International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 3, March-April 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Study on Bituminous Mix Design with Different Percentages of Crumb Rubber to Improve Pavement Strength

Pawan Kumar Pandit, Prof. Afzal Khan

Department of Civil Engineering, Millennium Institute of Technology, Bhopal, Madhya Pradesh, India

ABSTRACT

Bitumen, also known as asphalt in the United States, is a substance that forms through the distillation of crude oil. It has waterproofing and adhesive properties. Bitumen production through distillation removes lighter crude oil components, such as gasoline and diesel, leaving the "heavier" bitumen behind. The producer often refines it several times to improve its grade. Bitumen can also occur in nature: Deposits of naturally occurring bitumen form at the bottom of ancient lakes, where prehistoric organisms have since decayed and have been subjected to heat and pressure.

Bitumen is generally for industry use. Bitumen was first used for its natural adhesive and waterproofing characteristics, but it was also used as a medicine. It was used to bind building materials together, as well as to line the bottoms of ships. Ancient civilizations traded the material. Herodotus, a fifth-century BC Greek historian, claimed that the walls of ancient Babylon contained bitumen.

How to cite this paper: Pawan Kumar Pandit | Prof. Afzal Khan "Study on Bituminous Mix Design with Different Percentages of Crumb Rubber to Improve Pavement Strength" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-3, April 2022, pp.583-594, URL: www.ijtsrd.com/papers/ijtsrd49575.pdf

IJTSRD49575

CRUMB RUBBER

Crumb rubber quality without fluctuation is one of the most important requirements for rubber bitumen production process and is a constant product quality. During crumb rubber production waste tyres are shredded, fabric and steel used as reinforcement material are removed. Tyres should be clear before shredding because impurities (sand, clay, gravel in the tread, etc.) are not allowed. From rubber bitumen production point of view most valuable component of tyres (and crumb rubber) is polyisoprene (natural rubber). Crumb rubber derived from passenger tyre contains 10-20% of it; this amount is around 35-45% in case of truck tyres. Further components of crumb rubbers are synthetic rubber (15-45%), carbon black (25-30%), plasticizers (5-15%) and inorganic additives (5-15%) as measured ac-cording to ASTM D297-93 standard .

STONE MATRIX ASPHALT

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 examination work total utilized according to the MORTH determination which was taken from an equivalent part. The examples are made with total with various degree, filler and fastener (bitumen 60/70). High convergence of coarse total expands stone-to-contact and interlocking in the blend which gives quality and the rich mortar folio gives toughness. It gives a higher impervious to rutting and gives adequate erosion to asphalt surface even it is presented to rehashed loads.

- In correlation with thick evaluated blends, SMA has higher extent of coarse total, lower extent of moderate size total and higher extent of mineral filler. Stone Lattice Black- top blend test are tried in Marshall Contraption.

Flexible pavements designing are preferred always over all other rigid pavements for road construction. Stone matrix asphalt mix sample were tested in Marshall Apparatus. SMA Mix is desired to have quality of resistance to wear & tear, greater strength for better performs during heavy loads.

World is starting at now focusing on substitute material sources that are condition pleasant and biodegradable in nature. The composite materials could be named as those materials which are incorporated by at least two materials having various properties. All things considered, composites materials have solid burden conveying strengthening material imbedded in flimsier cross section materials. The essential constituent of composites have a relentless stage which is the huge a bit of the composite is called lattice. Grid are all things considered increasingly bendable and less hard and these are commonly either inorganic or regular. Discretionary constituent of composites have pliable called fortification and they are embedded in the lattice. The constituents of composite materials have their property anyway when they are united together, they give a mix of properties that a particular can't have the ability to give. For the most part, composite materials are organized based on network materials as:

1. Ceramic Lattice Composites
2. Polymer Framework Composites
3. Metal Framework Composites

OBJECTIVES OF THE RESEARCH WORK

- To analyze the cost of bituminous pavement and also reduce the total construction cost.
- To study the strength of SMA by partial replacement of coarse aggregate with 5%,10% and 15%crumb tier waste by weight of aggregate.
- Preparation of Marshall Specimens and getting optimum mix content with the help of Marshall Test data and to study the Thermo-economic feasibility of rubber tire crumbs for its use as 60/70 grade of bitumen.
- To conduct techno-economic study of the desire material feasibility.
- To utilize the crumb tire rubber as it is a waste.

RESULT AND DISCUSSION

INTRODUCTION

In this chapter Result and Observation of test carried out in previous chapter is presented, analyzed and discuss. First section is deals with parameter used for analysis. Second section deals with calculation of Optimum binder Content (OBC). Third section deals with calculation of Optimum binder Content (OBC).

