The study of split mastic asphalt pavement with latex addition for flooded road

by Elsa Eka Putri

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Abstract. This study aims to determine the effect of latex addition to the durability of the Split Mastic Asphalt (SMA) pavement mixture in order to increase its durability when the road is flooded. Durability test conducted where the sample was immersed in water for 0, 24, 48, 72, 96 hours, with latex variations of 1.5%, 2%, 2.5%, 3%, 3.5%. From the results of the study it was found that the durability of asphalt mixture without latex was higher than that of SMA with latex. The durability indexes were 6.740%, 10.648, 11.717, 13.884, 14.766 and 9.991 for 0%, 1.5%, 2%, 2.5%, 3%, 3.5% latex in the mixture respectively. The higher the index the lower the strength. In addition, the longer the soaking time the lower the strength. However, as the latex in the mixture increases, the stability was also increase achieved at 3% latex. The SMA pavement mixture with the addition of latex does not increase its durability but can increase its stability value. So, it is recommended that SMA pavement mixture with latex is only for pavement where the water level is not high.

1. Introduction

Pavement can be divided into flexible pavement, rigid pavement and composite pavement. In general, flexible pavement is a mixture of asphalt and aggregates. According to [1], Split Mastic Asphalt (SMA) is a flexible pavement with a gap graded having a high proportion of coarse aggregate content, which results in higher void in mixture thus, the resulted in thicken asphalt film when blended with the filler, fibre and or polymer [2]. It is undeniable that pavements play essential part of our daily life as we use them as roads, runways, parking lots and driveways. Like any other engineered structure, pavements are expected to be adequate strong and durable for their design life [3,4].

Figure 1. Latex

Latex is defined as thick gum obtained from trees that are tapped as seen in Figure 1. Latex is suitable for asphalt mixtures because it can increase the thickness of the asphalt liquid so that asphalt is stronger against deformation, because latex has a high resistance to elasticity. The idea of using latex in the mixture is actually the same behaviour with the asphalt, where soften when temperature increase and harden when temperature decrease [5]. Hence, in this study the use of latex in the asphalt mixture was expected to increase the durability of the pavement.

2. Literature review

Traffic loads, temperature and moisture content are the parameter that influence the number of damage of the pavement, hence reduced the structural capacity of the road. The inundate pavement that experience to the wheel load passing above it, will deteriorate the pavement [6,7].

The durability of a flexible pavement is a measure of its resistance to weathering (water and temperature) and the abrasive action of traffic within its design life [6]. Depending on the parameter of interest, it can be measured using the thin-film oven test, rolling thin film oven test, pressure ageing vessel method, the concept of durability index from the Marshal test or any other suitable method. In the Marshall test using durability index concept, specimen was subjected to water to the effects of water and temperature by immersing the specimen at 60°C.

The durability, or the stripping resistance of the mixture, was characterized by the mechanical response under long exposure to water and temperature. This was expressed by durability curves that reflect the variation of retained strength with the hot immersion time. Usually, pavement mixture was immersed in a 60°C water bath and were tested for strength (Marshall Stability, Resilient Modulus, diametrical split tests, and so forth) after 0, 1, 3, 7, and 14 days of continuous hot immersion [8]. The durability curves can be analyzed based on trend and shape and by a durability index developed to characterize the entire durability curve in a single parameter [8]. The durability index is defined as the average strength loss area enclosed between the durability curve and the line s_0 *100 percent. Based on Figure 2, this index is expressed as follows:

$$a = \frac{1}{t_n} \sum_{i=1}^{n} a_i = \frac{1}{2t_n} \sum_{i=0}^{n-1} (s_i - s_{i+1})[2t_n - (t_i + t_{i+1})] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

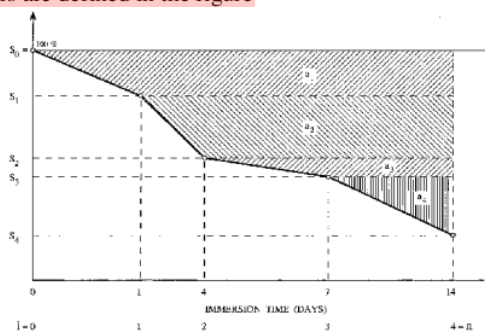where all the parameters are defined in the figure

Figure 2. Durability Curves with parameters defining durability indexes
(Source: [8])

The durability index also expresses an equivalent 1-day strength loss. Positive values of (a) indicate strength loss, negative ones a strength gain. Under its definition, a < 100. Consequently, it is possible to express the percentage 1-day equivalent retained strength (s_a) as follows:

$$S_a = (100 \quad a)$$ ………………….. ...………………... ………... ………….....(2)

