MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

MARI

Vol. 5 No. 1 (2024) 147-154
https://publisher.uthm.edu.my/periodicals/index.php/mari

The Influenced of Steel Fiber in Hot Mix Asphalt Mixture to Enhance the Tensile Strength

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DOI: https://doi.org/10.30880/mari.2024.05.01.022

Article Info

Received: 1 September 2023
Accepted: 10 December 2023
Available online: 31 January 2024

Keywords

Steel Fiber, Asphalt Binder, Aggregate, Marshall Stability

Abstract

Deformation of the road was the main factor of the repeated loaded at high temperature to the asphalt pavements and one of the main distress mechanisms. Asphalt mixture incorporated with steel fiber to enhance the tensile strength would have investigated by used grade 60/70 of asphalt binder and 5% of optimum asphalt binder. The percentages of steel fiber that were used for the studied was 0, 1.2, 1.5, 2.1, 2.4% by total weight of aggregate. Purpose of this studied is to investigate the effect of steel fiber toward the asphalt mixture on improved the asphalt pavement. To decrease the road deformation and to compute the pavement cracked at incorporating steel fiber using Marshall Stability Test. The result from this study has shown that the mixture incorporating steel fibers for stability is decrease between control sample with 2.7% steel fiber which is 21.357 kN and 13.193 kN. The performance test due to stiffness analysis passed the requirement JKR, which is more than 2.6 kN/mm, even if the value of the steel fiber modified sample is lower than the control sample and it still relevance to implement.

1. Introduction

Asphaltic mixture is the most important engineering material that have its mixing properties improved by adding or eliminating particular components. Generally stated, heavy traffic loads are repeatedly applied to pavement, inducing distress and damages. Their impact is significantly impacted by moisture and temperature [1]. Previous research has been done recently to improve the long-term performance of asphalt mixtures in changing content materials. The construction of road pavements with using fibers in hot mix asphalt (HMA) has emerged as a significantly more appealing option [2]. Furthermore, the development of road pavement with using of fiber in asphalt mixtures has become more significantly in terms of strength and effective. Previous studies have found a strong correlation between fiber and increased strength of hot mix asphalt mixtures [3]. Additionally, by improving the mixture characteristics and extending the service life of the road, the inclusion of fibers to asphalt mixes promotes sustainability [4].

However, Pavement design consists of determining pavement thickness or the thickness of individual layers of the pavement to serve traffic for an anticipated design period. By [5] explains that the pavement is constructed in multiple layers of different material. The longitudinal cracks are parallel slits to the pavement's centrelines; these cracks include structural faults (paving layer weakness) and functional defects (roughness of the paving surface). According to [6] found some basic requirements of a pavement; it should be structurally sound enough

to withstand the pressure on it. Ravelling is loss of material that covered asphalt surface or is the progressive disintegration of HMA layer because of the dislodgement of aggregate particles Besides, addition of steel fiber in the mixture also increases the stability, the resilient modulus, and the strength. Steel fiber is one of the main composite materials formed by asphalt to reduce cracking [7]. Previous studies had showed that the combining of these two materials between steel fiber and asphalt at different percentage to better access the stability and indirect tensile strength.

According to study, are thought to give asphalt mixes physical changes [8]. So, this study aims to evaluate the performance of hot mix asphalt mixture incorporating steel fiber by investigating the steel fiber, aggregate and asphalt binder materials characteristic and variability. Furthermore, it also assesses the volumetric properties of HMA incorporating steel fiber and conduct a comparative study on effect of steel fiber to the stiffness at higher mix temperature.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, this section show a detail about the process of the hot mix asphalt mixture and the preparation of asphalt binder and aggregate that would going through the loads from the road. However, this part purpose to find the strength and durability of the materials to combine. The test has been done to achieve the expected outcome from the combination of the materials and steel fiber.

