Evaluating the Characteristics of Stone Mastic Asphalt by Using Natural Fibers and Filler

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Abstract-In India most of the case the roads are developed by using asphalt materials and its mixtures. Because of using asphalt materials and mixes its durability and performance has improved. Asphalt roads are suitable for repair works to improve its life span. The Stone Mastic Asphalt (SMA) mix is mostly suitable for asphalt mixtures. SMA is used firstly in European countries. SMA is a gap graded mix consisting of crushed stone as coarse aggregate, different grades of bitumen as binder, both natural and artificial fibers as stabilizers and crushed rock powder, cement, and quarry waste as fillers are used. For developing country like India has to implement some new techniques and adopting new materials for asphalt mixes can reduce the cost and improve the durability and performances.

There are different waste materials are available in India like coconut shells, coconut fiber and sugarcane fiber these can be used as fillers like coconut shell charcoal powder and fibers can be used as stabilizers these techniques can reduce the cost. In this project work our main objective is to determine the characteristics of SMA Mix prepared by using different fillers of coconut shell charcoal powder, stone dust, Portland cement and fly ash are combined with two different fibers of coconut fiber and sugarcane fiber. These samples are prepared by adopting different proportions in filler content and binder content. The filler content is increased by 0.5% from 12% to 13% simultaneously the binder content is also increased by 0.5% for each proportion from 6% to 7%. From this, total 3 types of proportions have introduced, and their properties are to be evaluated. The Stability and Flow values are to be determined by Marshall Test. By this work we must check the suitability of natural materials and also the performance of each mix.

Key words: SMA Mix, Marshall Test, Binder, Filler, Stability and Flow value.

1. INTRODUCTION

Generally, in India mostly consists of bituminous roads. The main reasons for this are the lower initial cost and amenability to stage development of bituminous roads. In a developing country like India bituminous roads are preferred because of very rapid expansion of the Indian road network. In bituminous asphalt pavements Hot Mix Asphalt (HMA) is most preferable method. There are few different types of HMA, each of which has unique performance properties and ideal usage applications. They include:

- Dense-graded mixes
- Stone matrix asphalt
- Porous asphalt

Among them stone matrix asphalt (SMA) is mostly considerable, and this project is also studies on stone matrix asphalt.

Stone mastic asphalt (SMA), also called stone-matrix asphalt, SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resists permanent deformation. The stone skeleton is filled with a mastic of bitumen and filler to which fibres are added to provide adequate stability of bitumen and to prevent drainage of binder during transport and placement.

1.2 COMPOSITION OF SMA

SMA provides a deformation resistant, durable, surfacing material, suitable for heavily trafficked roads. SMA has found use in Europe, Australia and the United States as a durable asphalt surfacing option for residential streets and highways. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resist permanent deformation. The stone skeleton is filled with mastic

of bitumen and filler to which fibres are added to provide adequate stability of bitumen and to prevent drainage of binder during transport and placement. Typical SMA composition consists of 70-80% coarse aggregate, 8-12% filler, 6.0-7.0% binder, and 0.3 per cent fibre. The deformation resistant capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes.

1.3 OBJECTIVES OF THE PROJECT

1. The main Objective is to check the suitability of Coconut shell charcoal as filler and Coconut fiber and sugarcane fiber (bagasse's) as stabilizer in SMA Mix.
2. Study of different Marshall Properties using different fillers (Stone dust, Portland cement, fly ash etc.), and then comparing the results with Coconut shell charcoal as filler and Coconut fiber and sugarcane fiber(bagasse's) as stabilizer.
3. To check the Stability and Flow values when the mix is prepared by using different proportions in binder content and filler content.
4. To determine the performance of the SMA Mix for each type of proportion.
5. To check the suitability of natural materials.
6. To examine properties of SMA Mix like volumetric properties for each proportion.
7. To suggest the better proportion of binder and aggregate for each different material.

2. LITERATURE REVIEW

D. Girish, S. V. S. Vinay Reddy, Ch. Hanumantharao (2020) the performance of stone dust and coconut shell charcoal powder in bituminous concrete mix (BC) was tested by Marshall Stability test. The optimum binder content obtained at 4.33%. From the results we have observed that coconut shell charcoal (CSC) powder can be used as a partial replacement of stone dust in surface course.

