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Determination of Optimum Binder Content in Stone Matrix Asphalt

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I. INTRODUCTION

Stone Matrix Asphalt (SMA) is a gap-graded asphalt mixture that improves stone-to-stone contact while also enhancing the strength of the mixture. The aggregates utilized in this study are from the same lot and meet MoRTH requirements. The samples are made with various gradations of aggregate, cement as a filler, and bitumen (60/70) as a filler. Fibers are utilized as stabilizers in this case. Fiber aids in the reduction of drain down as well as the strengthening and stability of the SMA mix. The Marshall device is used to test these SMA mix samples. In this experiment, SMA mix with and without fiber is compared. Many research studies are conducted mostly with cellulose, synthetic, polypropylene, and polyester fibers. SMA manufactured in Europe and the United States generally uses cellulose fibers. The fibers improve the qualities of the SMA mix by generating a type of micromesh in the asphalt mix to prevent the asphalt from draining down, hence increasing the mixture's stability and longevity. We used banana fiber instead of cellulose fibers in this experiment, and it performed similarly to cellulose fiber. The more binder in the mix, the more durable it becomes. The fibers or modifiers keep the binder in the mixture at a high temperature and keep it from draining throughout production, transporting, and laying. For high-volume roads, stone matrix asphalt (SMA) has proven to be more cost-effective than dense graded mixes. Changes in binder supplier and grade of mix, types of aggregate, environmental circumstances, production and building procedures, and other elements, according to Brown (1992), will all influence the performance of SMA mixtures. A thorough investigation of these elements would aid in determining SMA's long-term performance and provide knowledge that might be used to make adjustments to fit diverse environmental situations. "A gap graded aggregate hot mix asphalt that will maximize the binder content and coarse aggregate fraction and creates a stable stone-on-stone skeleton that is kept together by a rich blend of filler, binder, and stabilizing additives," according to the FHWA SMA technical working group.

II. LITERATURE REVIEW

GENERAL

In the United States, federal and state highway authorities acknowledged the need for stiffer, more rut-resistant pavements in the 1980s. As a result, in 1990, American professionals took part in the European Asphalt Study Tour, which focused at SMA pavements. This was the first genuine attempt to understand how to use SMA.

T.Subramani 2017: Has investigated on coir fiber in bituminous mix of 4 %, 5%, 6% bitumen and 10mm, 15mm, 20mm coir length of different percentages are added to improve the mix and increase the stability. The stability value has been increased by 1.3 times when compared to the nominal and flow with an increment of 1.8 times.

MS.P.Baikiya and C. Kamaraj 2018 : Has investigated on different proportions of coir i.e, 0.3%,0.5%,0.7% of different length are added in bituminous mix to increase the stability, indirect tensile strength test, short and long term ageing test and stiffness modulus test are investigated to achieve the optimum binder content.

Mohammad Altaf Bhat et al 2018: Has studied the Effect of Fillers on Bituminous Mixes. To satisfy the design requirements of stability and durability the bituminous mixes should be designed effectively. The ingredients of the mixture include dense grading of coarse aggregates, fine aggregates, fillers and bitumen binder. In this Study an attempt was made to find the effect of filler on the behavior of bituminous mixes. Fillers play an important role in the filling of voids and hence change the physical and chemical properties. Thus their effect is of utter importance. Bitumen in combination with filler forms mastic. This mastic can be seen as a constituent of mixture of asphalt that holds the aggregates together. An important role is played by the fillers that pass through 0.075mm sieve. With the increase in the amount of filler, Marshall Stability of the bitumen mix increases directly. Use of 4-8% filler in asphalt concrete is recommended by the Asphalt Institute. In India, waste concrete dust and brick dust are considered to be cheaper and are available in plenty. In this study an attempt was made to find the effect of fillers on the bitumen mixes. In this study, concrete dust and brick dust was used as filler. The properties of bituminous mixes containing these fillers were studied and compared with each other. For the purpose of comparison Marshall Method of mix design was used. In this study various tests were also conducted on aggregates and bitumen and the results were compared with the specifications. The study revealed that use of concrete dust and brick dust as filler improves the physical characteristics of bitumen. Marshall Stability and flow value of bitumen mix also improved.