PARAMETERSUSED

Based on volume considered in evaluating specific gravity of an aggregate, some definitions of specific gravity are proposed. As per Das A. and Chakroborty P. (2010); the definitions and other formulae used in calculations hereafter are as follows:

$$G_{se} = \frac{P_{mm} - P_b}{\left(\frac{P_{mm}}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$$

Where:

G_{se} = Effective specific gravity of aggregate
P_{mm} = total loose mixture = 100%
P_b = asphalt, percent by total weight of mixture
G_{mm} = maximum specific gravity of paving mixture (no air voids), **(KT-39)**
G_b = specific gravity of asphalt

If mix composition is determined as percent by weight of the total mixture:

$$VMA = 100 - \frac{G_{mb} \; P_s}{G_{sb}}$$

Where:

VMA = voids in mineral aggregate (percent of bulk vol.)
G_{sb} = bulk specific gravity of aggregate.
G_{mb} = bulk specific gravity of compacted mixture. **(KT-15)**
P_s = aggregate, percent by total dry weight of mixture.

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

Where:

G_{mm} = maximum specific gravity of paving mixture (no air voids)
P_{mm} = total loose mixture = 100%
P_s = aggregate, percent by total weight of mixture ($P_1 + P_2 + P_3 + P_n$)
P_b = asphalt, percent by total weight of mixture.
G_{se} = effective specific gravity of aggregate.
G_b = specific gravity of asphalt.

$$VFA = \left(\frac{VMA - P_a}{VMA}\right)100$$

Where:

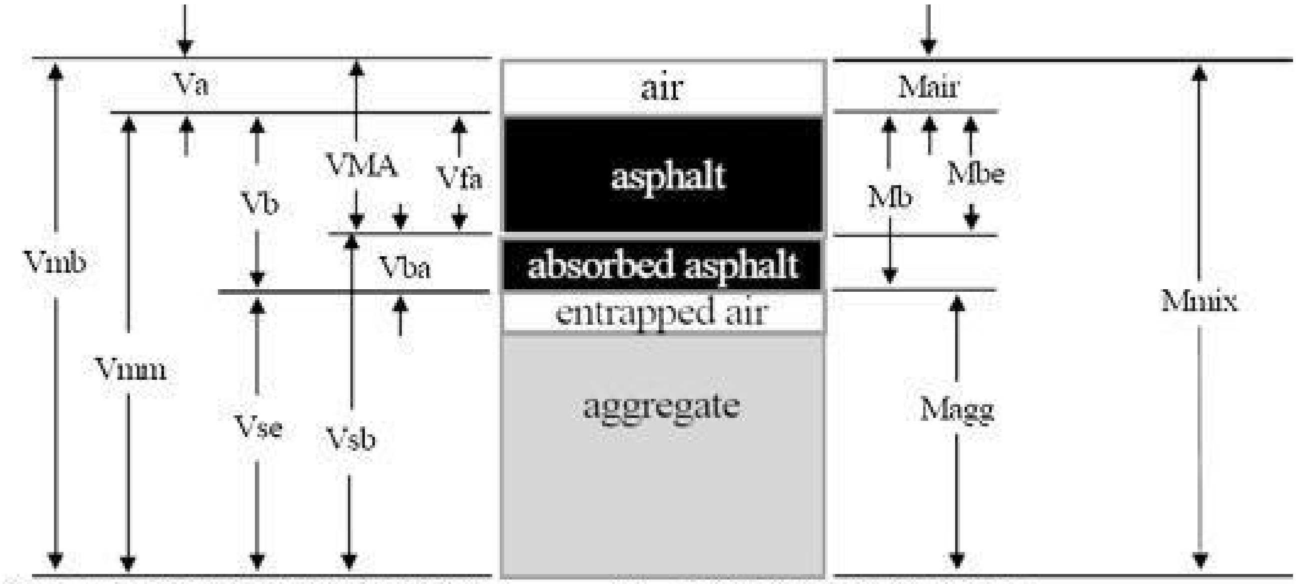
VMA = voids in mineral aggregate, percent of bulk vol.

P_{be} = effective asphalt content.

G_b = specific gravity of asphalt.

G_{mb} = bulk specific gravity of compacted mixture.

Observations and Tabulation



VMA = Volume of voids in mineral aggregate
V_{mb} = Bulk volume of compacted mix
V_{mm} = Voidless volume of paving mix
V_{fa} = Volume of voids filled with asphalt
V_a = Volume of air voids
V_b = Volume of asphalt binder
V_{ba} = Volume of absorbed asphalt binder
V_{sb} = Volume of mineral aggregate (by bulk specific gravity)
V_{se} = Volume of mineral aggregate (by effective specific gravity)

M_{mx} = Total mass of asphalt mixture
M_b = Mass of asphalt binder
M_{be} = Mass of effective aggregate binder
M_{agg} = Mass of aggregate
M_{air} = Mass of air = 0

Fig. 5.1 Phase Diagram of bituminous mix

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.

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.

