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Experimental Study on Resilient Modulus of Asphalt Mixture with Fibre

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Abstract: Generally, in Malaysia all the road used are consists of flexible pavement and using asphalt mixture as the wearing course. However, due to heavy traffic loads effects, most of the roads are experience failure and distress such as stripping, fatigue and so on. This research is conducted to study the analysis on resilient modulus of asphalt mix with steel fibre. To perform this study, samples for each mixture based on super pave design is prepared and tested. Once design samples were complete and the optimum binder content was achieved, about eighteen (18) samples are prepared to evaluate the resilient modulus value on each sample towards the presence of percentage of steel fibre in three (3) different parameter which is (0% ,1% ,1.5% ,2% ,2.5% ,3%). Resilient modulus test was conducted to determine the sample capability in receiving the loads and under tensile strength. Data for this this research were analyzed based on test conducted. Variation on the temperature control which is 25ºC can be made to obtain more various result and widen the study perspective.

Keywords: Highway, Steel Fiber, Resilient Modulus

1. Introduction

From 2010 to the first quarter of 2021, Malaysia's population increased by about 14.5 percent [1]. The economy is also growing in tandem with the growing population. Malaysians' mobility is increasing as the country's economy grows, particularly in terms of land transportation. As a result, the pavement structures' well-being, particularly in terms of physical properties and performance, may remain safe for users to use every day for years. Pavement damage or distress, particularly permanent deformation or rutting, can affect the user's comfort and safety. Highway is a main network that connects all the roads in a country and it is increasing opportunities for people to travel for work, trade, or leisure, as well as providing trade routes for goods. A modern highway or public transportation infrastructure improves a community's ability to get to other locations. This extends a company's labor pool, lowers the cost of obtaining input products and facilities, and raises the size of its future demand. This could lead to greater "economies of scale" in manufacturing operations, resulting in higher efficiency and lower costs per unit of production. In Malaysia we used the best controlled- access expressway in southeast Asia and it is considered the nest among Asian country. Other than that Malaysia has been using the Malaysia Federal Road system as main national road network in Malaysia. Malaysia's road

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network spans 250,023 kilometers, with paved/unpaved highways accounting for 248,067 kilometers and expressways accounting for 1,957 kilometers. The North–South Expressway, the country's longest highway, runs for 800 kilometers between Thailand and Singapore.[2]

They are two types of pavements which is flexible pavement and rigid pavement. Most of the countries in the world using flexible pavement design includes Malaysia .The flexible pavement in Malaysia consists of bituminous surfacing ,granular road base , sub-base and formation of subgrade was designed based on Jabatan Kerja Raya (JKR) / Spesifikasi Pembinaan Jalan (SPJ) 2008.The design of flexible pavement are based on the axle loads limits and the climate conditions . Flexible pavement should also provide a durable, skid resistance surface under its service life.[3]

A modification of the existing asphalt mixture can be made by adding steel fibre as an enhancement the function of the asphalt mixture, to reduce the rutting problem also improving the characteristics and behavior of the asphalt mixture. Steel fibre commonly used in concrete to strengthen the concrete structure [4]. Using Steel fibre as a supporting material in asphalt mixture should improve the function of preventing permanent deformation of pavement structures.The purpose of this study is to assess the rutting resistance permanent deformation of the pavement structure when the wearing course incorporating with steel fibre. The use of steel fibre to asphalt mixture is predicted to enhance the pavement structure's permanent deformation under any traffic load as the addition of steel fibre was expected to soften the binder

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

2.1 Material Preparation

Material preparation are very important to obtained a define results for this research. The material used must follow all the specification required based on JKR/SPJ/2008. Material preparation is very important to ensure the material used to perform the test followed the standard and specification requirement provided. The materials that were chose can affect the results of the laboratory test were performed and the accuracy of data obtained. The material that were test was fine and coarse aggregate and also bitumen. [3]

- Aggregate

  The selection of aggregate play major role in here to determine the strength of the mixture. The aggregate mixture must be complied with the all the value according to the specification provided in super pave design

- Bitumen
  Generally, most of the Malaysian road are paved with petroleum bitumen. Bitumen also can refer as binder in any mixture such as aggregate mixture for road construction work. The purpose of bitumen in road construction is to produce a strong and stable mixture. During high temperature the bitumen exhibit viscous behavior meanwhile exhibit elastic behavior during low temperature.