The Retained Strength Index (RSI) based on Marshall Stability is determined using Equation (3):

$$RSI = \frac{S_i}{S_o} \times 100$$ ………...………...………...………...………...…(3)

Where;
RSI   = retained strength index
S_i = stability after immersion at time t_i or stability of conditioned specimen
S_0 = stability before immersion or stability of unconditioned specimen

For the Durability Index, it is divided into two parts which are ; (a)first durability index and (b)second durability index.

a)   First Durability Index (FDI) is defined as the sum of the slopes of the consecutive sections of the durability curves [8] and obtained as presented in equation (4).

$$FDI = \sum_{i=0}^{n-1} \frac{S_i - S_{i+1}}{t_{i+1} - t_i}$$ ………...………………... …………..(4)

Where;
S_{i+1} = percent retained strength at time t_{i+1}
S_i = percent retained strength at time t_i
t_i, t_{i+1} = immersion times

b)   Second Durability Index (SDI) is formulated as in equation (5).

$$SDI = \frac{1}{t_n} \sum_{i=o}^{n-1} A_i = \frac{i}{2t_n} \sum_{i=0}^{n-1} (S_i - S_{i+1}) \times [2t_n - (t_{i+1} - t)]$$ ……………………. ………...………... . (5)

Where
S_{i+1} = percent retained strength at time t_{i+1}
S_i = percent retained strength at time t_i
t_i, t_{i+1} = immersion times (calculated from beginning of test)

Based on the literature review, there is growing concern to improve the durability of pavement in terms of materials used. Latex showed potential improvement of durability based on tested strength. Hence there is a need to further test the materials on the effects of moisture since moisture damage is crucial at tropical region due to the heavy annual rainfall.

3. Material and method

3.1   Aggregate
Physical properties of aggregate used in this investigation are shown in Table 1. The influence of particle size distribution on interparticle force. Aggregates are the major component of the pavement mixtures [9]. The properties of aggregates and the way of aggregate packing have important influence on the mixture performance. As can be seen from Figure 3, the aggregate for SMA pavement is categorized as gap graded pavement due to the intermediate sizes are absent from the gradation curve.

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Table 1. Aggregate properties

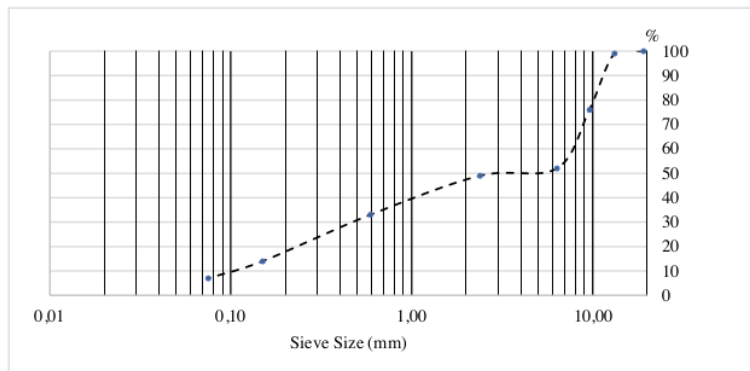| No	Parameter	Standard	Value	Standard Value
1	Coarse Aggregate			
	- Bulk density	SNI 1969: 2008	2.612	-
	- Absorption (%)		1.880	< 3%
2	Fine Aggregate			
	- Bulk density	SNI 1969 : 2008	2.484	-
	- Absorption (%)		5.552	< 3%
3	Lost on Los Angeles Abrasion (%)	SNI 2417 : 2008	28.924	< 30 %
4	Aggregate Crushing Value (%)	BS 812-110:1990	19.750	< 30 %
5	Aggregate Impact Value (%)	BS 812-110:1991	13.287	< 30 %

Figure 3. Particle size distribution of SMA mixture

3.2   *Bitumen*

The properties of bitumen used for SMA mixture in this study is 60/70 pen as can be seen from Table 2.

Table 2. Properties of bitumen

No	Parameter	Method	Value	Standard Value
1	Penetration	SNI 2456:2011	62	60-70
2	Penetration (from TFOT)	ASTM D 1754	55	≥54
3	Thin Film of Test (%)	SNI 06-2440-1991	0	≤0.8%
4	Flash Point (°C)	SNI 2433:2011	256	≥232°C
5	Burning Point (°C)	SNI 2433:2011	282	≥232°C
6	Softening Point (°C)	SNI 2433:2011	54	≥48°C
7	Ductility (cm)	SNI 2433:2011	≥100	≥100 cm
8	Adhesion to aggregate (%)	PA-0312-76	≥95	≥95%
9	Bitumen density	SNI 2441:2011	1.045	≥1.0

Specification used for investigation was based on SNI (Indonesia Standard) for Hot mix asphalt General Specifications 2010 [10].

