research work done before by using cellulose fibre, synthetic fibre, polypropylene fibre and polyester fibres. Cellulose fibres are extensively used in SMA in Europe and USA. These fibres are patented. The fibres improve the service properties of the mix by forming micromesh in the asphalt mix to prevent the drain down of the asphalt so as to increase the stability and durability of the mix. Here we have tried to use sisal fibre which is more economic than cellulose fibres , doing same work as cellulose fibre.

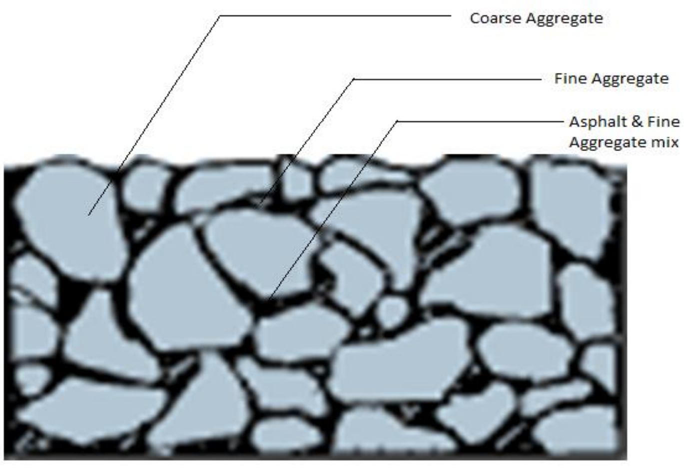

Fig.1 Gap Graded Mix Structure

LITERATURE REVIEW

In the 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.[14]

The objectives of GDOT's first SMA research project, No. 9102, were (1) to evaluate the performance of SMA asphalt under the stresses of heavy truck loadings, and (2) to compare the performance of SMA to the performance of conventional GDOT mixes. In 1991, various combinations of SMA and standard mixes were placed in a 2.5-mile, high traffic volume test section on Interstate 85 northeast of Atlanta. SMA was evaluated as both an intermediate and surface course. The location on I-85 in northeast Georgia was selected due to its average daily traffic (ADT) of 35,000, including 40% trucks. This traffic roughly equals 2 million equivalent single axle loads (ESALs) per year.[1]

Bradely et.al. (2004) studied Utilization of waste fibres in stone matrix asphalt mixtures. They used carpet, tire and polyester fibres 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 SMA mix containing cellulose or mineral fibre.[4]

Kamaraj C., G. Kumar, G. Sharma, P.K. Jain and K.V. Babu (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.[5]

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.[7]

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%.[10]

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.[12]

Shaopeng Wu et al. (2007) used slag after 3 year of ageing with PG76-22 modified binder, lime stone filler, short chopped polyester fiber (3%) for the SMA mix in Marshall method and found it to be suitable for use.[13]

Chui-Te Chiu, Li-Cheng 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.[11]

Yongjie Xue, Haobo Hou, Shujing Zhu, Jin Zha (2008) used municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler and BOF Slag as part of coarse aggregate with polyester fiber of 6.35 mm in length obtained from recycled raw materials, PG76-22 binder in the SMA mix and performed Marshall and superpave method of design and found it’s suitability for use in the SMA mix.[15]

1.3 Objectives

- The main objective of this project is use of non-conventional natural fibre as sisal fibre instead of other conventional fibre and to study how they affect the various properties of SMA.
- Preparation of Marshall Specimens and getting optimum mix content with the help of Marshall Test data.
- To find suitability of Sisal fibre 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 (Sisal fibre)
4. Cement as filler

2.1.1 COARSE AND FINE AGGREGATE:

The aggregates are crushed by using jaw crusher to get different size of aggregates varying from 16mm to 75micron. Quality of aggregates were check through various tests as per MoRTH specification given below.

Test conducted for aggregates

1. Impact Value Test (IS 2386 -Part1) [17]

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.

Table 1. Tabulation for determination of Impact Value

Sl No.	Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm) B	Impact Value	Avg. Imapct Value
1	355	303	52	14.64	14.71
2	354	300	54	15.25	
3	358	307	51	14.24	

According to MoRTH the aggregate impact value should be < 18%

2. Crushing Value (IS 2386 -Part1) [17]

The standard aggregate crushing test shall be made on aggregate passing a 12.5-mm IS Sieve and retained on a 10-mm IS Sieve.

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

Aggregate crushing value = (B/A) x 100

where
B = weight of fraction passing the appropriate sieve, and
A = weight of surface-dry sample.

Table 2. Tabulation for determination of Crushing Value

Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm) B	Crushing Value
3086	2634	452	14.64

3. Los Angel's Abrasion Value (IS 2386 -Part1) [17]

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

Table 3. Tabulation for determination of Los Angel's Abrasion Value

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

10000	8502	1498	14.98

According to MoRTH the Los Angle's Abrasion value should be < 25%

4. **Flakiness and Elongation Index (IS 2386 -Part1)** [17]

The elongation index is the total weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

The flakiness index is the total weight of the material passing the various thickness gauges or sieves, expressed as a percentage of the total weight of the sample gauged.

Table 4. Tabulation for determination of Flakiness and Elongation Index

Size In mm	Wt. of sample taken in gm.	Aggregate passing in the gauge in gm.	Flakiness index	Average flakiness index	Aggregate retained in the elongation gauge in gm.	Elongation index	Average elongation index
25-20	392	60	15.36	18.83	130	33.16	21.5
20-16	734	135	18.39		131	17.84	
16-12.5	547	91	16.6		103	18.8	
12.5-10	280	78	27.2		54	19.28	
10-6.3	90	15	16.6		38	18.4	

According to MoRTH the Flakiness and elongation index value should be <30%

The gradation of aggregate was taken as per MoRTH specification given below in table1.

Table 5 :Gradation of Aggregates [2]

Total weight of sample= 1200gm

Sieve size in mm	% passing		%retained adopted	amount of aggregate taken in this binder content in gm						
	Intermediate	adopted		4%	4.50%	5%	5.50%	6%	6.50%	7%
				1152	1146	1140	1134	1128	1122	1116
16	100	100								
13.2	90-100	94	6	69.12	68.76	68.4	68.04	67.68	67.32	66.96
9.5	54-70	62	32	368.6	366.72	364.8	362.9	360.96	359.04	357.12
4.75	26-39	34	28	322.6	320.88	319.2	317.5	315.84	314.16	312.48
2.36	21-28	24	10	115.2	114.6	114	113.4	112.8	112.2	111.6
1.18	17-25	21	3	34.56	34.38	34.2	34.02	33.84	33.66	33.48
0.6	15-22	18	3	34.56	34.38	34.2	34.02	33.84	33.66	33.48
0.3	13-19	16	2	23.04	22.92	22.8	22.68	22.56	22.44	22.32
0.15	09-15	12	4	46.08	45.84	45.6	45.36	45.12	44.88	44.64
0.075	08-13	10	2	23.04	22.92	22.8	22.68	22.56	22.44	22.32
Filler	0	0	10	115.2	114.6	114	113.4	112.8	112.2	111.6

2.1.2 BITUMEN

Bitumen is act as a binder in SMA mix. Different grade of bitumen are used in different mix like hot-mix or gap-graded mix or dense-graded mix. For preparation of SMA mix we used 60/70 bitumen in this research work.