- Steel Fiber
  Steel Fiber is a type of metal that is used to reinforce structures. Short, precisely defined lengths of steel fibres with an aspect ratio (length to diameter ratio) of around 20 to 100, with various cross-sections, and sufficient size to be randomly disseminated in an unhardened concrete

mixture using standard mixing processes are defined as steel fibre for structural materials. In this research steel fibre is main component for the mixture

2.2 Sample Preparation

2.2.1Sample Preparation

Characterization of asphalt mixture including evaluation of material properties conducted at Advance Highway Laboratory UTHM. Most testing methods and procedure strictly followed as per the American society Testing Method (ASTM) , British Standard (BS) and American Association of State Highway and Transportation Officials (AASHTO)

2.2.2 Apparatus and material

Crushed aggregate were batched and dried into selected size range according to Superpave gradation. The batch of aggregate was measured in appropriate quantities to produce the specimen of 1200g.The batched aggregate ere preheated in the oven for a period at least 4 hours at desired mixing temperatures

The specimen were compacted in a mould using super pave gyratory compactor with 100 gyration. The applied pressure was 600 kPa and , apply the gyratory internal angle of 1.16°.Lastly the sample were taken out form the mould .The total samples that were produce are eighteen (18) .Three sample for each for different steel fibre content which are 1% ,1.5% , 2% , 2.5% , 3% and one temperature for each percentage of steel fibre which are 25ºC.

2.2.3 Testing

The resilient modulus test was conducted by cyclic loading of 1250kPa and testing temperature of 25°C in order to determine the rutting resistance and permanent deformation asphalt mixture. one analysis was conducted to evaluate the permanent deformation properties asphalt mixture steel fibre incorporating steel fibre. Resilient modulus analysis were done in order to evaluate the relation between asphalt mixture with steel fibre affecting on resilient modulus value and he permanent deformations of the mixtures.

3. Results and Discussion

The results and discussion section presents data and analysis of the study. the performance of the hot mix asphalt mixture with steel fiber is presented and discussed, followed by an analysis of result using indirect tensile test. Accordingly, the main objective that is to evaluate resilient modulus of asphalt mixture incorporating steel fibre.

3.1 Results

3.1 Result of aggregate properties

Table 1: Result of the aggregate properties

Properties	Standard	Specification	Result
Flat and elongated particles in coarse aggregate (%)	ASTM D4791	Max 10	3.75
Aggregate impact value (%)	BS812-112	Max 30	11.56

Table 2: Specific gravity and water absorption sizes for coarse aggregate

Aggregate size (mm)	Specific Gravity		Water absorption (%)
	Bulk	Apparent	
12.5	2.555	2.571	0.630
9.5	2.546	2.563	0.690
4.75	2.522	2.532	0.370

Table 3 Specific gravity and water absorption of fine aggregate

Aggregate size (mm)	Specific Gravity		Water absorption (%)
	Bulk	Apparent	
2.36	2.626	2.648	0.321
1.18	2.597	2.689	1.276
0.6	2.692	2.774	1.092
0.3	2.688	2.725	0.503
0.15	2.614	2.703	1.256
0.075	2.577	2.630	0.786
Pan	2.610	2.676	0.949