4. Results and discussions

Samples of Split Mastic Asphalt were made initially without latex addition for Optimum Bitumen Content determination. As Optimum Bitumen Content were determined then samples were made with various latex addition. The latex variations were 0, 1.5, 2, 2.5, 3, 3.5 at 3 samples at each variation. Then the durability was then examined at this Optimum Latex Content by conducting immersion test Marshall.

4.1 Optimum latex content determination

Optimum Latex Content (OLC) in the SMA mixture were determined before durability assessment. Three samples were made at each various latex content. The optimum latex content for SMA pavement mixture is the mixture that achieved the highest stability and the other Marshall parameter were at the standard.

Table 3: Marshall parameter result for OLC determination

Latex	Marshall Parameter					
	Stability (kg)	Flow (mm)	MQ (kg/mm)	VIM (%)	VMA (%)	VFA (%)
0	1114.25	3.35	346.54	2.81	20.56	86.35
1.5	1257.08	3.53	357.41	1.95	20.24	90.37
2	1091.33	3.73	292.47	2.07	18.78	88.98
2.5	1213.45	3.43	353.07	1.99	19.99	90.06
3	**1335.00**	3.40	397.96	2.23	20.46	89.09
3.5	1126.32	3.57	316.36	2.33	20.20	88.46

Based on Table 3, the Optimum Latex Content that obtained the highest Stability, and the other Marshall parameter where within the standard was 3% Latex.

4.2 The relationship between Marshall Parameter vs. Immersion time

To determine the durability of the SMA pavement mixture, fifteen samples were made. Some parameters in the Marshall tests were examined vs immersion time as shown in Figure 4 to 8.

4.2.1 Stability vs. Immersion Time. As can be seen from Figure 4, the relationship between the immersion time and stability. The results obtained that all the stability values are fulfil into the standard specifications > 750 kg. In the comparison mixture, the stability value decreases with the increasing immersion time. Likewise, in the asphalt mixture with added latex material, the value of stability is also decreased. The value of asphalt mixtures with 2%, 2.5% and 3% latex added materials has a higher stability than the 0% Latex mixture.
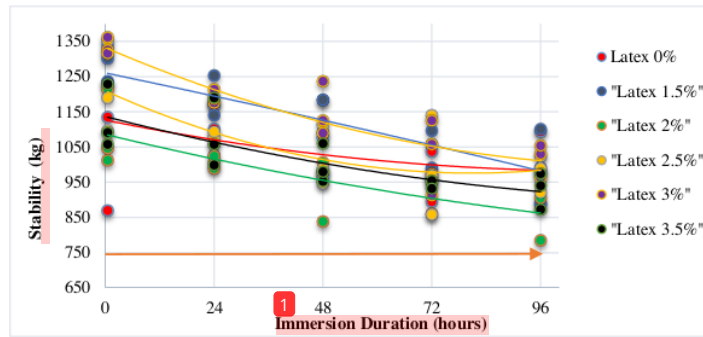
Figure 4. Stability (kg) vs. Immersion duration (hours)

4.2.2 Flow vs. Immersion time. Figure 5 is the relationship between the immersion time and the flow value. As can be seen from the figure that not all the flow values fulfil the standard specifications between 2 - 4mm. For 0% latex as well as the mixture with latex, the flow value increased with the increasing of immersion time. The flow value of the mixture with latex is higher than that of the 0% latex mixture.
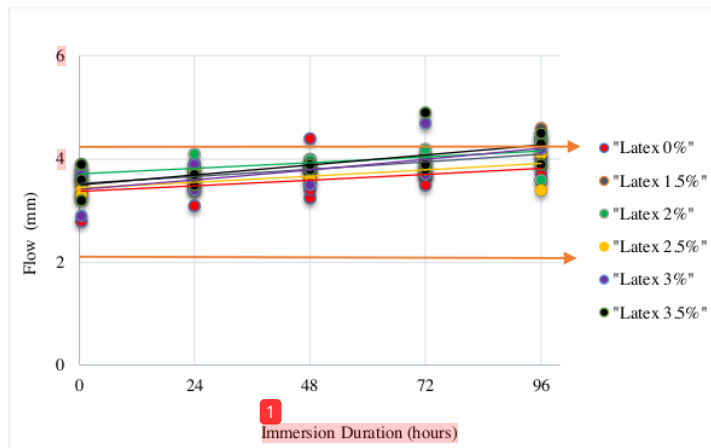

