International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

Laboratory Evaluation of SMA Mixtures Modified With Stabilizing Agent

Shreya[1], Swathi KS[2], Vidyashree DM[3], Vivek Agarwal[4], Dr Shiva Kumar G[5]

[1,2,3,4]*UG Student, Dept. of Civil Engineering, Dayanand Sagar college of Engg., Karnataka, India*
[5]*Assistant Professor, Dept. of Civil Engineering, Dayanand Sagar college of Engg., Karnataka, India*

Submitted: 15-05-2021 Revised: 26-05-2021 Accepted: 28-05-2021

ABSTRACT-Stone matrix asphalt (SMA) is a gap graded mixture that consists of two parts, a high concentration coarse aggregate skeleton and a high binder content mortar. The coarse aggregate skeleton provides the mixture with stone-stone contact, giving strength, while the high binder content mortar adds durability. The mortar is typically composed of fine aggregate, mineral filler, asphalt binder, and a stabilizing agent. A stabilizing additive such as mineral fibers, natural fibers, or polymer is added to SMA mix to prevent drain down. In addition, it has the potential of reinforcing and improving the tensile strength and cohesion of SMA mixtures. In this study, basalt fiber (BF) is used as stabilizing additives to prepare SMA mixtures with conventional viscosity-grade (VG) 30 bitumen. Mixtures were prepared with different levels of BF content and another mixture without any stabilizers was also prepared using polymer-modified bitumen (PMB). Marshall mix design and volumetric properties were evaluated. Results indicated that addition of basalt fiber increases the strength of mix.

keywords: stone matrix asphalt; stabilizing additive; basalt fiber.

I. INTRODUCTION

SMA was initially developed in Europe as a mix design for its ability against durable wearing courses. When applied to a suitable pavement structure it shows great resistance to rutting and tire wear. The use of SMA was first proposed in 1990 European asphalt study tour sponsored by AASTHO, FHWA, the national asphalt pavement association, the asphalt institute, and TRB. Since 1991, the use of SMA has increased steadily in the Unites States. Because of its cost-effective surface treatment, The United Kingdom is currently resurfacing most of its heavy traffic roadways with a SMA-type surface. SMA is a gap-graded mix consisting of two parts, a high concentration coarse aggregate skeleton and a high binder content mortar. The coarse aggregate skeleton adds strength, while the high binder content mortar adds durability. The mortar is typically composed of fine aggregate, mineral filler, asphalt binder and a stabilizing additive. These stabilizing additive acts to hold the asphalt binder in the mixture during the high temperatures of production and placement. The concept behind working of SMA is the coarse aggregate skeleton stone portion provides a stone-on-stone contact to prevent rutting and provide skid resistance. The mix is held together with sufficient specialized mortar to prevent drain down of the binder and provide durability.

The Conventional bituminous pavements have less strength, durability and longevity than SMA. SMA are used on pavement carrying traffic load or where there is high tyre pressure. SMA also shows improved resistance to fatigue effects and cracking at low temperatures. SMA can be compacted using the same compacting hands and equipment as used for normal hot mix. The surface characteristics of SMA are similar to open graded asphalt so that the noise generated by the traffic is lower. Because of all these advantages SMA has been proved to be superior over HMA mixes.

The bituminous paving mixes as specified in specifications (, 2001) are commonly used in India. Year after years, the increase of potholes in India have created a lot of problems and lead to various and dangerous accidents. Bituminous mixes are used in a flexible pavement to serve the following three important functions such as improved structural strength, facilitating subsurface drainage and providing surface friction especially in wet condition. Since April 2009 Indian roads are being constructed using SMA

Objectives

- To find the suitability of basalt fiber as a stabilizer for use in stone matrix asphalt.
- To compare the marshall properties of SMA samples for different gradation and analyse the

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

result for deciding the optimum binder content (OBC) for further studies.

- To compare marshallproperties for SMA samples with and without basalt fiber using mid gradation which involves stability,bulk density, flow,percent air void,volume of asphalt,percent voids in aggregate,percent air void in asphalt.

II. LITERATURE REVIEW

"Effect of Fibers on Mixture Design of Stone Matrix Asphalt". By Yanping Sheng, Haibin Li, Ping Guo in the year 2017

Summary

This study analyzed the effect of different fibers and fiber contents on the VMA in SMA mixture design. A surface-dry condition method test and Marshall Stability test were applied on the SMA mixture with four different fibers. The mixture evaluation suggested no statistically significant difference between lignin fiber and polyester fiber on the stability.

"Laboratory investigations on SMA mixes with different additives". By PAWAN KUMAR, SATISH CHANDRA and SUNIL BOSE in the year 2007

Summary

In this paper, naturally occurring jute fibers were coated with low viscosity binder and were used in the present study as an alternative to the patented fibers. Use of crumb rubber modified binder (CRMB) is also investigated as stabilizer in SMA mixes.

"Rutting evaluation of stone mastic asphalt for basalt and basalt-limestone aggregate combinations". By Erol iskender in the year 2013

Summary

The study is aimed to investigate the rutting of basalt and basalt-limestone aggregate combinations for coarser and finer SMA mixtures with a LCPC wheel tracking test. The sensitivity of this test was also evaluated with different maximum aggregate sizes and changes in gradation.

