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A Study on Stone Matrix Asphalt

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Abstract: Stone Matrix Asphalt (SMA) is a bituminous mixture with enhanced rut resistance and durability due to its gap-graded structure with higher coarse aggregate and binder content. Stone-on-stone contact is crucial for SMA, but drain down at high temperatures can be managed with stabilizing additives. In a study, Stone Mastic Asphalt (SMA) blends were created using different aggregate sizes, binders like VG 40 bitumen and PMB grade 40, Cellulose Fiber (CF), and Stone Wool Powder (SWP). Drain down was controlled by adjusting fiber and SWP content. Mixtures were evaluated for various properties using Marshall mix design and Superpave Gyratory Compactor. PMB 40 and CF mixtures showed superior performance, with 8% and 12% SWP content performing well. SMA 1 gradation generally outperformed SMA 2, except in moisture susceptibility. Cost analysis revealed PMB 40 and CF mixtures were both effective and cost-efficient for road construction.

Keywords: Stone Matrix Asphalt, stone to stone contact, drain down, fiber additives, modified bitumen, Shredded Waste Plastic

Introduction

Road transportation is crucial in India, facilitating majority of goods and passenger movement, contributing significantly to the GDP. The extensive road network includes National Highways, State Highways, and other roads. National Highways carry a substantial portion of the total road traffic despite forming a small percentage of the road network. The rise in traffic volume in India underscores the need for continuous road development to support the growing economy. Government projects like BharatmalaPariyojana aim to enhance road connectivity and reduce travel time. Initiatives like PMGSY focus on providing rural areas with all-weather road access for inclusive growth. There is a push for sustainable transportation solutions like electric vehicles and improved public transport to reduce environmental impact. Indian roads mostly have flexible pavements with layers like subgrade, sub-base, base, and Hot Mix Asphalt (HMA) surface for durability against heavy traffic. Factors like traffic, temperature, and moisture cause distress, leading to cracking and potholes. To improve longevity, engineers use modified binders and Stone Matrix Asphalt (SMA) known for strength and durability. Despite higher costs, SMA's extended lifespan justifies its use in high-traffic areas.

Stone Matrix Asphalt (SMA) is a gap-graded bituminous mixture with high coarse aggregate and binder mastics. Stone-to-stone contact creates a strong skeleton for load distribution, enhancing rut resistance and strength. SMA is suitable for heavy traffic due to its shear strength and load distribution. The rich binder mortar includes bitumen, mineral filler, and a stabilizing additive for durability. The additive prevents drain down issues caused by high temperatures during production and placement.

SMA (Stone Mastic Asphalt) was developed in Germany in the 1960s to counter studded tire damage. Despite the ban on studded tires, SMA gained popularity in Europe for its durability and rut resistance. AASHTO's European Asphalt Study Tour in 1990 led to the adoption of SMA in the US. SMA has since been widely used globally in countries like Canada, Japan, and Australia for heavy-duty pavements. The benefits of Stone Matrix Asphalt (SMA) include:

- Enhanced pavement performance with less rutting and cracking
- Noise reduction compared to traditional asphalt
- Improved frictional resistance for safety on wet roads
- Better visibility at night with reduced glare and increased pavement markings visibility

SMA mixtures are used on pavements with heavy traffic or loads for increased service life. SMA can be used in high-stress areas, thin overlays, and to resist wear from studded tires. Studies show that increasing aggregate size in SMA reduces wear from studded tires.

SMA in India

In October 2006, the Central Road Research Institute in New Delhi conducted field trials for Stone Matrix Asphalt surfacing on Road No. 59. The trial aimed to evaluate the effectiveness of SMA in a busy corridor with diverse traffic. The Indian Roads Congress introduced an SMA specification in 2008, endorsed by the Ministry of Road Transport and Highways. The full potential of SMA in India is yet to be fully explored despite ongoing studies by different institutions.

LITERATURE REVIEW

The research focuses on permeable asphalt pavement, which allows water infiltration while resembling conventional asphalt. It includes polymer fibers for strength and examines aggregate properties and bitumen through various tests. Stone matrix asphalt uses coarse particles with bituminous mortar, offering durability and stability in high-traffic areas and diverse climates at a cost-effective rate.