Figure 5. Flow (mm) vs. Immersion duration (hours)

4.2.3 Void in mixture (%) vs. Immersion time. Figure 6 is the relationship between the immersion time and the void value of the mixture. In the test results obtained that all the void values of the mixture into the standard specifications used are 2% - 4%. For 0% latex mixture as well as 1.5%, 2%, 2.5%, 3% latex decreased the VIM value of the mixture decreased with immersion time, while the mixture with 3.5% latex experienced the higher VIM. The VIM value of the 0% latex is higher than the mixture with latex addition.
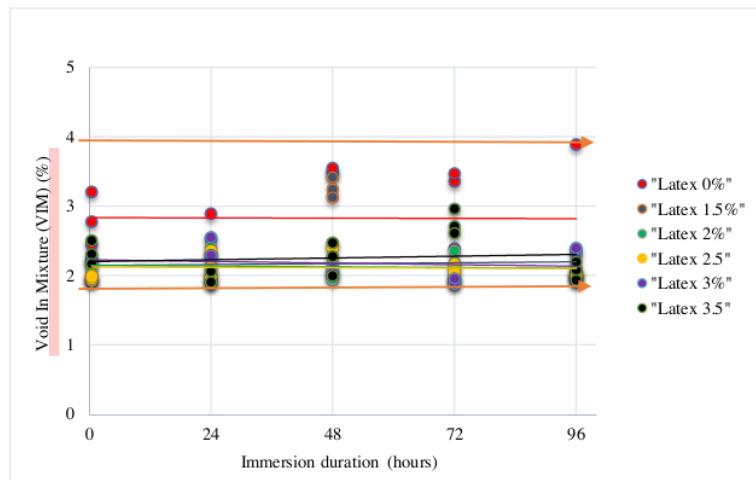
Figure 6. Void in Mixture (%) vs. Immersion duration (hours)

4.2.4 Void in mineral aggregate (%) vs. Immersion time. As can be seen from Figure 7, the relationship between immersion time and VMA, all the VMA values fulfil the standard specification that is ≥15%. As the value of void in mix increases, the length of immersion also increases for both type of mixtures without or with Latex addition. In addition, the VMA value for 0% Latex is higher than the VMA value for mixture with latex addition.
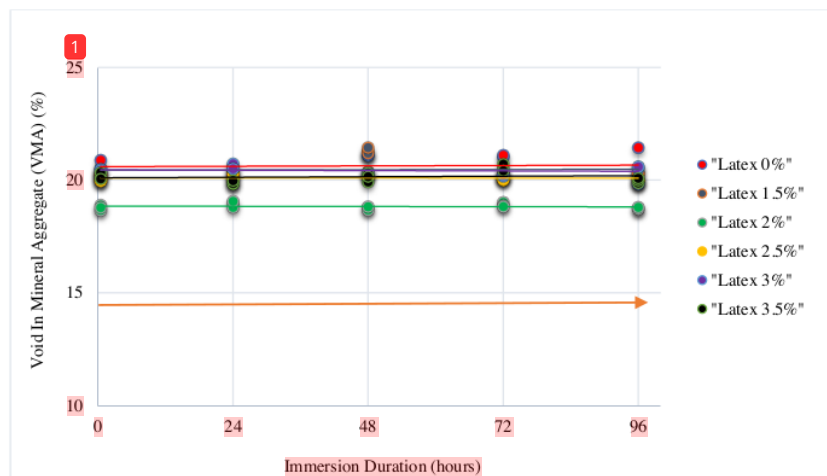

Figure 7. Void in Mineral Aggregate (%) vs. Immersion duration (hours)

