Performance Evaluation of Stone Mastic Asphalt (SMA) For Heavy Traffic Roads in Indian Conditions

Prof. More Ashish V.[1], Dr. P.M. Patil[2], Pagare Amol Vijay.[3]
[1]*Guide, Civil Engineering, Adsul's Technical Campus*
[2]*Principal & Director, Adsul's Technical Campus*
[3]*Student, Civil Engineering, Adsul's Technical Campus*

Abstract—**Stone Mastic Asphalt (SMA) is a high-performance bituminous pavement mix designed to improve the durability, strength, and rutting resistance of flexible pavements subjected to heavy traffic conditions. Conventional bituminous pavements such as Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) often fail due to rutting, cracking, bleeding, and surface deformation under increasing axle loads and adverse environmental conditions. This research paper evaluates the performance characteristics of SMA and compares them with conventional bituminous mixes under Indian road conditions. The study includes analysis of materials used in SMA, mix design methodology, construction practices, laboratory testing procedures, and performance evaluation. Parameters such as Marshall Stability, density, air voids, rutting resistance, skid resistance, and drain down characteristics are analyzed. The results indicate that SMA exhibits significantly higher stability, improved rutting resistance, better durability, and enhanced skid resistance compared to conventional mixes. Although the initial construction cost of SMA is comparatively higher, the reduced maintenance requirements and longer service life make it economical in the long run. Therefore, SMA is considered a suitable pavement solution for highways, expressways, urban roads, and industrial corridors in India.**

Index Terms—**Stone Mastic Asphalt, Rutting Resistance, Flexible Pavement, Marshall Stability, Bituminous Mix, Pavement Performance.**

I. INTRODUCTION

Road transportation is one of the most important components of infrastructure development in India. Roads carry a major share of passenger and freight traffic, making pavement quality and durability extremely important. With increasing traffic volume, higher axle loads, urbanization, and industrial growth, conventional bituminous pavements are subjected to severe stresses and environmental variations. Traditional flexible pavements constructed using Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) often experience failures such as rutting, cracking, bleeding, potholes, and deformation under repeated traffic loading. These failures reduce pavement life and increase maintenance costs. Stone Mastic Asphalt (SMA) is an advanced bituminous mix developed to improve pavement performance under heavy traffic conditions. SMA was first developed in Germany during the 1960s to resist wear caused by studded tyres. The major characteristic of SMA is its gap-graded aggregate structure that forms strong stone-on-stone contact. This aggregate skeleton carries the traffic load efficiently and provides excellent rutting resistance. In addition to coarse aggregates, SMA contains higher bitumen content, mineral filler, and stabilizing additives such as cellulose fibers. The fibers prevent binder drainage and improve the stability of the mix. SMA also provides better skid resistance, improved durability, reduced traffic noise, and lower maintenance requirements.

Due to these advantages, SMA is widely used for highways, expressways, urban roads, industrial roads, airport pavements, and bridge decks.

II. OBJECTIVES OF THE STUDY

1. To study the characteristics and composition of Stone Mastic Asphalt.
2. To compare SMA with conventional bituminous pavements.

3. To evaluate Marshall Stability and flow characteristics.
4. To analyze density, air voids, and rutting resistance.
5. To study the role of stabilizing fibers in SMA.
6. To determine the suitability of SMA for Indian road conditions.
7. To examine the long-term benefits of SMA pavements.

III. LITERATURE REVIEW

Several researchers have studied the performance of Stone Mastic Asphalt pavements under heavy traffic conditions.

Brown and Mallick (1998) reported that SMA mixtures provide excellent rutting resistance due to strong aggregate interlocking and higher binder content. Kandhal and Cooley (2002) concluded that SMA pavements exhibit better durability and lower maintenance requirements compared to conventional bituminous pavements.

Sharma and Jain (2011) investigated rutting resistance of SMA mixtures and found that the use of cellulose fibers significantly improves stability and prevents binder drainage. Singh and Kumar (2015) compared SMA with conventional bituminous mixes and observed that SMA performs better under high axle load conditions.

Previous studies indicate that SMA is highly suitable for highways, industrial corridors, and heavy traffic urban roads where conventional pavements fail frequently.

