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Performance of Stone Mastic Asphalt incorporating Kenaf fiber

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Abstract. Stone mastic asphalt (SMA) is a type of gap-graded asphalt mixture that contain large gap between big size and small size of aggregate. These criteria tend to reduce the tensile strength of mixture. To solve this, SMA usually mixed with synthetic fiber to increase tensile strength. However, synthetic fiber is costly and rarely obtained from local supplies. Thus, the aim of this study is to utilize different percentages of natural fiber which is kenaf fiber in SMA to overcome issues related to SMA. Among the test involved were LA Abrasion, Marshall Stability, Resilient Modulus, and Dynamic Creep. From the results, it shows that the addition of 0.2% fiber contributes to lowest value of abrasion. In addition, 0.2% fiber also produces the highest density of SMA20 (Stone Mastic Asphalt Grade 20). It could be seen that 0.6% of kenaf fiber producing highest value of resilient modulus. Dynamic creep also shows a significant value for 0.2% amount of kenaf fiber. Thus, it can be concluded that the existence of fiber is capable in enhancing the performance of SMA which is evident for instance, the density. The outcome of this study also contributes to the improvement of current guideline in designing SMA mixture especially for Public Work Department of Malaysia.

1. Introduction

Stone Mastic Asphalt (SMA) usage started back in Germany during the 1970s to give greatest protection from rutting brought about by the studded tires on European streets. 'Strabag', a gigantic German development organization, prompted the advancement of SMA. At the point when studded tires were never again permitted, it was discovered that SMA displayed such high protection from rutting by overwhelming truck traffic and ended up being amazingly viable in opposing wear. In acknowledgment of its fantastic execution, a national standard was set in Germany in 1984. From that point forward, SMA has spread all through Europe, North America and the Asia Pacific. A few individual Countries in Europe currently have a national standard for Stone Mastic Asphalt, and CEN, the body of the European guidelines, is building up a European item standard. In the United States, Australia, New Zealand and in Asia, the utilization of SMA is expanding in prevalence among street specialists and the black-top industry. Although asphalt mixture is approximately composed of only 5% asphalt binder and the remaining is aggregate, the mechanical properties and behaviour of asphalt binder affect significantly the properties of asphalt mixture and hence play a big role in the performance of asphalt pavements [1]. Use of SMA for surfacing road pavements is expected to significantly increase the durability and rut-resistance [2]. Due to high content of bitumen it fills the voids between the aggregates effectively and binds them together, thus contributing to its durability from premature cracking [2].

Drainage and bleeding are a potential problem associated with SMA. Bleeding is caused by difficulty in obtaining the compaction required. Therefore, stabilizing additives such as cellulose fibers, mineral fibers or polymers are used to stabilize the matrix, thus significantly reducing drain and bleeding. The various types of stabilizing agents commonly used in SMA are generally expensive, so there is a need to obtain an alternative, low-cost stabilizer that serves essentially the same purpose, in the same way as other commonly used stabilizing additives. Thus, by introducing a natural fiber as an additive it could greatly enhance the performance of SMA while lessening the cost too.

Recently, due to the increase of environmental awareness, concern of environmental sustainability, growing global waste problem, initiation of ecological regulations as well as regulations, decrease of fossil fuels, increase of crude oil price have created interest to renewable resources like Kenaf [3]. The use of Kenaf Fiber in SMA mixture is worth to be investigated as the availability of Kenaf resources in Malaysia will result in lower production cost of SMA pavement [4]. In addition, it could also be considered as an eco-friendly material which promotes sustainability in pavements [5]. According to Public Work Department (PWD) and Malaysian Highway Authority (MHA), weather is one of the main causes for deteriorating road conditions. Not only that, it has been revealed that the road constructed does not follow the specifications as the contractors hired are cutting down on materials and this led to more issues as the road are exposed to increasing traffic volume over the years. Instead of lasting for another five or ten years, the road crumbles faster and need regular maintenance [6]. Malaysia only has two extreme weather which are dry throughout the year and rainfall season making the roads condition deter from their original condition. Over the years, even with maintenance the roads have shown a lot of deficiencies such as rutting and stripping. Not only that, some of the road designed cannot occupy the heavy traffic load from heavy trailers making the road susceptible to potholes too [7]. Hence, the aim of this study is to evaluate the performance of stone mastic asphalt (SMA) using Kenaf fiber as a modifier. The aim of the study is to enhance the performance of stone mastic asphalt in terms of cantabro loss, stability, stiffness, density, resilient modulus and dynamic creep with the existence of Kenaf fiber. The objectives for this study are to evaluate mechanical performance of Kenaf fiber modified stone mastic asphalt in terms of its cantabro loss, stability, stiffness, density, resilient modulus and dynamic creep and to determine the optimum fiber content (OFC) by evaluating the physical properties of asphalt binder.