Pragnya P. (2020) established the importance of additives in Stone Mastic Asphalt (SMA) and introduces eco-friendly alternatives to synthetic fibers like banana and coconut fibers. Incorporating these fibers improves pavement integrity, with 0.3% fiber content notably enhancing Marshall Features. Coconut fiber stabilized SMA shows higher specific gravity than banana fiber stabilized SMA. Optimal fiber content for best results is found to be 0.3%, enhancing Marshall Quotient and maintaining controlled flow values.

Mustafa Musleh Razahi1, Avani C. (2020) examines Sisal and Coir fibers in stone matrix asphalt (SMA) to enhance stability. Fibers help prevent drainage and improve strength. Studies use tests like Marshall Stability and Drain Down to evaluate mix properties.

N.L.N Kiran Kumar, A. Ravitheja (2019) investigates the impact of natural fiber additives like coir, sisal, and banana fibers on Stone Matrix Asphalt (SMA) mixes for pavement. The research aims to enhance SMA properties and develop a sustainable surface course for roads. The study utilizes the Marshall Test to analyze mixtures and improve engineering properties. By integrating natural fibers, the research aims to improve SMA behavior, increase confidence in practical application, and suggest environmentally friendly road construction methods. Advanced techniques like SEM and XRD were used to observe microstructural changes, showing enhanced bonding and reduced cracking susceptibility. This sustainable approach contributes to reducing environmental impact in civil engineering and promotes innovative engineering practices.

K. Karunakar (2018) explored incorporating carbon and glass fibers into Shape Memory Alloys (SMA) to analyze composite characteristics. Carbon fibers, widely available in India, will be blended with glass fibers in asphalt concrete mixes at different dosages for laboratory experiments. The study aims to evaluate volumetric properties and marshal stability of the mixtures.

Siva Gowri Prasad S. (2018) assessed coconut and banana fiber impact on Marshall properties of bitumen mix stability to prevent drainage issues. Research aimed to determine the potential of using both fibers as stabilizing agents with cement filler and VG30 bitumen. Fiber additives in stone matrix asphalt mix improved stability and bulk specific gravity, with optimal levels at 0.3% for coconut fiber and 0.4% for banana fiber, showing minimal drain down effects.

Prashanth M D, Divyesh (2018) examined Marshall properties of asphalt mixes with hospital waste plastic and areca nut fiber. Results showed stability initially increased with higher plastic percentages, peaking before declining. Optimal bitumen content was found to be 5.82%. A mix with 8% plastic and 0.3% fiber enhanced stability, outperforming the control mix. This approach not only improves material properties but also offers a sustainable waste management solution, addressing environmental concerns and promoting a circular economy.

Uma MaruthiVenkatesh V, Siva Gowri Prasad S. (2018) evaluated Stone Matrix Asphalt (SMA) Mix with varying fibers. An optimal Fiber Content of 0.3% and Fiber Length of 6-8mm is recommended. Coconut fibers showed superior stability. Natural fibers like coconut outperformed polymer fibers in preventing asphalt drain down. Fiber inclusion enhances stability, modifies flow, and reduces void spaces. Waste plastics can alter SMA mix characteristics positively. Coconut fibers at 0.3% and 6-8mm length are preferred. Optimal fiber content and length are crucial for SMA mix enhancements. PET improves resistance to deformation for durable road surfaces, reducing maintenance costs and enhancing safety. 6% PET content enhances mix rigidity and deformation resistance.

Shaik. Dilkusha, K.V. Manikanta (2018) established the research explores the impact of natural fibers (coir, sisal, banana) as additives in SMA mixtures for bituminous pavements. Different fiber percentages were tested in Marshall tests, with 0.3% by weight considered optimal. Coir exhibited the highest stability, while sisal and banana fibers had similar properties.

Sambhav Jain, Harpreet S., Tanuj C. et al. (2017) explored stone matrix asphalt mixtures using VG

30 bitumen with different fibers like coconut, glass, and jute. Cellulose fiber showed higher stability and lower drain down. Despite meeting drainage limits, cellulose fiber had the least drainage, suggesting minimal drain down during field production.