Santoshkumar, Nagesh S, Ramesh B, Bharath K (2020) VG 10 grade is used as the binder and hydrated lime is used as filler and Arbocel as fiber. From the Marshall Stability test results, it is observed that the 0.30% of addition fiber optimum dosage. The results showed that the SMA Mix has better resistance with 0.3% of fiber, max 3% of lime and cement.

J. K. Patil, Ankit Biradar, Roshni Upare, Gaurav Kudale, Sushant Shelar (2020) the main objective is to compare a result obtained by the using fillers like Stone dust, Portland cement, Fly ash with Coconut Shell charcoal. For carrying out the experiment, Marshall Test method is used for obtaining better results. It can be a concluded that coconut shell charcoal can be used as a substitute for a filler as it satisfies all the criteria to be used as a filler.

Mahabir Panda, Arpita Suchismita and Jyoti Prakash Giri (2013) the engineering properties under both static as well as repeated load conditions and moisture susceptibility characteristics have been studied. It is observed that only a marginal 0.3% coconut fiber addition brings significant improvement in the engineering properties of SMA mixes.

S. Mansor, N. I. Zainuddin, N. A. Aziz, et al. (2020) the idea of using sugarcane bagasse as fibre in SMA Mix can be considered and commercialized for road construction industry thus will provide durable and quality pavement. In addition, the use of natural fibre has environmental significance and is a cost-effective solution.

3. MATERIALS USED IN SMA

Coarse aggregates
Fine aggregate
Fillers used

1. Stone dust
2. Portland cement
3. Fly ash
4. Coconut shell charcoal powder

Fibers used

- Coconut Fiber
- Sugarcane Fiber

Binder

In this project we are using bitumen of VG30.

The required properties of materials are determined by conducting tests and the materials are prepared for next procedure.

3.1 AGGREGATE PROPERTIES

The aggregates were examined for different physical properties including the Indian standard specifications.

The results of different tests which are conducted on aggregate are given in following table,

The aggregate shall satisfy the physical requirements which are given in the above-mentioned table as per IRC SP 79-2008.

Table-1 Physical properties of coarse aggregate and its requirements as per IRC specifications for Stone Mastic Asphalt

S. No	Aggregate test	Method	Result	Requirement as per IRC SP: 79:2008
1	Aggregate crushing test	IS: 2386 (Part-IV)	17.81%	<18%
2	Aggregate impact test	IS: 2386 (Part-IV)	16.80%	<18%
3	Los Angeles abrasion test	IS: 2386 (Part-IV)	24.44%	<25%
4	Flakiness index test	IS: 2386 (Part-I)	8%	<30%
5	Elongation index test	IS: 2386 (Part-I)	28%	<30%
6	Water absorption test	IS: 2386 (Part-III)	1.72%	<2%
7	Specific gravity test	IS: 2386 (Part-III)	3.05	>2

Table-2 Bitumen characteristics

S. No	Bitumen test	Method	Result	Requirement as per IRC: SP: 53:2010
1	Penetration test	IS :15462-2004	64	60/70
2	Ductility test	IS :15462-2004	51.5 cm	>50 cm
	Softening point test	IS :15462-2004	68.8^0 C	$>60^0$C

3.2 BITUMEN PROPERTIES

Bitumen grade of VG 30 is used as the binder in Stone Mastic asphalt mix preparation throughout this project. The test results of bitumen are given in following tabular form.

3.3 AGGREGATE GRADATION

The particle size distribution of an aggregate as determined by sieve analysis is termed as gradation of aggregates. If all the particles of an aggregate are of uniform size, the compacted mass will contain more voids whereas aggregate comprising particles of various sizes will give a mass with lesser voids. it is essential that coarse and fine aggregates be well graded to produce quality mix.

For a well graded asphalt mix here we considered the Gap-graded aggregate.