2. Methodology

2.1 Materials

Asphalt binder (bitumen) with a 60/70 penetration grade is used in this study. Cellulose fibres, mineral fibres, polymers and plastics are among the commonly used fiber but the chosen modifier to be used is Kenaf fibre which is a natural fiber. About 2kg of Kenaf is obtained before cutting them into 1cm in size. The fiber replaced into the mix in the range of 0% to 0.6% or 3g to 7g in grams.

Table 1. Result of Softening Point, Penetration and Ductility [8].

Test	Result	Specifications	Status
Penetration (mm)	65	60-70	Pass
Softening point ($°C$)	49	47min	Pass
Ductility (cm)	150	100min	Pass

2.2 Testing

Preparation and aggregate testing, which covers *Sieve Analysis, LA Abrasion Value test, Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV), Flakiness and Elongation.* While to determine the asphalt binder physical properties, *Penetration Test, Softening Point Test and Ductility Test* is done. Marshall Mix Design is followed to prepare the samples which were further tested by *Marshall Stability test, Resilient Modulus test, and Dynamic Creep test.*

2.3 Marshall Stability

This test was conducted on 12 samples with two samples for each percentage of 0%, 0.2%, 0.3%, 0.4%, 0.5% and 0.6% according to ASTM D6927 standard method. Prior to testing, the samples would be conditioned by placing them in a water bath at a temperature of 60 C for 30 minutes. The sample would then be placed on the machine and will be loaded with force required for breaking the sample that would be measured as the Marshall Stability [9].

2.4 Cantabro Test

As for LA Abrasion test or Cantabro test, there are 12 samples involved for each percentage of Kenaf fiber same as Marshall Stability only that they are put inside the abrasion machine to be rotated for about 300 cycles. The weight and diameter of the sample before were taken and their respective weight would be recorded for every 100 cycles until it reaches 300 cycles. It is done according to ASTM C-131 but without the steel balls.

2.5 Resilient Modulus test

The test is done according to ASTM D7369-11 and was conducted at two different temperatures which are 25C and 40C. The test would take approximately 3 hours for 3 samples having a total of 6 samples for each temperature the sample reading would be test in 0- and 90-degree position. The average reading is taken for each sample [10,1].

2.6 Dynamic Creep test

This test was done by using the UTM machine and a software of permanent deformation on the computer. The sample would be conditioned at a temperature of 40 C in the machine before being placed into the dynamic creep apparatus. The testing occurred for about 2 hours before the end result is produced on the computer. This test was done according to ASTM D704-15.

3.Results and Discussions

3.1 Cantabro test results

From Figure 1 it is shown that 0.2% addition of Kenaf Fiber has the lowest abrasion value compared to the others. It is proven that by adding some amount of Kenaf fiber it could enhance the abrasion of the SMA while the increasing the values of kenaf fiber addition into the samples makes the abrasion value become higher every revolution. Thus, the aggregates could stand more abrasion when adding 0.2% of kenaf fiber.