STABILITY

Table 4.1 Stability vs. crumb rubber Content

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES STABILITY(KN)
1.	**M-1**	0	10.7 10.6 10.8 Av=10.7
2.	**M-2**	**5**	12.9 12.7 12.6 **Av=12.7**
3.	**M-3**	**10**	11.9 12.0 11.8 **Av=11.9**
4.	**M-4**	**15**	11.5 11.5 11.7 **Av=11.5**

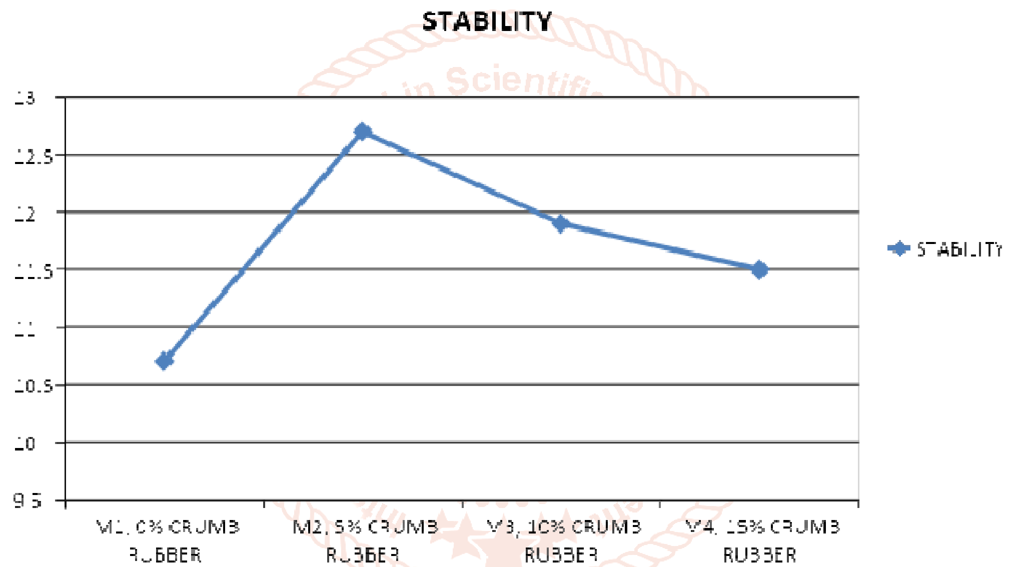


Fig 4.2. Stability vs. crumb rubber Content

FLOW VALUE

Table 4.2 Flow vs. crumb rubber Content

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES STABILITY(KN)
1.	**M-1**	0	3.88 3.48 3.69 Av=3.71
2.	**M-2**	5	3.55 3.22 3.34 Av=3.42
3.	**M-3**	10	2.89 2.65 2.77 Av=2.75
4.	**M-4**	15	2.56 2.36 2.58 Av=2.53

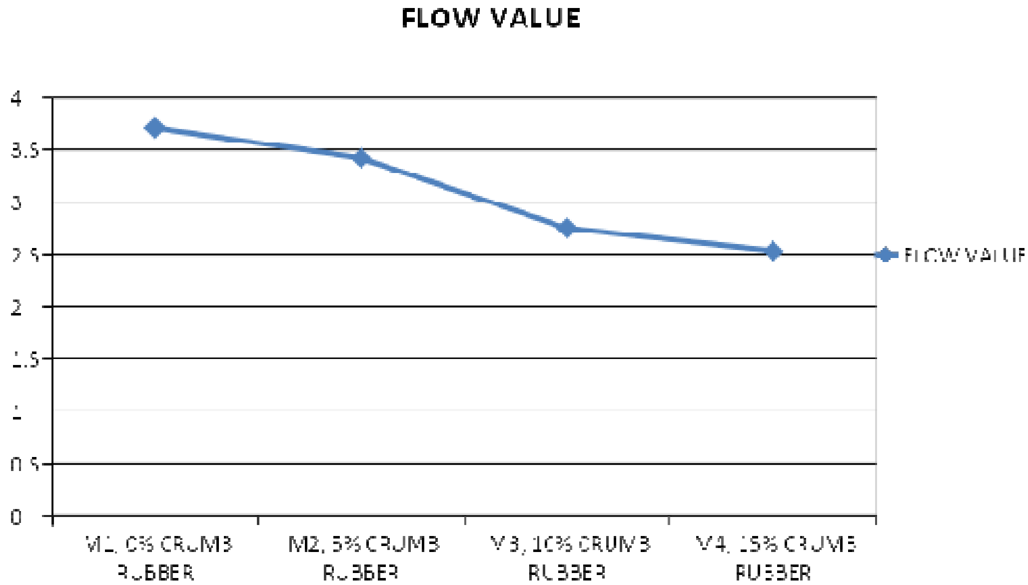


Fig 4.3. Flow vs. crumb rubber Content

VMA

Table 4.3 VMA vs. crumb rubber Content

. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES (VMA %)
1.	M-1	0	18.7 18.6 18.8 Av=18.7
2.	M-2	5	19.9 19.7 19.6 Av=19.7
3.	M-3	10	18.9 18.0 18.8 Av=18.9
4.	M-4	15	18.5 18.5 18.7 **Av=18.5**

