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Experimental Study of Stone Matrix Asphalt in Pavement

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Abstract- New technologies such as Stone Matrix Asphalt are now being adapted to provide long lasting roads and are having a capability of improvement in roads by using stabilizing additives such as Natural material in a Stone Matrix Asphalt Mixture. To verify the performance of Stone Matrix Asphalt various material are selected. For this analysis Characteristic, Volumetric properties and Test evaluation are to be done. Here in synopsis, various literature related to this have been presented. Methodology for performance evaluation for Stability Test and Volumetric properties is also being suggested. In this synopsis the steps carried out for the study of Stability Test as regards to guidelines, Test study to be carried out using (AASHTO T305).

Keywords - Stone Matrix Asphalt, Natural Fibre, Marshall Characteristic, Volumetric properties and Drain Down Test.

I. INTRODUCTION

Stone Matrix Asphalt (SMA) material specifically refers to the components used in the production of Stone Matrix Asphalt, a type of high-performance asphalt mix commonly used in highway construction. SMA is designed to withstand heavy traffic loads, resist rutting, and enhance pavement durability. The materials used in SMA construction include:

Aggregates: SMA relies on a combination of coarse and fine aggregates. These aggregates are typically crushed stone, gravel, and sand. The aggregate gradation is carefully engineered to create a dense aggregate skeleton that provides excellent structural support and resistance to deformation under traffic loads.

Asphalt Binder: The asphalt binder used in SMA is a high-quality bitumen that forms the binder matrix holding the aggregate particles together. It is crucial for providing flexibility, waterproofing, and overall durability to the SMA mix.

II. STONE MATRIX ASPHALT (SMA) BASED PAVEMENT DESIGN

Stone Matrix Asphalt (SMA) based pavement design refers to a specific approach to designing asphalt pavements that incorporates the use of SMA mixes. This design methodology focuses on creating durable, high-performance pavements capable of withstanding heavy traffic loads, harsh environmental conditions, and minimizing rutting and cracking. Here are the key components of SMA-based pavement design:

Traffic and Environmental Analysis: The design process begins with an analysis of the expected traffic loads, including the volume and types of vehicles that will use the pavement. Environmental factors such as climate, temperature variations, and precipitation are also considered as they can affect pavement performance.

Material Selection: SMA mixes are designed using a combination of coarse aggregates, fine aggregates, asphalt binder, and often additives or fibers. The selection of these materials is critical to achieving the desired performance characteristics, such as rut resistance, durability, and fatigue resistance.

Types Of Sma Materials

Stone Matrix Asphalt (SMA) materials can be categorized into several types based on the specific components used in their formulation or the intended performance characteristics. Here are some common types of SMA materials:

Standard SMA: Standard Stone Matrix Asphalt typically includes coarse and fine aggregates, asphalt binder, and additives or fibers. The aggregates are carefully graded to create a dense aggregate skeleton, while the binder and additives enhance the mix's durability, rut resistance, and fatigue performance. Standard SMA is suitable for a wide range of highway applications and offers excellent overall performance.

Polymer-Modified SMA: Polymer-modified Stone Matrix Asphalt incorporates polymer-modified binders, such as styrene-butadiene-styrene (SBS) or styrene-butadiene rubber (SBR), into the mix. These polymers improve the asphalt binder's elasticity, adhesion, and resistance to aging and temperature fluctuations. Polymer-modified SMA is often used in areas with high traffic volumes and heavy truck loads.

Fiber-Reinforced SMA: Fiber-reinforced Stone Matrix Asphalt includes synthetic or natural fibers, such as cellulose fibers, polyester fibers, or fiberglass, in addition to the standard mix components. These fibers enhance the mix's tensile strength, crack resistance, and resistance to reflective cracking. Fiber-reinforced SMA is particularly beneficial for overlaying existing pavements or addressing cracking issues in pavements subjected to heavy loads.

III. PROPOSED METHODOLOGY

Experimental Study

Here's a general outline of the experimental study for SMA mix design:

Material Characterization:

Aggregates: Evaluate the properties of aggregates, including gradation, shape, angularity, and texture. The aggregate skeleton in SMA is crucial for its stability and durability.

Binder: Characterize the asphalt binder to determine its properties, including penetration, softening point, viscosity, and elastic recovery. The choice of binder is critical for achieving desired performance.

Selection of Aggregate Gradation:

Use a balanced mix design approach to select the optimal aggregate gradation. This involves determining the proportions of coarse and fine aggregates to achieve the desired volumetric properties.

