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Mechanical Performance of Stone Mastic Asphalt Incorporating Steel Fiber

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Abstract. Stone Mastic Asphalt (SMA) is a gap-graded hot mix asphalt that contains a large percentage of course aggregate and bitumen filler mastic. SMA is suffered from severe binder drain down due to the gap graded aggregates mixtures. Large difference between the sizes of aggregate tend to reduce tensile strength of the asphalt mixture. To overcome this, a type of fiber which is steel fiber is utilized to improve the tensile strength of SMA. Thus, the aim of this study is to increase the strength of SMA by utilizing steel fiber. To prepare SMA mixtures, specimens were compacted by applying 50 blows on each face using Marshall Compactor. Then, the modified specimens were tested to investigate the performance in terms of Los Angeles Abrasion Test, Marshall Stability Test, Resilient Modulus Test, and Dynamic Creep. From the results, it indicates that the addition of 0.3% fiber leads to better stability and stiffness while 0.5% fiber for resilient and enhanced modulus dynamic creep at 25°C and 0.4% fiber at 40°C. Thus, it can be concluded that the addition of steel fiber in the mixture significantly enhance the overall performance of SMA.

1. Introduction

Stone mastic asphalt is a gap graded hot mix asphalt with more than 65% of course aggregates, and according to [1], optimal asphalt binder for designing aggregate gradation of SMA mixtures are at 5.5 percent. Stone mastic asphalts the mixing of the aggregates with polymer-modified binder. The polymer modified binder in stone mastic asphalt mixing is in between the range of 5.5 to 7.5 percent. Stone mastic asphalt is good in skid resistance since it offers an improvements surface in texture depth where it is in between 0.7 to 1.0mm. The course aggregate composition is in contact from point to point, forming a skeleton structure tends to provide great internal friction between the wearing course and the tires of the vehicles. In general, the asphalt binder mixed with the aggregate at the desired temperature to fully coated aggregate and binder and prepare for suitable for paving. This reduced viscosity allows the aggregate to be fully coated at a lower temperature than what is traditionally required in HMA production Kilas et al. [2]. However, when the temperature is lower, the asphalt tends to lose its adhesive bond with the aggregate. These will contribute to the combined weakening of the mastic and weakening of the aggregate-mastic bond. According to Sengul et al. [3], stone mastic asphalt has its advantages as it has shown to be very durable surfacing, exhibit high resistance to rutting due to heavy axle loads since its stable aggregate skeleton structure and generates less tire

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noise inexperienced countries that have adopted stone mastic asphalt. Furthermore, it is reported that stone mastic asphalt has its ability to meet the United Kingdom surface texture requirements with a great choice of aggregate size. Unfortunately, SMA forming a stone skeleton structure by containing high course aggregate content that leads to having voids in the structural matrix where the voids are filled with high viscosity bituminous mastic with any stabilizing agent like bitumen, crushed sand or filler. The stabilizing agent is usually made up of fiber which prevents binder drainage in stone mastic asphalt mixing. Fibers reinforced bituminous mixture is now not rare in the industry. It is now widely used especially in SMA. A study by Arabani and Shabani [4] utilized the ceramic fiber to improve the properties of asphalt binder. In addition, Tanzadeh et al. [5] used glass fiber to improve the performance of open-graded friction course. The binder drain down happened when there is a high content of binder content, and the mix is at high temperature [6]. To prevent the binder drain down from getting worst, the addition of mineral fibers, steel fiber are well known to enhance the performance of the stone mastic asphalt. The production of steel fiber reinforced bituminous mixtures might be very costly as compared to other modified fibers, but at the end of the day, steel fiber may reduce and save the maintenance cost. This research study is done to identify the characteristics and the performance of stone mastic asphalt incorporating steel fiber. According to Bindu [7], the addition of fiber including steel fiber may play the significant roles in volumetric and mechanical properties as well as the binder drain down the problem of stone mastic asphalt mixture. This research might provide ways of optimizing fiber performance in asphalt pavement. It can be concluded that the addition of steel fiber in the mixes may enhance the performance of Stone Mastic Asphalt Mixtures.

2. Methods

2.1. Materials
This research was carried out by using 60/70 penetration-grade asphalt and Steel Fibre, as shown in Figure 1 as the additive of hot asphalt mix additive material. The amount of Steel Fibre contents was used in this study were 0%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% by weight. The effects of Steel Fibre that mixed will be evaluated. It is typically mixed directly with the asphalt mixture at temperatures of 160°C–180°C. The crush aggregate granites have been dried and sieved into a selected size range with nominal size 20 mm of aggregates according to to a standard specification (SMA 20). Portland cement as the filler has been used.

Figure 1. Steel Fiber

2.2. Sample Preparation
The bituminous mixture was prepared by using SMA graded aggregates with 60/70 penetration grade bitumen with the mineral fiber used, Steel Fibre. The crush aggregate granites have been dried and sieved into a selected size range with nominal size 20 mm of aggregates. The dry blending method has been used in this research which the fiber was added to the mixture before the binder the optimum binder content for this researched was 6.2% by weight of the mix, where this percentage of optimum binder content comes from the past research. The fiber length in the mixture was preserved as a constant parameter that equal to mm with a maximum length of 6mm. All specimen was prepared

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using Marshall Compactor machine to have the identity samples. The number of compaction for each of the samples are 50 blows at the top and the bottom side of the specimen. The temperature used for all specimens were in the range of 160°C to 180°C.