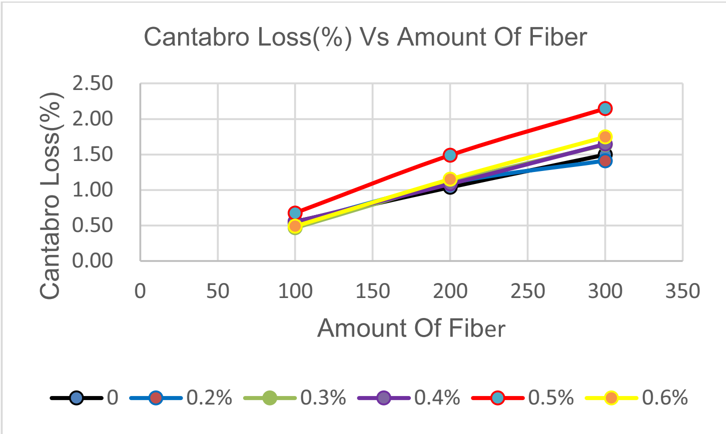
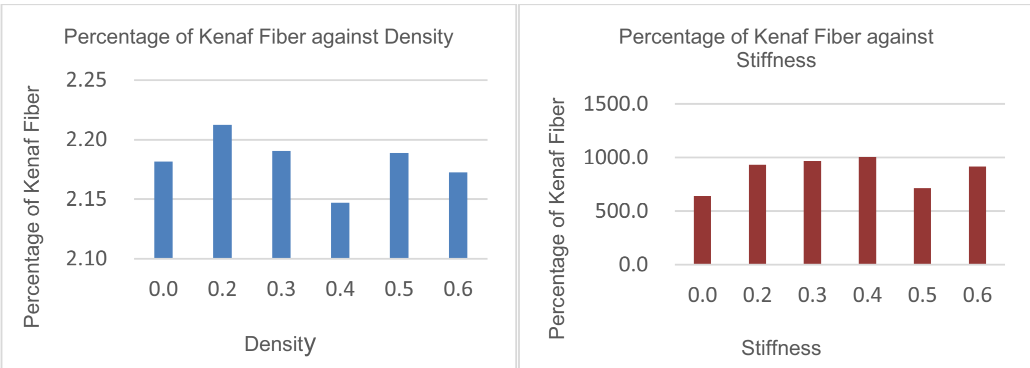


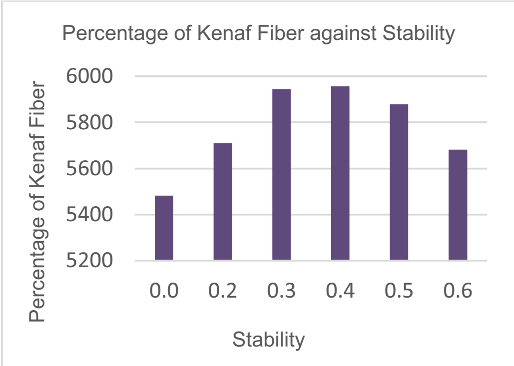
Figure 1. Cantabro Loss.

3.2 Marshall Stability results

This test is done to evaluate the sample in the terms of Density, Stiffness and Stability. From Figure 2 (a), 0.2% of Kenaf fiber records the highest value of Density which represent the air voids, since it has high density there are lesser air voids. Thus, making it less susceptible to moisture induced damage and more uniform. From Figure 2(b), 0.4 % shows the significant value for Stiffness. The equivalent could be said for the Stability at 0.4% Kenaf fiber at Figure 2(c). Since asphalt constantly exposed to traffic load, it is essential to have a bituminous material which has great solidness.



(a) (b)



(c)

Figure 2. Marshall Stability results.

3.3 Resilient Modulus results

For the Resilient Modulus test, all the addition of Kenaf fiber shows an increase in the pulse value for the first 1000 except for 0.3%. Then all of them shows a constant reading on the 2000 pulse but when it reaches to 3000 pulse the reading decreases showing Kenaf fiber has low strength when the load is increasing. Overall, the reading for 0.6 % shows a great resistance in the strength of the Kenaf fiber when the load is increasing.