Binder Content Determination:

Conduct tests to determine the optimum asphalt binder content. This can be done through various methods, such as the Marshall Stability test or the Superpave Gyratory Compactor (SGC).

Laboratory Testing:

Perform laboratory tests to assess the mechanical and volumetric properties of the SMA mix. Common tests include:

Marshall Stability and Flow Test: Measure the resistance of the mix to deformation and evaluate its flow behavior under load.

Indirect Tensile Strength (ITS) Test: Assess the tensile strength of the mix to understand its resistance to cracking.

Void Properties: Evaluate air voids, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA) to ensure adequate compaction and durability.

Moisture Sensitivity Testing:

Investigate the susceptibility of the mix to moisture damage. This may involve tests such as the Hamburg Wheel Tracking Test or the Tensile Strength Ratio (TSR) test.

Hot Bin Individual Gradation

In Stone Matrix Asphalt (SMA) production, the hot bin individual gradation refers to the specific gradation or particle size distribution of aggregates within the individual hot bins or storage compartments before they are combined to create the SMA mixture. Here's a breakdown of this concept:

Hot Bin: A hot bin is a storage compartment or silo used in asphalt plants to store different sizes of aggregates (such as coarse aggregates, fine aggregates, and mineral filler) before they are mixed together to produce asphalt mixtures like SMA.

Individual Gradation: This term refers to the gradation or distribution of aggregate particle sizes within each hot bin. Each hot bin typically contains aggregates of a specific size or range of sizes. For example, one hot bin may contain coarse aggregates (e.g., 13 mm maximum size), while another hot bin may contain fine aggregates or mineral filler.

Gradation Specification: The individual gradation in each hot bin is specified according to the desired aggregate size distribution for the SMA mixture. This specification ensures that when aggregates from different hot bins are combined in the correct proportions, they will create an SMA mix with the desired aggregate gradation.

The Specific Gravity Of Aggregates

The specific gravity of aggregates used in Stone Matrix Asphalt (SMA) is an important parameter that influences the design and performance of the asphalt mixture. Specific gravity (SG) is a measure of the density of a material compared to the density of water. It is typically expressed as a ratio without units.

Water Absorption In Stone Matrix Asphalt (Sma)

Water absorption in Stone Matrix Asphalt (SMA) refers to the capacity of the aggregates used in the SMA mixture to absorb water. This property is important in asphalt mixtures because it can influence several aspects of the mixture's performance and durability. Here's a breakdown of the concept:

Aggregate Characteristics: Aggregates used in SMA include coarse aggregates, fine aggregates, and mineral filler. These aggregates can be natural or manufactured materials such as crushed stone, gravel, sand, or mineral powders. Each type of aggregate has its own water absorption characteristics.

Water Absorption Measurement: Water absorption is typically measured as a percentage of the dry weight of an aggregate sample. The process involves saturating the aggregate sample with water, allowing it to absorb water for a specified period, and then determining the weight gain due to water absorption.

IV. MARSHALL TEST

The Marshall Test is a common laboratory procedure used to evaluate the asphalt mix design for various types of asphalt pavements, including Stone Matrix Asphalt (SMA). Here’s a detailed explanation of the Marshall Test in the context of SMA:

Purpose: The primary purpose of the Marshall Test is to determine the optimal asphalt binder content for an asphalt mixture to achieve desirable properties such as stability, flow, and density. These properties are crucial for the performance and durability of asphalt pavements, including SMA pavements.

Sample Preparation: To conduct the Marshall Test for SMA, a compacted cylindrical specimen is prepared using a specified aggregate gradation, aggregate types (coarse, fine, and mineral filler), and a range of asphalt binder contents. The specimen typically has a diameter of 4 inches (101.6 mm) and a height of 2.5 inches (63.5 mm).

Asphalt Binder Content: Multiple specimens are prepared with varying asphalt binder contents, usually ranging from low to high percentages based on the design requirements. The purpose is to find the optimum binder content that provides the best combination of stability, flow, and density.

V. RESULT AND SIMULATION

1.Survey Project Description

Construction of Eight Lane Carriageway starting near Major Bridge on Mej River to Junction with SH-37A (Ch. 331.030 - 359.170) section of Delhi - Vadodara Access Controlled Green field Alignment (NH-148N) on EPC Mode under Bharatmala Pariyojana in the State of Rajasthan.

2. Sma Mix Design (13 Mm)

Fig.1 Survey Under construction

Fig.2 Survey sample observation.