K. Shravan, K.B.R. Prasad R. (2017) investigated enhancement of Stone Mastic Asphalt (SMA) for urban roads by adding coir and cellulose fibers. Varying fiber doses will be tested to assess mix properties like volumetrics and Marshall stability.

Uma Shankar D. (2017) explored the use of Stone Mastic Asphalt (SMA) Mix with banana and jute fibers for stabilization. Flow tests will evaluate mix characteristics and mechanical properties with varying bitumen concentrations. Cement is used as a filler, and bitumen serves as the binder in the mix.

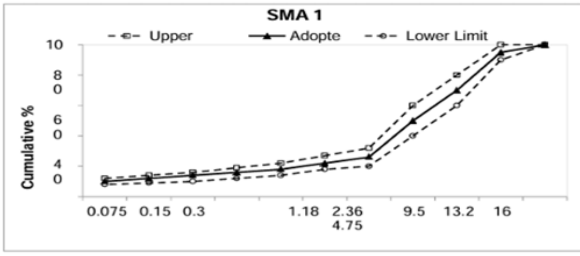
Research Methodology

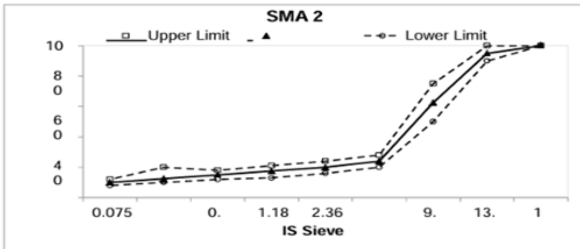
The current study utilized Marshall's mix design method, adhering to the specifications outlined by the Asphalt Institute in Manual Series – 2 (MS – 2). The MoRT&H 5th Revision guidelines for Stone Matrix Asphalt (SMA) mixtures, as detailed in Table 7, were followed. Initial assessments involved loose SMA mixtures to ascertain parameters such as maximum theoretical density (Gmm), drain-down tendencies, and resistance to stripping. Subsequently, cylindrical samples were prepared to assess volumetric properties, Marshall attributes, Indirect Tensile (IDT) strength, fatigue performance, and susceptibility to moisture. These samples were compacted using the Troxler 4140 Superpave Gyratory Compactor (SGC). Bitumen content ranging from 5.0% to 7.0% by the total mixture weight was added, followed by 100 gyrations to achieve compaction. Additionally, rectangular slab specimens were fabricated to analyze rutting behavior. The types and characteristics of materials utilized in any bituminous mixture are crucial. This study involves utilizing aggregates, bituminous binder, mineral filler, stabilizing additive, and more to create an SMA mixture. Aggregates from the Yamunanagar Quarry were evaluated for use in Stone Matrix Asphalt (SMA), meeting Indian Roads Congress guidelines. Physical properties were tested per IS 2383 standards, ensuring compatibility with SMA. The research compared traditional bitumen with Polymer Modified Bitumen (PMB) in Stone Mastic Asphalt (SMA) mixtures. Both bitumen types were tested for properties according to IS codes, with results meeting specifications for standard and modified bitumen. Fine aggregates between 2.36 mm and 0.075 mm sieves must be crushed manufactured sand, clean, hard, durable, mostly cubical, free of soft fragments, organic matter, or harmful materials. They must pass the Sand Equivalent Test with a minimum value of 50 as per IS: 2720, Part 37, and exhibit non-plastic properties. The study uses hydrated lime as a mineral filler in bituminous mixtures, improving resistance to moisture, stiffness, strength, toughness, bond between asphalt and aggregate, permanent deformation, and fatigue resistance, particularly at high temperatures. To address drainage issues in Stone Matrix Asphalt (SMA) mixtures, stabilizing additives like cellulose fibers are recommended. The Indian Roads Congress advises using pelletized cellulose fibers at a minimum of 0.3% by weight. Fibers must meet specific criteria including maximum length of 8mm, ash content below 20%, oil absorption over 4 times fiber weight, and moisture content under 5%.