4.2.5 Marshall Quotient (kg/mm) vs. Immersion Time. As shown from Figure 8, the relationship between the immersion time and the MQ value. The test results show that MQ values are between 190-300 kg/mm. For 2% latex in the comparison mixture and mixture with latex added ingredients the Marshall Quotient value decreased with the length of immersion time. Marshall Quotient values with 2% and 3.5% latex added ingredients were lower than the comparison mixture, but it fulfils the required specifications.
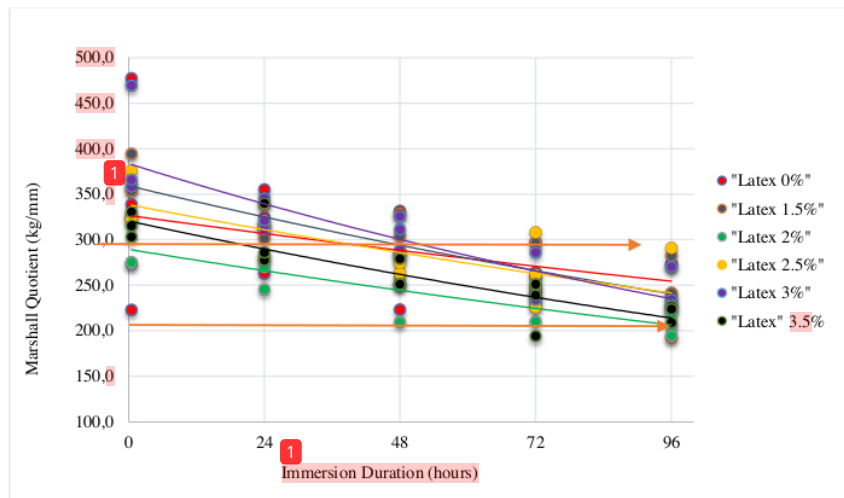

Figure 8. Marshall Quotient (kg/mm) vs. Immersion duration (hours)

4.3   Index durability of the asphalt mixture

4.3.1 Retained Strength Index (RSI). The value of RSI of the mixture substitute by latex at shows lower value than that of 0% latex. The higher the percentage of the latex in the mixture the lower the value of RSI. The lowest value of RSI was at 3.5% it follows by 3%, 2.5%, 2%, then 1.5%. It seems that the latex addition into the SMA mixture were not suitable to improve the strength due to change in weather or the pavement is immersed by the flood. Due to, there were not resulted in better value of durability in term of RSI. Moreover, the longer the immersion time the higher the lost in strength of the SMA mixture.
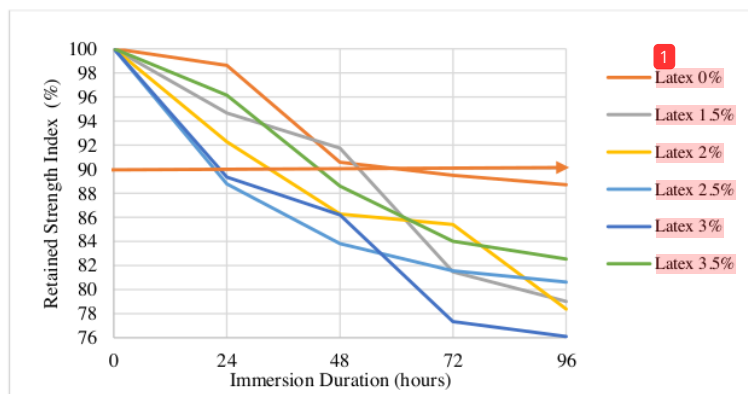

Figure 9. Retained Strength Index (%) vs. Immersion duration (hours)

5. Conclusions

The durability of the SMA pavement mixture were tested for two conditions, without Latex and with Latex addition in order to assess the suitability of the pavement for flooded road condition. The Marshall parameter and durability tests were conducted. Based on the above experimental results, the conclusions are as follows,

1. the value of the relative durability of the mixture decreases with increasing immersion time due to an increase in the stiffness of the asphalt which is increases the mixture becomes harder and brittle, which results in decreased durability or decreased strength to be greater.

2. As the immersion time increase, the stability decrease. The durability value of the 0% Latex has a good quality compared to the mixture with latex. The durability value of 0% latex has a durability index value of 6.740, this value is lower than all the mixture with latex addition. Such as, 10.648, 11.717, 13.884, 14.766 and 9.991 for the 1.5%, 2%, 2.5%, 3%, 3.5% Latex addition respectively.

3. Fortunately, the stability value for SMA with latex addition were higher than without latex addition. The stability for SMA with 0% latex were 1114.249 kg. Hence, 1257.076 kg, 1091.333 kg, 1213.448 kg, 1335.003 kg, and 1126.321 kg, for 1.5%, 2%, 2.5%, 3% and 3.5% Latex respectively. That 3% latex was achieved the highest stability.

In the conclusion, the use of latex in the SMA pavement mixture can increase the stability value, mean the pavement more stable under wheel load, however, the SMA with latex addition was not suitable for road submerged continuously by water. Thus, it is recommended that SMA pavement mixture with latex is only for pavement where the water level is not high.

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