Influence of glass fibres in stone mastic asphalt

V Udaya Bhanu¹, NVLN Pavan Kumar²

¹Assistant Professor, Civil Engineering, SVCET, Srikakulam, Andhra Pradesh, India.
²Assistant Professor, Civil Engineering, SVCET, Srikakulam, Andhra Pradesh, India.
E-mail: bhanu.12256@gmail.com

Abstract. The study in this paper examines the effect of fibres on the stability of Stone Mastic Asphalt (SMA) mixture in flexible pavement. Two types of fibres namely Class-C Glass fibres (Glass – C), and Alkali Resistant Glass Fiber (ARGF) were used in this investigation. From the results, it was found that the addition of glass fibres showed the improvement in the properties of the stone mastic asphalt mix. The addition of fibres at 0.4% with 6% binder content results in increased stability values and low draindown values.

Keywords: Class-C Glass Fiber; Alkali Resistant Glass Fiber; Draindown; Stability.

1. Introduction

Stone Matrix Asphalt (SMA) is a mixed proportion of the coarse aggregate with fine aggregate and the bitumen to obtain the strong and durable mix to withstand the traffic loads. As the SMA offers rut resistance, durable and textured surface course, it has been successfully utilized in many of the developing countries. SMA consists major portion of coarse aggregates. SMA has a typical composition consisting of coarse aggregate of 70–80%, filler of 8–12%, a binder of 6.0–7.0%, and fibre of 0.3 - 0.5%. Aggregate grading, filler, binder, proportion and the type of stabilizer additive will determine the stability of the mix. The interlocking and binding properties of the SMA Mix are influenced by the type of fibre used. The binding, as well as the property of interlocking, are influenced by the type of fibre used in SMA. Fibre affects the asphalt in its properties like Penetration, Ductility of the Mix, also affect the rut Resistance.

The Fibres utilization in the Stone Mastic Asphalt helps in the reduction of the Draindown, which also affects the stability of the mix. In this, the Paving Mixes were examined in terms of Stability, Void filling Resistance to Displacement and its Consistency (Bhanu and Venkateswara Rao (2016) [1]). The performance of SMA with various types of fibres was studied in the earlier investigations. Bindu et al (2010) [2] has conducted the experimental investigation with waste plastic as the stabilizer in the SMA from 0-12%. Laboratory tests like Marshall Stability and draindown were conducted and concluded that 10% of plastic waste increased stability and also reduced the draindown. Ahmadinia et al (2011) [3] has studied on Stone Mastic Asphalt properties using plastic waste bottles as additive. From the experimental investigation, it was come to know that up to 0.4% addition of additive increased the stability and further addition decreases significantly. Moghaddam et al (2012) [4] has studied regarding the properties of SMA containing waste polyethylene terephthalate. From the test results indicated that 0.4% addition of waste polyethylene terephthalate has increased the stability. Suresh et al (2013) [5] studied on the performance of modifying strength parameters using glass fibres of lengths 0.3 millimeters and 0.6 millimeters. From the test results of stability and penetration, it was found that fibres with 0.3 mm lengths performed better results compared to the mix with 0.6 mm lengths. Thanh et al (2013) [6] has studied the influence of three different types of fibres in stone mastic asphalt. The fibres used are lignin. Mineral and polyester fibres respectively. From the Marshall stability and rutting tests,
it was identified that mineral fibre has increased the properties compared to the lignin and polyester fibres.