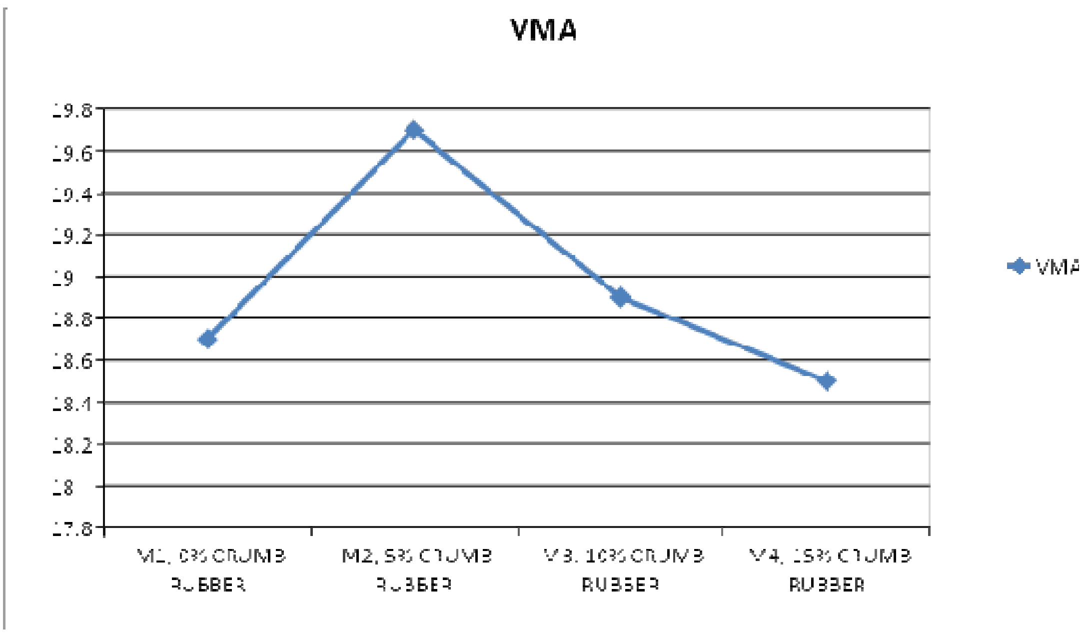


Fig 4.4. VMA vs. crumb rubber Content

VFB

Table 4.4 VFB vs. crumb rubber Content

S. NO.	Mix	CRUMB RUBBER (%)	3-3 SAMPLES (VFB %)
1.	**M-1**	**0**	78.7 78.9 78.2 **Av=78.6**
2.	**M-2**	**5**	78.9 78.7 78.6 **Av=78.7**
3.	**M-3**	**10**	79.9 79.0 79.8 **Av=79.9**
4.	**M-4**	**15**	78.5 78.2 78.8 **Av=78.5**

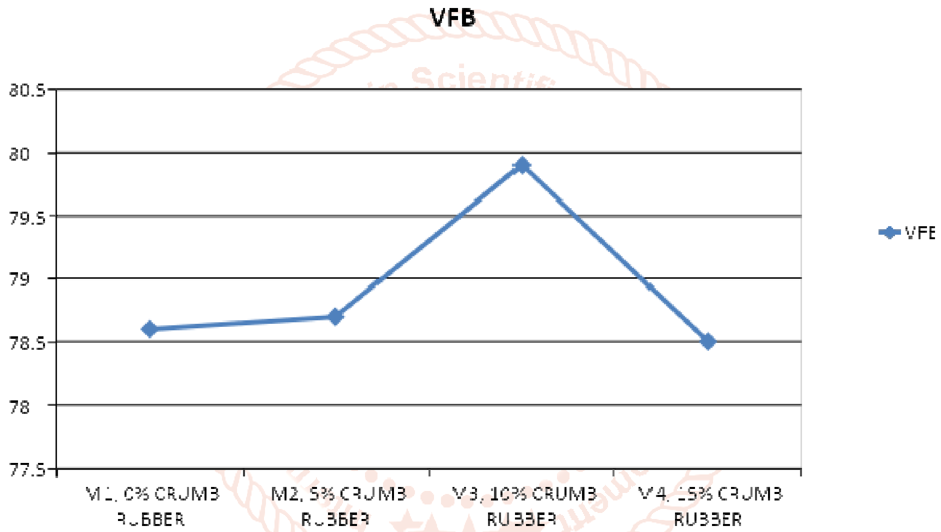


Fig 4.5. VFB vs. crumb rubber Content

Graphs obtained

Stability vs. bitumen content

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

Table 4.5. Flow vs. bitumen content

Binder Content	Stability value without crumb rubber	Stability value with crumb rubber
4	10.62	12.13
4.5	10.89	12.32
5	11.3	12.52
5.5	12.72	13.86
6.5	8.04	8.55