"Utilization of waste fibres in stone matrix asphalt mixtures". By Bradley J. Putman, Serji N. Amirkhanian in the year 2004

Summary

This study compared the performance of SMA mixtures containing waste tire and carpet fibres with mixes made with commonly used cellulose and other polyster fibres produced specifically for use in hot mix asphalt (HMA).

"Hybrid Modification of Stone Mastic Asphalt with Cellulose and Basalt Fiber". By You Huang, ZhaohuiLiu, LiLiu, Yunbao Zhang, in the year 2020

Summary

In this study, cellulose and basalt fiber were introduced simultaneously to stone mastic asphalt (SMA) to investigate the effects of hybrid modification on performance improvement of asphalt mixture.

"Engineered Cementitious Composites (ECC)-Material, Structural and Durability Performance". By Victor c.li in the year 2007

Summary

Beyond the peak load, ECC is no different than normal fiber reinforced concrete showing tension softening response the high tensile ductility is of great value in enhancing the ultimate limit state (ULS) in terms of structural load and deformation capacity as well as energy absorption.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

III. METHODOLOGY AND MATERIALS

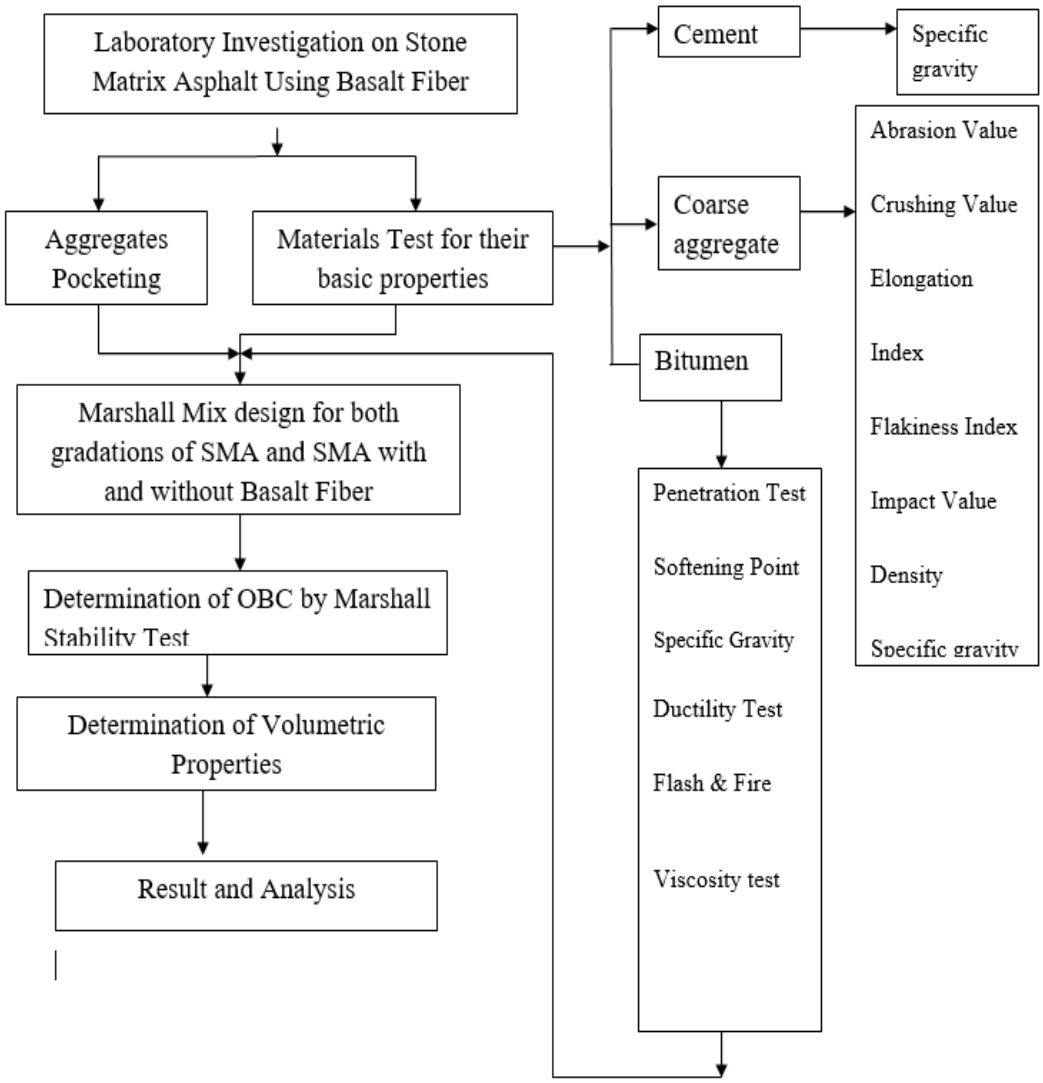


Figure 1**: Flow diagram of Methodology**

Bitumen

Plain bitumen of viscosity grade 30 was used for preparation of specimens. The tests conducted on the bitumen and their results are tabulated in table 1.