2. Properties of Different Materials Using Different Test Methods

2.1 Identification of Material Properties

In this experimental investigation, the coarse and fine aggregates used were used from the near quarry. The aggregate particle size is ranging from between 75µ to 13.2 millimeters. Different test methods are conducted to the collected aggregates to determine their properties are shown below.

| Characteristic Property | Parameter                          | Result Obtained (%) |
|-------------------------|------------------------------------|---------------------|
| Strength                | Impact Value                       | 17.7                |
|                         | Abrasion Value                     | 18                  |
|                         | Crushing Value                     | 25.3                |
| Particle shape          | Combined Index of Elongation and Flakiness | 26.7                |
| Water Absorption        | Water Absorption                   | 0.5                 |

The grade of bitumen is VG – 30, which is brought from HPCL, Vizag. 1.02 is the obtained specific gravity. The properties of bitumen are mentioned below.

| Characteristic Property       | Method Obtained | Result                  |
|-------------------------------|-----------------|-------------------------|
| Test for Penetration          | IS 1202 [8]     | 64                      |
| Test for Softening Point      | IS 1205 [9]     | 50                      |
| Test for Ductility            | IS 1208 [10]    | Greater than 100        |

The glass fibres used in this investigation are obtained from Ashwin ceramics and reliance industries and their properties are mentioned below.

| Property                     | Glass – C Fibre | Alkali resistant glass Fibre |
|------------------------------|-----------------|------------------------------|
| Density                      | 2.70            | 2.60                         |
| Tensile strength             | 3600 MPa        | 3500 MPa                     |
| Elastic modulus              | 760 GPa         | 740 GPa                      |
| Abrasion                     | High resistance | High resistance              |

2.2 Aggregate Gradation

Stone mastic asphalt mixes were prepared using IRC SP 79 2008 [11] of SMA gradation. It is represented in figure 1.

2.3 Procedure for the Preparation of SMA Specimens

As per standard specifications of AASHTO MP8 [12], the stone mastic asphalt mixes were designed. Two different fibres were used to prepare two different mixes. The percentage of fibre addition is obtained from the draindown test. For the first mix Glass - C type fibre is used as a stabilizer additive. In case next mix alkali-resistant glass fibre is added as the stabilizer additive. For the determination of
optimum bitumen content, aggregate and filler of 1200 gm are heated to 175 – 190°C. Then the fibres are added and uniformly mixed. Bitumen was heated and maintained temperature from 121°C to 125°C for trail 1, the content of bitumen was taken as 5% by weight of aggregates.

![Figure 1. Grading of Aggregates](image)

The aggregate and bitumen were mixed thoroughly at 154 - 160°C temperature. The mix was placed in the mould which is preheated at 110°C. the mix is prepared by compacting the mix for 50 blows of either side by maintaining the temperature at 138°C – 149°C. The thickness of the compacted specimen must be 63.5±3 mm. Bitumen content for the next mixes is varied by 0.5% and the above procedure is repeated.

2.4 Test Procedures

2.4.1 Binder Runoff Test (Draindown)
To identify the runoff of the binder from the mix, the draindown test was used. fibres of different percentages were added to the mix. The percentage fibre addition giving the draindown value less than 0.3 is considered as the optimum additive and used in further analysis.

2.4.2 Test for Marshall Stability
This is to analyze Stability and Flow values, with different mixes of bitumen. Here in this mix Stability, Flow, Percentage of Air Voids (%Vv), Percentage of Voids filled with Bitumen (%VFB), Percentage of voids in Mineral Aggregates (%VMA). At 4% Air voids (%Vv), the Optimum Binder Content (OBC) was considered.

3. Analysis of Test Results
Initially, the test of draindown was performed to obtain the optimum content of fibre added with the bitumen. Later the Marshall Stability tests were performed on the specimen with optimum fibre content and the results were discussed below.

3.1 Draindown Test for Optimum Fibre Content
The Draindown test was performed using the basket drainage test as per ASTM D 6390 (2005) [13] for the obtained gradation mix with 7% bitumen content. It is conducted at a temperature of 160°C with fibre addition in percentage of 0.05%, 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%.

It is found that the optimum stabilizer additive content for both the fibres was obtained at 0.4%. The draindown values obtained for the Glass - C and ARGF are 0.199 and 0.159 respectively. Hence it satisfies the minimum condition of draindown as per IRC: SP 79 – 2008, the draindown test value should be less than 0.3.
Figure 2. Variation of draindown value for glass fibres as stabilizer additive.