2.1.3 FIBRE

Fibres are used as stabilizer in SMA mix. Fibres helps to increase the strength and stability and decrease the drain down in SMA mix. There are different types of fibres are used in SMA mix like cellulose fibre, polymer fibre, mineral fibre, natural fibres. Here we used SISAL fibre (natural fibre) as stabilizer in SMA mix which act the same role as other fibre.

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

As per MoRTH specification generally 0.3%-0.5% fibre is used in SMA mix. In this study, 0.3% fibre by weight of aggregate was used.

The sisal fibres are usually creamy white, average from 80 to 120 cm in length and 0.2 to 0.4 mm in diameter. Sisal fibre is fairly coarse and inflexible. It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater.[5] Brazil, mexico, china are the main source of producing sisal fibres.

Generally sisal fibres are used in rope making, paper industry etc. Very few research are done by using sisal fibres in SMA mix. So here we attempt a research with sisal fibre which is more economical than other fibres.

Fig 2. Sisal Fibre (stabilizer)

2.1.3 FILLER

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

2.2 EXPERIMENTAL PROCEDURE

Experiment was performed in following steps

1. Sieve analysis

Sieve analysis was done and aggregates of appropriate sizes were collected and stored in place with sizes as per MoRTH gradation. Weight of one sample is 1200 gms here. The distribution of aggregates was taken as per table 1.

2. Sample preparation

For sample preparation some steps given below are taken:

- **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 first of all weight of sample was taken as per table 1. 0.3% of fibre was taken in each of 3 samples.

- **Heating of aggregates**

After weighing of aggregates, aggregates with of all gradation are mixed with each other to make one sample of weight 1200gms. All samples were heated in oven at a temperature of 130^0 centigrade for 24hrs so that fibre is not burnt. Overheating of sample was avoided.

- **Heating of bitumen**

60/70 bitumen was heated with a high temperature to liquefy. So that it will mix with all aggregates and fibre easily.

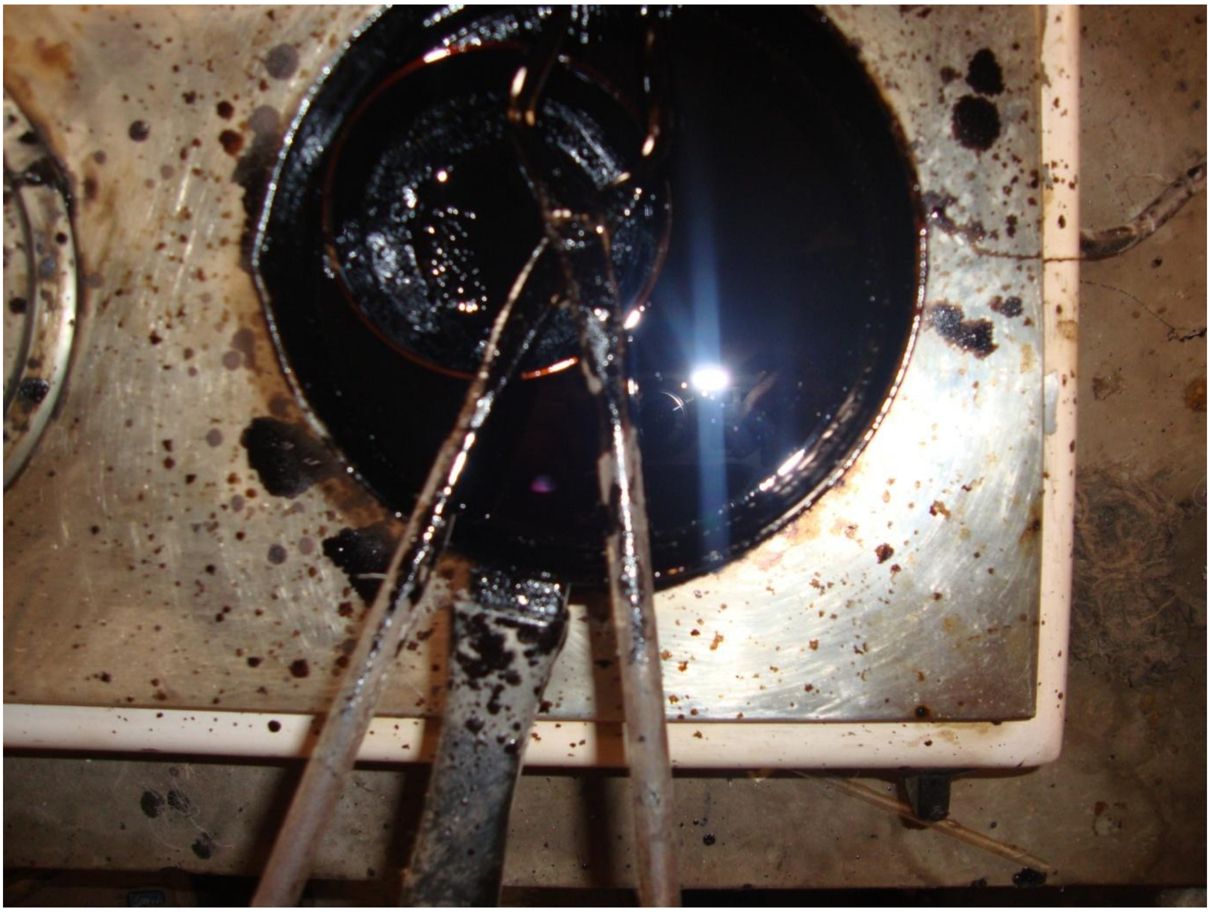

Fig 3. Bitumen

- **<u>Mixing of components</u>**

All components (aggregate, cement, bitumen and fibre) are mixed to make a homogeneous SMA mix sample.

Fig 4. Mixing of Aggeregate

- **Putting in mould**

For preparation of samples the mixture prepared was put in moulds. A standard mould is a cylindrical mould made of iron having a diameter of 100 mm. mould was also heated before use so that before hammering mixture may not be cold. A typical mould is shown in fig below:

Fig 5. A Typical mould

- **Compaction**

After putting in mould hammering was performed. For hammering a standard hammer was used. Usually hammering was done by giving 50 or 75 blows to each side of specimen. In this research each sample was given 50 blows each on both faces. For hammering first of all mould was attached to a fixed arrangement to make sure that mould is not staggered during hammering. A piece of paper of size of mould was put in mould over fitting so that mix is not glued to fitting. For the same purpose oiling was done in inner faces of mould and bottom of hammer.