Aggregates

Coarse Aggregate: The coarse aggregates consisted of crushed granite rock retained on 2.36 mm sieve. They were free of dust, soft organic and other harmful substances, and were safe, hard, and durable. The aggregates meet the physical specifications specified in Table-2.

Fine Aggregate: Fine aggregates (passing 2.36mm sieve and retained on 0.075 mm sieve) consisted of 100 percent crushed sand resulting from granite rock crushing operations. The fine aggregate was clear of soft fragments, organic or other harmful substances, and was clean, hard, sturdy, and of a fairly cubical form.

Mineral filler: The filler material used in the study is granite stone dust and cement. Fly ash is not permitted as a filler material in SMA. As it creating difficulty in mixing when binder is added to the aggregates. Of the 8% (passing 0.075mm IS sieve) filler used, 6% is stone dust and 2% is cement.

Basalt fiber

Basalt fiber has high tensile strength and very high modulus. When mixed with SMA, its lead to the formation of a strong network of fibers and restrict movement and thus help in eliminating the anti-deformation properties of SMA.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

Figure -2 Basalt fiber

Table- 1 physical properties of bitumen

Sl no	Tests	As per IS code Test procedure	Range	Results
1	Penetration test ($1/10^{th}$ of mm)	IS 1203-1978	60-70	66
2	Ductility test (cm)	IS 1208-1978	75 minimum	79
3	Softening point (°C)	IS 1205-1978	45-55	51
4	Flash point (°C)	IS 1209-1978	175 minimum	330
5	Fire point (°C)	IS 1209-1978	175 minimum	345
6	Viscosity at 135°C, centipoise	IS 1206-1978 (PART 3)	350 minimum	361

Table -2 physical properties of coarse aggregates

Sl. No.	**Tests**	**As Per IS-Codes Test Procedure**	**Specifications (2009)**	**Results**
1	Specific gravity	IS-2386 Part III	-	2.62
2	Crushing Value	IS-2386 Part IV	-	24.8%
3	Abrasion Value	IS-2386 Part IV	Max 25%	22.0%
4	Impact Value	IS-2386 Part IV	Max 24%	20.89%
5	Water Absorption	IS-2386 Part III	2%	0.25%
6	Combined Elongation and Flakiness Indices	IS-2386 Part I	Max 30%	29.0%

Marshall Test

The Marshall Stability test was performed on bituminous mixes containing varying amounts of bitumen, at various temperatures, and with various stabilizer rates. It was used in research to find the Optimum Binder Content (OBC), with a focus on maximum stability, unit weight, and 4 percent voids or 75% voids filled with bitumen. This test is commonly used in paving job routine testing programmes. A maximum load borne by a compacted specimen at a typical test temperature of 600C is used to determine the mix's stability. The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test (flow value may also be measured by deformation units of 0.1mm.The test was carried out according to the ASTM: D: 1559-65

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

Figure -3 Marshall apparatus

IV.RESULTS AND DISCUSSIONS

Design of SMA mix

The Marshall Stability specimens were prepared with plain bitumen by varying the binder content from 5 per cent to 6.5 per cent by an increment of 0.5 per cent. Three specimens were prepared for each binder content. In the conventional Marshall mix design 1.2 kg of aggregates were used to prepare the specimen.

Marshall Stability test was conducted and properties like stability, flow, bulk density, volume of voids and voids filled with bitumen are found for mid gradation. The Marshall Stability test results are shown in the table.

The graphs were plotted between bitumen content and Marshall Stability, Bulk density and Air voids. The bitumen content corresponding to maximum stability, Bulk density and 4.0% air voids was obtained from these graphs. The average of the three bitumen contents was calculated and treated as optimum bitumen content (OBC).

Marshall Properties

The Marshall Stability first increases with bitumen content, reaches a maximum value when the bitumen content is almost equal to the OBC value and then decreases. At OBC the Marshall Stability values for SMA samples prepared using Mid gradation is 6.119kN. The flow value increases with increase in bitumen content for both SMA mixes. Flow values were between 3.6-5.80mm.

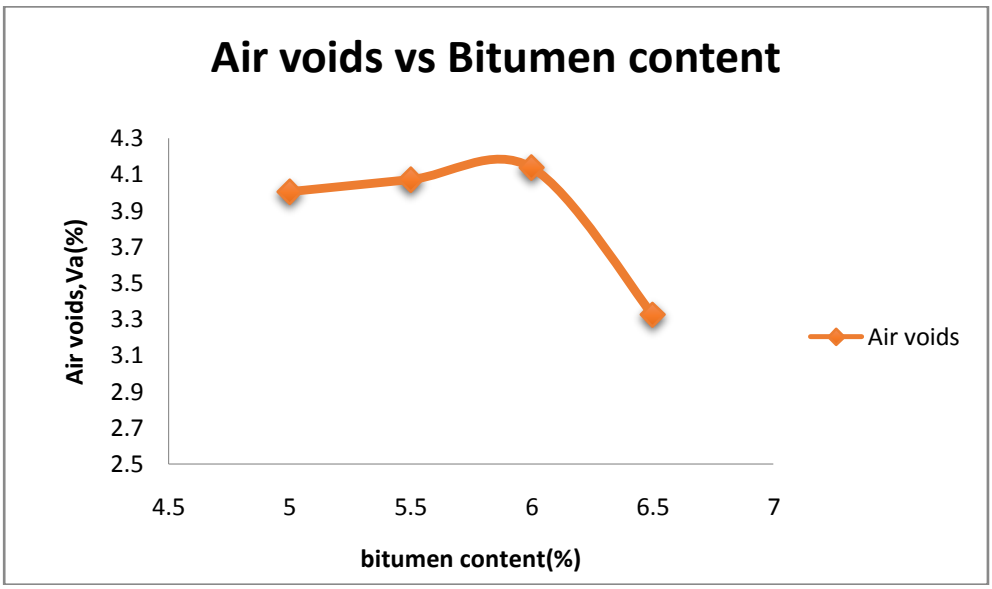
The Voids in Mineral Aggregates (VMA) for all with bitumen content.samples were between 15%-18%. Voids Filled with Bitumen (VFB) is in the range of 70-90% and it shows a gradual increasing trend with bitumen content.