2.1 Materials

All the material preparations that had been chosen to have produce the experiment's best result. The main characteristics of the mix are defined by the proportions of coarse aggregate, fine aggregate, and mineral filler in addition to the quantity and quality of asphalt utilized [9]. This experiment would use granite aggregate to find out the ability of aggregates to avoid permanent deformation. Besides, there were other materials to use such as asphalt binder and steel fibre. The addition of steel fiber in the mixture to know their tensile strength capacity and been used to improve tensile stress and concrete spalling. Fig.1 depicts the researched study's flowchart.

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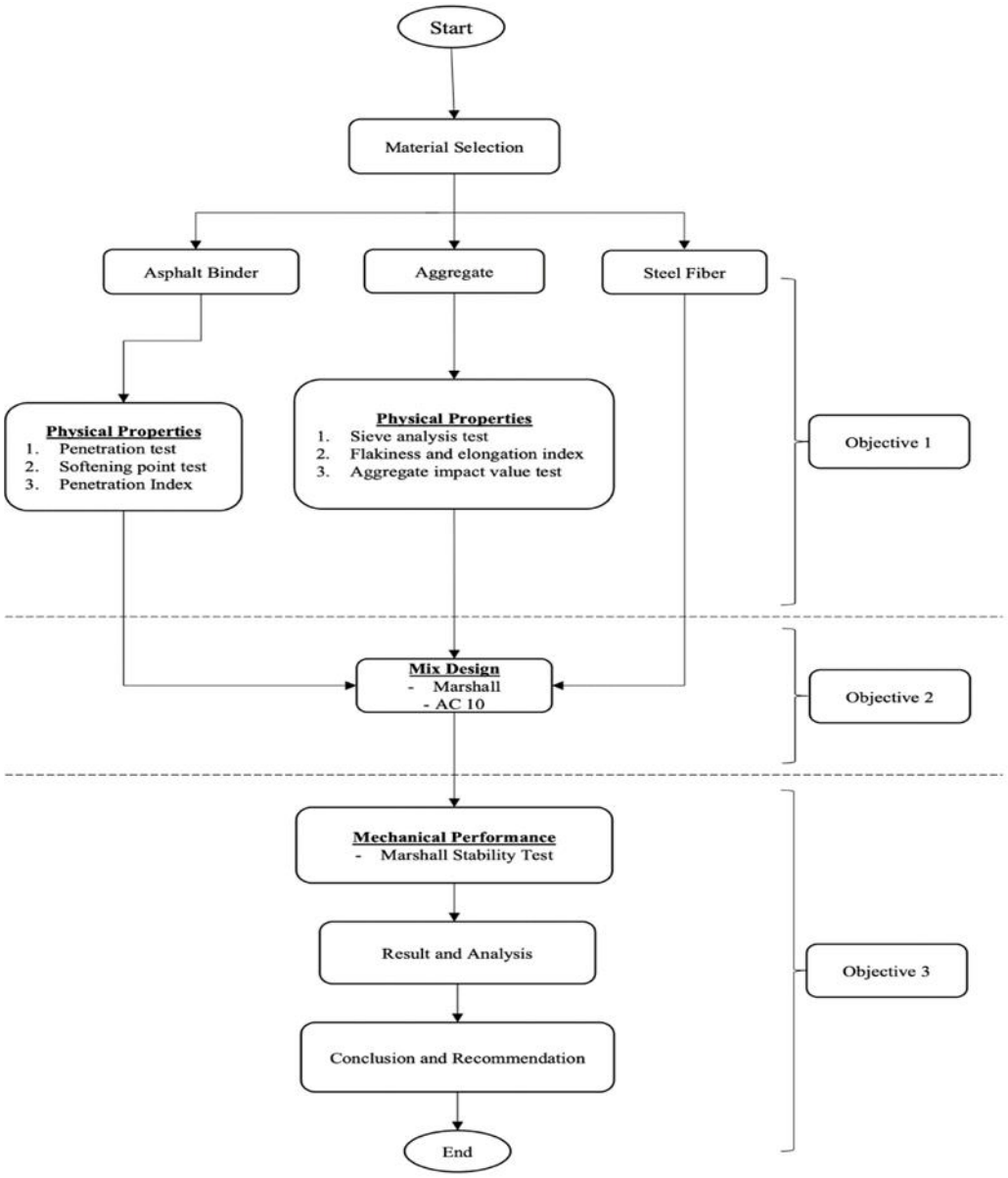