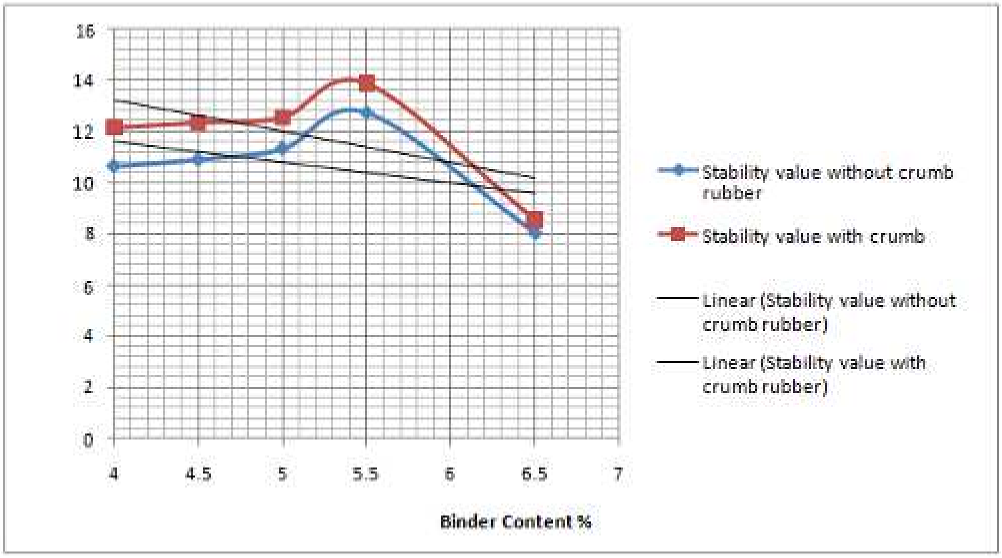


Fig 4.6. Stability vs. Bitumen Content

Flow value vs. bitumen content

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

Table 4.6 Flow vs. bitumen content

Binder content	Flow value without crumb rubber	Flow value with crumb rubber
4	2.07	2.40
5	2.33	2.47
5.5	2.67	2.53
6	2.73	2.70
6.5	2.90	2.83

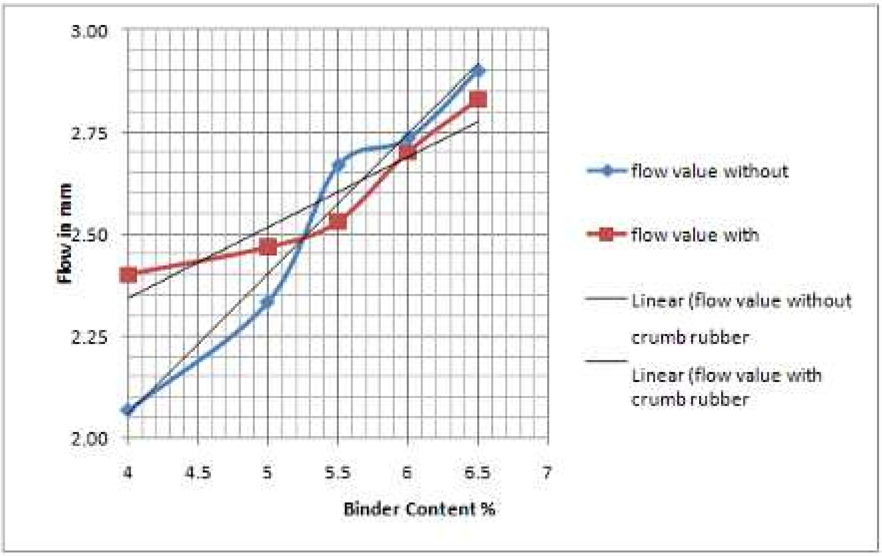


Fig. 4.7 Flow vs. bitumen content

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 4.7. VMA vs. bitumen content

Binder Content	VMA
4.0	15.23
4.5	15.08
5.0	16.65
5.5	18.51
6.5	15.30

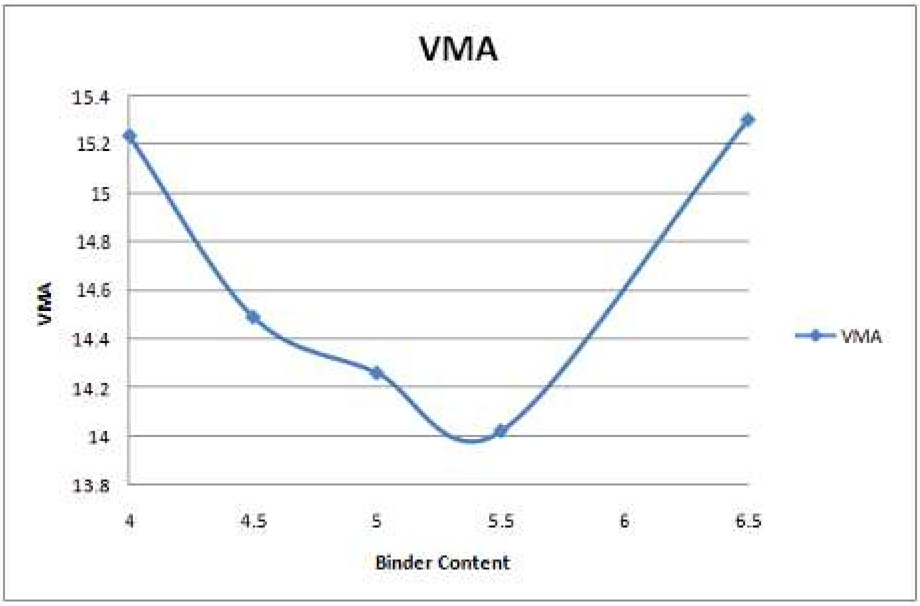


Fig. 4.8 VMA vs. bitumen content

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 4.8 VFB vs. bitumen content

