Volumetric Properties and Resilient Modulus of Stone Mastic Asphalt incorporating Cellulose Fiber

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Abstract. Stone mastic asphalt (SMA) is well known as a high coarse aggregate content that interlocks to form a stone skeleton that resist permanent deformation. However, it facing a lot of problems such as rutting and stripping because of the high temperature and repeated axial load. It also suffers with creep issue. The cellulose fiber is a type of synthetic fiber that can enhance the properties of asphalt mixture. Thus, the aim of this study is to utilize the cellulose fiber that has high tensile strength to overcome the problem of SMA. Among the tests involve are Resilient Modulus, Marshall Stability and Cantabro Loss. From the results, it shows that the addition of cellulose fiber improved the recovery ability of asphalt binder. From each test, the addition of 0.2% cellulose fiber contributes to lowest value of abrasion, while 0.3% producing highest value of resilient modulus. Thus, the addition of cellulose fiber is capable in enhancing the properties of SMA.

1. Introduction

Stone Mastic Asphalt (SMA), which has been utilized in Europe for around 40 years ago to supply resistance to scraped spot by studded tires [1]. Within the 1970s, studded tires were prohibited in Germany, and the utilize of SMA blends declined since of the higher material and construction costs and there now not showed up to be a basic require for these mixtures. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resist permanent deformation [2]. Hence, the asphalt concrete facing a lot of problems such as rutting and dynamic creep. Subsequently, the mixture's resistance to moisture damage and rutting specifically will effects the life span of the paving mixture. Sufficiently, high binder contents cannot be achieved using unmodified or unstabilised bitumen [3]. The drainage of bitumen would occur during transport and laying. Therefore, most stone mastic asphalt mixture uses a fiber stabilizer mixed with asphalt binder in the bitumen to keep it homogenous [4]. Cellulose fibers has been selected as the modified binder to improve the pavement performance of asphalt mixture. The addition of cellulose fibers into the control asphalt improved the recovery ability of asphalt binder. The natural cellulose fibers are fibers that are still recognized as being from a part of the original plant because they are only processed as much as needed to clean the fibers for use [5]. This studies were done to enhance the performance of asphalt mix with cellulose fiber. One type of binder modification is the cellulose fiber which promising result in improving binder properties. This study focus on the cellulose fiber act as addictive for the asphalt binder. The aim of this study to enhance the properties of SMA in terms of resilient modulus, dynamic creep, Marshall Stability and abrasion with the existence of fibre content.

2. Methods

2.1. Materials
In this study, Penetration Grade 60/70 (PEN60/70) types of binder was mixed with cellulose fibers with amount of 0%, 0.2%, 0.3%, 0.4%, 0.5% and 0.6% by weight of mixture. Cellulose fiber acts as the modifier for SMA. The size of the cellulose fiber is about 100 mm. Table 1 and Table 2 show the properties of aggregate and asphalt binder. Both materials passed the requirement stated in JKR specification [6].

Table 1. Aggregate Properties

Aggregate Testing	Observed Test Result	Limit
AIV test	15%	<25%
ACV test	15.09%	<35%
LA Abrasion	21%	<25%
Flakiness	20%	<25%
Elongation	20%	<25%

Table 2. Asphalt Binder Properties

Asphalt binder Testing	Observed Test Result	Limit
Penetration Test in 25^{o}C	60 mm/10	60-70 mm/10
Softening Point Test	50^{o}C	49-56^{o}C
Ductility at 25^{o}C	102.5 cm/s	.>100 cm/s

