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To cite this article: N A M Radzi *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **712** 012027

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Stability and Resilient Modulus of Porous Asphalt Incorporating Steel Fiber

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Abstract. Porous Asphalt (PA) is known as a highly permeable asphalt surface that design to be permeable pavements for stormwater control and reduce the stormwater runoff. However, the structure is subjected to damage from cracking, rutting, stripping, and rapid aging under the effects of repeated vehicle loading, hot climates, and heavy rainfall. To overcome this, PA needs to modify using high tensile strength like steel fiber. Thus, this study aims to evaluate the performance of PA with the addition of steel fiber and overcome the issue that is related to PA. A mixture contains varying percentages of steel fiber were assessed to check which samples gives the best performance as per the requirement by using laboratory tests which are LA Abrasion, Resilient Modulus, Marshall Stability, and Density. The results show that the additions of 0.6% steel fiber give the lowest value of abrasion, while 0.5% fiber content contributes the highest value of Resilient Modulus and Marshall Stability respectively. PA mixtures modified with steel fiber produce the performance enhancement of PA as a road surfacing material. It is concluded that the asphalt mixtures containing steel fibers could increase the stability and strength of the mix.

1. Introduction

Porous asphalt pavements are known as highly permeable asphalt surface that also called as open-graded asphalt. The primary purpose of the design is to be water permeable pavements for stormwater control and reduce the storm water runoff. The benefits of open-graded asphalt are improving runoff quality, sustainability, long life through proper maintenance, and less costly. It also gives benefits in reduction of spray-on higher speed roads, reduces the noise of the tires, and prevents the pollution by eliminating surface runoff. However, the open structure of porous asphalt allows quick drainage of water from the road surface during wet weather. However, an inefficient drainage system can result in hydroplaning, which is dangerous to fast-moving traffic. This can reduce contact between tire and pavement, leading to the loss control of braking and steering during driving [1]. The problems caused by the high air void content consist of increased material deterioration, for example, raveling effects [2] and increased physical aging effects of bitumen due to water and air infiltration (for example causing moisture damages, stripping effects or embrittlement of the aggregate). Due to these factors, porous asphalt has a shorter structural service life than conventional asphalt pavements. In Malaysia,



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we are facing or dealing with high temperature and heavy rainfall throughout the day. An asphalt facing a lot of deficiency like rutting and stripping. Besides that, heavy traffic loads tend to affect the performance of the asphalt mixture in term of its resilient modulus. A common method to overcome this distressing problem is by modifying the asphalt by the properties. Hence, steel fiber tends to provide improvement of properties for porous asphalt pavements. Steel fiber can be defined as discrete, short length of steel having ratio of its length to diameter in the range of 20 to 100 with any of that and that are sufficiently small to be easily and randomly dispersed in fresh Marshall mix using conventional mixing procedure throughout the porous asphalt [3]. Steel fibers are used to enhance their tensile strength and to increase the pavement toughness and help to control cracking. Normal asphalt pavement is brittle with low tensile strength and strain capacity. Fibers are generally utilized in the pavement or mix to manage the problem. The fibers are bonded to the material and allow to withstand considerable stresses. As a result, steel fibers additions can be used in the binder course of flexible pavements because of its positive stability impact. In terms of efficiency, fiber-asphalt mixture shows a slight increase in the optimum asphalt binder content compared with the pure asphalt mixture. In this way, adding fibers to asphalt is very similar to the addition of very fine aggregates. Thus, fibers can stabilize asphalt to prevent leakage. This is due to the adsorption of asphalt on fibers [4,5]. The reported results indicate that fiber–asphalt mixtures have good moisture resistance, creep compliance, and rutting resistance, low-temperature anti-cracking properties, and durability [6]. Thus, the objectives of this study are to evaluate the performance of PA incorporated with steel fiber. The addition of fiber into the asphalt mixture may improve certain properties of PA, such as reducing drain down, enhancing the moisture sensitivity and compressive strength in PA. Therefore, this research shows how optimum fiber content perform in asphalt pavement.

2. Methods

2.1. Materials

For this study, the asphalt binder used was 60/70 PEN, and porous asphalt mixtures were modified with steel fiber to enhance the performance of porous asphalt. A total of 42 samples were prepared for porous asphalt mixtures at different fibre content ranging from 0%, 0.2%, 0.3%, 0.4%, 0.5% and 0.6% and the 0% as a reference between modified and unmodified asphalt binder. The design binder content adopted from a study by Masri et al. [7]. The specification used for this research is by the Malaysian Public Work Department for road works [8].