Fig. 1 *Flowchart of research study*

2.2 Methods

There were many methods that been used in the study such as AASHTO, ASTM, and follow the JKR requirement. Meanwhile, Marshall stability test and Marshall mix design also been used to achieve the objectives of the study. This experiment would use 1100g granite aggregate per sample and asphalt binder grade 60/70 from Dorotech brand with optimum asphalt binder content rate for the design was 5% to create HMA.

2.2.1 Aggregates Properties

The element work to manufacture a designed granular assembly is to acquire grain sizes of compose aggregates [10]. The performance of aggregate has been utilized by doing some properties that had mentioned. The sieve analysis or gradation was a very effective test to isolate the aggregate by the size and the quality control with method AASHTO T27-88. However different for the flakiness and elongation index where it been tested to determine the shape of the aggregate by preparing the specimen method according to the method MS 30: Part 3& 5:1995. The aggregate particles formed was very important to access especially in terms of flakiness and elongation. Moreover, aggregate impact value was a gauge material resistance to shocked or abrupt impact. The test has utilized by according to MS 30: Part 10: 1995 technique.

2.2.2 Asphalt Binder Properties

Asphalt binder properties were the test to get the consistency and strength for performance of the mixture. There were two tests for asphalt binder properties have been done to know the consistency and the strength of the asphalt binder and there were two types of the test which is softening point and penetration test. The softening point of asphalt binder been maintained the temperature to not less than 10°C for 30 minutes by referring to ASTM D36-2006. However, the test for penetration test have been evaluating at different distance by follow the method ASTM D5-2005. This test was the most popular ways for asphalt binder to get the consistency.

2.2.3 Marshall Mix Design Preparation

According to study, are thought to give asphalt mixes physical changes [9]. All the materials been utilized with marshall mix design by according to ASTM D1559. However, the test has been utilized by using 1100g of aggregate batching and been heated at 160°C for 2 and 4 hours. Fig. 2 show the materials has been mixed and blended before it been molded for 2 hours. The sample need to compact by using the marshall hammer and cool the sample before opened the mold. Moreover, this test design procedure was to increase the performance of the mixture by determine the content of asphalt.

Fig. 2 *Material preparation*

2.2.4 Performance Test

Accordance to ASTM D1559, marshall stability test was a method to designing and evaluating HMA by measuring the stability and flow of an asphalt mixture samples. Furthermore, this test has done in the lab with standard value 60°C to intend the maximum pavement temperature. The samples that been through the marshall stability test have been utilized by two methods standards. Moreover, these methods were to determine the strength and durability of the sample after performing the mix to the sample. Therefore, the test result need to analyze and documented the data to determine whether the sample follow the requirement from JKR. Fig. 3 show the test been utilized.

Fig. 3 *Machine compression test*

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3. Results and Discussion

For the result and discussion, this research had conducted and analyze the aggregate and asphalt binder to evaluate the performance of the sample. Preparations of the materials have been assessed before performing the mixture to achieve the standards. The materials for each sample had been measure and conducted it perfectly for enhance the tensile strength for the pavements.