Table -4 properties of SMA sample for different gradation by marshall method

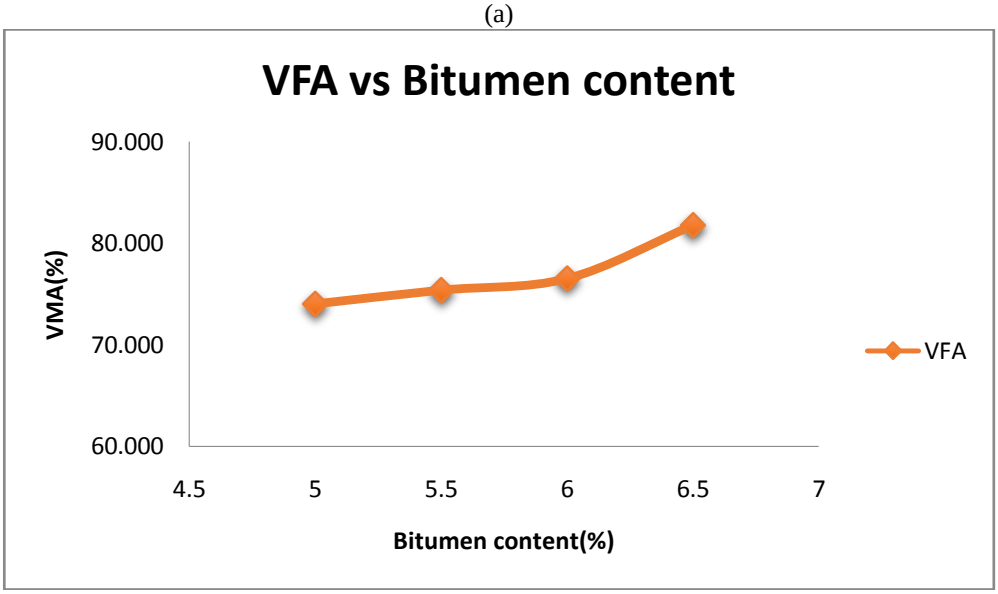
Properties	Bitumen content			
Mid Gradation	**5.0%**	**5.5%**	**6.0%**	**6.5%**
Marshall stability (kN)	6.105	6.116	6.119	5.091
Flow Value (mm)	3.6	4.20	nn	5.80
Bulk density (kg/m^3)	2324.984	2308.312	2291.997	2298.342
Volume of voids Vv (%)	4.004	4.071	4.139	3.267

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

Voids in Mineral Aggregate VMA (%)	15.401	16.518	17.621	17.913
Void filled with bitumen VFB(%)	74.003	75.354	76.513	81.764
Optimum binder content	6%			

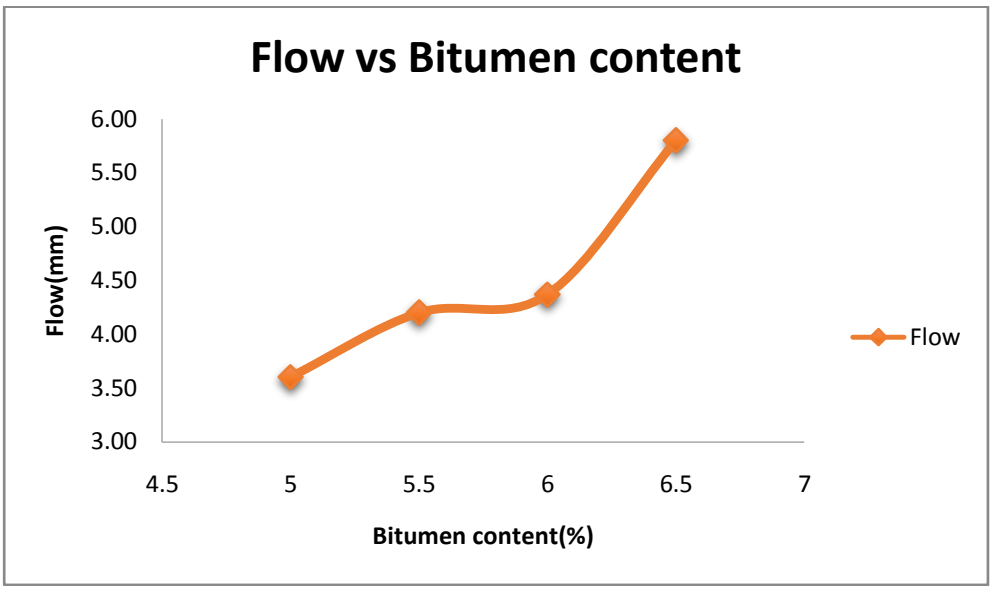


(a)