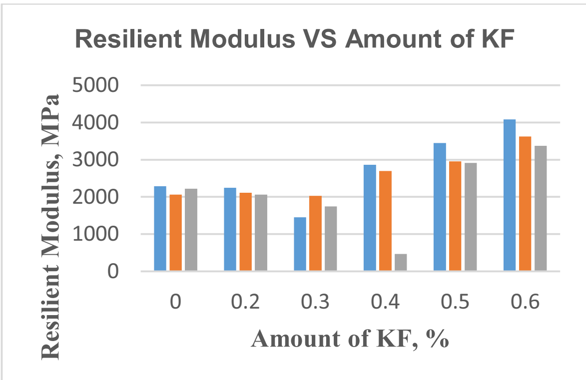


Figure 3. Percentage of Kenaf Fiber vs Resilient Modulus at 25°C.

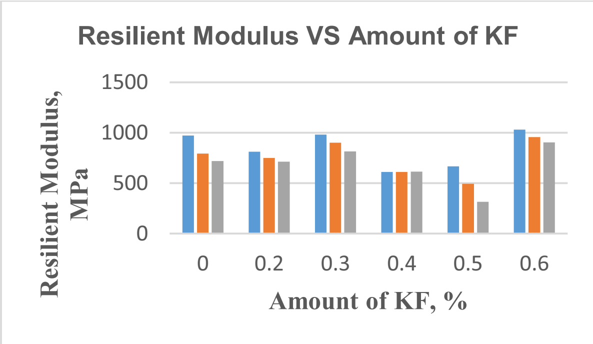


Figure 4. Percentage of Kenaf Fiber vs Resilient Modulus at 40°C.

3.4 Dynamic Creep results

From Figure 5, it can be seen that 0% of Kenaf fibre shows the lowest number of permanent strains. In order to access the sample creep behaviour, a control sample is present while testing for other sample with addition of 0.2%, 0.3%, 0.4%, 0.5% and 0.6% of Kenaf fibre. This could be seen that the increasing amount of Kenaf fibre does not influence the strain value of the sample indicating that the resistance against permanent deformation does not influenced by increasing the amount of the fiber.

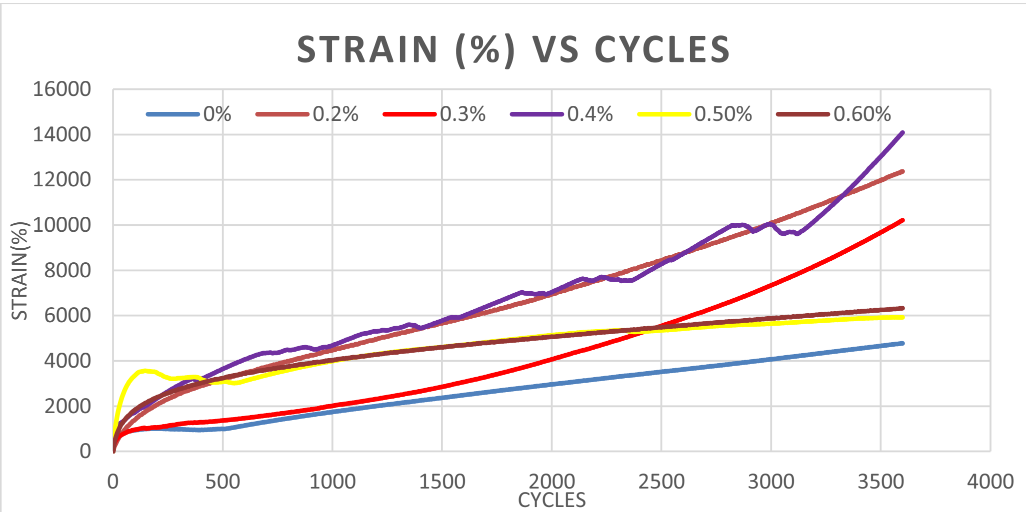


Figure 5. Strain (%) vs no of Cycles at 40°C.

From Figure 6, it can be seen that 0.6% of Kenaf fibre shows the lowest number of permanent strains. Lowest value for permanent strain is good for the permanent deformation such as rutting. It can be seen that by adding more fibre after 0% makes the permanent strain value increases and adding less fibre also does not affect the permanent strain value. Only by adding the optimum content of fibre in the mix could lessen the permanent strain value. From this, the addition of Kenaf fibre could improve the asphalt pavement condition. The strain value shows a more promising improvement in low temperature.