Maximum Specific Gravity Of Asphalt Mix- Astm-D-2041

Table 1 Maximum Specific Gravity Of Asphalt Mix-Astm-D-2041

Description	1 Sample	2 Sample
Wet of dry sample in air (gm)	1295.3	1296.5
Weight of a flask and water (gm)	2953.5	2953.5
Weight of a flask + sample+ water (gm)	3728.3	3729.3
GMM=A/A-(C-B)	2.489	2.490

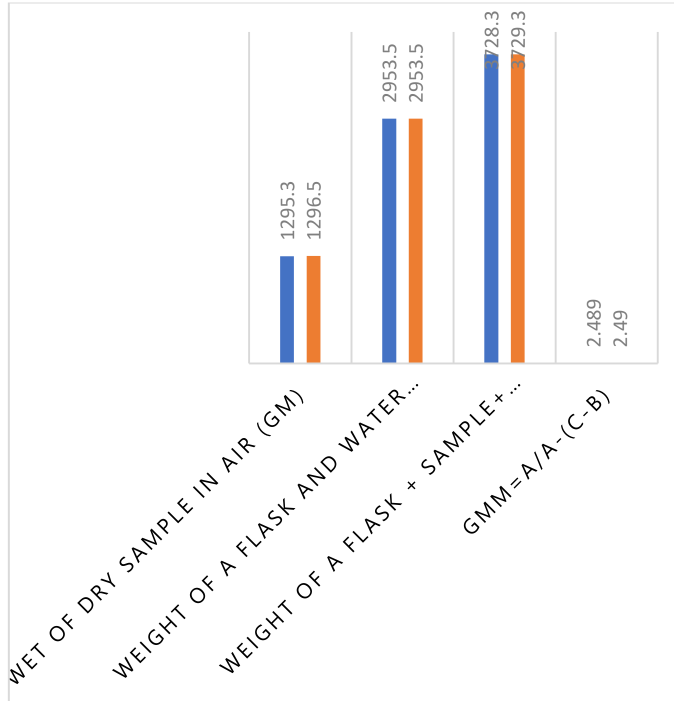

Fig.3Maximum specific gravity of asphalt mix

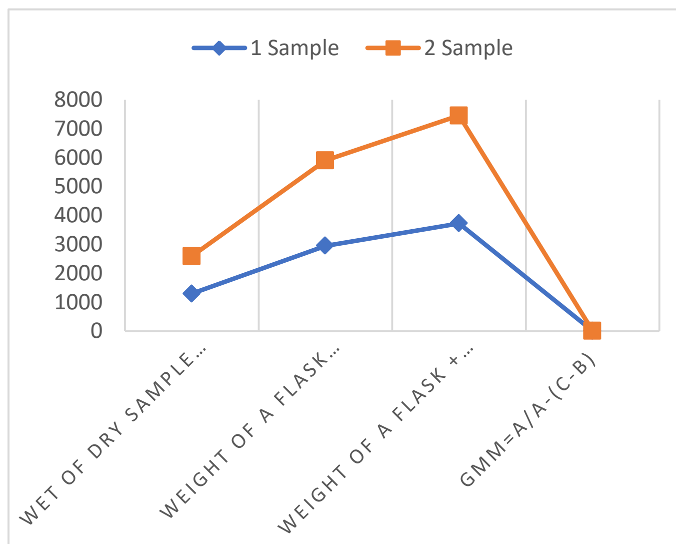

Fig.4 Weight Of A Flask + Sample+ Water (Gm).

SIEVE ANALYSIS FOR SMA

Table.2 Sieve Analysis For Sma.

Sieve Size in (mm)	Material Retained (gm)	Cumulative material Retained (gm)	Retained	%Passing	Specific limit as per as IRC SP 79 2008/MORTH 500-37
19	0	0	0	100	100
13.2	811	811	8.11	91.89	90-100
9.5	2340	3151	31.51	68.49	50-75
4.75	4469	7680	76.2	23.8	20-28
2.36	404	8024	80.24	19.76	16-24
1.18	269	8293	82.93	17.07	13-21
0.6	236	8529	85.29	14.71	12-18
0.3	132	8661	86.61	13.39	10-20
0.075	375	9036	90.36	9.64	8-12

Fig.5 Sieve analysis for SMA.

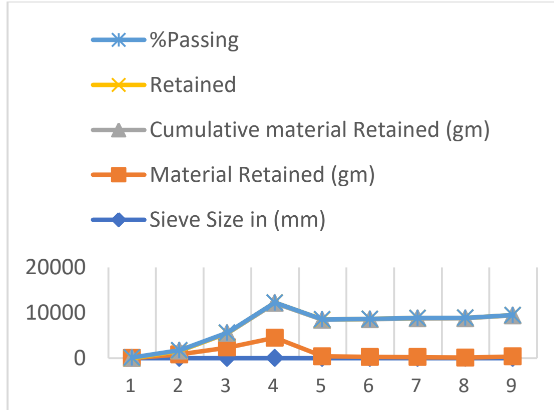

Fig.6 Sieve analysis for SMA comparative analysis.