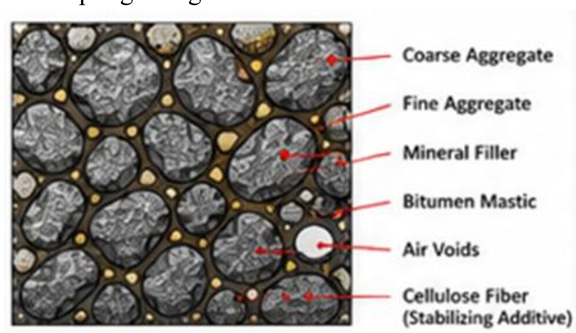
IV. MATERIALS USED IN SMA

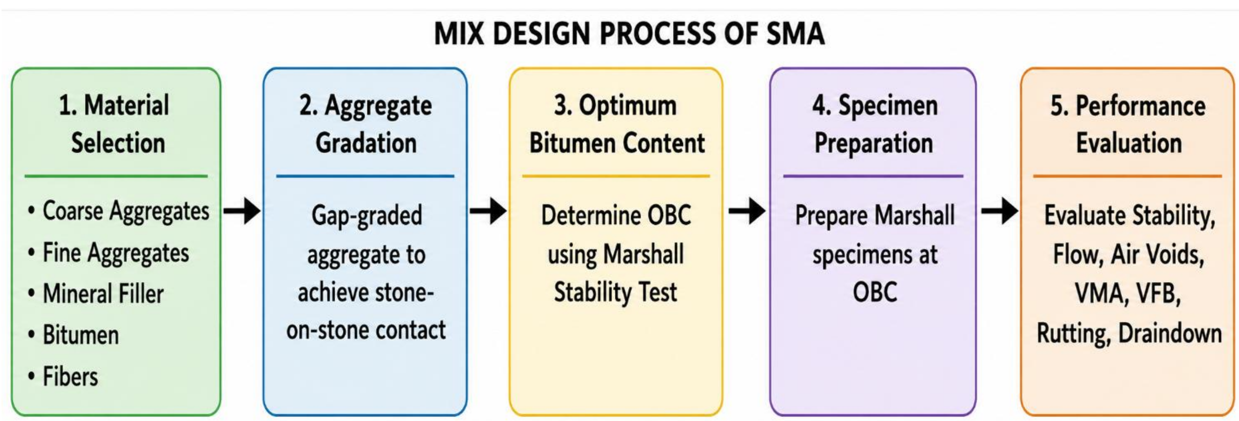
A. Coarse Aggregates

Coarse aggregates form the primary load-bearing skeleton of SMA. The aggregates used should be hard, angular, durable, and free from dust and organic impurities.

Properties Required:

- High crushing strength
- High abrasion resistance
- Angular shape
- Proper grading





Aggregate Test Results

Test	Result	IRC Limit
Aggregate Crushing Value	18%	< 30%
Los Angeles Abrasion Value	22%	< 35%
Water Absorption	1.20%	< 2%

The aggregate properties satisfy IRC requirements for SMA pavements.

B. Fine Aggregates

Fine aggregates fill the voids between coarse aggregates and improve the workability and compactness of the mix.

Fine Aggregate Properties

- Specific Gravity = 2.65

- Water Absorption = 1.1%

C. Mineral Filler
Mineral fillers improve bonding between aggregates and bitumen.
Common Fillers Used
- Cement
- Fly ash
- Limestone dust

D. Bitumen
VG-30 grade bitumen is commonly used in SMA mixtures.
Bitumen Properties

Property	Value
Penetration Value	65
Softening Point	52°C
Specific Gravity	1.02

E. Stabilizing Fibers
Cellulose fibers are commonly used to prevent binder drainage.
Fiber Content
0.3–0.5 % by weight of total mix.

V. MIX DESIGN OF SMA

The SMA Mix design is based on stone-on-stone aggregate contact. The voids between aggregates are filled with rich mortar consisting of bitumen, filler, and fibers.