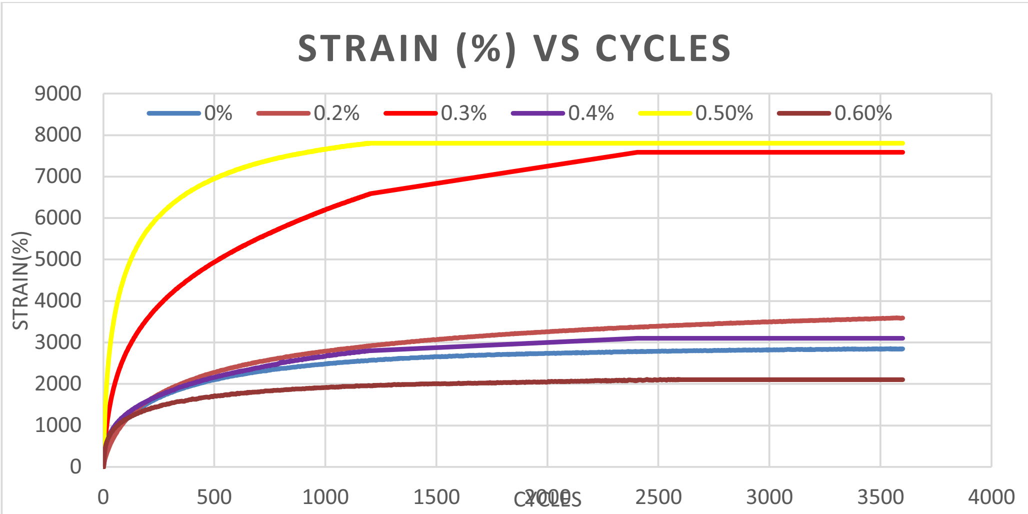


Figure 6. Strain (%) vs no of Cycles at 25°C.

3.5 Optimum Fiber Content

Each performance tests are done with 6 samples each, then they are ranked from number 1 to 6. Number 1 shows the most enhancement which are good while number 6 shows the lowest. The samples are ranked based on each requirement of the performance test and is total up. Lastly, between those 6 values, the lowest value is then decided as the Optimum fibre content. The Optimum fibre Content (OFC) is 0.3 %.

Table 2. Ranking of Optimum Fibre Content.

Fibre % / Test	0	0.2	0.3	0.4	0.5	0.6
Stiffness	6	3	2	1	5	4
Stability	6	5	2	1	3	4
Density	4	1	2	6	2	5
Resilient Modulus at 25°C	4	5	6	3	2	1
Resilient Modulus at 40°C	3	4	2	6	5	1
Dynamic Creep at 40°C	5	6	2	1	3	4
Cantabro Loss	2	1	3	4	6	5
Total	30	25	**19**	22	26	24

4.Conclusions

From the test conducted, the range of kenaf fiber used has shown quite an improvement on the mechanical performance. On the abrasion test, 0.2% addition shows the lowest value on abrasion loss making it more durable to abrasion. While from the Marshall Stability test, the stability shows a significant value at 0.4% of Kenaf fibre addition, showing it has less air voids thus, increasing the pavement strength. Next, the stiffness of asphalt increases at 0.4% of Kenaf fibre presence showing that it improves the resistance and low temperature cracking of asphalt. For the density, 0.2% addition of fibre shows the highest density making it less exposed to premature pavement distresses. As for resilient modulus at 25 ºC, it shows that the highest percentage of Kenaf fiber which is 0.6% gave the highest resilient modulus value. The higher the percentage of Kenaf, the higher the resilient modulus value. Based on the resilient modulus results that were obtained, it shows that the existence of natural fiber such as Kenaf fiber could influence the strength of pavement especially for low traffic. The same could be said for temperature of 40 ºC. For dynamic creep test, at temperature of 40 ºC, 0% of Kenaf fibre shows the lowest number of permanent strain while for 25ºC, 0.60% addition of Kenaf fibre indicate lower permanent strain. This shows that, at lower temperature, the addition of Kenaf fibre in A could contribute in less permanent deformation. From the ranking table of each performance tests, Optimum fibre Content (OFC) is 0.3 %.

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