To prepare Stone Matrix Asphalt (SMA) mixtures, two aggregate gradations with different Nominal Maximum Aggregate Sizes were selected for examination. The gradations featuring 16mm and 13.2mm NMAS were sourced from the MoRT&H 5th Revision guidelines (Table No. 500-37). Details of the gradation ranges and specific values for SMA 1 and SMA 2 can be found in Table 5 and Figures 5. The aggregates collected underwent sieving according to the specified sieve sizes in the selected gradation, with materials retained on each sieve separated accordingly. During the mixture preparation process, these segregated aggregates were combined in adherence to the gradation criteria. This meticulous approach to aggregate mixing was instrumental in ensuring consistency across all mixtures.

Table 1 Aggregate Gradation of SMA Mixtures

SMA Designation	13 mm SMA	19 mm SMA
Course where used	Wearing course	Binder (intermediate) course
Nominal aggregate size	13 mm	19 mm
Layer thickness	40-50 mm	45-75 mm
IS Sieve (mm)	umulative % by weight of total aggregate passing	umulative % 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



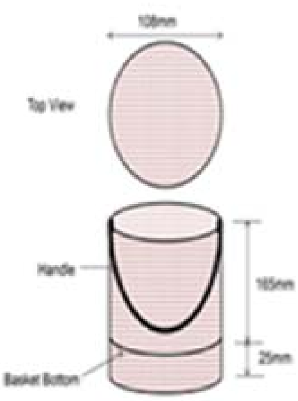


Mixture Notations

The Stone Matrix Asphalt (SMA) mixture will be formulated in accordance with AASHTO MP8, the Standard Specification for Designing Stone Matrix Asphalt, and AASHTO PP 41, the Standard Practice for Designing Stone Matrix Asphalt. The compaction of the SMA mixture will entail 50 blows on each side, following the Marshall procedure outlined in the Asphalt Institute MS-2 (Sixth Edition). The steps involved are: Loose Mixture Preparation (Components proportioned and mixed thoroughly, aimed for uniformity to avoid inconsistencies, mixture transported to compaction site), Mix Preparation (Aggregates proportioned and heated to 150 – 170 °C, waste plastic mixes with SWP added in varying percentages, bitumen added at 150 – 165 °C in specific quantities, for modified bitumens, aggregate and binder heated to 165 – 185 °C), Compaction in SGC (Mixture placed in preheated SGC mold, process involved adjusting pressure, gyration angle, rate, and number of gyrations, specimen's height measured after each gyration, results analyzed to assess asphalt mixture quality and durability)

Mixture Performance Tests

The Marshall test assesses bituminous mixture resistance to deformation following ASTM guidelines. Marshall Stability (MS) measures maximum resistance at 60ºC. Flow value quantifies deformation, while Marshall Quotient (MQ) combines stability and flow values. Specimens with varied bitumen content are tested to optimize density and stability.



$$\text{Marshall Stability, MS (kN)} = 0.0808 \times (\text{Proving Ring Reading}) - 0.0176$$

$$\text{Marshall Quotient, MQ (kN/mm)} = \frac{\text{Marshall Stability}}{\text{Flow}}$$

Drain Down Test: The drain down test, following ASTM standards, evaluates the segregation of bituminous mixture components outside the wire basket. It assesses draining characteristics of Stone Mastic Asphalt (SMA) at different bitumen contents. Results indicate drain down as a percentage of material weight post-testing, ensuring compliance with standards.

Rut Resistance Test: The resistance to rutting or permanent deformation of asphalt mixtures underwent assessment using the Hamburg Wheel Tracking Device (HWTD) following the procedures outlined in BS EN12697 - 22 at 50°C. Evaluation of rutting potential was based on the mean rut depth, where a greater rut depth indicates a higher susceptibility to rutting.

Moisture Susceptibility Test: The resistance of asphalt mixtures to rutting or permanent deformation was evaluated using the Hamburg Wheel Tracking Device (HWTD) in accordance with the guidelines specified in BS EN12697-22 at a temperature of 50°C. The assessment of rutting potential was determined by measuring the mean rut depth, with a deeper rut indicating increased susceptibility to rutting.