3.1 Material Properties

The tests that have been performed for preparation of the materials to assess the grade, consistency, and strength of the materials to be blended and mix it perfectly. Aggregate impact value (AIV) was carried out on aggregate and the result of aggregate impact value showed that the average aggregate impact value because of the experiment is 32.03%. This is because it falls within the 20–30% range, which is considered followed the specification from JKR. Moreover, different result for flakiness and elongation when the result showed that the flakiness index was 11.17% and elongation index was 38.05%. the test for the aggregates has fulfil the JKR requirement. From the Fig. 4, the result of sieve analysis or gradation test have been assessed to get the information of the aggregate. However, for asphalt binder test which is softening point result showed that the average temperature 52°C was the normal value for asphalt binder. This experiment's objectives have been met. Different for penetration test, the result told that 6.3mm the average penetration was the requirement consistency for asphalt binder. Table 1 show the result for the aggregate and asphalt properties.

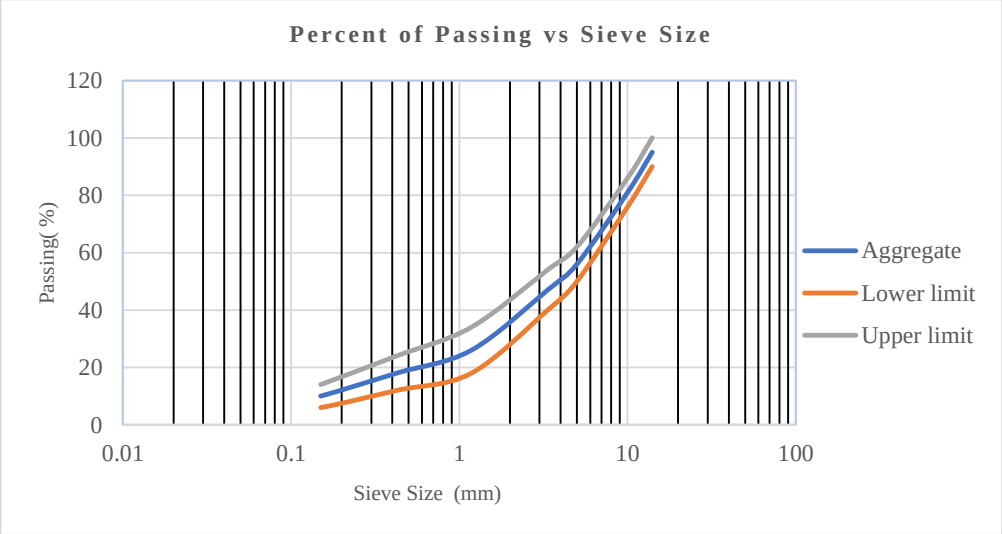


Fig. 4 *Graph sieve analysis*

Table. 1 *Aggregate and asphalt properties result*

Aggregate Properties	
Aggregate type	Granite
Aggregate Impact Value (AIV)	32.03%
Flakiness	11.17%
Elongation index	38.05%
Asphalt binder properties	
Softening point	52°C
Penetration point	6.3mm

3.2 Volumetric Properties

The maximum compressive load that could be measured and the displacement of the specimen under that load, respectively, were used to define the stability and flow values in this case [10]. The analysis was conducted on stability, flow, Void in Total Mix (VTM), density and Void That Filled with Bitumen (VFB).