2.3. Performance Testings

Four tests are conducted to evaluate the performance of steel fiber-modified SMA which are Marshall Stability, Cantabro Loss, Resilient Modulus and Dynamic Creep. Marshall Stability was performed to evaluate the tensile strength capability of modified SMA [8]. The specimens were prepared using the optimum binder content (OBC) from Arshad et al. [9]. For Cantabro Loss Test, the test has been done to indicate aggregate toughness and abrasion characteristics to provide high-quality hot mastic asphalt. The specimens were kept at a temperature of 25°C for six hours before testing. The specimens were weighed after it had been kept for the specified time and placed into the Los Angeles machine without the steel balls. Then, the drum was switched on at a velocity between 188 and 208 rad/s and subjected to 300 revolutions without steel ball [10]. Resilient Modulus and dynamic creep were performed to evaluate the stiffness characteristics of modified SMA [9].

3. Results and discussion

3.1. Marshall Stability

Figure 2 presents the stability and Voids in Mix for different Steel fiber contents, respectively. Figure 2 shows that there was a slightly increase in stability from 0% to 0.2% fiber content. This is due to the small amount of steel fiber within the mix, which affect the foal of SMA by having contact points between the aggregates, therefore, lead to a good value of stability. The addition of steel fiber in figure 3 shows that the increase of steel fiber content in the mix results in a decrease in the voids in mixes. Mixes with higher fiber content experiencing higher compact ability and therefore, the air voids might be decreased.

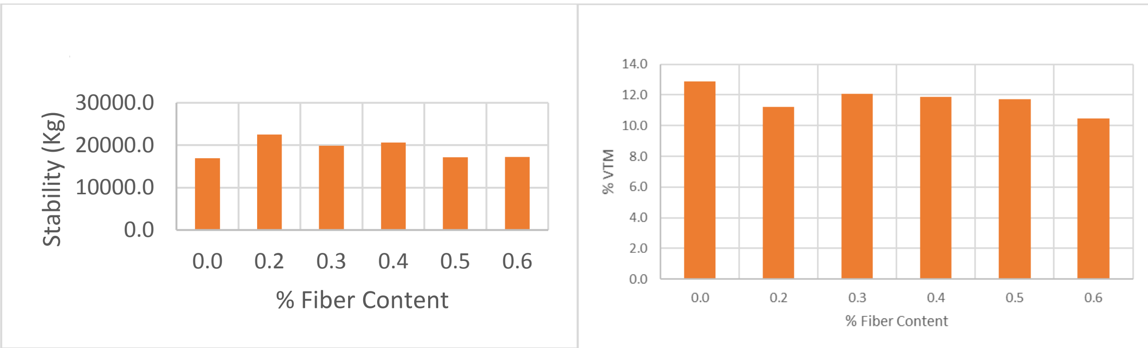


Figure 2. Stability and VTM

3.2. Cantabro Loss

Figure 3 shows that the addition of 0.4% of steel fiber reduced Los Angeles Abrasion loss after 300 turns. This proved that the addition of steel fiber had improved the cohesiveness and the abrasion of Stone Mastic Asphalt (SMA) mixture, making it more durable to accept higher forces due to traffic loads.

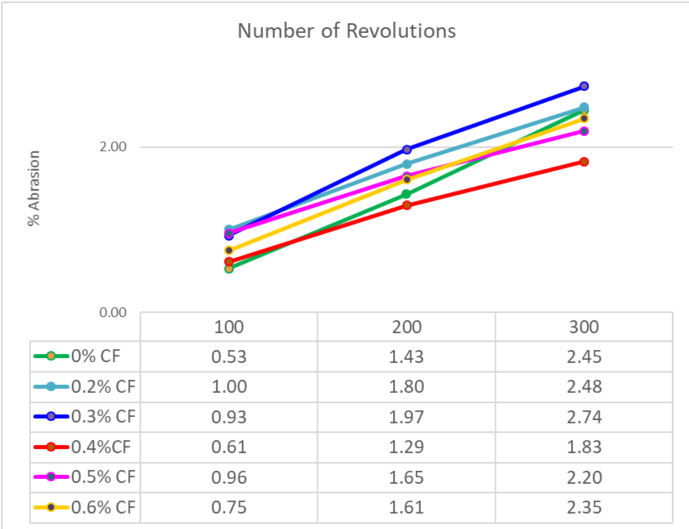
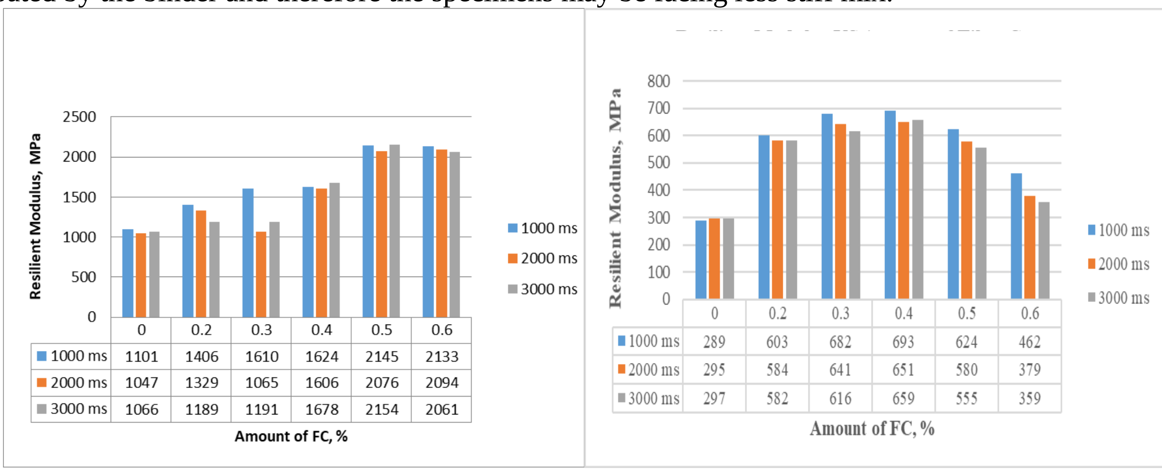