Typical SMA Composition

Material	Percentage
Coarse Aggregates	74%
Fine Aggregates	12%
Mineral Filler	8%
Bitumen	6%
Fibers	0.40%

VI. NUMERICAL EXAMPLE FOR MARSHALL STABILITY TEST

Given Data
- Weight of specimen in air = 1245 g
- Weight of specimen in water = 725 g
- Stability value = 13.2 kN
- Flow value = 3.4 mm

Step 1: Bulk Volume Calculation
Formula:
$V = W_{air} - W_{water}$
Where:
- W_{air} = Weight in air
- W_{water} = Weight in water

Calculation:
$V = 1245 - 725$
$V = 520\ cm^3$

Step 2: Bulk Density Calculation
Formula:
$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$

Calculation:
$\text{Density} = \frac{1245}{520}$
Density = 2.39 g/cc

Step 3: Stability Evaluation
Observed Stability = 13.2 kN
IRC Recommended Stability > 9 kN
Therefore, the SMA mix satisfies IRC requirements.

VII. TESTING AND RESULTS

A. Marshall Stability Test

Mix Type	Stability (kN)	Flow (mm)
SMA	13.2	3.4
Conventional Mix	9.1	3.8

Analysis
SMA exhibits higher stability compared to conventional mixes due to strong aggregate interlocking and stone-on-stone contact.

B. Density Test

Mix Type	Density (g/cc)
SMA	2.42
Conventional Mix	2.36

Higher density in SMA improves strength and resistance to deformation.

C. Air Voids Analysis

Mix Type	Air Voids (%)
SMA	3.5
Conventional Mix	4.8

SMA maintains air voids within the desired range.

D. Rutting Test

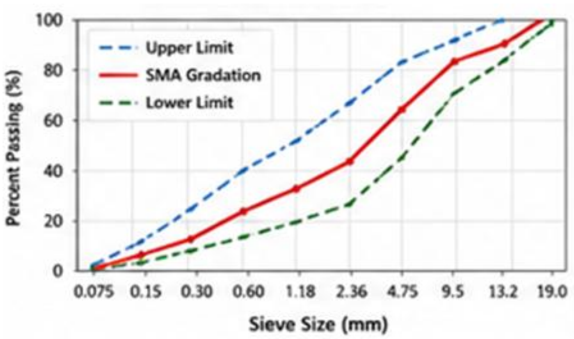
Mix Type	Rut Depth
SMA	3 mm
Conventional Mix	8 mm

SMA exhibits significantly lower rutting due to strong aggregate structure.

E. Drain Down Test

Mix Condition	Drain Down (%)
SMA with Fibers	0.25
SMA without Fibers	1.5

The use of fibers effectively reduces binder drainage.



VIII. DISCUSSION OF RESULTS

The results clearly indicate that SMA provides superior pavement performance compared to conventional bituminous mixes. Marshall Stability values are significantly higher in SMA due to better aggregate interlocking. The rutting resistance of SMA is also much higher because the stone-on-stone contact effectively distributes traffic loads. Air voids remain within acceptable limits, improving moisture resistance and durability.

The use of cellulose fibers prevents binder drainage and improves stability. Although the initial cost of SMA is higher, the reduced maintenance requirement makes it economical over the pavement life cycle.

IX. ADVANTAGES OF SMA

1. High rutting resistance
2. Better durability
3. Improved skid resistance
4. Reduced maintenance
5. Longer service life
6. Better performance under heavy traffic
7. Better moisture resistance
8. Improved riding quality

X. LIMITATIONS OF SMA

1. Higher initial construction cost
2. Requires skilled labor
3. Strict quality control required
4. Proper temperature control necessary
5. Fibers are mandatory

XI. APPLICATIONS OF SMA

1. National highways
2. Expressways
3. Airport runways
4. Industrial roads
5. Urban roads with heavy traffic
6. Bridge decks
7. Container terminal pavements

XII. CONCLUSION

Stone Mastic Asphalt is a superior pavement material compared to conventional bituminous mixes. SMA provides higher stability, better rutting resistance, improved skid resistance, and enhanced durability. The Marshall Stability test and rutting analysis clearly indicate the effectiveness of SMA under heavy traffic loading.

Although SMA involves higher initial construction cost, the reduced maintenance and longer service life make it economical in the long run. Therefore, SMA is highly suitable for Indian highways, expressways, industrial roads, and urban heavy traffic corridors.

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