Optimum Bitumen Content: For Stone Mastic Asphalt mixtures, determining the Optimum Binder Content (OBC) is crucial to achieve the desired air void content. An OBC of 5.0-7.0% is correlated with 4% air voids. Properties at the OBC are compared to standards for compliance.

Indirect Tensile Strength: Indirect Tensile (IDT) strength assesses bituminous mixtures' tensile strength along a cylindrical specimen's diametrical plane. It predicts rutting or cracking susceptibility. Stone Matrix Asphalt (SMA) IDT strength was evaluated following ASTM D 6931 standards. Specimens prepared at Original Bitumen Content (OBC) were tested in a water bath at 25°C before undergoing vertical compressive loading in a Marshall stability testing apparatus to determine maximum load at specimen failure for IDT strength calculation.

Fatigue Behaviour: Fatigue cracking in bituminous pavements due to repeated loading is addressed through evaluating Stone Matrix Asphalt (SMA) mixtures using a Repeated Load Testing machine. The machine applies dynamic diametrical tensile loads to specimens, allowing for real-time data collection on material

Properties of Materials

response and mechanical properties. The setup ensures uniform stress distribution for accurate measurements, with the machine interfaced with a computer program for control and parameter input.

Retained Stability Retained stability test assesses bituminous mixtures' moisture susceptibility based on Marshall stability values. It compares stability before and after conditioning in hot water, indicating moisture susceptibility.

Stripping/ Boiling Test: The adhesion between aggregate and binder in bituminous materials is crucial for road infrastructure performance. A boiling test following ASTM standards assesses the stripping potential of Stone Matrix Asphalt mixtures by immersing them in boiling water to evaluate adhesion quality.

Results and Discussion

Job Mix Formula –SMA

The job mix formula for stone matrix asphalt-13mm has been conducted in accordance with IRC: SP: 79- 2008, asphalt institute MS-2 7th Edn, AASTHO-325-08 & AASTHO R 46-08 methodology by volumetric base aggregate blend design.

Materials

Coarse aggregate 1-(13.2mm), 2-(9.5mm), fine aggregate –crushed stone, binder (VG-40), hydrated lime, cellulose fiber, antistripping agent.

Table 2 Coarse aggregate 1-13.2mm (P-16mm—R-4.75mm)

Sr.no.	Characteristic Parameters	Test Method	Result	MoRT&H Limit
1	Grain size analysis	IS:2386 Part-1	0.2	2 Max.
2	Combined flakiness & elongation	IS:2386 Part-1	18.8	30 Max.
3	Los Angeles Abrasion Value	IS:2386 Part-4	14	25 Max.
4	Aggregate Impact value	IS:2386 Part-4	12	18 Max.
5	Soundness- Na2SO4	IS:2386 Part-5	-	12 Max.
6	Soundness- MgSO4	IS:2386 Part-5	-	18 Max.
7	Polished stone value	BS:812(P114)	0.31/2.658	55 min.
8	Water absorption & Sp. Gr.	IS:2386 Part-3	-	2 Max.
9	Stripping Value	IS:6241	-	95 Min.

Table 3 Coarse aggregate 2-9.5mm (R-4.75mm)

Sr.no.	Characteristic Parameters	Test Method	Result	MoRT&H Limit
1	Grain size analysis	IS:2386 Part-1	1.6	2 Max.
2	Combined flakiness & elongation	IS:2386 Part-1	18.8	30 Max.
3	Los Angeles Abrasion Value	IS:2386 Part-4	14	25 Max.
4	Aggregate Impact value	IS:2386 Part-4	12	18 Max.
5	Soundness- Na2SO4	IS:2386 Part-5	-	12 Max.
6	Soundness- MgSO4	IS:2386 Part-5	-	18 Max.
7	Polished stone value	BS:812(P114)	0.31/2.656	55 min.
8	Water absorption & Sp. Gr.	IS:2386 Part-3	-	2 Max.
9	Stripping Value	IS:6241	-	95 in.

