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Experimental Examination on Use of Recycled Materials in Stone Matrix Asphalt

Swastik S Shinde[1], Dr. A D Katdare[2], Shivanjali Bodhale[3]

[1,2,3]*Department of Civil Engineering, Sanjay Ghodawat University Kolhapur*

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Abstract - SMA (stone matrix asphalt or stone mastic asphalt) was initially discovered in German & European and countries as impermeable or highly resilient wearing surface for bridge decks. Generally, it consists of two parts, a binder rich mortar and a coarse aggregate. It is made by a mixture of crushed fine and coarse aggregates, stabilizer such as polymers or fibres, cement & mineral filler. In present work, an effort has been made to study the properties of Stone Matrix Asphalt mixes with cellulose fibre and using recycled pavement material as well as slag in partial replacement of stone aggregates as coarse and fine aggregate grades. This research project was done to check the usage of recycled pavement material in Stone Matrix Asphalt mixture by conducting Marshall test in the lab in which flow & stability value was examined along with other properties of mixtures. Here IRC -SP-79 specification, aggregate gradation is taken for stone matrix asphalt. Binder used is 60/70 penetration grade bitumen. Binder content is varied as 4%, 5%, 5.5%, 6%, and 7% by weight of aggregates and fibre used is optimum fibre content at 0.3% by the weight of aggregate.

***Key Words*:** SMA (Stone Matrix Asphalt), RAP (Recycled Asphalt Pavement)

1. INTRODUCTION

SMA is a gap graded aggregate hot mix bitumen that will make best use of the binder content and coarse aggregate portion and offers a stable stone-on-stone skeleton that is kept together by a rich blend of filler, binder, and stabilizing elements.

It provides additional and higher strength to the combination by enhancing the stone to stone contact. By incorporating a large amount of coarse aggregate into the mixture, a skeleton-like structure is created that improves stone to stone contact and increases rutting resistance. In this study work, aggregates with different gradations stone dust as filler and bitumen (60/70) as space filler used. Here fibers are used as stabilizers. Here fiber helps in lessening the drain down and also to boost the strength of mix and stability of the SMA mixes. Here, the fibers maintain the binder in the mixture even at high temperatures, helping in the prevention of issues like drainage throughout operations like production, transportation, and placing. Assessing all of these factors will help to find the long-term performance of SMA and would provide info that would make changes as determining the long-term performance of SMA mixes and provide information to make changes wanted to suit for different environmental condition.

2. Objectives

1. To study effect of RAP and stone as coarse aggregate, slag as fine aggregate.
2. To find optimum binder content by using Marshall Method.
3. To study Marshall Stability value of samples, flow value of samples, voids in mineral aggregate value.
4. To study performance of stone matrix asphalt by using Marshall Stability test

3. Marshall Stability Test

The 'Marshall Stability' of the bituminous mix is defined as a maximum load carried in Kg at the standard testing temperature of 60°C when load is applied under specified test conditions. It involves mainly 2 processes:

i. Preparation of Marshall Samples
ii. Marshall Test on samples

Fine and course aggregates are sampled for the SMA composition recommended by IRC: SP-79. The total weight of the sample, including filler and binder is 1200gm. After sampling, the sample was heated in an oven at 160 degrees Celsius for 12 hours. It is then removed, mixed with bitumen, and compacted using a hammer with a falling weight of 4.54kg from a height of 40cms, with 50 strikes on each side. The sample is allowed to dry for the following 24 hours before being ejected from the mould using the Sample Ejector. Its weight in air, radii, and thickness/height are computed, and a wax coating is applied to them. Before performing the Marshall test, each sample was placed in a hot water bath for 30 minutes at 60°C. Weight in water is also computed. Two samples of 4%, 5%, 5.5%, 6%, and 7% bitumen were prepared for the bituminous course, and the Marshall Test was used to determine their stability & flow.

4. Results and Discussion

Three combinations of samples are considered in this study

1. Fiber samples with coarse and fine aggregates made from stone.
2. Sample with fiber and coarse and fine aggregates made from slag.
3. Sample with fiber utilizing RAP (recycled asphalt pavement) as coarse and fine aggregate.

4.1 Fiber Sample with Stone as Coarse aggregate

Table -4.1(a): Stability & flow value of sample using Stone as coarse aggregate

Sample No.	Bitumen Content %	Weight in air, gm	Weight in water, gm	Height of the sample, mm	Flow Value, mm	Stability, KG	Corrected Stability, KG
S-4-1	4.0	1204	732	57	2.7	601	1914.79
S-4-2	4.0	1197	721	60	2.8	625	1991.25
S-4.5-1	4.5	1206	723	55	3	665	2118.69
S-4.5-2	4.5	1192	730	57	3.1	671	2137.81
S-5-1	5.0	1194	736	58	3.2	740	2357.64
S.-5-2	5.0	1193	735	56	3.2	761	2424.55
S-5.5-1	5.5	1198	725	54	3.6	816	2599.78