Binder content	VFB
4.0	53.95
5.0	67.81
5.5	73.17
6.0	82.53
6.5	93.40

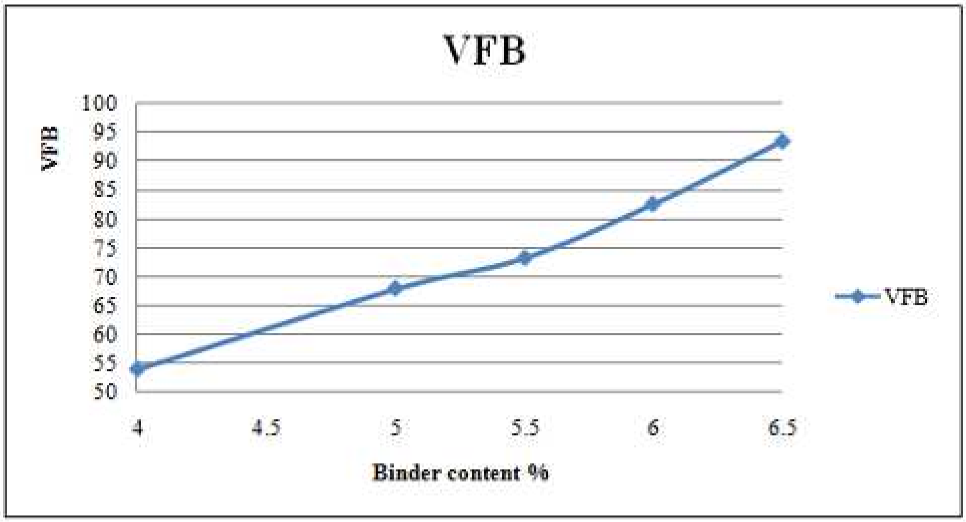


Fig. 4.9 VFB vs. bitumen content

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 4.9. VA vs. bitumen content

Binder content	VA
4.0	7.04
5.0	4.54
5.5	3.98
6.0	2.59
6.5	1.21

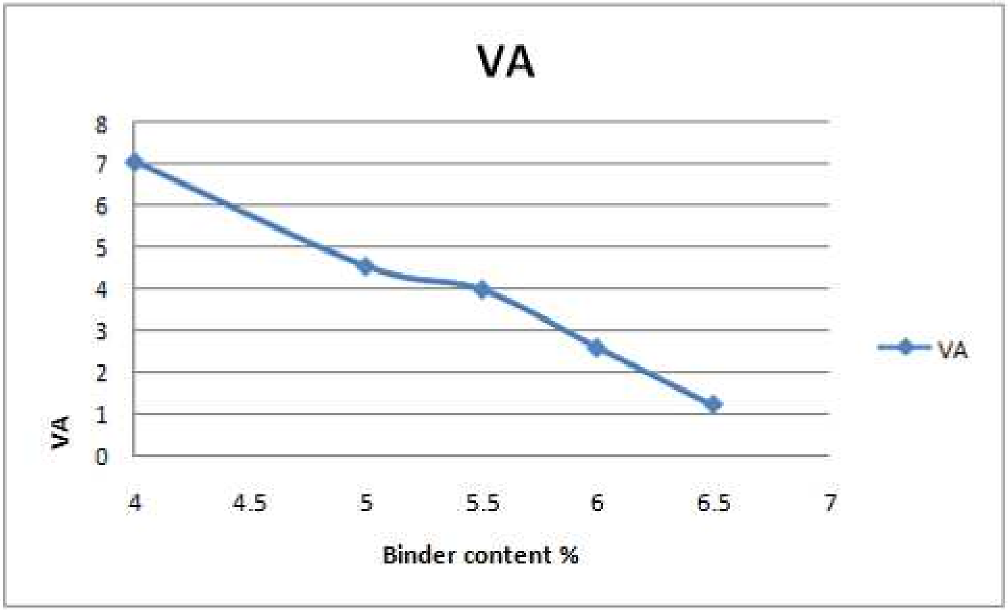


Fig. 4.10 VA vs. bitumen content

DETERMINATION OF MIX DESIGNPARAMETER

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

SMA With crumb rubber content

Requirements of SMA according to IRC SP-79-2008 IS

Table 4.10 IRC SP 79-2008 Specification mix design requirements of SMA & Mix properties at 4% air void

Property	Specification	Result obtained with 5% Crumb Tire
Minimum binder content by weight of mix, (%)	>6.5	5.5%
Stability (kN)	8 Minimum	13.86
Flow (mm)	2 – 4	2.53
VMA (%)	17 Minimum	18.51
VFB (%)	75 – 80	73.17
Binder Type	60/70 grade binders	60/70 and modified binders

Here OBC is 5.5% with 5% Crumb tire.