Table 4 Fine Aggregate-Crushed Stone (P-4.75mm)

Sr.no.	Characteristic Parameters	Test Method	Result	MoRT&H Limit
1	Sand Content(2.36- 0.075mm)	IS:2386 Part-1	80.6	To report
2	Deleterious material Test	IS:2386 Part-2	-	2 Max.
3	Organic impurities	IS:2386 Part-3	-	To report
4	Water absorption& Sp. Gr.	IS:2386 Part-3	0.32/2.658	2 Max.
5	Plasticity Index	IS:2386 Part-5	-	Non Plastic
6	Sand Equivalent Value	IS:2386 Part-37	-	50 min.
7	Silt-75 micron passing	IS:2386 Part-1	12.8	To report
8	Soundness- Na2SO4	IS:2386 Part-5	-	10 Max.
9	Soundness- MgSO4	IS:2386 Part-5	-	15 Max.
10	Bulk Density	IS:2386 Part-3	-	To report

Table 5 Mineral Filler – Hydrated lime

Sr.no.	Characteristic Parameters	Test Method	Result	MoRT&H Limit
1	Penetration at 25 C	IS:1203	40	35 Min.
2	Absolute Viscosity at 60 C	IS:1206	3664	3200-4800
3	Kinematic Viscosity at 135 C	IS:1206	547	400 Min.
4	Flash Point	IS:1448	342	220 Min.
5	Solubility	IS:1216	99.8	99 Min.
6	Softening Point	IS:1205	52.5	50 min.
7	Viscosity Ratio at 60 C	IS:1206	2.73	4 Max.
8	Ductility	IS:1208	82.5	25 Min.

Cellulose fibres: Cellulose fiber used in this study are having following properties: - pH value – 6.5 – 8.5, Color – Grey, Solvent content – 0%, Package density – 25-45 kg/m3

Laboratory test results of Marshall Test for SMA with VG-4:

India, the Marshall Mix Design method is employed for formulating bituminous mixes. Stone Matrix Asphalt (SMA) designs specifically utilize this method. Following the grading of various raw materials, molds for Bituminous Concrete (BC) and Dense Bituminous Macadam (DBM) are prepared, and design test parameters such as air voids, stability, and flow are assessed using the Marshall Test. Cellulose fiber dosages are typically set at 0.3% of the weight of the binder.