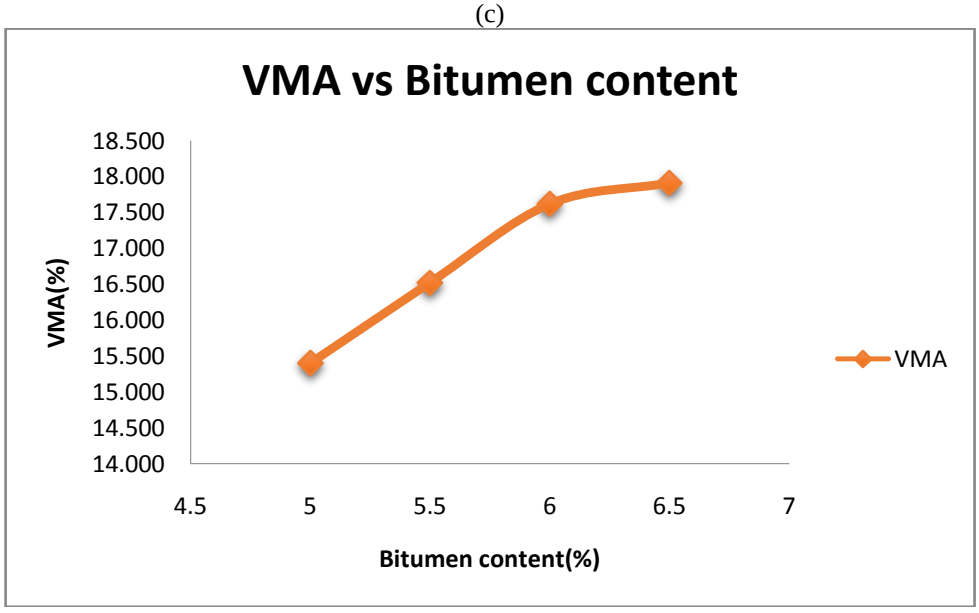


(b)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

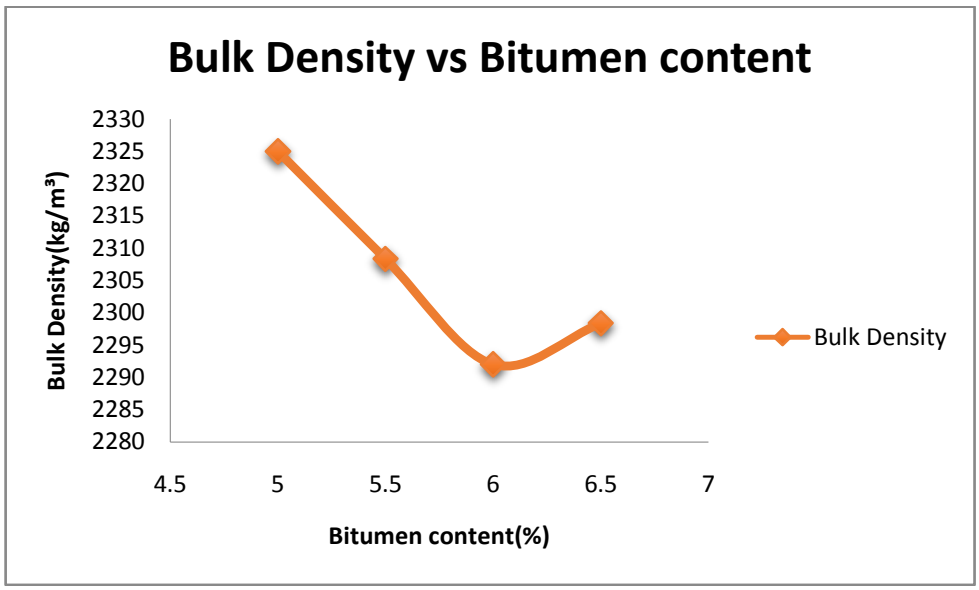


(c)