A typical hammer is shown in fig below:

Fig 6. Hammer used in sample preparation

- **Finalizing the sample**

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

Fig 7. A SMA sample

All the samples are shown in the figure below:

Fig 8. SMA Samples

2.3 EXPERIMENTS PERFORMED

When the sample is prepared it was supposed to go under Marshall Test. The test was performed as per ASTM D 6927 – 06. This test gives the results of flow and stability number. To get that first of all dry weight of samples is taken and recorded. Weight of sample in water is also desirable. Because sample has voids so water may enter in voids. To prevent that wax was coated around the sample. Wax was heated upto liquification then sample is immersed in wax by holding it through a thread holding the sample. Once the sample was dipped fully in wax it is allowed to cool so that wax is glued to sample properly.

Fig 9. Wax coated sample

The figure above shows a wax coated sample. After wax coating the weight of waxed sample is taken. Now weight of sample in water is also recorded. After weighing the sample is put in water bath before testing upto a maximum of ½ hours. In water bath temperature of 60^0 C is maintained throughout. If sample is heated more than that wax may come out. So overheating is avoided. Only 6 samples may be put in Waterbath. Waterbath is shown in figures 8 and 9 shown below:

Fig 10. Waterbath

Fig 11. Top view of Waterbath

Once the sample is heated upto 60^0 C for half hours it is ready for Marshall Test.

2.3.1 Marshall Test

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

2.3.1.1 Breaking Head: [9]

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.

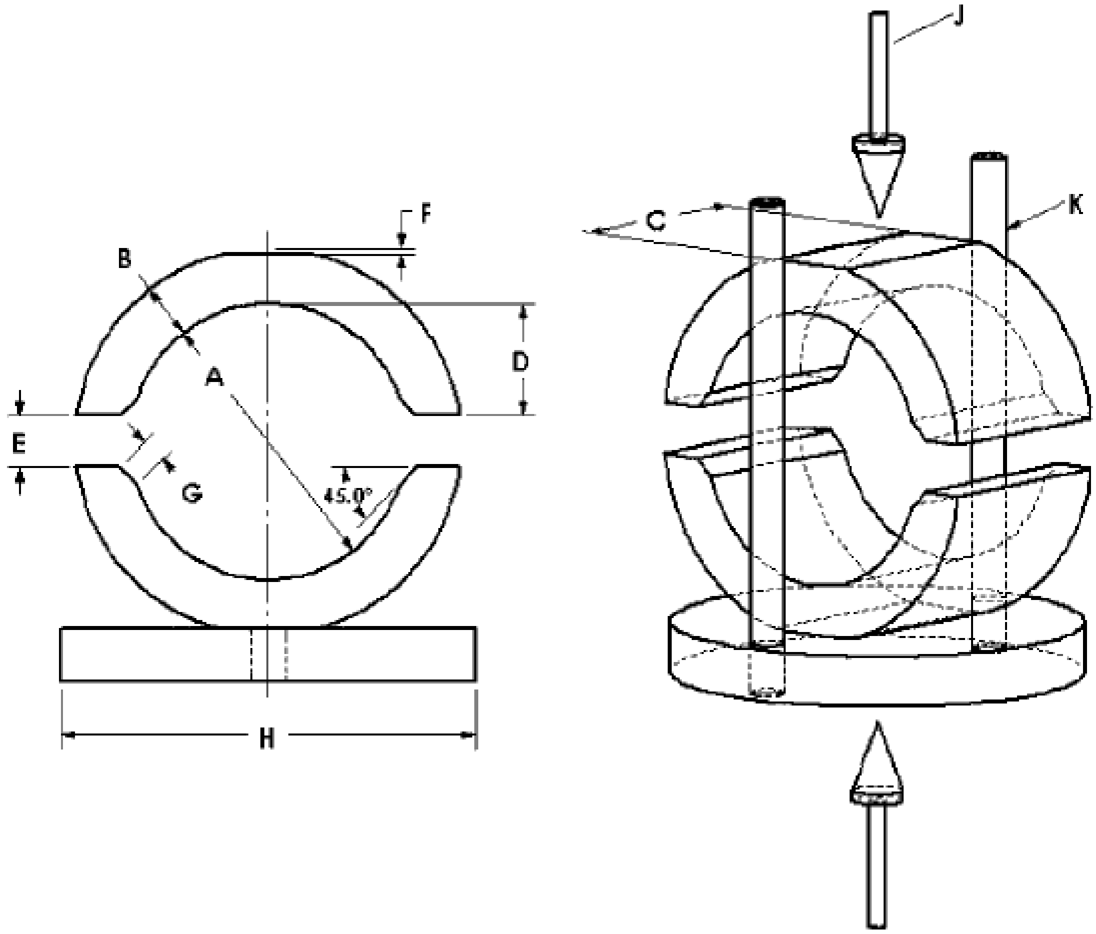

Fig 12. Breaking head

Values of dimensions shown in fig. are given by table below:

Table 2. Dimensions for breaking head

	mm
A	101.5 to 101.7
B	21.7 minimum
C	76.2 minimum
D	41.15 to 41.40
E	18.92 to 19.18
F	2.0 reference
G	8.89 to 9.09
H	101.3 minimum

2.3.1.2 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. [8]

2.3.1.3 Load Measuring Device

A calibrated 20 kN ring dynamometer with a dial indicator to measure ring deflection for applied loads is provided. The 20 kN ring have a minimum sensitivity of 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 to transmit load to the breaking head. Usually this is called as proving ring. [8]

2.3.1.4 Flowmeter

For measuring the flow a dial gauge is used. By dial gauge initial and final values during test is recorded and their difference is taken as flow for the sample.