Table 6 Binder – Paving Bitumen VG-40

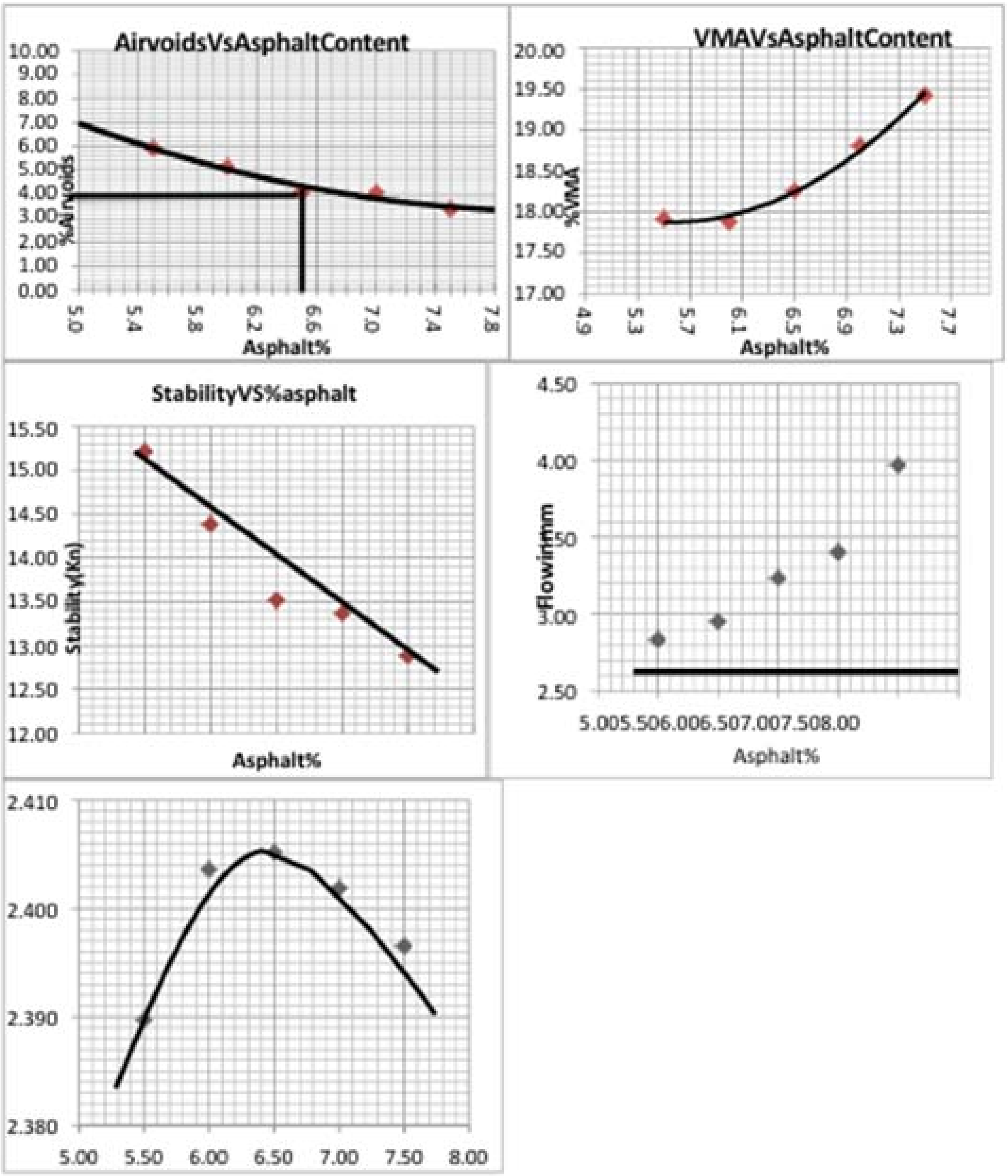
Sr.no.	Characteristic Parameters	Test Method	Result	MoRT&H Limit
1	Available lime as Ca(OH)2	IS:1514:1990	90.7	90 Min.
2	600 micron Passing	IS:2386 Part-1	100	100 Min.
3	300 micron Passing	IS:2386 Part-1	100	95-100
4	75 micron Passing	IS:2386 Part-1	98.9	85-100
5	Plasticity Index	IS:2386 Part-5	-	Non Plastic

Table: 7 Gradation of aggregate mix by volume for Stone Matrix Asphalt-13mm

S SIEVE	% of Passing				10mm	Stone Dust	Filler Rock Dust	Filler (Hydrated Lime)	Total % of Passing	MID LIMIT	MORTH LIMIT TABLE -500-	
	10mm	Stone Dust	Filler Rock Dust	Hydrated Lime	77.00%	15.00%	0.00%	8.00%	100		Lower Limit	Upper limit
19	100	100	100	100	77	15	0	8	100	100	100	100
13.2	97.96	100	100	100	75.43	15	0	8	98.43	95	90	100
9.5	55.52	100	100	100	42.75	15	0	8	65.75	62.5	50	75
4.75	2.54	99.58	100	100	1.96	14.94	0	8	24.89	24	20	28
2.36	0	81.89	100	100	0	12.28	0	8	20.28	20	16	24
1.18	0	52.59	100	100	0	7.89	0	8	15.89	17	13	21
0.6	0	35.14	100	100	0	5.27	0	8	13.27	15	12	18
0.3	0	26.1	99.12	100	0	3.92	0	8	11.92	15	10	20
0.075	0	6.7	95.54	96.08	0	1	0	7.69	8.69	10	8	12