Table 4: Gradation used for 1200g asphalt mixture sample

Sieve size (mm)	Percentage passing (%)	Percentage retained (%)	Weight of sample (gm)
19	100	0	0
12.5	93.1	6.9	82.8
9.5	79.9	13.2	158.4
4.75	57.9	22	264
2.36	41.9	16	200
1.18	24.9	17	210
0.600	16	8.9	106.8
0.300	4	7	84
0.150	9	5	65
0.075	4	1	12
Pan	4	1	12
Total	-	100	1200

3.2 Result of binder properties

Table 5: Result for penetration grade 60/70

Number of penetrations	Penetration(mm)
1	69.7
2	64.9
3	68.6
4	73.0
5	72.6

Table 6: Softening point result

Number of tests	Softening Point(˚C)
1	55.1
2	55.8
Average	55.45

Table 7: Rotational viscosity test result for binder 60/70 penetration grade

Binder 60/70 (MPa/s)			
°C	**Sample 1**	**Sample 2**	**Average**
125	1080	1080	1080
145	380	380	380
155	300	300	300
165	280	280	280

3.3 Result of the resilient modulus

Table 8: Summary of the resilient modulus test result

Sample of asphalt mixture	Test temp (ºC)	MR Value (MPa)	Total Deformation (mm)
0	25	3479	3.6
1.0%	25	2500	7
1.5%	25	5828	7.53
2.0%	25	6675	3.32
2.5%	25	1624	8.08
3.0%	25	2250	13.17

3.2 Discussions

3.2.1 Effect of steel fibre in asphalt mixture

Figure 3.1 illustrates the resilient modulus of the normal asphalt mixture and asphalt mixture incorporating with steel fibre at 25°C. As seen in Figure 1 a general trend indicating that the mixes prepared with 1.5% and 2% of steel fiber gradually increases and drastically decrease after adding 0.5% for the following two sample.

The range of resilient modulus ,M_R ,data were recorded in the range between 1624 MPa to 6675 MPa at 25°C test temperature .These data clearly shows that the resilient modulus value not consistent after the 2% sample ,M_R reduce by approximately 76% after the 0.5% added to the 4th sample .Moreover for the control the normal asphalt mixture the range of M_R show a better value of ,M_R compare to the 1% ,2.5, and 3 % sample's. The value of M_R is increase around 51% compared to the normal asphalt mixture.

The previous study conducted by [4] presents the test results of M_R of both normal mixture and steel fibre specimens. The author stated that the asphalt mixture with fibre specimens had relatively higher M_R value than the laboratory mixed specimens. The finding shows that incorporating of 2% and 1.5 % steel fibre have resulted higher potential in improving the flexibility of pavement. This is due to soften of asphalt binder that enhance pavement strength. Therefore, the specimens exhibiting high resilient.

3.2.2 Permanent deformation

Figure 2 present the result of the permanent deformation on asphalt mixture incorporating various percentage of steel fibre. To obtain a consistent result an average value from three specimen was recorded Asphalt mixture with 2% leading to result values comparable to the normal asphalt mixture at 25°C. The decline in the stiffness of the asphalt mixture was related to the addition of steel fibre, which create more voids [5]. Moreover, the sample contain 2% of steel fibre's deformation is far lower than the other sample.