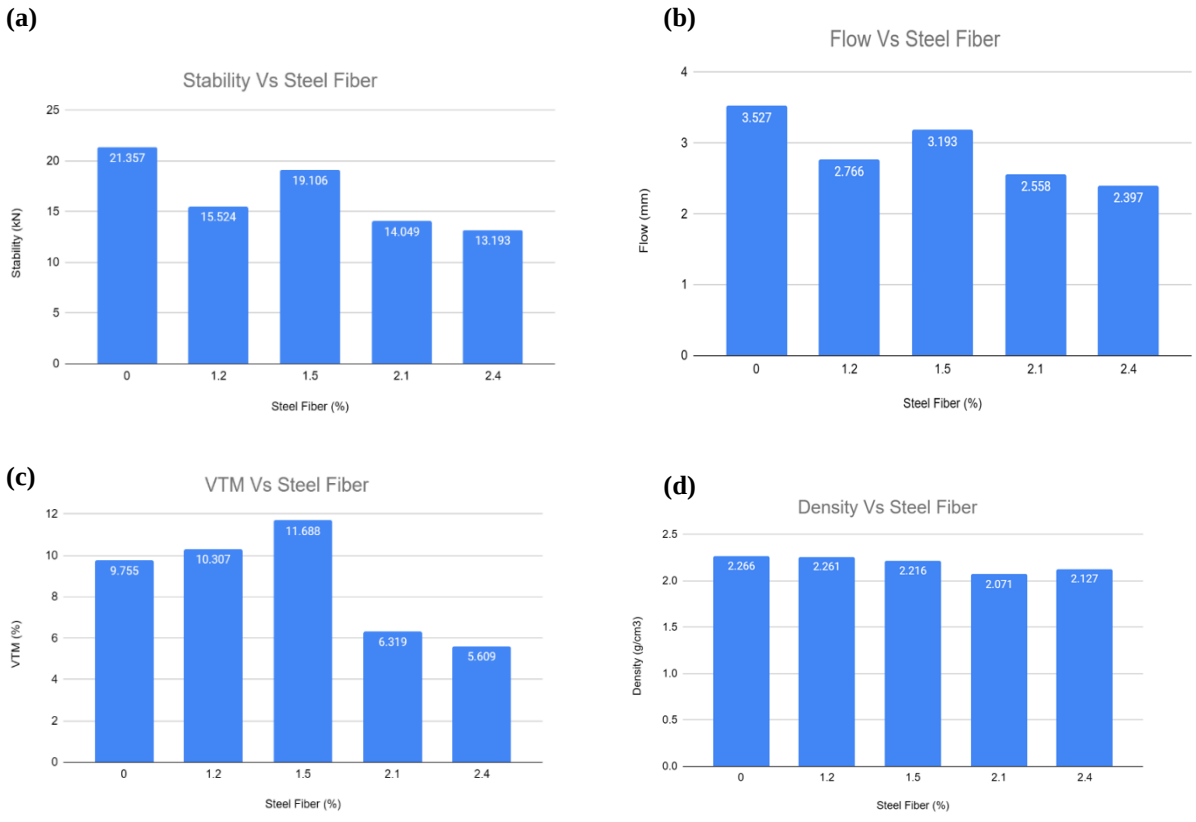
Fig. 5 (a) shows the value of the stability value that has been recorded for all five samples. Generally, the graph pattern shows that the recorded value is decreasing from the 0% sample of 21.357 kN to 13.193 kN which is a sample of 2.4%. However, there was a slight increase in the sample 1.5% at 19.106 kN. The 0% steel fiber sample shows the highest Marshall stability value than others. Thus, all five samples achieved the requirement set by JKR which is more than 13000 kN.

Based on Fig. 5 (b), all samples record non-uniform flow values. The highest flow value is at 0% fibre steel at 3.527mm and the lowest flow value is at 2.4% fibre steel which is 2.397mm. But there was a slight increase in the value of the 1.5% sample which was 3.193mm and then reduced again. According to previous studies, samples containing steel fiber will record a higher value compared to samples without steel fiber. However, according to the data obtained, samples without steel fiber recorded a higher value compared to samples containing steel fiber [4]. Sample without steel fiber has more flow than sample without steel fiber. Thus, all five samples achieved the requirement set by JKR which is between 2.0 to 5.0mm.

The value of The Void in Total mix (VTM) for all samples is shown in graph form according to Fig. 5 (c). The highest VTM value was at 1.5% steel fiber at 11.688% while sample 2.4% steel fiber showed the lowest at 5.609%. This shows that the 1.5% fiber steel content is the sample that contains the most voids compared to other samples. All the VTM value does not follow the standard range of 3.0% - 5.0% according to the JKR specification.

According to Fig. 5 (d), a density graph has been made with almost equivalent values. Sample without steel fiber content recorded the highest density value of 2.266g/cm3 while the sample with 2.1% steel fiber content recorded the lowest density value of 2.071g/cm3 after conducting the compaction test. This shows that the sample without steel fiber content has higher density than the sample containing steel fiber.