K.Karthik 2018 et al: Has studied the carbon fiber modified bitumen in bituminous macadam. In the present study, an attempt has been made to study the effects of use of a mineral fiber called Carbon fiber is used as an additive in Dense Bituminous Macadam (DBM). An experimental study is carried out on conventional bitumen and fiber modified binder. Using Marshall Procedure, Optimum Fiber Content (OFC) and Optimum Binder Content (OBC) for DBM are found respectively. Detailed laboratory investigations will be carried out by preparing asphalt concrete mixtures by adding carbon fiber with dosages of 0.5% to 2.5% by weight of binder. Volumetric properties of the mixes will be determined and various strength tests such as Marshall stability will be conducted. In the present paper, an approach was developed to mix carbon fibers and bitumen which guarantees the uniform fiber distribution.

DR.P. Sravana 2018 et al: Has studied the properties of Stone Matrix Asphalt Mixture by Altering Aggregate Gradations and Filler Types. In this present work, an attempt has been made to study the effect of aggregate gradation and filler type in properties of SMA. Four of different aggregate gradations with two types of fillers, such as Hydrated Lime and Crushed Stone Dust have been tried for preparation of mixes. First three gradations; upper, middle, and lower curves, middle gradation curve had better Marshall Properties of them. For fourth gradation that modified curve, crushed Stone has been improves the Marshall properties such as Marshall Stability and unit weight values more than Hydrated Lime. Hydrated Lime of SMA mixes has been improves air voids and Moisture Susceptibility in the same gradations of samples with Crushed Stone.

III. MATERIALS USED

Aggregates: The structure and quality of aggregates in SMA is an important factor to make the mixture resistant to rutting. Therefore, the stability of the aggregate structure is crucial in order to ensure the proper design of a mixture.

Mineral Filler(Basalt Dust) : The quality of SMA mixes affected by mineral filler hence it is occupied by a good portion in SMA. Therefore it is essential to study the effect of fillers in SMA

Bitumen: SMA contains very high content of bitumen when compared to conventional mixes. It is used to bind the aggregates, fillers and stabilizing additives. Different studies on SMA have been conducted by using different bitumen grades. Modified bitumen can also be used in SMA for better results.

Stabilizing Additives (Banana Fiber): Bananas are the second most widely produced fruit in Brazil and have great importance in the country's economy Nonetheless, banana farming is a major generator of postharvest rejects, which corresponds to 40% of fruit production. The pseudostem is the part of the plant that represents the largest portion of these residues.



**MATERIAL TESTING
TESTS ON AGGREGATES
Aggregate Impact Value Test**

Tabulation for determining of Impact value

Sl. No.	Weight of oven dried sample (gm)	Weight of aggregate retained through 2.36mm sieve (gm)	Weight of passing aggregate (gm)	Impact value	Average Impact value
1	758	586.3	171.7	22.65	21.5
2	854	700.6	153.4	17.96	
3	827	629.3	197.7	23.91	

Aggregate Crushing Value Test

Tabulation for determining crushing value

Weight of oven dried sample (g)	Weight of aggregate retained through 2.36mm sieve (g)	Weight of passing aggregate (g)	Crushing value
5000	4130	870	17.4

Specific Gravity And Water Absorption Test:

Tabulation for water absorption test

Weight of Saturated sample (W1) (gm)	Weight of material + basket suspended in water (W2)	Water absorption (%)
2578	3998	0.4



Tabulation for determination of specific gravity

Weight of Dry basket (W2) (gm)	Weight of basket + material in water (W3)	Weight of saturated dry sample (W1) (gm)	Specific gravity
8	1	2000	2.76
8	2		
6	7		
	5		