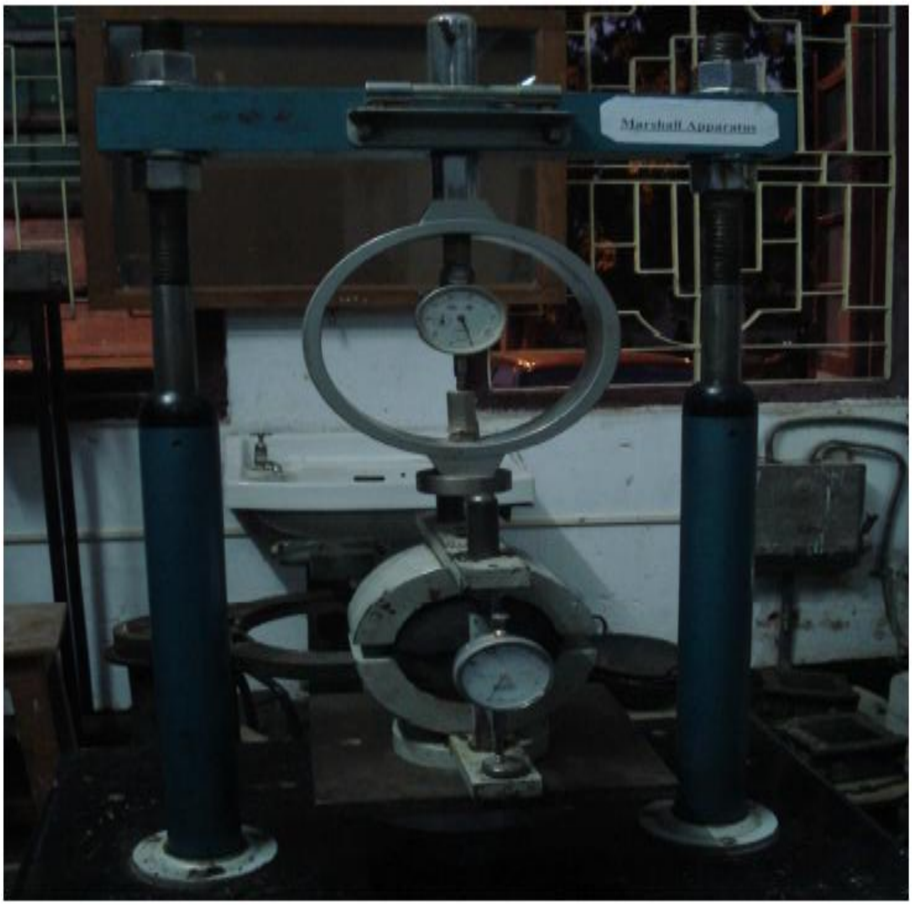

Fig13. Marshall Apparatus

2.3.2 Test procedure[6]

The guide rods and inside surfaces of the test head segments prior to conducting the test are thoroughly cleaned. 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 Waterbath 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.

Chapter 3

Analysis

3.1 PARAMETERS USED :

Based on volume considered in evaluating specific gravity of an aggregate, some definitions of specific gravity are proposed. The definitions and other formulae used in calculations hereafter are as follows: [4]

1. **Bulk specific gravity (G_{sb})** of aggregates

$$G_{sb} = \frac{Magg}{volume\ of\ (aggregate\ mass + air\ void\ in\ aggregate + absorbed\ bitumen}$$

Where M_{agg} is the mass of aggregate.

2. **Effective specific gravity (G_{se})** of aggregates in mix

$$G_{se} = \frac{Magg}{volume\ of\ (aggregate\ mass + air\ void\ in\ aggregate\ )}$$

$$G_{se} = (M_{mix} - M_b) / \left(\frac{Mmix}{Gmm} - \frac{Mb}{Gb}\right)$$

Where M_b is the mass of bitumen used in mix

G_b is the specific gravity of bitumen

3. **Apparent specific gravity (G_a)** of aggregates

$$G_a = \frac{Magg}{Volume\ of\ aggregate\ mass}$$

4. **Theoretical maximum specific gravity (G_{mm})** of the mix

$$G_{mm} = \frac{\text{Mmix}}{volume\ \ of\ \ (mix - air\ \ vods)}$$

5. **Bulk specific gravity (G_{mb})** of the mix

$$G_{mb} = \frac{\text{Mmix}}{bulk\ \ volume\ \ of\ the\ mix}$$

6. **Voids in mineral aggregates (VMA)**

$$\text{VMA} = \left[\left(\frac{\text{Mmix}}{\text{Gmb}} - \ \frac{\text{Mmix Ps}}{\text{Gsb}}\right) / \frac{\text{Mmix}}{\text{Gmb}}\right] * 100$$

Where P_s is the percent of aggregate present, by total mass of the mix (that is, $M_{agg} = P_s * M_{mix}$)

$$\text{So VMA} = \left(1 - \frac{\text{Gmb}}{\text{Gsb}} *\ \text{Ps}\right) * 100$$

7. **Air voids (VA)**

$$\text{VA} = \left[1 - \frac{\text{Gmb}}{\text{Gmm}}\right] * 100$$

8. **Voids filled with bitumen (VFB)**

$$\text{VFB} = \frac{VMA - VA}{VMA} * 100$$

3.2 Observations and Tabulations

1. **Weights of samples**

Once the sample is prepared its dry weight, weight after wax coating and weight in water is taken. By these values bulk volume of the sample is calculated and hereafter G_{mb} is calculated by formula 5 given above. For calculation of bulk volume, volume of paraffin is deduced from total volume. Specific gravity of wax is taken as 0.9 g/cc and for water it is taken as 1 g/cc for calculation. Data obtained in this case is tabulated below:

Here W_{pca} = wt. of wax coated sample in air.

W_{pcw} = wt. of paraffin coated sample in water.

W_s = wt. of sample in air

B_{vs} = bulk volume of sample

G_{mb} = bulk specific gravity of the mix

For every percentage average specific gravity is calculated.

Table 6. Weights and specific gravities of mixes

binder	sample	Wpca	Wpcw	Ws	Bvs	Gmb	avg Gmb
4%	1	1196.2	704	1192.1	487.6444	2.444609	2.357778
4%	2	1195	706	1191.2	484.7778	2.457208	2.357778
4%	3	1200	703	1197.4	494.1111	2.423342	2.357778
4%	4	1198.3	678	1195.2	516.8556	2.312445	2.357778
4%	5	1212.2	668	1208.7	540.3111	2.237045	2.357778
4%	6	1208.3	674	1204.6	530.1889	2.27202	2.357778
5%	1	1202	707	1198.2	490.7778	2.441431	2.409459
5%	2	1200	705	1196.4	491	2.43666	2.409459
5%	3	1200	703	1196.7	493.3333	2.425743	2.409459
5%	4	1205	697	1201	503.5556	2.38504	2.409459
5%	5	1204	698	1200.3	501.8889	2.391565	2.409459
5%	6	1204.5	695	1200.7	505.2778	2.376317	2.409459
5.50%	1	1201	699	1196.7	497.2222	2.406771	2.37416
5.50%	2	1201	706	1198.5	492.2222	2.434876	2.37416
5.50%	3	1197	703	1194	490.6667	2.433424	2.37416
5.50%	4	1218	686	1209.7	522.7778	2.313985	2.37416
5.50%	5	1213	684	1205.3	520.4444	2.315905	2.37416
5.50%	6	1220	692	1210.3	517.2222	2.34	2.37416
6%	1	1202	709	1198.2	488.7778	2.451421	2.434185
6%	2	1200	706	1196.7	490.3333	2.440585	2.434185
6%	3	1200	707	1196.4	489	2.446626	2.434185
6%	4	1203	700	1198.5	498	2.406627	2.434185
6%	5	1213	707	1203	494.8889	2.430849	2.434185
6%	6	1202	704	1197.5	493	2.429006	2.434185
6.50%	1	1194	703	1190.5	487.1111	2.444001	2.432669
6.50%	2	1202	707	1198.6	491.2222	2.440036	2.432669
6.50%	3	1201	708	1197.3	488.8889	2.449023	2.432669
6.50%	4	1200	701	1196	494.5556	2.418333	2.432669
6.50%	5	1202	704	1197.8	493.3333	2.427973	2.432669
6.50%	6	1204	703	1200	496.5556	2.416648	2.432669
7%	1	1198	707	1195.8	488.5556	2.447623	2.440636
7%	2	1193	705	1191.8	486.6667	2.448904	2.440636
7%	3	1197	705	1192.4	486.8889	2.449019	2.440636
7%	4	1200	705	1197	491.6667	2.434576	2.440636
7%	5	1196	702	1193.3	491	2.430346	2.440636
7%	6	1202	706	1199.1	492.7778	2.433348	2.440636
Wpca=wt of paraffin coated sample in air							
Wpcd=wt of paraffin coated sample in water							
Ws=wt of sample in air							
Bvs=Bulk Volume of the sample							
Gmb=Bulk specefic gravity of the mix							