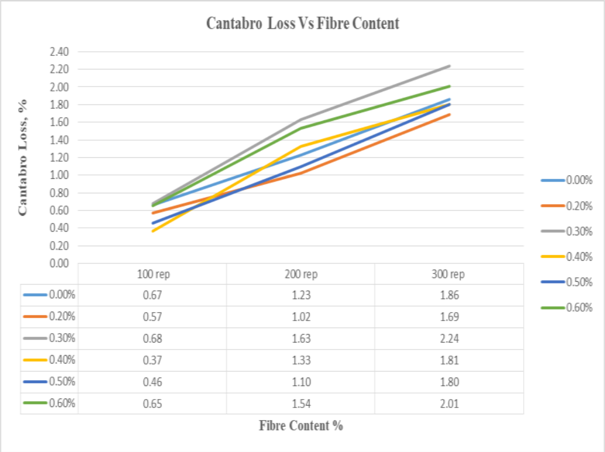
2.2. Marshall Mix Design
To prepare SMA Mixture, Marshall Mix Design process was carried out in accordance to the Malaysian Public Works Department [6]. Two specimen were prepared for each binder content with the range of 0.2% - 0.6% of cellulose fiber for SMA with the increment of 0.1%. The bulk specific gravity, the stiffness, the stability and flow value, the percentage air voids in mineral aggregate (VMA) and the percentage of air voids in the compacted mix (VIM) was obtained and plotted separately against the fiber content and a smooth curve was drawn through the plotted values to determine the volumetric properties of modified specimen. The optimum binder content (OBC) use in this study is adopted from a study by Arshad et al. [7].

2.3. Mixture Testing
Among the tests involve to evaluate the performance of modified specimen are Marshall Stability, Resilient Modulus and Cantabro Loss. The resilient modulus is determined by the elastic modulus based on the recoverable strain under repeated loads [8,9]. The data provides the total resilient axial deformation response of a specimen subjecting with the cylindrical specimen to loads using Universal Testing Machine (UTM) Machine. For this test, two specimens were prepared for each cellulose fiber content (0%,0.2%,0.3%,0.4%, 0.5% and 0.6%). All the samples were tested at fixed temperature of 25°C and 40°C with two positions and three different pulse repetitions (1000ms, 2000ms and 3000ms). The Cantabro Loss test is performed to determine the abrasion loss of compacted SMA specimens. This test measures the breakdown of compacted specimens due to repeated rotation in Los Angeles drum mixer equipment. Then, the percentage of weight loss (Cantabro loss) is an indication of PFC durability and relates to the quantity and quality of the asphalt binder [10].

3. Results and discussion

3.1. Loss Angeles Abrasion

From Figure 1, at 300 revolutions, 0.3% CF has the highest value of abrasion and 0.2% has the lowest value of abrasion loss. This may cause by the increased tensile strength of the SMA due to the existence of cellulose fiber. The cellulose fiber helps to increase the tensile strength of SMA, thus improving the performance of the SMA. From the result, 0.2% CF has the lowest abrasion loss value.

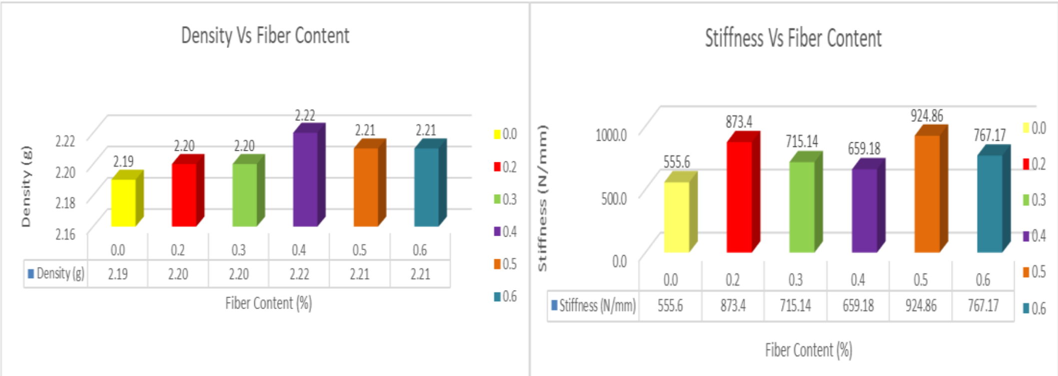


	100 rep	200 rep	300 rep
0.00%	0.67	1.23	1.86
0.20%	0.57	1.02	1.69
0.30%	0.68	1.63	2.24
0.40%	0.37	1.33	1.81
0.50%	0.46	1.10	1.80
0.60%	0.65	1.54	2.01