Figure 2 represents the draindown of the SMA mix with the fibre fraction. As the fibre fraction increases the draindown decreases gradually. The reason may be attributed to the presence of fibres due to which void space will be reduced in the bitumen mix. The better interlocking of fibre and aggregate helps in attaining the maximum stability. Comparatively Glass - C showed the lesser draindown than the ARGF. The draindown values obtained for both types of fibres were less than 0.3 at the optimum fibre content of 0.4 % fibre.

3.2 Preparation of Stone Matrix Asphalt Samples with Optimum Stabilizer Additive

The SMA specimens were prepared by varying the binder content from 5.5% to 7.0% i.e., 5.5%, 6.0% 6.5% and 7.0% respectively at optimum stabilizer additives (0.4% obtained by draindown test). Then the Marshall properties are identified and represented below.

3.2.1 Stability

Figure 3 represents the comparison of the stability value to percentage binder varying from 5.5% to 7.0% at 0.5% increment at optimum stabilizer additives (glass - C, ARGF). Both the mixes gradually increased the stability and obtained maximum stability at 6% and thereafter stability decreases gradually with the increased binder content.

The maximum stability obtained for Un-modified mix is 13.38 kN. For the Glass - C and ARGF are 18.30 kN and 17.36 kN. For glass - C, an increment of 36.8% in the stability to unmodified mix was observed and 5.4% increment in its stability was found compared to the mix with ARGF.
3.2.2 Flow

Figure 4 represents the comparison of the value of the flow of the mixes at optimum stabilizer additives (glass - C and ARGF) with the increased percentage binder. The flow value for glass – C fibre is ranging from 2.32mm to 3.12mm and the flow value of glass fibre is ranging from 2.31mm to 4.28mm. The results showed that the increase in the flow value is due to the increase in the binder content. Due to the elastic nature of the binder and the fibres used in the mixes increased the flow values. Mix with ARGF fibre showed a higher flow value compared to the mixes with unmodified and glass –C fibre.

![Flow Graph](image_url)

**Figure 4.** Comparison of the Flow Value with the content of fibre for stabilizer additives.

3.2.3 Air voids

Figure 4 represents the comparison of the value of % air voids with the % increment in the binder content in the mixes with stabilizer additives. The results show the increase in the content of fibre reduced air voids percentage for the mixes. The reason may be considered as the fibres coated with the binder helps in filling the vacant space in the specimens, thereby resulted in a decrease in the air voids. By the addition of glass – C fibre at different binder percentages resulted in the reduction of air voids from 5.74% to 1.68% and by the addition of ARGF, air voids reduced from 5.33% to 2.52%. In the case of glass – C fibres at a lower percentage of binder high amount of air voids were observed. Beyond 6% binder content the less percentage of air voids were observed in the case of glass – C fibre compared to the unmodified mix and mix with ARGF.

![Air Voids Graph](image_url)

**Figure 5.** Comparison of the value of % Air Voids with the content of binder for stabilizer additives.
3.2.4 Percentage of Voids in Mineral Aggregates
Figure 6 shows the comparison of the value of % Voids in Mineral Aggregates for the mixes to the increase in the percentage binder. In case of glass – C fibre as stabilizer additive the voids in mineral aggregates gradually decreases from 18.14% to 17.74%. In case of ARGF as stabilizer additive, it was observed that from 5.5% to 6.0% there is decrement from 17.79 to 17.31% and thereafter there is an increment up to 7% binder by obtaining 18.44% in the % VMA. Mix with ARGF attained the lower VMA at 6% binder and thereafter increased up to 7%. For glass – C fibre there is a continuous decrement in VMA.

Figure 6. Comparison of Percentage VMA with the Content of Binder for stabilizer additives.

3.2.5 Percentage of Voids filled with Bitumen (VFB)
Figure 7 shows the comparison of percentage VFB with the % for the mixes to the increase in the percentage binder.