2. Marshall Test Values

For every sample Marshall Test data is recorded and tabulated in following table:

Here stability number is in kN and flow is in mm.

Table 7. Marshall test Values and stability numbers

binder	sample	dial1	dial2(flow va	avg flow value	stability numb	avg stability no
4%	1	310	1.8	2.06667	8.611111111	10.55555556
4%	2	420	2.2	2.06667	11.66666667	10.55556
4%	3	410	2.2	2.06667	11.38888889	10.55556
4%	4	410	2.1	2.4	11.38888889	12.12962963
4%	5	470	1.8	2.4	13.05555556	12.12963
4%	6	430	3.3	2.4	11.94444444	12.12963
5%	1	510	2.3	2.33333	14.16666667	13.7037037
5%	2	490	2.5	2.33333	13.61111111	13.7037
5%	3	480	2.2	2.33333	13.33333333	13.7037
5%	4	510	2.4	2.46667	14.16666667	14.62962963
5%	5	530	2.4	2.46667	14.72222222	14.62963
5%	6	540	2.6	2.46667	15	14.62963
5.50%	1	410	1.9	2.6667	11.38888889	11.2962963
5.50%	2	420	2	2.6667	11.66666667	11.2963
5.50%	3	390	4.1	2.6667	10.83333333	11.2963
5.50%	4	470	2.5	2.53	13.05555556	12.5
5.50%	5	440	2.8	2.53	12.22222222	12.5
5.50%	6	440	2.3	2.53	12.22222222	12.5
6%	1	350	2.8	2.733	9.722222222	10.09258
6%	2	380	2.8	2.733	10.55555556	10.09258
6%	3	360	2.6	2.733	10	10.09258
6%	4	450	2.7	2.7	12.5	12.2223
6%	5	420	2.6	2.7	11.66666667	12.2223
6%	6	450	2.8	2.7	12.5	12.2223
6.50%	1	280	2.9	2.9	7.777777778	8.05556
6.50%	2	310	2.9	2.9	8.611111111	8.05556
6.50%	3	280	2.9	2.9	7.777777778	8.05556
6.50%	4	330	2.8	2.83	9.166666667	8.7037
6.50%	5	320	2.9	2.83	8.888888889	8.7037
6.50%	6	290	2.8	2.83	8.055555556	8.7037
7%	1	280	3.9	4.63	7.777777778	7.22223
7%	2	230	5.3	4.63	6.388888889	7.22223
7%	3	270	4.7	4.63	7.5	7.22223
7%	4	330	4.4	4.03	9.166666667	8.51851
7%	5	300	4.3	4.03	8.333333333	8.51851
7%	6	290	3.4	4.03	8.055555556	8.51851

3.3 Calculations and results

We will calculate the values of G_{mm}, G_{sb}, G_{mb}, VA, VMB, and VFB . For all these calculations formulae given above are used.

All values of weights in table are in gms and all values of volumes are in cc.

Table 8. Calculation of G_{sb}, G_{mm}, VA, VMA, VFB

bitum	coarse	fine	filler	Gmm	Gsb	avg Gmb	Va	VMA	VFB	Gse
4	576	495.36	80.64	2.560903	2.729969	2.35778	7.93	17.09	53.58	2.729969
4	576	495.36	80.64	2.560903	2.729969	2.35778	7.93	17.09	53.58	2.729969
4	576	495.36	80.64	2.560903	2.729969	2.35778	7.93	17.09	53.58	2.729969
4	576	495.36	80.64	2.560903	2.729969	2.35778	7.93	17.09	53.58	2.729969
4	576	495.36	80.64	2.560903	2.729969	2.35778	7.93	17.09	53.58	2.729969
4	576	495.36	80.64	2.560903	2.729969	2.35778	7.93	17.09	53.58	2.729969
5	570	490.2	79.8	2.521858	2.729969	2.40946	4.46	16.15	72.41	2.729969
5	570	490.2	79.8	2.521858	2.729969	2.40946	4.46	16.15	72.41	2.729969
5	570	490.2	79.8	2.521858	2.729969	2.40946	4.46	16.15	72.41	2.729969
5	570	490.2	79.8	2.521858	2.729969	2.40946	4.46	16.15	72.41	2.729969
5	570	490.2	79.8	2.521858	2.729969	2.40946	4.46	16.15	72.41	2.729969
5	570	490.2	79.8	2.521858	2.729969	2.40946	4.46	16.15	72.41	2.729969
5.5	567	487.62	79.38	2.502779	2.729969	2.37416	5.14	17.82	71.16	2.729969
5.5	567	487.62	79.38	2.502779	2.729969	2.37416	5.14	17.82	71.16	2.729969
5.5	567	487.62	79.38	2.502779	2.729969	2.37416	5.14	17.82	71.16	2.729969
5.5	567	487.62	79.38	2.502779	2.729969	2.37416	5.14	17.82	71.16	2.729969
5.5	567	487.62	79.38	2.502779	2.729969	2.37416	5.14	17.82	71.16	2.729969
5.5	567	487.62	79.38	2.502779	2.729969	2.37416	5.14	17.82	71.16	2.729969
6	564	485.04	78.96	2.483986	2.729969	2.43419	2	16.18	87.61	2.729969
6	564	485.04	78.96	2.483986	2.729969	2.43419	2	16.18	87.61	2.729969
6	564	485.04	78.96	2.483986	2.729969	2.43419	2	16.18	87.61	2.729969
6	564	485.04	78.96	2.483986	2.729969	2.43419	2	16.18	87.61	2.729969
6	564	485.04	78.96	2.483986	2.729969	2.43419	2	16.18	87.61	2.729969
6	564	485.04	78.96	2.483986	2.729969	2.43419	2	16.18	87.61	2.729969
6.5	561	482.46	78.54	2.465474	2.729969	2.43267	1.33	16.68	92.02	2.729969
6.5	561	482.46	78.54	2.465474	2.729969	2.43267	1.33	16.68	92.02	2.729969
6.5	561	482.46	78.54	2.465474	2.729969	2.43267	1.33	16.68	92.02	2.729969
6.5	561	482.46	78.54	2.465474	2.729969	2.43267	1.33	16.68	92.02	2.729969
6.5	561	482.46	78.54	2.465474	2.729969	2.43267	1.33	16.68	92.02	2.729969
6.5	561	482.46	78.54	2.465474	2.729969	2.43267	1.33	16.68	92.02	2.729969
7	558	479.88	78.12	2.447235	2.729969	2.44064	0.27	16.86	98.4	2.729969
7	558	479.88	78.12	2.447235	2.729969	2.44064	0.27	16.86	98.4	2.729969
7	558	479.88	78.12	2.447235	2.729969	2.44064	0.27	16.86	98.4	2.729969
7	558	479.88	78.12	2.447235	2.729969	2.44064	0.27	16.86	98.4	2.729969
7	558	479.88	78.12	2.447235	2.729969	2.44064	0.27	16.86	98.4	2.729969
7	558	479.88	78.12	2.447235	2.729969	2.44064	0.27	16.86	98.4	2.729969