Figure 3. Cantabro Loss Value

3.3. Resilient Modulus

The stiffness properties of the reinforced SMA mixes are at 25°C and 40°C are shown in Figure 4. The results show the trends where the specimens with fiber contents had slightly higher stiffness compared to the specimen without fiber content added. The result displayed that as the fiber content increases until the optimum fiber content reached, and then the result decreases back. The optimum value of fiber content for resilient modulus at the temperature of 25°C was at 0.5% while 0.4% at 40°C. Mixture with 0.5% fiber content exhibited higher stiffness modulus compared to other mixes at 25°C while 0.4% for 40°C. The increase in resilient modulus might be due to the higher modulus of elasticity and low ability of extension of the fiber and randomly oriented in a different direction. The result is consistent with a study by Arshad et al. [11], where the resilient modulus of SMA was increased due to modification process using alternative material. The declination in this test that was beyond certain value is most probably due to high inclusion of fiber thus higher surface area to be coated by the binder and therefore the specimens may be facing less stiff mix.

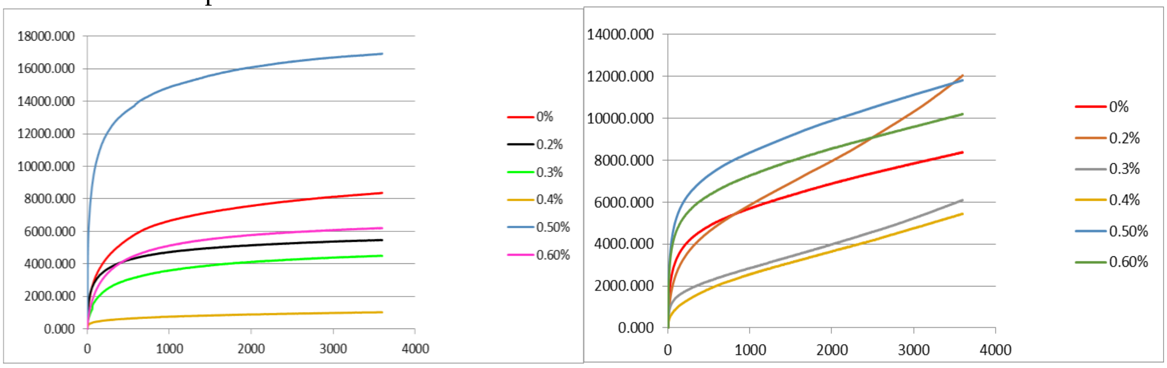


(a) 25°C (b) 40°C

Figure 4. Resilient Modulus

3.4. Dynamic Creep

Permanent strain deformation value of the reinforced SMA mix with steel fibers are illustrated in Figure 5 for both 25°C and 40°C. The results show the trends where the specimens with fiber contents had decreased the strain value. The result displayed that as the fiber content increases until the optimum fiber content reached, and then the result decreases back. The optimum value of fiber content for dynamic creep at both temperatures of at 0.4% with strain value of 1023.8 and 5440.4, respectively. Mixture with 0.5% fiber content exhibited higher permanent strain value compared to other mixes at 25°C while 0.4% for 40°C. The asphalt mixture is less prone to permanent deformation if the value for a permanent strain from the test is lower.



(a) 25°C (b) 40°C

Figure 5. Dynamic Creep

4. Conclusion

Based on the research work described:

- The addition of Steel Fibre significantly reducing the binder drain down a problem that might be caused by the voids of the aggregates structure.
- Addition of Steel fiber in the mixture also increases the stability, the resilient modulus, and the dynamic creep.
- The research objectives also have been achieved, which the steel fiber was proved in enhancing the performance of the stone mastic asphalt.
- Based on the mechanical performance tests, the optimum fiber content is 0.4%.

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