Marshall Stability

It can be observed that with increase binder content stability value increases up to certain binder content and there after it decreases. Similarly by addition of Crumb tire stability value also increases up to certain limits and further addition of Crumb tire stability value starts decreasing. May be this is due to excess amount of Crumb tire which is not able to mix in asphalt matrix properly.

OPTIMUM BINDERCONTENT

Optimum Binder Content is found out by taking average value of following three bitumen content found from above graph i.e.

1. Bitumen content correspond to maximum stability
2. Bitumen content corresponding to the Air void.

SMA with 5% Crumb tire waste & OBC is 5.5% were found. Hence for SMA OBC is found as 5.5%.

CONCLUSIONS AND FUTURE SCOPE OF WORK

General Conclusions

Based on the results and discussion of experimental investigation carried out on mixes SMA following conclusion are drawn.

- It is found that by addition of 5% crumb rubber to SMA mix, the OBC value is5.5%
- By addition of 5% crumb rubber to SMA, Stability value increases significantly, further addition to it stability decreases.
- From the graph of stability vs. bitumen it is learnt that optimum binder content for samples prepared by use of 5% tire Crumb is found to be 5.5 %. For SMA mixes value of optimum binder content is quite high that makes it very costly. So we can say here that use of tire crumb would result into sufficient cost effective and money saving measure.

- Here maximum stability obtained is 13.86 KN This value as compared to other substitutes is little higher.
- 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.
- 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.

Future scope of work

- In future performance of crumb rubber with other grades of bitumen can also be tested.
- Use of crumb rubber may also be tested not only for SMA but also for different other HMA.
- Indirect tensile test of SMA mix can give us an idea about tensile strength of mix.
- Repeated load testing can be studied on SMA Mix.

REFERENCES

[1] Anderson, R. and H. Bahia, Evaluation and selection of aggregate gradations for asphalt mixtures using Superpave. Transportation Research Record: Journal of the Transportation Research Board, (1583), 1997. p. 91-97.

[2] AbdelazizMahrezand Mohamed RehanKarim, ―Prospect Of Using Glass Fiber Reinforced Bituminous Mixes‖, Journal of the Eastern Asia Society for Transportation Studies, **5**, 794-808, 2003.

[3] Al-Mistarehi, B., Superpave System versus Marshall Design Procedure for Asphalt Paving Mixtures (Comparative Study). Global Journal of Research In Engineering, 14(5), 2014. p. 44-52.

[4] Asiamah, S. A., Relationship Between Laboratory Mix Properties and Rutting Resistance for Superpave Mixtures. Ph. D. Dissertation: University of Florida, 2002.

[5] Beena, K. and C. Bindu. Influence Of Additives On The Drain Down Characteristics Of Stone Matrix Asphalt Mixtures. International Journal of Research in Engineering and Technology, 3(7), 2014, p. 83-88.

[6] Bisanda ETN and Ansell MP, ―Properties of sisal-CNSL composites‖, Journal of Materials Science, 27, 1690-700, 1992.

[7] Bradely J. Putman, Serji N. Amirkhanian, ‖ Utilisation of Waste tyres in stone matrix asphalt mixtures‖, Resources, Conservation and Recycling, Volume 42, Issue3, October 2004, Pages265-274.

[8] Brown E. R., ―Experience with Stone Matrix Asphalt in the United States‖, NCAT Publication, Auburn University, Alabama, 1992.

[9] C. Kamaraj, G. Kumar, G. Sharma, P. K. Jainand K. V. Babu―Laboratory Studies on the Behaviour of Stone Matrix Asphalt Vis-Vis Dense Graded Bituminous Mixes Using Natural Rubber Powder (Wet Process)‖, Highway Research Bulletin, No 71, December 2004, Pages39-60.

[10] ChakrabortyPartha, Das Animesh , Principals of transportation engineering, PHI 2003, page no294-309.

[11] Chand, N., K. G. Satyanarayana, . and P. K. Rohatgi, ―Mechanical characteristics of sunhemp fibres‖, Indian Journal of Textile Research, 11, 86-89, 1989.

[12] Cho, D. -W., H. Bahia, and N. Kamel, Critical evaluation of use of the procedure of superpave volumetric mixture design for modified binders. Transportation Research Record: Journal of the Transportation Research Board, (1929), 2005. p. 114-125.

[13] 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, Pages1027-1033.

[14] Cominsky, R. J., Huber, G. A., Kennedy, T. W., and Anderson, M. The superpave mix design manual for new construction and overlays. Washington, Strategic Highway Research Program, DC, 1994.

[15] D-6926-04 , Standard practice for preparation of Bituminous Specimens using Marshall Apparatus.

[16] D-6927-06, Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures.

[17] Georgia Department of Transportation, 'Summary of Geogia's Experience with Stone Matrix AsphaltMixes', 2003.