Graphs obtained

1. **Stability vs. bitumen content**

Values of stability and bitumen content are plotted against bitumen in x-axis and stability in y-axis.

Table 9. Stability vs. bitumen content

binder content	stabilty no without fiber	stability no with fiber
4	10.55556	12.12962963
5	13.7037037	14.629629
5.5	11.2963	12.5
6	10.09258	12.2223
6.5	8.055556	8.7037
7	7.222223	8.51851

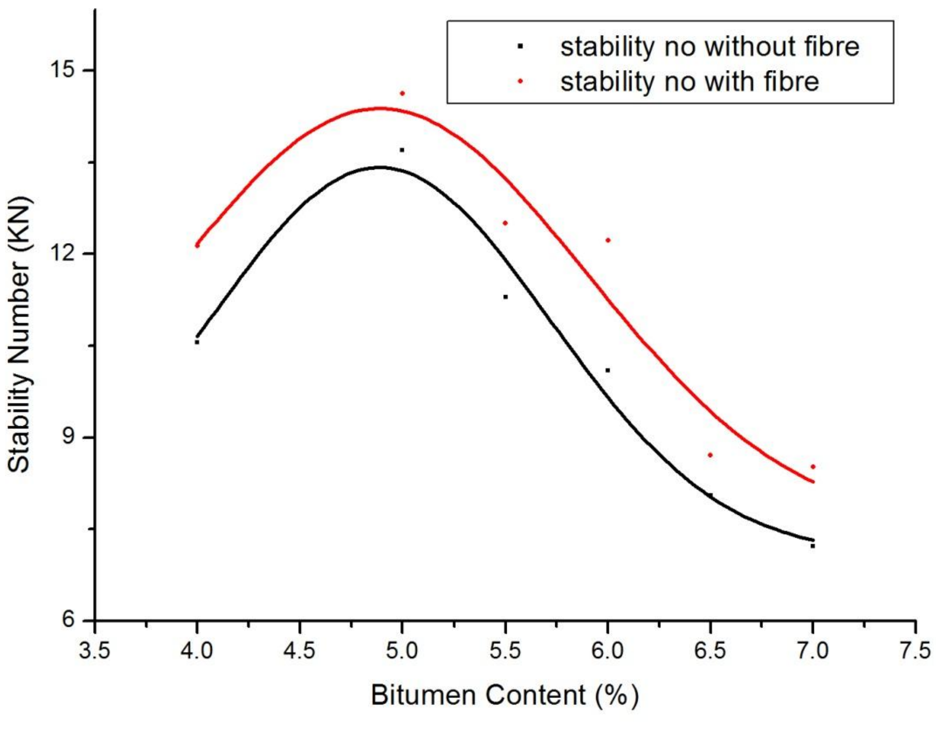

Fig 14. Stability vs. Bitumen Content

2. Flow value vs. bitumen content

Values of flow values in mm and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and Flow in y-axis.

Table 10. Flow vs. bitumen content

bitumen content	flow value without fibre	flow value with fibre
4	2.06667	2.4
5	2.33333	2.46667
5.5	2.6667	2.53
6	2.733	2.7
6.5	2.9	2.83
7	4.63	4.03

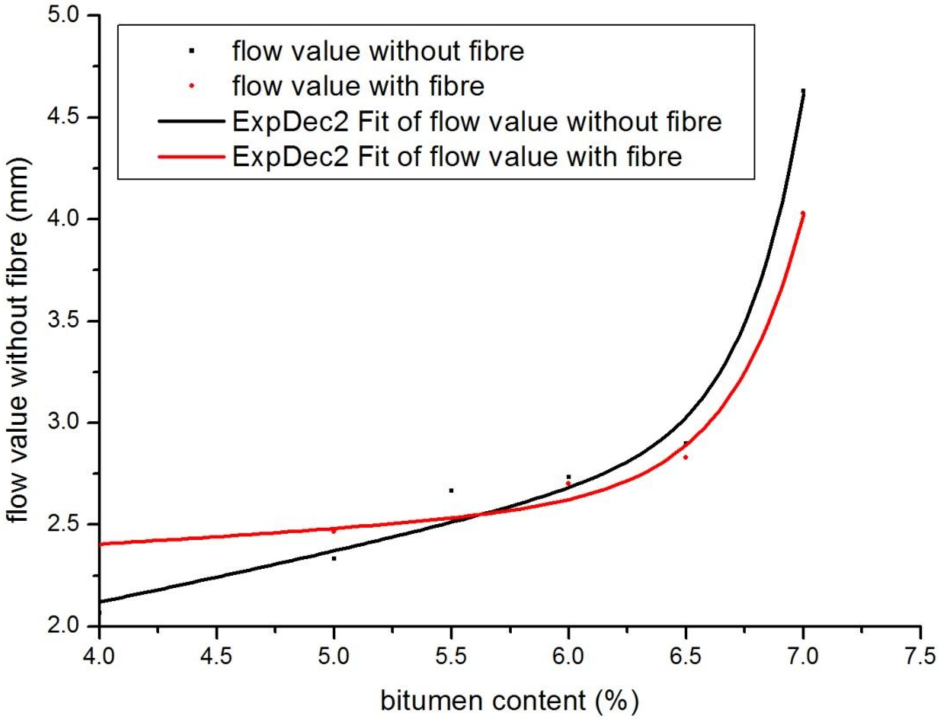

Fig 15. Flow vs. bitumen content

3. VMA vs. bitumen content

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

Table 11. VMA vs. bitumen content

binder content (%)	VMA (%)
4	17.08818
5	16.1534
5.5	17.8166
6	16.18461
6.5	16.68236
7	16.8565