2.2. Material Testing

Abrasion Among the test of asphalt binders, the physical test is including penetration test at 25oC, softening point test and ductility test were carried out on asphalt binders. From a penetration test, we can know the hardness and consistency of bitumen before it may be applied on the road. To determine the temperature at which given bitumen reaches a certain degree of softness and get the result for flow and consistency of asphalt binder can be known from the softening point test. Last but not least, the ductility test is to characterize the ductility of asphalt binders.

2.3. Mixture Testing

After all of the samples of porous asphalt mixtures modified with steel, fiber are done by using the Marshall mix design method; the performance test porous asphalt is performed. Among the tests involve evaluating the performance of fiber modified porous asphalt was LA Abrasion, Marshall Stability, and Flow test, and Resilient Modulus. Abrasion loss value for performance test was evaluated using the Los Angeles Abrasion machine without steel ball. Stability and density values, specific gravity and void analysis, which is to determine the percentage of air voids in mineral aggregate, and air voids in the compacted mixture can be known from the Marshall Stability test.

3. Results and discussion

3.1. Loss Angeles Abrasion

As shown in Figure 1 (a), the abrasion loss value for control samples is much higher than modified samples of porous asphalt which is 8.60%, 9.22% and 14.76% for 100 to 300 revolution respectively. Then, the abrasion loss value for the modified sample is lessened than the control sample, as seen in Figure 1 (b). From the graph above, we can conclude that the fiber content of 0.6% is much lower from others. Therefore 0.6% fiber content is the best fiber content for LA abrasion test. Besides that, the average loss of mass is less than 15%, which is acceptable according to the JKR specification.

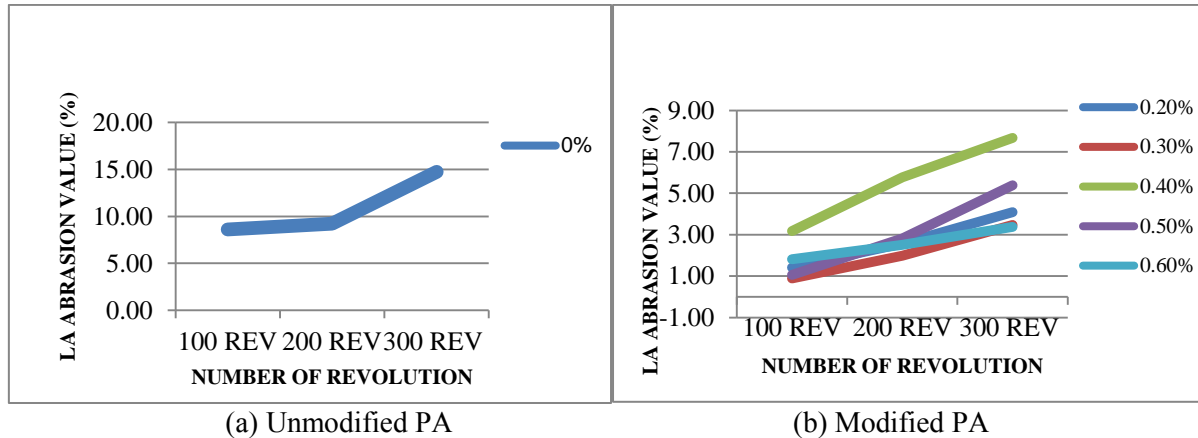


Figure 1. Abrasion Loss

3.2. Marshall Stability and Density

The Marshall method is to analyze two features of pavement mixes, which is stability (flow analysis) and density (voids analysis). The stability and flow values are directly recorded during the test. These will show the maximum load which the mix can take before deforming to failure. From Figure 2 (a), the result is taken from the Marshall Stability and Flow test. The higher stability is from fiber content 0.5% while the lowest value of stability is 0.2% of fiber content. As shown in Figure 2 (b), the most efficient fiber content can be determined with the highest number of density value, which is 0.2% of fiber content.