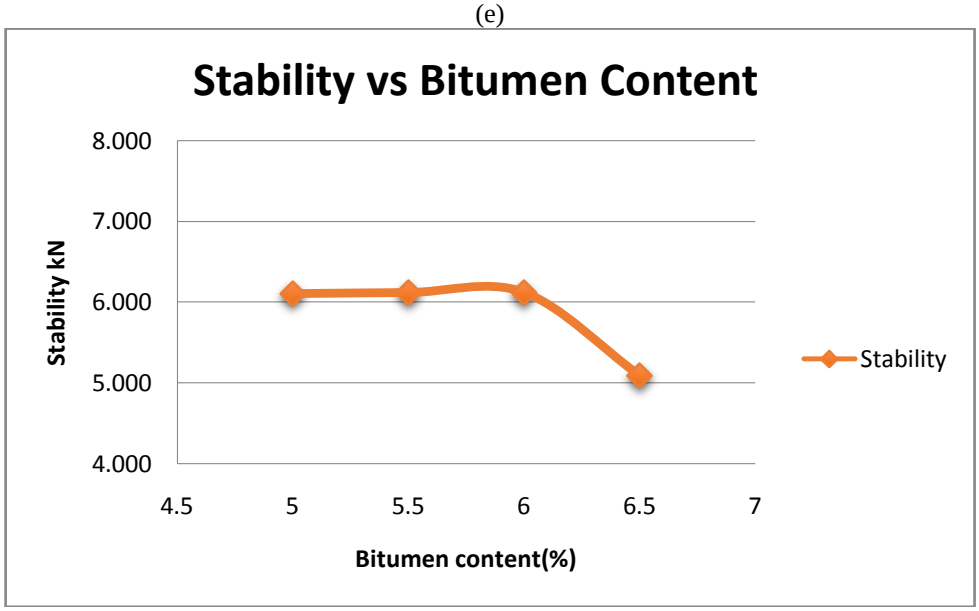


(d)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252



(e)



(f)

Figure -4 (a-f) properties of SMA sample for mid gradation by marshall method

Preparation of Stone Matrix Asphalt samples with and without basalt fiber usingMarshall Method for Mid Gradation

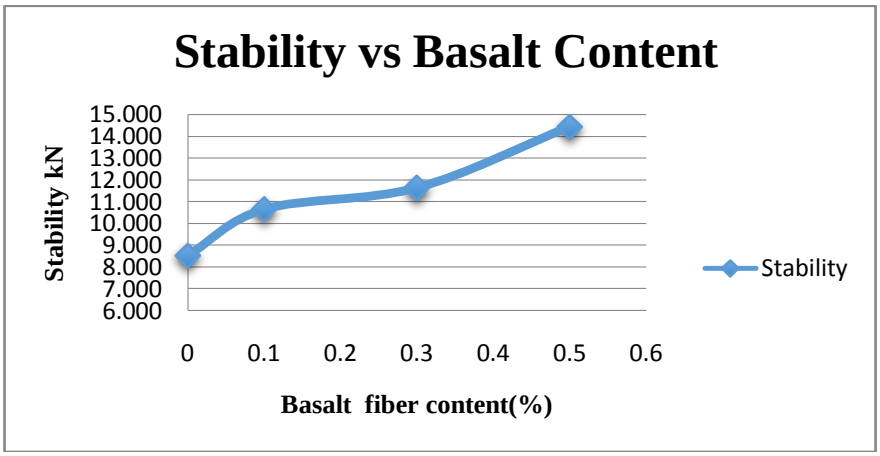
SMA specimens were prepared in Marshall Apparatus with 50 blows on either side. Samples were prepared with and without basalt fiber using Marshall Method at Mid Gradation for Optimum Binder content of 6% by varying fiber content of 0%, 0.1%, 0.3%, and 0.5%. Here fiber areadded directly.

Marshall Properties

The Marshall properties increases with increase in the fiber content, reaches a maximum value at 0.5%. The flow value first decreases with increase in fiber content and again reaches a maximum value at 0.3% and flow values are between 5.93 to 8.75mm. The voids in mineral aggregates for all samples were between 18-21%. voids filled with bitumen is in the range of 25-52%.

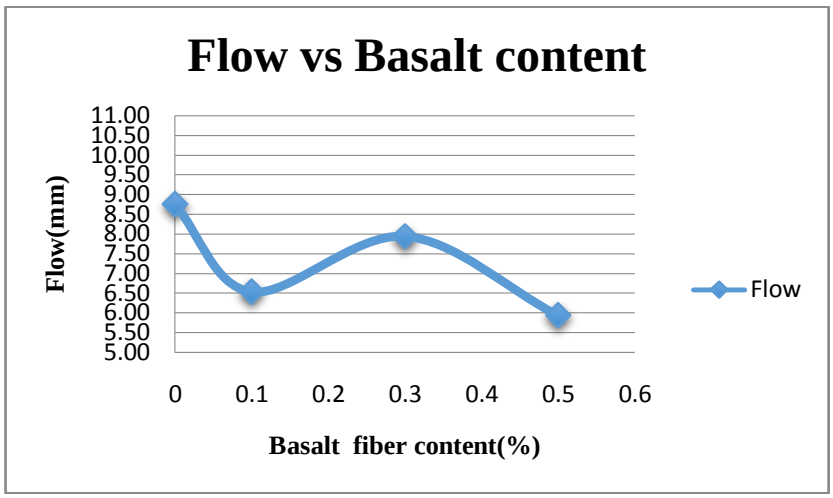
International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252

Properties	**Fiber content**			
Direct Fiber	0%	0.1%	0.3%	0.5%
Marshall stability (kN)	8.515	10.658	11.628	14.430
Flow Value (mm)	8.75	6.53	7.93	5.93
Bulk density (kg/m^3)	2203.451	2328.154	2316.332	2328.80
Volume of voids Vv (%)	15.274	10.340	10.683	9.764
Voids in Mineral Aggregate VMA (%)	20.741	18.795	19.975	20.064
Void filled with bitumen VFB (%)	26.359	44.984	46.517	51.337