Fig. 5 (e) shows the Void That Filled with Bitumen (VFB) value for all five samples. The highest VFB value was at 0% steel fiber at 113.518% while the lowest VFB value was at 2.4% steel fiber at 66.012%. It shows that the 0% sample has a lot of voids compared to other samples. Sample 1.2% and 1.5% recorded declining values of 96.716%, 87% respectively. Sample 2.1% showed a slight increase of 87.568%. All five samples do not follow the requirements of JKR which has been set in the range of 60% - 80%. It shows that there are some errors when carrying out the mixture process that should be paid attention.



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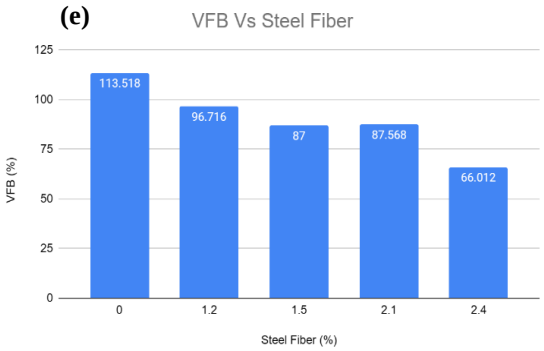

Fig. 5 *Volumetric properties (a) Graph effect steel fiber on stability; (b) Graph effect steel fiber on flow; (c) Graph effect steel fiber on VTM; (d) Graph effect steel fiber on density; (e) Graph effect steel fiber on VFB*

3.3 Marshall Stability Performance

Referring to Fig. 6, the control sample stiffness value is 6.055 kN/mm, whereas the 1.5% steel fiber sample optimum total stiffness is 5.984 kN/mm. Although the value of the steel fiber modified sample was lower than the control sample and it was still relevant to implement, the performance test results of the stiffness analysis exceeded the JKR requirement of more than 2.6 kN/mm.

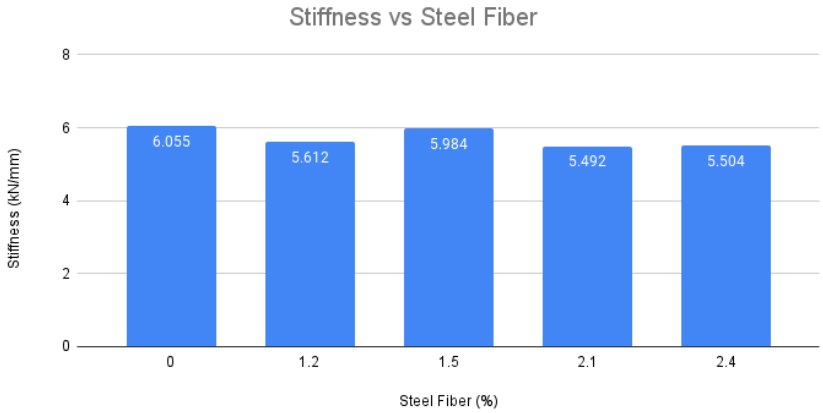

Fig. 6 *Graph effect steel fiber on performance*

Conclusion

As a result, the addition of steel fibre to hot mix asphalt (HMA) mixtures can significantly increase the tensile strength of the pavement. Steel fibres, which are typically mixed into the HMA during the production process and act as reinforcement materials, provide additional tensile strength to the asphalt mixture. It's important to note that many elements, like fibre content, fibre geometry, and fibre distribution, affect how well steel fibres perform in HMA mixes. To obtain the needed performance benefits without compromising other qualities of the asphalt mixture, optimal fibre dose and optimum mix design are essential.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (Vot Q141). The authors would like to thank the Centre for Diploma Studies (CeDS), Universiti Tun Hussein Onn Malaysia for their support.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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