3.3.1 GAP GRADED AGGREGATE

Gap-graded aggregate contains only a small percentage of aggregate particles in the mid-size range. The curve is flat in the mid-size range. Some PCC mix designs use gap graded aggregate to provide a more economical mix since less sand can be used for a given workability. When gap-graded aggregate is specified, certain particle sizes of aggregate are omitted from the size continuum. Gap-graded aggregate are used to obtain uniform textures in exposed aggregate concrete. Close control of mix proportions is necessary to avoid segregation.

The percent of aggregate passing through a sieve should exhibit with in the following gradation limits.

Table-3 gradation limits of aggregates for Stone Mastic Asphalt

SMA Designation	13 mm SMA	19 mm SMA
Course were used	Wearing course	Binder (intermediate)course
Nominal aggregate size	13 mm	19 mm
Nominal layer thickness	40-50 mm	45-75 mm
IS Sieve (mm)	Cumulative % by weight of total aggregate passing	Cumulative % by weight of total aggregate passing
26.5	-	100
19	100	90-100
13.2	90-100	45-70
9.5	50-75	25-60
4.75	20-28	20-28
2.36	16-24	16-24
1.18	13-21	13-21
0.600	12-18	12-18
0.300	10-20	10-20
0.075	8-12	8-12

3.4 BLENDING OF AGGREGATES

Aggregate blending is the process of intermixing two or more fine or coarse aggregates to produce a combination with improved grading or other properties. In our project we used trial and error method to determine the correct blending proportion of different grades of aggregates for good mix.

The three different bags of aggregates have taken and they are sieved through the critical sieves which we are using and the passing percentage of aggregate through their respective sieve size.

The blending proportion is obtained by multiplying the pass percentage of aggregate with the factor of percentage of their respective bag. The obtained blending percentage of each size aggregates and the same size aggregates percentage from three different bags has added and the result was checked that the proportion is in the limits of gradation table which is also named as composition of SMA with respect to the type of course.

4 EXPERIMENTAL PROCEDURES

In experimental procedure it describes about how the SMA sample is prepared and the step-by-step procedure of SMA sample preparation.

4.1 SAMPLE PREPARATION

Take a whole sample of 1200 grams of coarse aggregate, filler and binder for mixing, the proportions of materials are considered as per the objective. The aggregates, fillers, stabilizers and mould, tools used are preheated to a temperature of 160^0 C in hot air oven and the bitumen of VG 30 grade is heated to temperature of 100^0 C to 170^0 C before mixing. The aggregates, fillers and fiber materials are mixed before placing it on stove to reduce the voids content in aggregate. The adopted proportion of bitumen content is taken and mixed it by pouring on aggregates using the trowels, because of using bitumen we must adopt hot mixing. The pan is placed on the stove to heat the mixture to avoid hardening of bitumen. The mixture is thoroughly mixed to not form any clotting's. After mixing the mixture is poured into fixed Marshall Moulds and by using the compacting hammer 50 blows are given on each face of the mould, after compacting the mould is kept at room temperature for 24 hours. The sample is extracted by using extruder after 24 hours of time kept at room temperature. The extracted sample weights are taken in air and water to determine its volumetric properties. By using the above procedure in our project, we had prepared eight different types samples, in each type of sample three different types of proportions for both filler and bitumen content. The adopted three different proportions for combined filler and binder are 12% filler and 6% binder, 12.5% filler and 6.5% binder, and the last is 13% filler and 7% binder, by adopting these three proportions for each type of sample samples are prepared. The 8 different types of samples are prepared by using different materials, they are:

Table-4 Results of volumetric properties, Stability and Flow value

Sample No	Bitumen %	Filler %	Weight of Sample in Air (Grams)	Weight of Sample in Water (Grams)	Gmm	Gmb	VA %	VMA %	VFB %	Stability value (KN)	Flow value (mm)
Sample-1	6	12	1182	655	2.35	2.24	4.68	38.41	87.81	14.6	2.98
	6.5	12.5	1186	647	2.30	2.20	4.37	39.51	88.93	15.74	3.34
	7	13	1193	645	2.26	2.17	4.06	40.34	89.9	15.23	5.42
Sample-2	6	12	1185	659	2.35	2.25	4.25	38.14	88.85	15.89	2.94
	6.5	12.5	1189	653	2.30	2.21	3.91	39.24	90.03	16.68	3.40
	7	13	1192	646	2.26	2.18	3.49	39.98	91.27	16.28	5.28
Sample-3	6	12	1105	663	2.61	2.5	4.21	31.27	86.53	17.70	3.18
	6.5	12.5	1109	658	2.56	2.46	3.9	32.37	87.95	18.66	3.60
	7	13	1116	655	2.51	2.42	3.89	33.47	88.37	18.18	5.64
Sample-4	6	12	1166	696	2.61	2.48	4.98	31.82	84.34	16.82	3.02
	6.5	12.5	1170	691	2.56	2.44	4.68	32.92	85.78	18.10	3.72
	7	13	1178	688	2.51	2.40	4.52	33.91	86.6	17.46	5.12
Sample-5	6	12	1134	693	2.67	2.57	3.74	29.34	87.25	13.88	3.32
	6.5	12.5	1138	688	2.62	2.53	3.43	30.44	88.73	14.83	3.92
	7	13	1142	684	2.58	2.49	3.35	31.46	89.36	14.35	5.74
Sample-6	6	12	1169	710	2.67	2.54	4.86	30.17	83.89	13.35	3.22
	6.5	12.5	1174	705	2.62	2.50	4.58	31.27	85.35	14.24	3.90
	7	13	1157	694	2.58	2.49	3.14	31.32	89.9	13.79	5.68
Sample-7	6	12	1154	678	2.54	2.42	4.72	33.47	85.89	13.93	3.90
	6.5	12.5	1159	674	2.50	2.39	4.4	34.29	87.16	14.68	4.02
	7	13	1147	661	2.45	2.36	3.67	35.12	89.55	14.43	5.72
Sample-8	6	12	1179	690	2.54	2.41	5.07	33.74	84.97	12.96	3.88
	6.5	12.5	1183	683	2.50	2.38	4.8	34.57	86.11	13.99	3.98
	7	13	1166	670	2.45	2.35	4.08	35.39	88.48	13.58	5.08

The samples weights are measured, their volumetric properties are evaluated and by testing of sample by Marshall Test machine the Stability and Flow values are obtained. They are given in above table.

5. CONCLUSION

In this project work we have observed the various properties of SMA Mix over different filler and fiber materials with different proportions of filler and binder contents, and their Stability and Deformation values are determined from that the suitability of those materials for Stone Mastic Asphalt pavement is identified. And, in the other hand the properties for each category are different; they are discussed as follows:

1. The natural materials like Coconut shell charcoal powder; Coconut fiber and Sugarcane fiber have better stability results and Flow values. They are suitable for the construction of pavements.
2. These natural fibers are performed well in controlling the flow while applying the load. But the flow increases monotonically with increase in bitumen content.
3. For all proportions of bitumen content their Stability value is more than the minimum required Stability that is 6.2 KN.
4. When the three bitumen proportions Stability values are compared among them 6% bitumen content has some poor values and 6.5% bitumen content has better values.
5. In this work we had considered a new proportion for filler is 13%. This samples have good Stability but because higher fine content voids have filled and then it increases the deformation at maximum loading condition.
6. By increasing the bitumen content to 7% it almost fills the Air voids and it leads to maximum deformation. It also increasing the percentage of voids filled with bitumen.
7. The samples which are prepared using 6.5% bitumen content has better results among the three different proportions.
8. But it does not work well at the hot areas most sunny areas which have higher temperatures because VG 30 bitumen is mostly used for cool areas. By taking some measures it can perform well in hot weather also.
9. From the results of Flow values and percentage of Voids filled with bitumen we suggest that these proportions will perform well in cool areas where the temperature does not affect the bitumen state.
10. The Coconut shell charcoal powder has good Stability and the Coconut fiber also have better capability against Flow and Sugarcane fiber have better strength than Coconut fiber these makes a good mix by adopting better proportion of bitumen.
11. These materials are waste materials and they are mostly available in India at free of cost and at cheap costs. These fibers are performed well with the fillers like Stone dust and Portland cement.

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