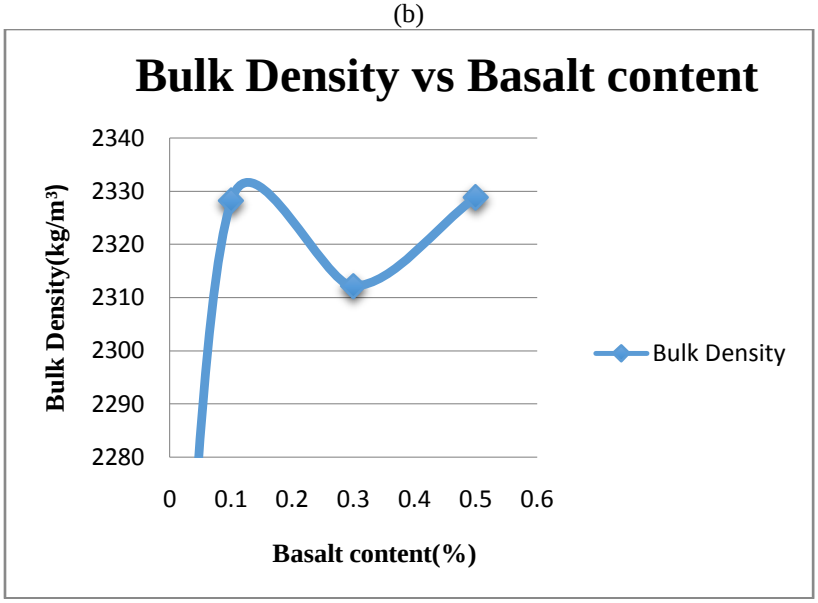


(a)

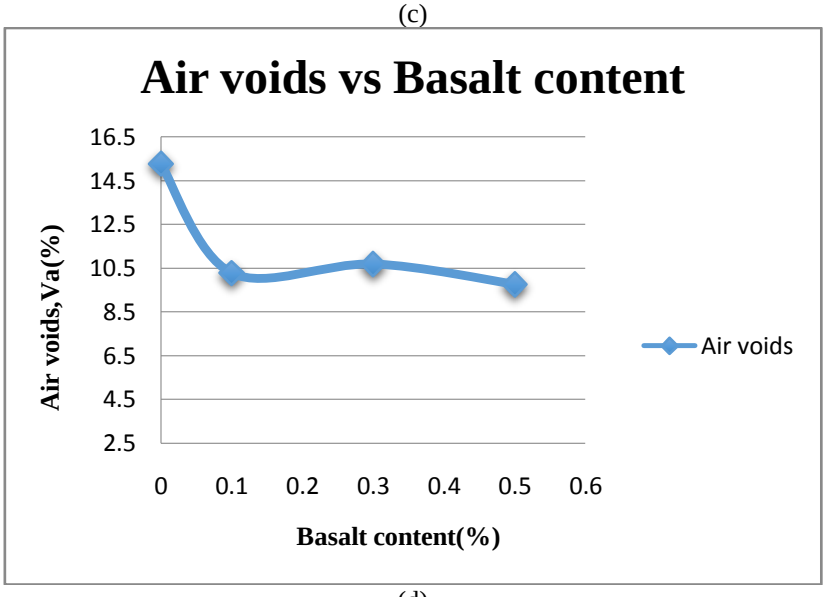
International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252



(b)

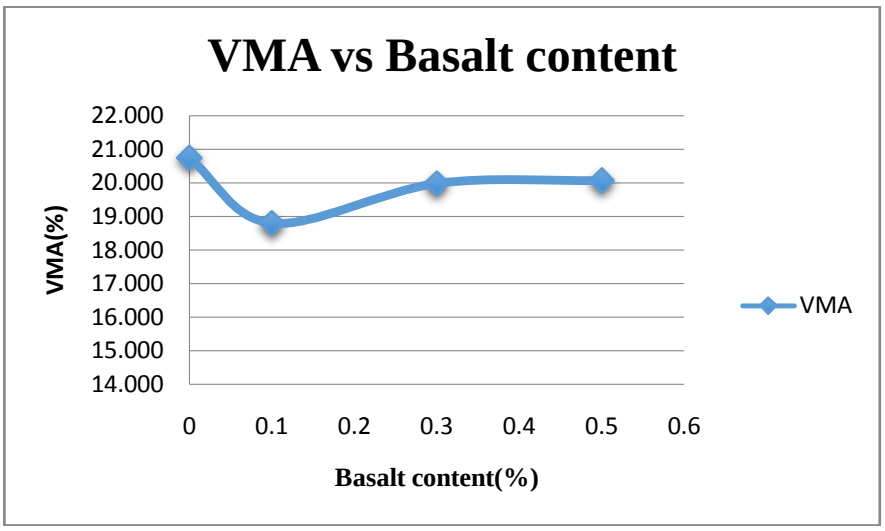


(c)