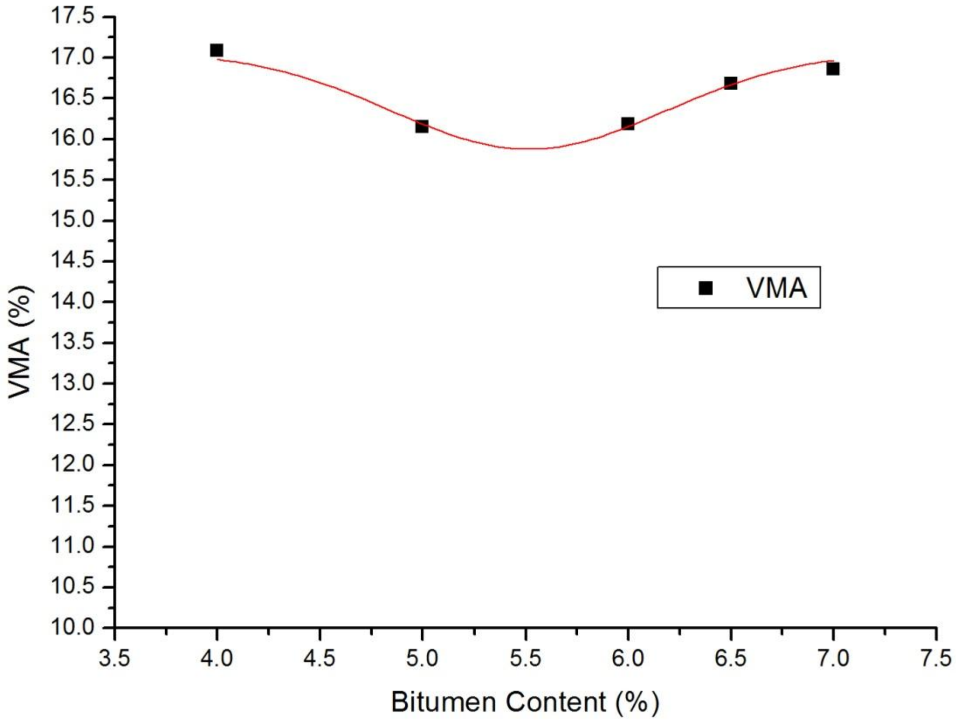

Fig 16. VMA vs. bitumen content

4. VFB vs. bitumen content

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

Table 12. VFB vs. bitumen content

binder content(%)	VFB (%)
4	53.58336
5	72.40831
5.5	71.15586
6	87.61234
6.5	92.02411
7	98.40028

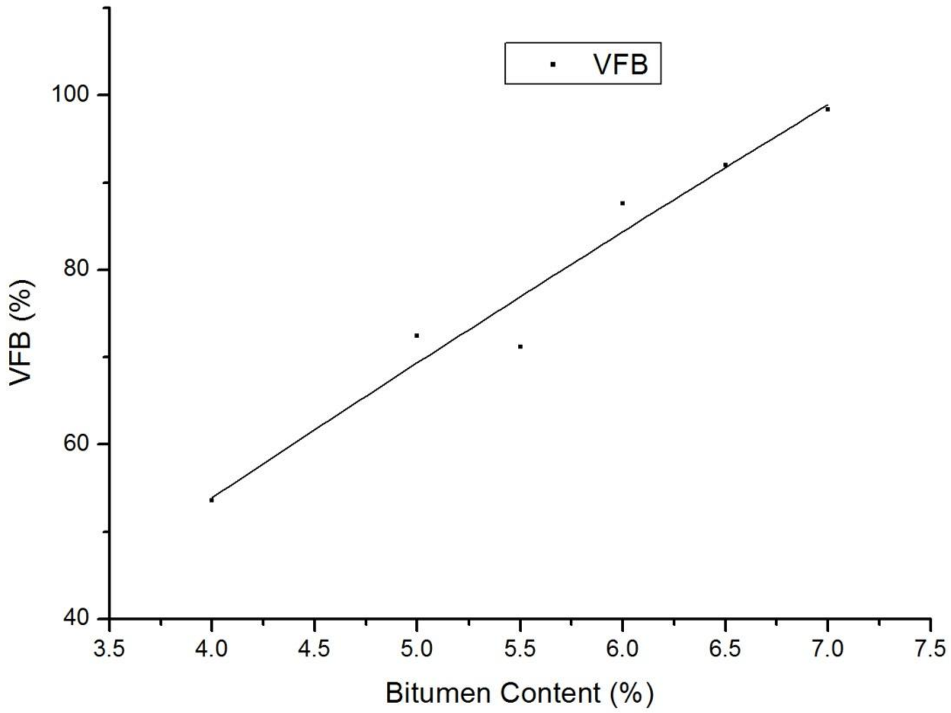

Fig 17. VFB vs. bitumen content

5. VA vs. bitumen content

Values of VA values in %ge and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and VA in y-axis.

Table 13. VA vs. bitumen content

bitumen content (%	VA (%)
4	7.931758
5	4.456995
5.5	5.139045
6	2.004895
6.5	1.330567
7	0.27

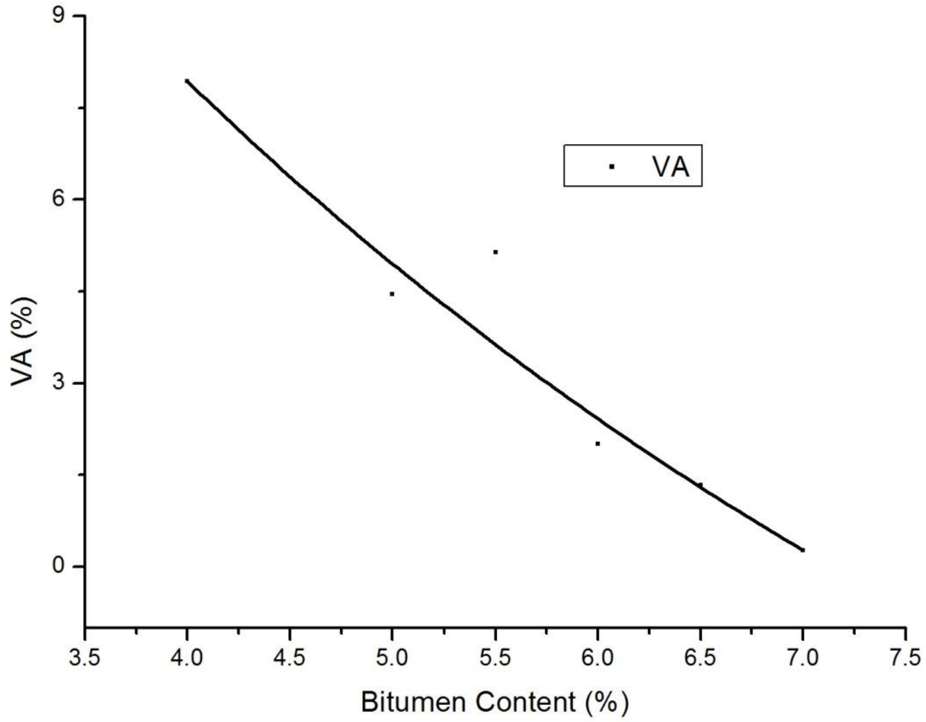

Fig 18. VA vs. bitumen content

6. Unit weight vs. bitumen content

Values of unit weight (G_{mm}) values in kg/m^3 and bitumen content in bitumen in %ge are plotted against bitumen in x-axis and Unit wt. in y-axis.