S-5.5-2	5.5	1194	729	56	3.8	802	2555.17
S-6-1	6.0	1191	725	58	4.5	730	2325.78
S-6-2	6.0	1186	734	58	4.6	732	2332.15

Table.4.1(b)- Stability & flow value of sample using Stone as coarse aggregate

Bulk Density (G_b) g/cc	(Gt) g/cc	% Air Voids (V_v)	% Vol of Bitumen (V_b)	VMA %	VFB %
2.55	2.48	3.01	9.28	12.29	75.50
2.51	2.49	4.38	9.14	13.53	67.60
2.50	2.51	5.06	10.21	15.28	66.87
2.58	2.51	1.90	10.55	12.45	84.76
2.61	2.50	0.88	11.85	12.72	93.12
2.60	2.49	0.96	11.84	12.80	92.51
2.53	2.47	3.70	12.66	16.36	77.40
2.57	2.50	2.37	12.84	15.21	84.43
2.56	2.48	2.82	13.94	16.76	83.17
2.62	2.59	0.23	14.31	14.54	98.40

4.2 Sample with fiber using slag as coarse aggregate

Table -4.2(a): Stability & flow value of sample using Slag as coarse aggregate

Sample No.	Bitumen Content %	Weight in air, gm	Weight in water, gm	Height of the sample, mm	Flow Value, mm	Stability, KG	Calibrated Stability, KG
S-4-1	4.0	1192	721	59	2.4	720	2293.92
S-4-2	4.0	1187	724	61	2.6	729	2322.59
S-4.5-1	4.5	1201	740	56	2.8	755	2405.43
S-4.5-2	4.5	1205	733	58	3	766	2440.48
S-5-1	5.0	1199	736	62	3	830	2644.38
S.-5-2	5.0	1195	730	60	3.1	855	2724.03
S-5.5-1	5.5	1190	725	57	3.4	899	2864.21
S-5.5-2	5.5	1211	721	58	3.5	912	2905.63
S-6-1	6.0	1185	728	61	3.9	845	2692.17
S-6-2	6.0	1200	732	59	4.2	829	2641.19

Table.4.2(b)- Physical properties of sample using Slag as coarse aggregate

Bulk Density (G_b) g/cc	(Gt) g/cc	% Air Voids (V_v)	% Vol of Bitumen (V_b)	VMA %	VFB %
2.53	2.59	3.77	9.20	12.98	70.93
2.56	2.50	2.52	9.32	11.84	78.72
2.61	2.48	0.94	10.66	11.60	91.87
2.55	2.48	2.93	10.44	13.37	78.10
2.59	2.59	1.53	11.77	13.31	88.46
2.57	2.49	2.29	11.68	13.97	83.64
2.56	2.47	2.69	12.80	15.49	82.61
2.47	2.50	6.03	12.36	18.39	67.21
2.59	2.48	1.41	14.14	15.55	90.95
2.56	2.59	2.51	13.99	16.49	84.81

4.3 Sample with fiber using RAP (Recycle Asphalt Pavement) as coarse aggregate

Table -4.3(a): Stability & flow value of sample using RAP as coarse aggregate

Sample No.	Bitumen Content %	Weight in air, gm	Weight in water, gm	Height of the sample, mm	Flow Value, mm	Stability, KG	Calibrated Stability, KG
S-4-1	4.0	1211	736	60	2.3	695	2214.27
S-4-2	4.0	1202	729	59	2.1	702	2236.57
S-4.5-1	4.5	1189	725	61	2.4	746	2376.76
S-4.5-2	4.5	1192	730	62	2.2	769	2450.03
S-5-1	5.0	1186	734	59	2.7	811	2583.85
S.-5-2	5.0	1195	735	58	2.6	821	2615.71
S-5.5-1	5.5	1210	725	59	2.9	889	2832.35
S-5.5-2	5.5	1195	736	57	3.1	900	2867.40
S-6-1	6.0	1191	735	62	3.8	795	2532.87
S-6-2	6.0	1202	734	60	3.7	801	2551.99

Table.4.3(b)- Physical properties of sample using RAP as coarse aggregate

Bulk Density (G_b) g/cc	(Gt) g/cc	% Air Voids (V_v)	% Vol of Bitumen (V_b)	VMA %	VFB %
2.55	2.48	3.06	9.27	12.33	75.17
2.54	2.49	3.38	9.24	12.62	73.25
2.56	2.51	2.57	10.48	13.05	80.33
2.58	2.59	1.90	10.55	12.45	84.76
2.62	2.50	0.23	11.93	12.16	98.09
2.60	2.48	1.22	11.81	13.03	90.61
2.49	2.55	5.14	12.47	17.61	70.82
2.60	2.48	1.01	13.02	14.03	92.81
2.61	2.48	0.69	14.25	14.94	95.38
2.57	2.60	2.34	14.01	16.35	85.67