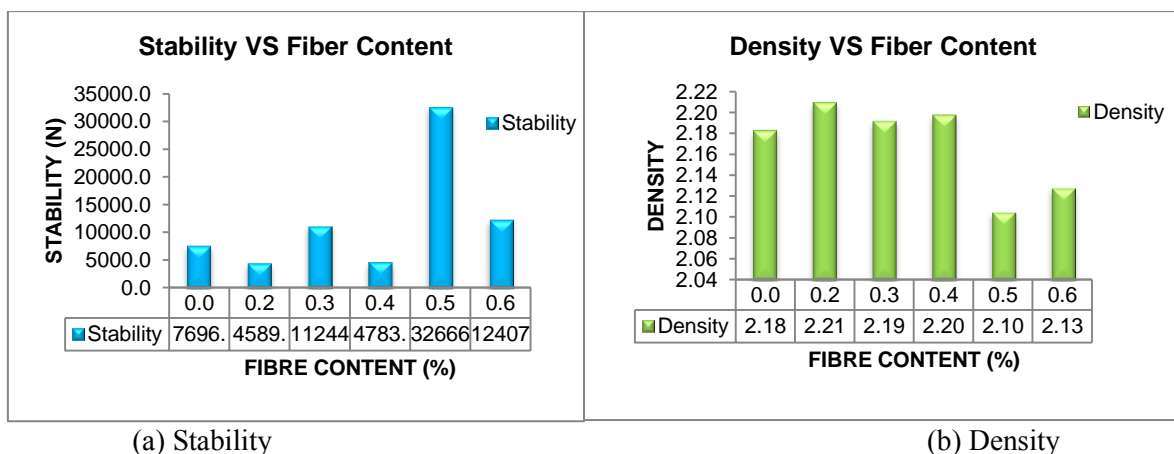


Figure 2. Marshall Properties

3.3. Resilient Modulus

The resilient modulus is the elastic modulus based on the strain under repeated loads. The testing is carried out by using 1000, 2000, and 3000 pulse repetition with two different temperatures, which are 25°C and 40°C. Based on Figure 3, the number percentage of fiber content with highest resilient modulus is 0.5% at temperature 25°C while 0.6% for temperature 40°C. This result is consistent with a study by Masri et al. [7] and Arshad et al. [9], where the modification of mixture improves the resilient modulus value significantly [10,11].

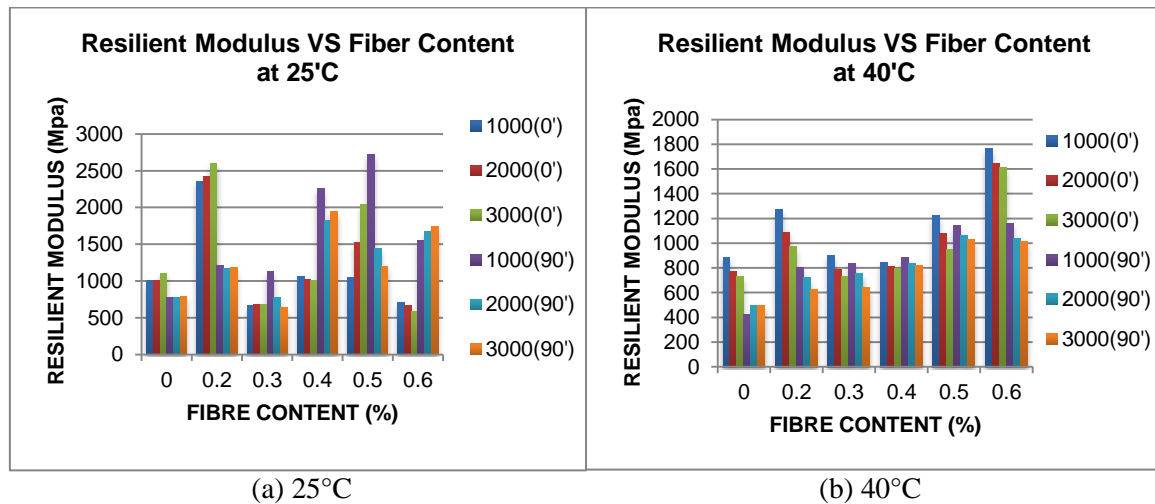


Figure 3. Resilient Modulus

4. Conclusion

- Steel fiber possessed a greater effect on porous asphalt absorption and stabilization than other fibre. This indicated that fiber could effectively improve the abrasion resistance of asphalt.
- With the addition of steel fiber in porous asphalt mix, the Marshall stability increases up to higher value.
- With the addition of steel fiber, the average resilient modulus increases up to 15% at 25°C, whereas the increases in resilient modulus are up to 10% at 40°C.
- It can be said that the steel fiber can be used to alter the phase composition and improve the engineering properties of porous asphalt.

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Acknowledgement

The authors would to acknowledge Universiti Malaysia Pahang for funding this research under the grant RDU 1803157.