Figure 7. Comparison of Percentage VFB with the content of Binder for stabilizer additives.
The result shows that the increase in the Voids filled with Bitumen is due to the increase in the percentage Binder. As a result, there is a decrement in percentage air voids, there must be an increment
in the percentage Voids Filled with Bitumen. The range of increment in Glass – C fibre is from 68.36 to 90.36% and for ARGF the increment is in the range of 70.14% to 86.33%. For both the fibres binder there is an increment in VFB with the increase in the binder content. Beyond 6% of binder content, the glass – C fibre showed a higher value of VFB. In the case of mix with ARGF, there is no appreciable increase in VFB with the increase in binder content.

4. Conclusions
From the laboratory tests, the influence of the glass fibres as the stabilizer additive in the SMA mix, which indicates that Marshall Stability Properties has been examined and compared for different properties. The following conclusions were suggested from the above tests conducted.
1) From the results of the draindown test, it was concluded that 0.4% fibre addition is optimum fibre addition for both the glass fibres.
2) The maximum stability values obtained for mixes with glass - C and ARGF are 18.30kN and 17.36kN.
3) Stability of the mix with glass – C showed an increment of 36.8% to unmodified mix and 5.4% increment when compared to the mix with ARGF.
4) Flow value is higher in case of mix with ARGF and lowers in case of glass – C fibre comparing with the unmodified mix.
5) Utilization of fibres in SMA increased the VFB compared to the unmodified mix.
6) Glass – C fibre showed better Marshall properties compared to the alkali-resistant glass fibre.

References
[1] Udaya Bhanu V, Venkateswara Rao J 2016 Influence of Glass Powder and Quartzite Rock Dust as Fillers in Stone Mastic Asphalt International Journal of Engineering Research & Technology 5 (11) p 222–6
[2] Bindu CS, Beena KS 2010 Waste plastic as a stabilizing additive in Stone Mastic Asphalt International Journal of Engineering and Technology 2 (6) p 379-87
[3] Esmaeil Ahmadinia, Majid Zargar, Mohamed Rehan Karim, Mahrez Abdelaziz, Payam Shafigh 2011 Using waste plastic bottles as additive for stone mastic asphalt Materials and Design 32 (10) P 4844–9
[4] Taher Baghaee Moghaddamand, Mohamed Rehan Karim 2012 Properties of SMA Mixtures Containing Waste Polyethylene Terephthalate International Journal of Chemical and Biological Engineering 6 (2) p 170-5
[5] Suresh T, Gobinath R, Kannan T, Saranya S, Sruthy Radhakrishnan, Neelima Singhvi, Chitavel V 2013 Studies on Modifying Strength Parameters of Bitumen Using Fibres International Journal of Engineering Research & Technology (IJERT) 2 (10) p 1085-93
[6] Dang Van Thanh, Cheng Pei Feng 2013 Influence of Different Fibres on High Temperature and Water Stability of Stone Matrix Asphalt International Journal of Applied Engineering and Technology 3 (1) p 1-10
[7] IS 2386 Part I 1963 Methods of test for aggregates for concrete Bureau of Indian Standards, New Delhi, India p 11-4
[8] IS 1203 1978 Methods for testing tar and bituminous materials: Determination of penetration Bureau of Indian Standards New Delhi, India p. 19-22
[9] IS 1205 1978 Methods of testing tar and bituminous material: Determination of softening point Bureau of Indian Standards New Delhi, India p 33-8
[10] IS 1208 1978 Methods of testing tar and bituminous material: Determination of ductility Bureau of Indian Standards New Delhi, India
[11] IRC SP 79 2008 Tentative specifications for stone mastic asphalt Indian Roads Congress, India
[12] AASHTO M 325-08 2012 Standard specification for Stone Mastic Asphalt (SMA) AASHTO ASTM D 6390 05 Standard test method for determination of draindown characteristics in uncompacted asphalt mixtures ASTM