Abrasion Test

Tabulation for Abrasion Test

Total weight of the aggregate sample (w1)	2.5 kg
Weight of aggregate retained (w2)	1510 grams
Weight of aggregate passing from 1.7mm (w3)	992 grams
Abrasion value = $w1 - w2 / w1 * 100$	39.68 %

Flakiness and Elongation Index Test

Tabulation for determination of flak in sand elongation index

wt of fraction consisting 200 pieces	thickness of gauge	wt of aggregate in each fraction passing thickness gauge	length of gauges	wt of aggregate in each fraction retained on length gauge
0	50-40	1240	58	350
82	40-31.5	1212	40.5	308
50	31.25-25	592	32.4	216
174	25-20	60	25.06	36
108	20-16	6	20.2	0
0	16-12.5	0	14.2	0
0	12.5-10			
0	10-6.3			

Flakiness index = 13.31

Elongation index = 19



TEST ON BITUMEN

Penetration Test

Tabulation for Penetration test

TESTNO.	SAMPLE1	SAMPLE2	SAMPLE3	MEANVALUE
Penetration(mm)	68.9	67	66	67.3

Softening Point Test

Tabulation for Softening point test

TESTNO.	SAMPLE1	SAMPLE2	SAMPLE3	MEANVALUE
SOFTENING°C	53	52	53	53

Flash Point Test

Tabulation for Flash point test

TESTNO.	SAMPLE1	SAMPLE2	SAMPLE3	MEAN VALUE
FLASHPOINT °C	222	220	221	222

Specific Gravity Test

Tabulation for Specific Gravity Test

Pycnometer (gm) A	Pycnometer +Water (gm) B	Pycnometer +Asphalt(gm) C	Pycnometer +Water +Asphalt(gm) D	Specific Gravity
23	74.2	55.5	75.1	1.028

Ductility Test

Tabulation for Ductility test

Observations	1	2	3
(a) Initial Reading	0	0	0
(b) Final Reading	63	62	62.5

MARSHAL METHOD

There are three principal bituminous mix design methods in general use. They are Marshall Method, Hveem Method and Superpave Method. Marshall Mix design is the widely used method throughout India. The mix design of bitumen content is usually done using the Marshall Test. The designed optimum bitumen content obtained from the Marshall Test mainly depends upon the Density – Voids and Stability - Flow value of the cylindrical specimen. The Marshall stability of a bituminous mix specimen is defined as the maximum load carried in kg or KN at the standard test temperature of 60°C when load is applied at a constant strain rate of 50.08 mm/minute. The flow value is defined as the maximum deflection of Marshall Test specimen at the maximum load, expressed in mm units. Marshall Test is conducted on a cylindrical specimen of dimensions 101.6 mm diameter and 63.5 mm height. From Marshall Test Stability, flow, unit weight,



air voids, percentage of voids in mineral aggregate and percentage of voids filled with bitumen are obtained by varying binder content for each percentage of waste plastics.

Mix Design

Mix Design

VARYING BITUMEN PERCENTAGES	DENOMINATIONS(gms) For 1 mould					Theoretical sp. gravity (Gt)
	12 MM (20%)	BANANA FIBRE (0.3%)	6MM (32%)	DUST (48%)	BITUMEN	
5.5%	240	3.6	384	576	66	2.47
6.0%	240	3.6	384	576	72	2.48
6.5%	240	3.6	384	576	78	2.47
7%	240	3.6	384	576	84	2.44