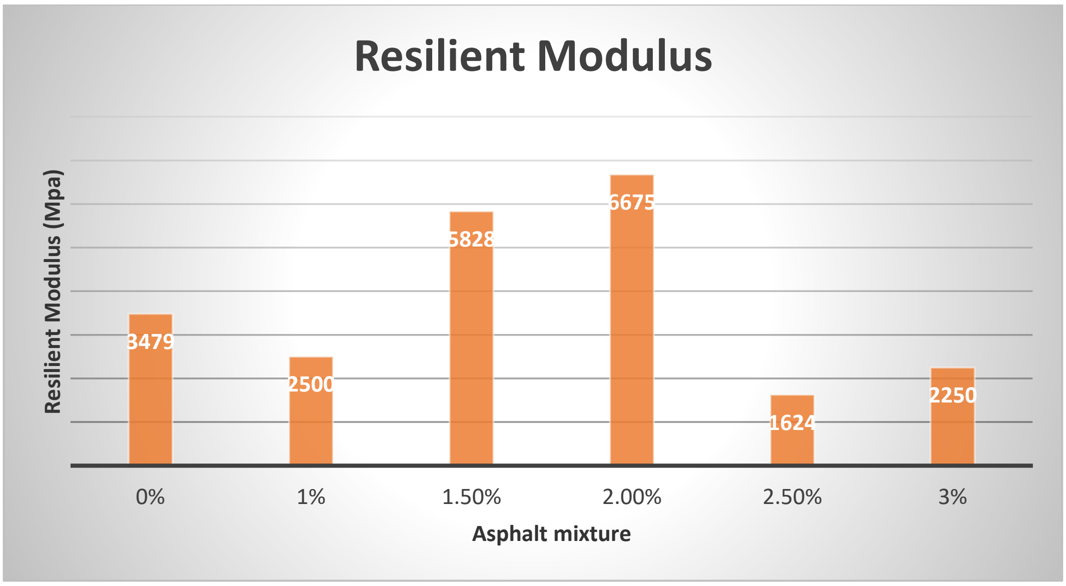

Figure 1: Result of stiffness modulus for asphalt mixture with different steel fibre rate

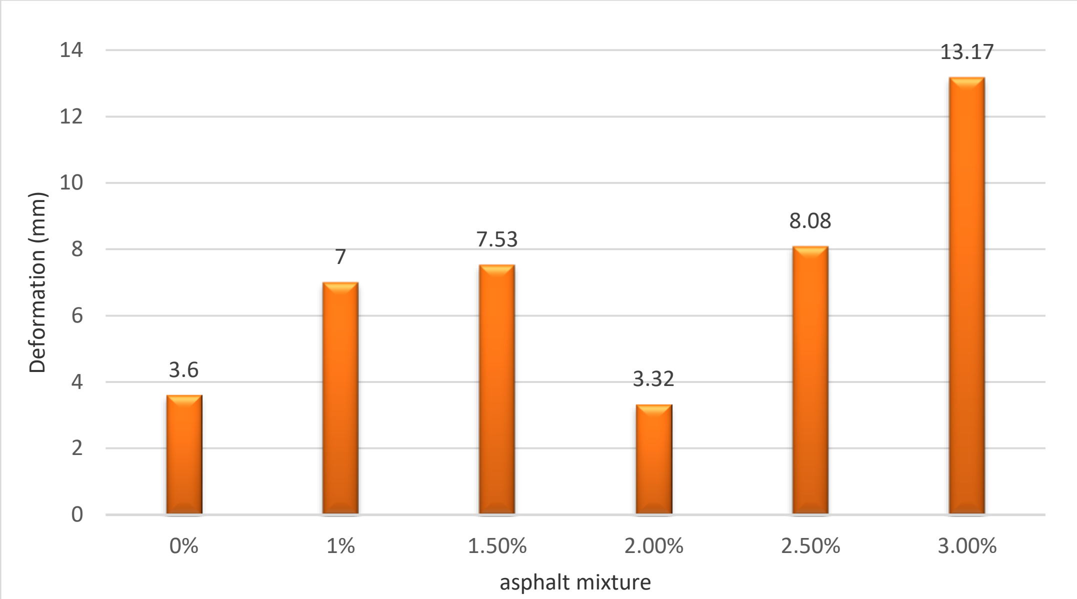

Figure 2: Result of permanent deformation

4. Conclusion

In summary, the objective of this research was to improve the characteristics of asphalt binders by incorporating steel fibre. Several inferences were drawn based on the findings. After that, the samples were put through resilient modulus test. According to the findings, 2% of steel fibre had the most favorable influence on permanent deformation at temperature of 25°C, while 3% had the lowest value.

Acknowledgement

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