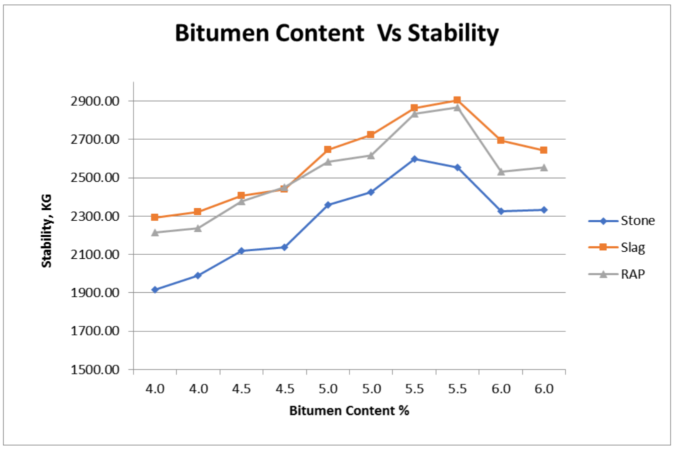

Fig-4.1: Comparison of Bitumen Content Vs Stability of Stone, Slag & RAP

The above graph represents comparison between bitumen content and stability of stone, slag and rap. On the X axis there is 4%,4.5%,5%,5.5%,6% of bitumen. On the Y axis there is stability values starts from 1500kg and goes up to 2900kg.

a. Stone graph keep on increasing up to 5.5% of bitumen content and then starts decreasing up to 6%.
b. Slag graph keeps increasing up to 5.5% of bitumen content and then it starts decreasing up to 6%.
c. Rap graph keeps on increasing up to 5.5% of bitumen content and then starts decreasing up to 6%.

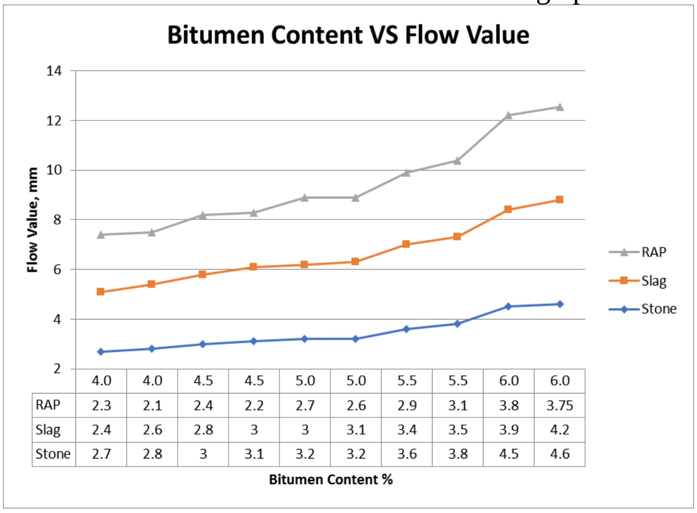

Fig-4.2: Comparison of Bitumen Content Vs Flow Value of Stone, Slag & RAP.

The above graph represent comparison between bitumen content and flow value of stone, slag and rap. On the X axis there is 4%,4.5%,5%,5.5%,6% of bitumen. On the Y axis there is flow value in mm. Flow value starts from 2mm and goes up to 14mm.

a. Stone graph keeps on increasing up to 6% of bitumen content.
b. Slag graph keeps on increasing up to 6% of bitumen content.
c. Rap graph keeps on increasing up to 6% of bitumen content.

5. CONCLUSIONS

In this project work, SMA samples were prepared with stone, slag, RAP as coarse aggregate. The results such as Marshall Stability, flow value, bulk density, volume of air voids, voids in mineral aggregate, voids filled with bitumen were obtained. RAP shows better stability value when compared to stone and slag aggregate. The following are the conclusions obtained based on the tests.

1. The maximum stability value obtained for recycled asphalt pavement as coarse aggregate is 2867.40kg at5.5% bitumen content when compare to stone as coarse aggregate and slag as fine aggregate. Minimum required marshall stability value is 820kg as per IRC:105-1988.
2. The maximum flow value observed for recycled asphalt pavement as coarse aggregate at 5.5%bitumen is 3.1%. Which is within the limit of 2-4% as per IRC:105-1988.
3. Bulk density obtained for recycled asphalt pavement as coarse aggregate is 2.60g/cc.
4. Average air voids value for recycled asphalt pavement as coarse aggregate is 3%. The percentage value of air voids should be in the limit of 3-5% as per IRC:105-1988.
5. Percentage for voids in mineral aggregate for recycled asphalt pavement at 5.5% bitumen is 14.03%. The percentage of voids in mineral aggregate should be in the limit of 13-16% as per IRC:105-1988.
6. Average percentage for voids filled with bitumen for recycled asphalt pavement at 5.5% bitumen is 81.81 which is within the limit of 75-85 as per IRC:105-1988.

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