[18] H. Behbahani, S. Nowbakht, H. Fazaeli and J. Rahmani , Effects of tyre Type and Content on the Rutting Performance of Stone Matrix Asphalt, Journal of Applied Science Year: 2009, Volume: 9, Issue 10, Page No. 1980-1984.

[19] Habib, A., Hossain, M., Kaldate, R., &Fager, G. Comparison of Superpave and Marshall mixtures for low-volume road sand shoulders. Transportation Research Record: Journal of the Transportation Research Board, (1609), 1998. p. 44-50.

[20] http://www.hawaiiasphalt.com/HAPI/modules/04_pavement_types/04_mix_types. ht m# sma (visited on February 17, 2010). http://www.sisal.ws/page6/page7/page7.html. IS2386 : Part I : 1963 (Reaffirmed 2002) , Methods of Test for Aggregates for Concrete.

[21] HuaxinChen, QinwuXu, ShuanfaChen, ZhengqiZhang, ―Evaluationnddesign of fiber-reinforced asphalt mixtures‖, Materials and Design, 30, 2595–2603, 2009.

[22] Indian Roads Congress, (Indian Highways, February 2007), 3, 37-42

[23] Jared, David. GDOT Research Project 9102: Evaluation of Stone Matrix Asphalt and Porous European Mix. Georgia Department of Transportation, 1997.

[24] 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.

[25] Mallick, R., Use of Superpave gyratory compactor to characterize hot-mix asphalt. Transportation Research Record: Journal of the Transportation Research Board, (1681), 1999. p. 86-96.

[26] Manual for construction and supervision of bituminous works, MoRTH, IRC, New Delhi, 2001.

[27] Mashaan, N. S., Ali, A. H., Koting, S., & Karim, M. R. Performance evaluation of crumb rubber modified stone mastic asphalt pavement in Malaysia. Advancesin Materials Scienc e and Engineering, 2013.

[28] McGennis, R. B., Anderson, R. M., Kennedy, T. W., and Solaimanian, M. Background of Superpave asphalt mixture design and analysis. Federal Highway Administration, 1995.

[29] Ministry of Road Transport and Highways, Manual for Construction and Supervision of Bituminous Works, New Delhi, 2000.

[30] Muniandy, R. and Huat, B. B. Laboratory diameteral fatigue performance of stone matrix asphalt with cellulose oil palm fiber. American Journal of Applied Sciences, 3(9) 2006. p. 2005-2010.

[31] Muniandy, R., Selim, A. A., Hassim, S., &Omar, H. Laboratory Evaluation of Ground Tire Rubber in Stone Mastic Asphalt. The Journal of Engineering Research, 1, 2004. p. 53-58.

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

[33] Murherjee, P. S. andK. G. Satyanarayana, ―Structure and properties of some vegetable fibres, part 1. Sisal fibre‖, Journal of Materials Science, 19, 3925- 34, 1984.

[34] PawanKumar, Satish Chandra And Sunil Bose, ―Laboratory investigations on SMA mixes with different additives‖, International Journal of Pavement Engineering, 8(1), 11–18, 2007.

[35] Pérez-Jiménez, F., Martínez, A. H., Miró, R., Hernández-Barrera, D., and Araya-Zamorano, L. Effect of compaction temperature and procedure on the design of asphalt mixtures using Marshall and gyratory compactors. Construction and Building Materials, 65, 2014. p. 264-269.

[36] Sarang, G., Lekha, B. M., Geethu, J. S., and Shankar, A. R. Laboratory performance of stone matrix asphalt mixtures with two aggregate gradations. Journal of Modern Transportation, 23(2), 2015. p. 130-136.

[37] Shaopeng Wu, YongjieXue, QunshanYe, Yongchun Chen, ‖Utilisation of steel slag as aggregates for stone mastic asphalt (SMA) mixtures‖, Building and Environment, 42(2007), Pages 2580-2585 (www.elsevier.com/locate/buildenv).

[38] Thulasirajan, K. andV. L. Narasimha., ―Studies on Coir Fibre Reinforced Bituminous Concrete‖, International Journal of Earth Sciences and Engineering, 04(06), 835-838, 2011.

[39] V. S. Punith, R. Sridhar, Dr. Sunil Bose, K. K. Kumar, Dr. A Veeraragavan‖, Comparative studies on the behaviour of stone matrix asphalt and asphalt concrete mixtures utilizing reclaimed polyethylene‖, Highway Research Bulletin, No 71, December 2004, Pages61-76.

[40] Watson, D., E. Brown, and J. Moore, Comparison of Superpave and Marshall mix performance in Alabama. Transportation Research Record: Journal of the Transportation Research Board, (1929), 2005. p. 133-140.

[41] Wright P. H., Dixon K. K., Highway Engineering, John Willey 2004, page528-545

[42] Xue, Y., Hou, H., Zhu, S., and Zha, J. Utilization of municipal solid waste incineration ash in stone mastic asphalt mixture: pavement performance and environmental impact. Construction and Building Materials, 23(2), 2009. p. 989-996.

[43] YongjieXue, HaoboHou, ShujingZhu, JinZha, ―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).