Tensile Strength Ratio Of Sma 13mm.

TABLE .3 Tensile strength ratio of SMA 13mm.

% Bit weight of mix	Ht of specimen	Bulk specific gravity (Gmb)	Gmm	Air voids	Load KN	Tensile strength
Group A 24h Room Tem+ Water Bath at 25^{0}c for 2h Min (s1)						
6.02	67.8	2.293	2.462	6.88	11.02	1.01
Group B Water Bath at 60+ 1^{0}c for 24h+2h Min (s2)						
6.02	68.0	2.289	2.462	7.05	9.80	0.92

Tensile strength ratio % $= \frac{s2}{s1}x100$

$= \frac{0.92}{1.01}x100$

$= 91.20$

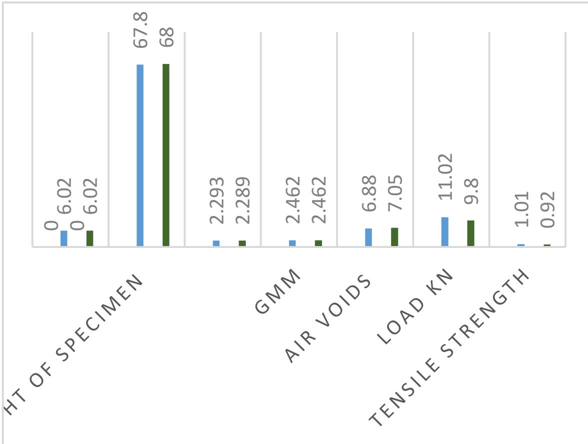

Fig.7 Tensile strength ratio of SMA 13mm.

Aggregate Impact Value As Per As Is: 238

Table 4 Aggregate Impact Value As Per As Is: 2386.

Description	1	2	3
(A) Weight of aggregate before testing (gm)	358.0	356.0	357.0
(B) Weight of aggregate retained on 2.36mm Sieve (gm)	312	309	313
(C) Weight of aggregate passing on 2.36mm Sieve (gm)	46	47.0	44.0
Aggregate impact value (%) C/A*100	12.85	13.2	12.32
Average impact value (%)	12.79		

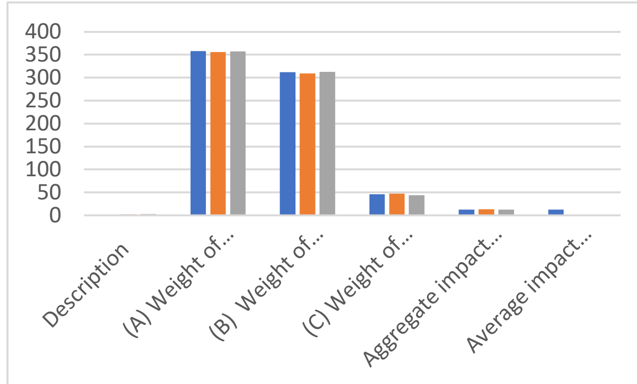

Fig.8 Aggregate impact value.

Bitumen Penetration Test (Is 1203-1978)

Table 5 Bitumen Penetration Test

Dial Reading in mm		Penetration (in mm)	Average Penetration in (mm)
Initial	Final		
0	39	39	41
0	43	43	
0	40	40	

Water Absorption 6mm Aggregate

Table: 5.6 Water Absorption 6mm Aggregate.

Description	Trail 1	Trail 2
Weight of pycnometer (gm)	488	488
Wt of SSD sample W1 (gm) W1	693.4	690.8
Weight of pycnometer + water+ sample (gm) W2	1965.8	1963.7
Weight of pycnometer + water W3	1530.5	1530.5
Weight of Oven dry sample W4	686.98	683.4
Bulk specific gravity	2.661	2.653
Apparent specific gravity	2.731	2.731
Waster absorption	0.96	1.08
Average Bulk specific gravity	2.657	
Average apparent specific gravity	2.731	
Average Water absorption	1.02	