IV. RESULTS AND DISCUSSIONS

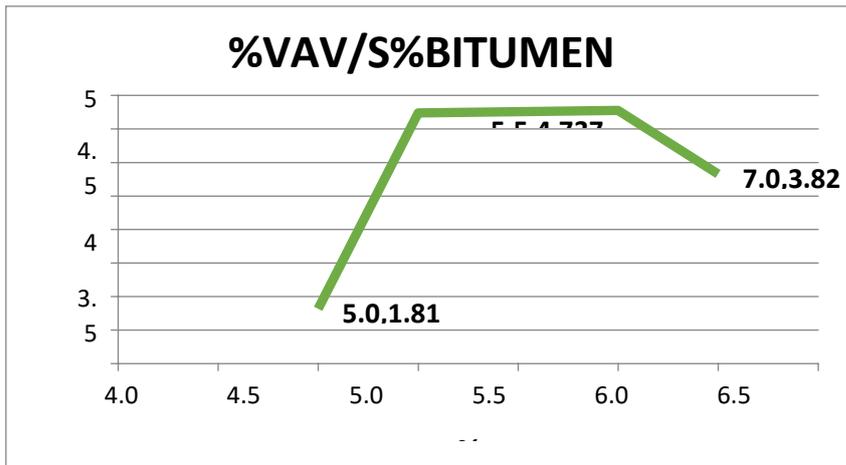
Volumetric Analysis of Marshall Specimen

Sl. No.	%	Wt of specimen (gm)			Bulk Volume (cc)	Bulk sp. gra of sample (Gmb)	Max spgr of sample (Gmm)	% of air voids (VA)	% of bitumen (Vb)	% of voids in mineral Aggregate (VMA)	% of voids filled with bitumen (VFB)	Stability (kn)			Flow in mm
		Wt in air	Wt in water	Wt in SD air								Measured	Correction factor	Corrected	
1	5	2	3	4	5	6	7	8	9	10	11	12	13	14 = 12*13	15
1	5.0	1210	715	1212	497	2.435	2.48	1.815	13.021	14.836	87.767	16.86	1.04	17.53	2
2	5.5	1252	722	1254	532	2.353	2.47	4.737	13.266	18.003	73.688	13.93	1	13.93	3

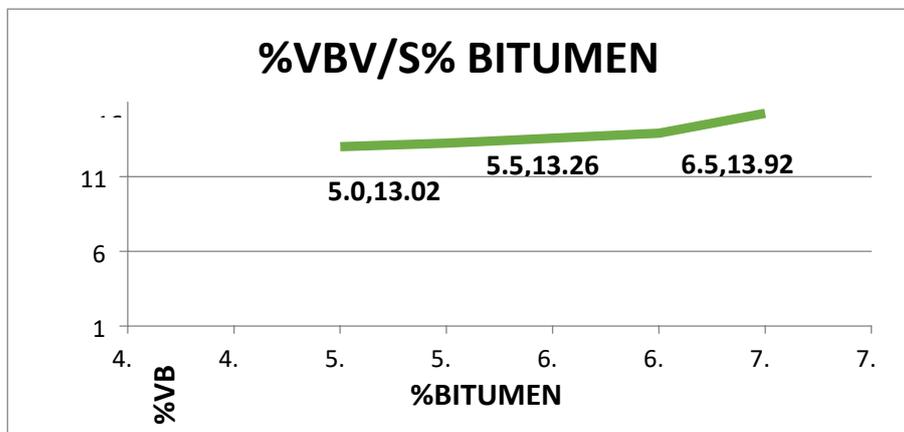


3	6	128	735	128	549	2.33	2.4	4.776	13.92	18.703	74.46	15.0	1	15.	4
	.5	1		4		3	5		7		7	3		0	
4	7	126	728	126	540	2.33	2.4	3.827	15.25	19.077	79.94	11.7	1	11.	8
	.0	2		8		7	3					3		7	