Figure 1. Abrasion Loss

3.2. Volumetric Properties

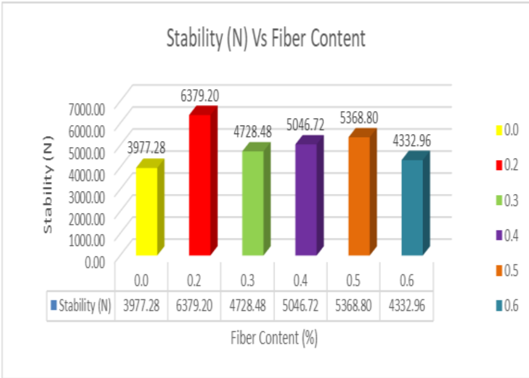
From Figure 1, 0.4% CF produces the highest density, while 0.5% CF produces highest stiffness and 0.2% CF produces the highest stability for SMA. It is found that the stability value is lower at less binder content, then increases with increment of content. The stability of the mix is primarily controlled by the cohesion and internal friction of the matrix which supports the coarse aggregates. The volumetric properties result verified the suitability of cellulose fiber to be used for SMA.



	0.0	0.2	0.3	0.4	0.5	0.6
Density (g)	2.19	2.20	2.20	2.22	2.21	2.21

	0.0	0.2	0.3	0.4	0.5	0.6
Stiffness (N/mm)	555.6	873.4	715.14	659.18	924.86	767.17

(a) Density (b) Stiffness

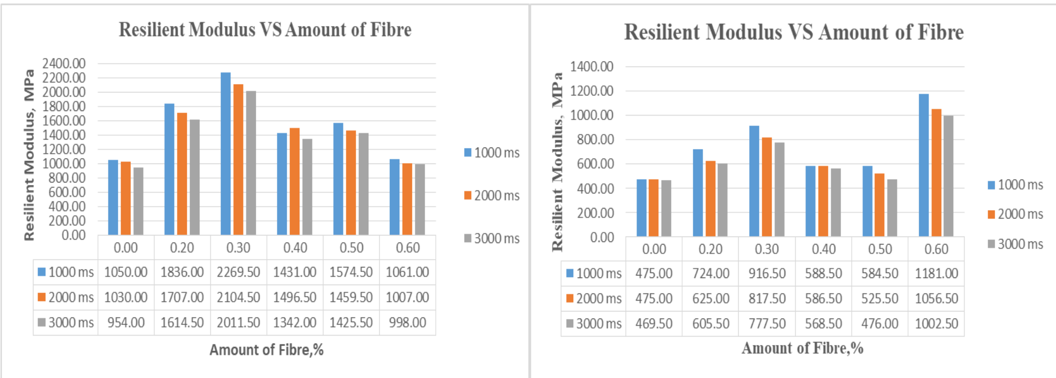


(c) Stability

Figure 2. Marshall Properties

3.3. Resilient Modulus

From Figure 3, 0.3% CF provides the highest resilient modulus value (Mr) at 25°C while 0.3% for 40°C. For SMA20, the increment in the amount of cellulose fiber will result in a higher value of Mr. At 25°C and at pulse 1000ms period, Mr for control specimen is lowest which is 1050 MPa. The highest Mr value obtained at 0.3% CF-SMA20 is 2269 MPa. However, the result for Mr values at different pulse period did not show any trend in uniformity. In addition, at 3000ms pulse repetition period, the Mr for 0.3% CF-SMA20 is 2011 MPa. In general, higher pulse repetitive period gives lower resilient modulus value. The result is consistent with a study by Arshad et al. [7]] and Masri et al. [11].



(a) 25°C (b) 40°C

Figure 3. Resilient Modulus

4. Conclusion

From the laboratory works and data analysis, the optimum cellulose fibre content is 0.2% and considered as the most effective amount for the performance enhancement of SMA mixtures. The addition of cellulose fiber also increased the overall performance of SMA in terms of volumetric properties, abrasion resistance as well as resilient modulus.

5. References

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