Table: 8Marshall Test results of SMA Mix with VG40

Sr No.	% of Bitumen	Mould No	Weight in air	Weight in water	Weight in air SSD	Bulk Volu me	Bulk Sp. Gr. of Speci men	Max. sp.Gr. of Samp le (loose) (GMM)Theoretical	Voids in Mineral Aggreg ate	Air Void s	Voi ds fille d with Bitu men	Marshall Stability (kN)			AverageStability (kN)
	Pb		Wa	Ww	Wss d	Wssd-Ww	Wa (Wss d-Ww)	Gmm=100/(Pb/Gb+ (100-Pb)/G se	VMA=10 0-(GmbxPs)/ Gsb	Va=100x (Gmm-Gmb) / Gmm	VFB= 100x (VMA-Va)/ VMA	Loa d (KN)	CF	Correct ed Load(K N)	
1	5.60%	1	1135	641.5	1139	497.8	2.281	2.424	19.53	5.69	70.8	4.7	1	4.98	4.92
			5		3							9	4		
		2	1131	649.5	1144	494.6	2.288					4.2	1	4.65	
			7		1							7	9		
		3	1123	635.5	1127	491.6	2.289					4.7	1	5.13	
			8		1							1	9		
2	5.80%	4	1139	644.5	1142	498.1	2.288	2.413	19.52	5.06	74.8	4.9	1	5.18	5.24
			7		6							8	4		
		5	1141	650	1146	496.8	2.297					5.1	1	5.36	
			1		8							5	4		
		6	1135	644.5	1140	496.2	2.288					4.9	1	5.18	
			2		7							8	4		
3	6.00%	7	1141	647	1142	498.2	2.292	2.402	19.45	4.33	77.7	5.8	1	6.04	6.08
			8		6							1	4		
		8	1142	648	1146	496.7	2.301					5.7	1	5.98	
			9		8							5	4		
		9	1139	649.5	1140	495.2	2.301					5.7	1	6.22	
			4		7							1	9		
4	6.20%	10	1149	652	1152	500.3	2.298	2.395	19.41	3.8	80.4	6.6	1	6.86	6.81
			6		3								4		
		11	1148	653	1151	498	2.306					6.2	1	6.54	
			4		5							9	4		
		12	1142	650	1145	495.2	2.308					6.4	1	7.03	
			9		2							5	9		
5	6.40%	13	1154	656.5	1159	502.9	2.295	2.386	19.72	3.6	81.7	6.3	1	6.6	6.64
			2		4							5	4		
		14	1152	655	1155	500	2.304					6.2	1	6.48	
			1									3	4		
		15	1150	657.5	1157	500.1	2.301					6.5	1	6.84	
			8		6							8	4		



Graphical representation of Marshall Test results with VG40

From the above graph between asphalt % and air void %, the optimum binder content is calculated as 6.1% with VG-40 bitumen

Table:9 Mix Proportion at OBC

Sr.no.	Characteristic Parameters	Limits	Test Method	Unit bituminous mix Proportion	Aggregate Mix Proportion
1	Coarse aggregate 1 (13.2mm)	-		17.78	19
2	Coarse aggregate 2 (9.5mm)	-		54.26	58
3	Fine Aggregate-Crushed stone	20%-28%		14.03	15
4	Filler- Hydrated Lime	NAPA		7.49	8
5	Cellulose Fiber-TOPCEL CFF	0.3% Min.		0.34%	-
6	Binder Content-VG40(OBC)	5.8% Min.		6.1	-
7	Antistripping Agent	0.10 Max.	IS 2386 (P01):1963 RA 2016	0.08% w/w of VG 40	-

Conclusion

The incorporation of fiber has been recognized for its positive influence on the properties of bituminous mixtures. It enhances stability, reduces voids, and diminishes flow values. In addition to filling voids, fillers interact with the binder, potentially increasing stiffness and brittleness in the mixture. The modification of mixture characteristics is closely associated with the properties of the fillers. An escalation in bitumen content is linked to a decrease in void volume. Both mineral aggregate-filled voids and bitumen-filled voids expand with higher bitumen content. The characteristics of asphalt mixtures are directly impacted by the type and particle size of the filler. Research suggests that fiber-reinforced bituminous concrete pavements demonstrate resilience in various Indian climatic conditions. These mixtures exhibit higher air voids than the typical recommendations for standard mixes. A higher bitumen content is essential to meet design specifications and align with conventional trends.

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