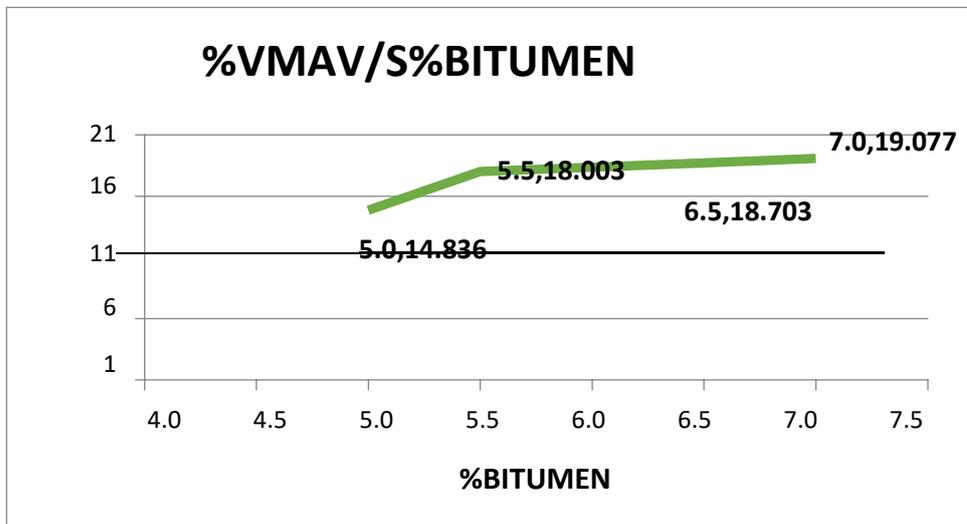
PERCENTAGE AIR VOID VERSUS PERCENTAGE BITUMEN



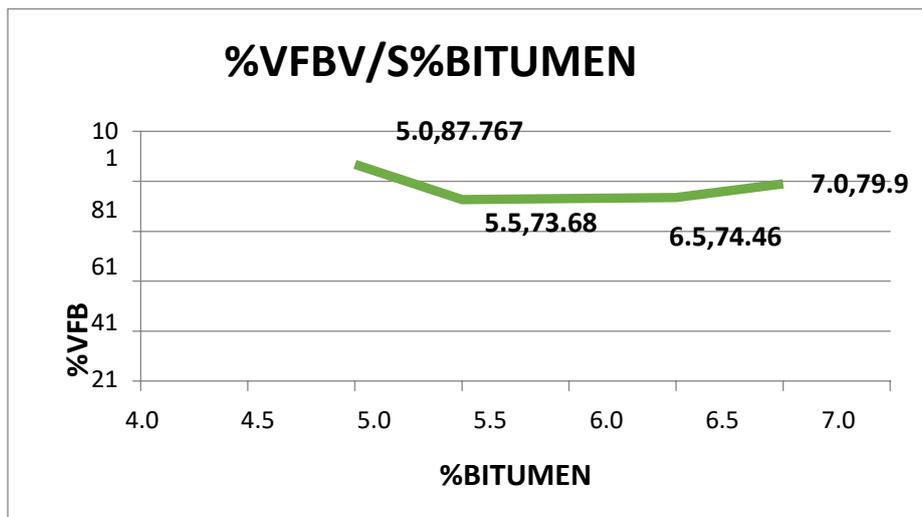
PERCENTAGE VOLUME OF BITUMEN VERSUS PERCENTAGE BITUMEN



PERCENTAGE VOLUME OF MINERAL AGGREGATES VERSUS PERCENTAGE BITUMEN

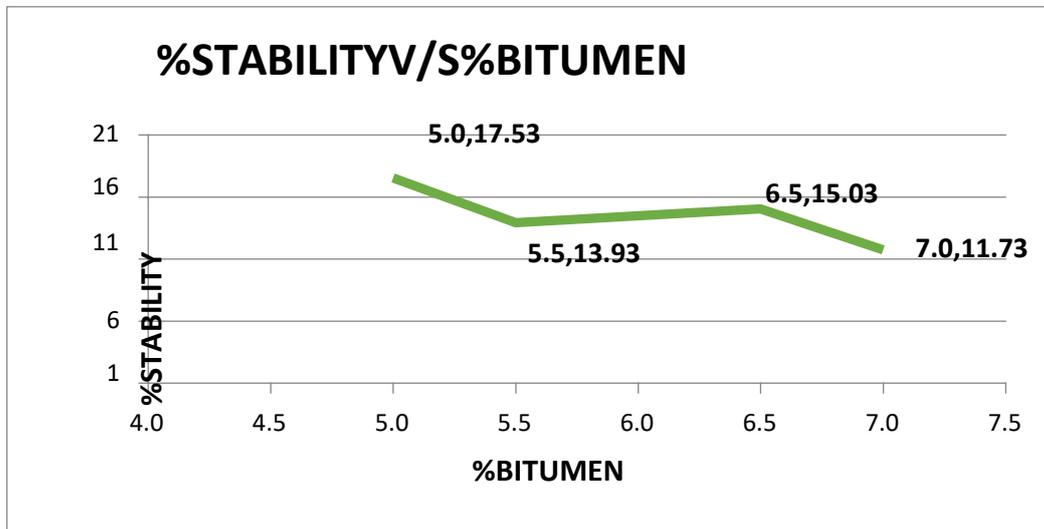


PERCENTAGE VOLUME FILLED WITH BITUMEN VERSUS PERCENTAGE BITUMEN

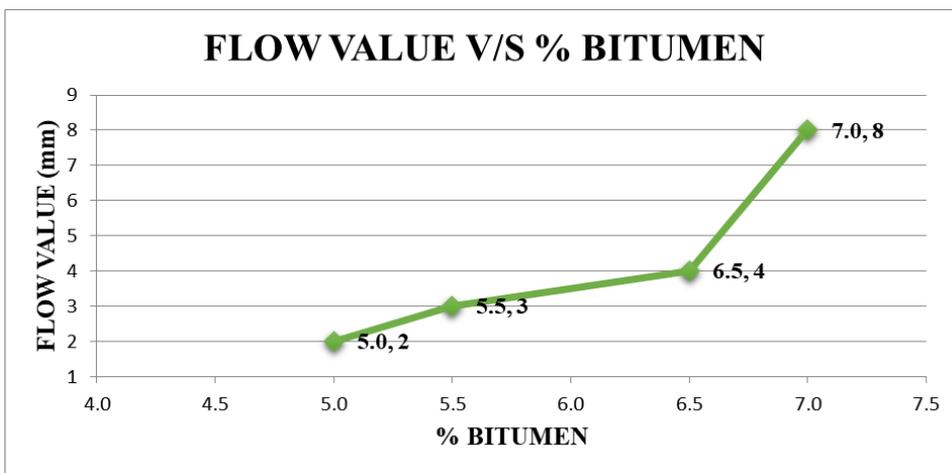




STABILITY VERSUS PERCENTAGE BITUMEN



FLOW VALUE V/S PERCENTAGE BITUMEN



V. CONCLUSIONS

It is observed that the air voids percentage increases up to the 6.5% and then decreases beyond this percentage. Air voids should be between 3% to 6% so that the bitumen mix will be in good condition. If the bitumen mix is not properly mixed and compacted, filled so that the strength decreases. If voids are not properly filled then the bonding nature between the aggregates, fillers decreases and the aggregates get dispersed away and the potholes get formed on the roads. When the heavy load vehicles travel on these roads then the damage of roads gets increased. As per MORTH limiting values satisfied by sample 1 and sample 2 that is at binder content at 6 and 6.5 percentage, we observed that increase in volume leads to non-bonding of aggregates.

We found out that when the VMA (Voids in Mineral Aggregate) increases then the voids decrease and the stability increases that means strength achievement is high and we can also say that when the stability increases the bonding nature between the aggregates is strong and resists the damaging of road so, we can conclude that the optimum binder content for the mix is at 6.5%

- The plot indicates that the stability value increases initially with the increase in bitumen content but then decreases gradually.
- This can be attributed to the fact that with the 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.

- Therefore keeping the fraction across the contact points of aggregates gets immobilized. This makes the mix weak against plastic deformation and the stability falls.

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