Table 14. Unit wt. vs. bitumen content

bitumen content (%)	unit weight (kg/m3)
4	2357.778
5	2409.459
5.5	2374.16
6	2434.185
6.5	2432.669
7	2440.636

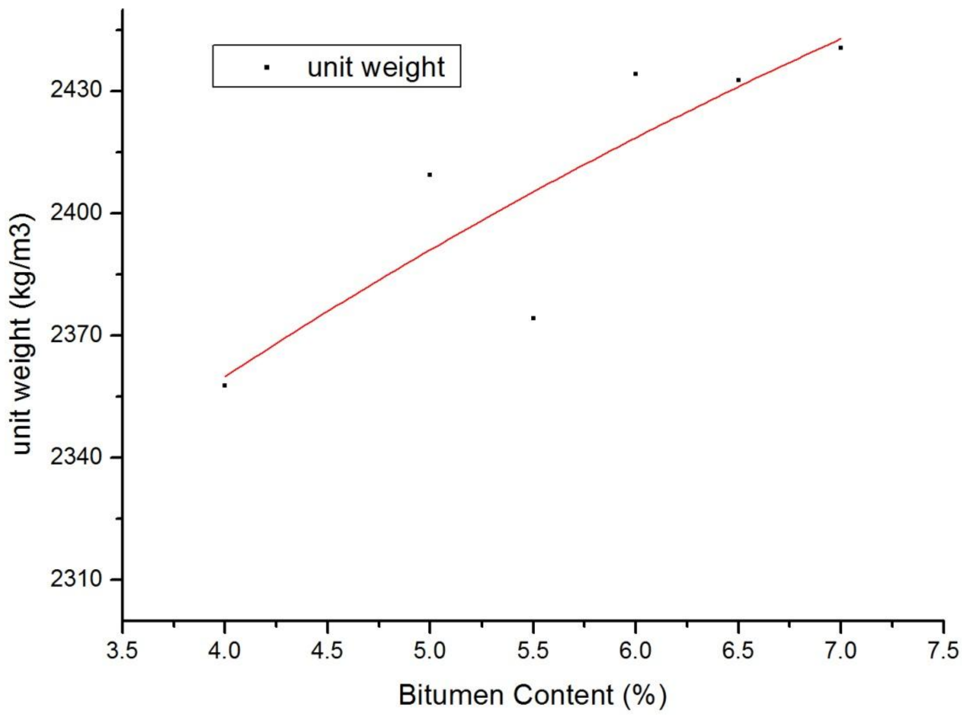

Fig 19. Unit wt. vs. bitumen content

3.4 DETERMINATION OF MIX DESIGN PARAMETER

From the curves, at 4 % air voids, the mix properties are as follows

Table 15. Mix properties at 4% air void

	Without fibre	With fibre
Asphalt content (%)	5.3	5.3
Stability (N)	12.7	13.8
Flow (mm)	2.47	2.5
VMA (%)	16	16
VFA (%)	74	74

Chapter 4

Interpretation of Results

4.1 INTERPRETATION OF RESULTS

1. From the graph of stability vs. bitumen it is learnt that optimum binder content for samples prepared by use of sisal fibre is found to be 5.3 %. For SMA mixes value of optimum binder content is quite high that makes it very costly. So we can say here that use of sisal fibre would result into sufficient cost effective and money saving measure.
2. Here maximum stability obtained is 13.8 kN. This value as compared to other fibres is a little higher. So we learn that sisal fibre can be used in case of general heavy traffic requirements and it would be suitable for severe traffic situations also.
3. Value of flow should increase by increase in binder content. In this case it is found that value of flow increases from 2.4 % to 4.03 %. A noteworthy observation in this project is obtained that flow value is not as high as in case of other fibres. So we see that use of sisal fibre results in less flow.
4. Theoretically VMA should remain constant for a given aggregate gradation with respect to binder content. Practically it is observed that at low bitumen content, VMA slowly decreases then increases after a pause. The initial fall in VMA is due to re-orientation of aggregates in presence of bitumen. In present case it is seen that VMA increases as binder increases. This may be explained by argument that due to thicker bitumen film, the aggregates move apart slightly resulting in increase of VMA.
5. With increase in bitumen content, VA of Marshall sample decreases, as bitumen replaces the air voids in the mix and subsequently, VFB increases with increase in bitumen content. In this case it is seen that results are in accordance with argument given above.
6. Further modification in design mixes can result in utilization of sisal fibre in bituminous pavement especially in SMA and reducing the biggest problem faced with SMAs i.e. cost of mixes for normal requirements.

Comparison

Table 16 : Comparison with other Binders

Type of stabilizers	Optimum Binder Content (%)	Density (Kg/m^3)	Stability (kN)	Flow (mm)	Air voids(%)	Voids in Mineral Aggregate(VMA)
Jute Fiber	6.2	2301	7.1	3.3	4.5	18.6
Imported cellulose fiber	6.1	2313	7.4	3.2	4.5	18.5
CRMB	6.2	2314	10.5	2.9	4.5	18.4
CRMB with Cellulose fiber	6.0	2306	8.9	N.A.	4.0	17.06
DBM MIX	5.21	2365	12.8	3	4	16
BC MIX	5.66	2361	13.2	2.6	3.8	17
Sisal fibre, Shukla,2009[20]	5.7	2424	10	3.55	4	17
Sisal fiber	5.3	2403	13.8	2.47	4	16

4.2 Future scope

1. In future performance of sisal fibre with other grades of bitumen can also be tested and seen whether it can be used successfully or not.
2. Use of sisal fibre may also be tested not only for SMAs but also for different other HMAs and Superpaves.
3. Indirect tensile test of bituminous mixes can give us an idea about tensile strength of bituminous mixes.
4. Repeated load testing can give us idea about the fatigue failure resistance of the specimen.
5. Wheel tracking test can give us idea about the rut resistance of the specimen.
6. Use of other fillers may result in better performance with sisal fibre. So it may also be evaluated in future.

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