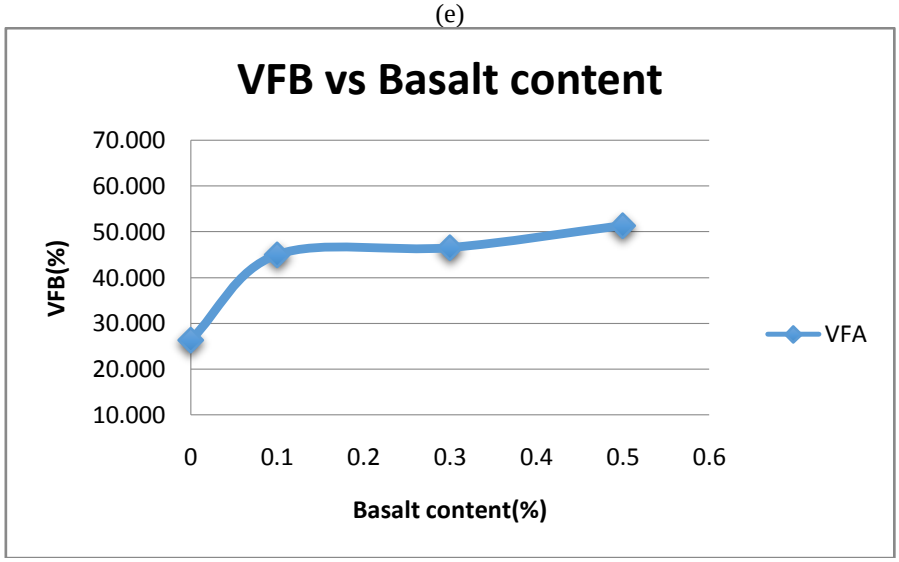


(d)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 1327-1338 www.ijaem.net ISSN: 2395-5252



(e)



(f)

Fig-5(a-f)Properties SMA samples using Direct fiber prepared by Marshall Method at OBC

CONCLUSIONS

Following conclusions are made based on the result obtained in the present investigation:

- Marshall stability initially increases with the increase in the bitumen content from 5.0% to 6.0%; further increases in the bitumen to 6.5% decreases the stability value for both the gradation.
- From the result of Marshall properties of SMA mix, fiber added at a rate of 0.5% weight of the sample shows maximum stability.
- Flow value is higher at 0% and it decreases with increase in the fiber content and again increase to maximum value of 7.93 at 0.3% and again decreases with increase in fiber content.
- The increase in bitumen content initially increased the bulk density but further increases in bitumen content decreases the bulk density. Due to addition of fiber it was seen that it is increased.
- The percent of air voids in the mix were found to decrease with the increase with the increase in the bitumen content. Due to addition of fiber it was seen that at 0.3% it has maximum value.

Scope for further research

- In the future performance of basalt fiber with other grades of bitumen, modified bitumen, cutbacks and emulsion can also be tested for their performance.
- Use of basalt fiber may also be tested not only for SMAs but also for different other HMAs and super pave.
- The work can be carried out using different mineral fibers other than basalt fiber.

- Bio-degradability of SMA using UV rays may be investigated in laboratory.

REFERENCES

[1]. Bradely J. Putman, Serji N. Amirkhanian," Utilization of Waste fibers in stone matrix asphalt mixtures", Resources, Conservation and Recycling, Volume 42, Issue 3, October 2004, Pages 265-274.

[2]. C. Kamaraj, G. Kumar, G. Sharma, P.K. Jain and K.V. Babu " Laboratory Studies on the Behaviour of Stone Matrix Asphalt Versus Dense Graded Bituminous Mixes Using Natural Rubber Powder (Wet Process)", Highway Research Bulletin, No 71, December 2004, Pages 39-60.

[3]. Muniandy, R.; Huat, B.B.K., American Journal of Applied Sciences, Vol-III, issue-9, 2006, 2005-2010.

[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.

[5]. Kumar Pawan, Chandra Satish and Bose Sunil, 'Laboratory investigations on SMA mixes with different additives', International Journal of Pavement Engineering, Volume 8, Issue1, March 2007, Pages11-18.

[6]. Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen," Utilization of steel slag as aggregates for stone mastic asphalt (SMA) mixtures", Building and Environment,42(2007),Pages 2580-2585 (www.elsevier.com/locate/buildenv).

[7]. Yongjie Xue, Haobo Hou, Shujing Zhu, Jin Zha, "Utilization of municipal solid waste incineration ash in stone mastic asphalt mixture: Pavement performance and environmental impact", Construction and Building Materials, In Press, Corrected Proof, Available online 13 June 2008 (www.elsevier.com/locate/conbuildmat).

[8]. Akoto, B.K. (2009) "Some of The Factors Responsible for Premature Failures of Flexible Pavements" African Journal of Science and Technology Vol.10, No.2, pp.1-17.

[9]. Brown, E.R. and Haddock, J. E. (1997). **"**A Method to Ensure Stone-On-stone Contact in Stone Matrix Asphalt Paving Mixtures." National Asphalt Pavement Association, NCAT Report No 97-02.

[10]. Druschner Lothar and Schafer Volker (2005). "Stone Mastic Asphalt", Asphalt guide, pp.1.

[11]. Kumar Pawan, Chandra Satish & Bose Sunil (2007), "Laboratory investigations on SMA mixes with different additives" International Journal of Pavement Engineering, Vol 8, pp. 11-18.

[12]. "MORT&H Annual Report 2010-2011" (Section 500) SMA, Ministry of Road Transport & Highways, 2011.