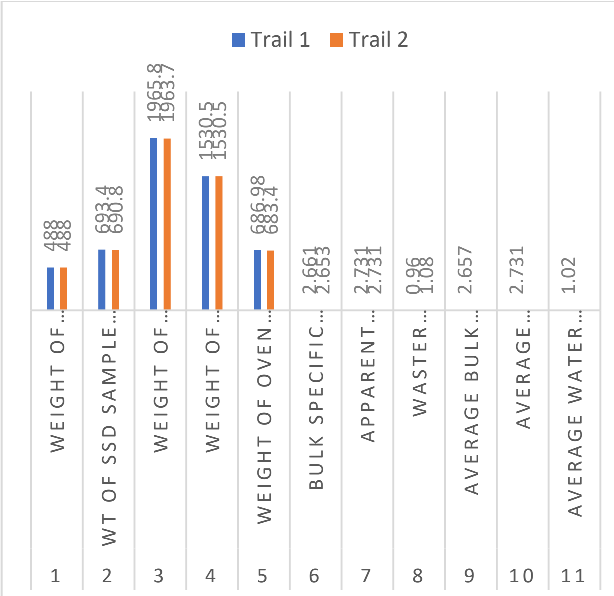

Fig. 9 Water absorption 6mm aggregate.

Marshall Test Data

Table .6 Marshall Test Data

% bit by mix	ht of specimen mm	In air (gm)	In water (gm)	SSD in air (gm)	Bulk Volume (cc)	Bulk sp. Gr. (gmb)	Theatrical Mix sp. Gr. (gmm)	Air void VA (%)	Void in Mineral Agg VMA (%)	Void in Coarse Agg VCA (%)
A	B		D	E	F=E-D	G=C/F	H	I	J	K
6.02	67.5	1248	720.3	1250	529.3	2.357				
	68	1248	722.1	1250	528.3	2.352				
	68.5	1249	723	1251	528	2.365				
Avg	68					2.361	2.462	4.09	17.81	33.06
6.02	68	1247	721.2	1249	527.3	2.364				
	68.5	1248	722.5	1250	527.1	2.367				
	67.5	1246	720.2	1249	527.3	2.359				
Avg	68					2.363	2.462	4.02	17.75	33.01
	Avg					2.362	2.462	4.06	17.78	33.03

VI. CONCLUSION AND FUTURE SCOPE

1.Conclusion

The Sieve Size in (mm) and Maximum specific gravity of asphalt mix- ASTM-D-2041 outcomes that there are different materials that can be used in the mix and make the mix economical and standard use for construction, in the investigation of SMA test is most commonly used which gives the stability and flow results of SMA from which we can know whether to use the mix or not. Suitable chemicals be used to modify the conventional bitumen and to treat the normal aggregates in SMA, can control drain down of the mixture without any additional stabilizer material. In a comparative studySieve Size in (mm) of SMA mixtures with modified treated 13mm aggregates, it is observed that mix with treated aggregates is performing better than the other.

- The work can be extended to determine more dynamic properties of SMA mixtures, including Maximum specific gravity of asphalt mix.
- Trial sections with SMA mixtures can be constructed in field and evaluation can be carried out for a period of years.
- More waste or marginal materials can be tried in SMA mixtures, including Recycled Aggregates, shingles, slag, waste fibers, etc.

Marshall Test is done to obtain stability and flow value, Drain down test is done to obtain amount of bitumen binder drain off from the surface of aggregate. According to the literature several additives are used such as have been utilized to improve the bituminous mixes. Stone Matrix Asphalt is traditionally made with synthetic. They aren't made in India and must be imported at a hefty price. Synthetics have polluted the environment due to their widespread use. The utilization of bio-renewable resources has become necessary as a result of the ecological crisis. Materials consumed in the building and maintenance of roads are extremely rare and limited. India generates a large amount of naturally obtain which can be use in bitumen road without compromising road strength, performance and increases the life time.

FUTURE SCOPE

The future scope of improving Stone Matrix Asphalt (SMA) in pavement passing involves advancements in materials, technology, and practices aimed at enhancing durability, sustainability, performance, and cost-effectiveness. Here are some potential directions for improvement:

Innovative Materials:

Develop and incorporate novel aggregate types with superior mechanical properties and durability.

Explore advanced modifiers and additives that can enhance the binder's performance under various traffic and environmental conditions. Investigate sustainable materials such as recycled aggregates, reclaimed asphalt pavement (RAP), and bio-based binders for eco-friendly SMA mixes.

Smart Asphalt Technologies:

Implement intelligent systems for real-time monitoring of SMA pavement conditions, such as embedded sensors for detecting moisture, temperature, and structural health. Utilize data analytics and predictive modeling to optimize mix designs, construction techniques, and maintenance schedules based on performance feedback and historical data. Integrate technologies like self-healing asphalt or nanomaterials for improved crack resistance and longevity.

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