THE IMPROVEMENT OF DURABILITY OF ASPHALT CONCRETE USING MODIFIED WASTE PLASTIC-BITUMEN

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ABSTRACT

Durability properties of asphalt mixture are an important criterion to ensure that the pavement materials maintain its desired properties. The objective of this study is to investigate the effect of waste plastic as a modifier in bitumen on durability of asphalt concrete. Waste plastic (HDPE) was used to modify 60/70 pen grade. The variation of waste plastic content used in bitumen was 0.75%; 1.5% and 3% (by the weight of optimum bitumen content) respectively. Tests used in assessment of moisture susceptibility were Marshall stability and the Indirect Tensile Stiffness Modulus. Cantabro test was used to assess disintegration resistance of aggregate mix.

Waste plastic proportion had a significant effect on the durability of asphalt concrete, which modified bitumen used in mix exhibited better than conventional mix. Test results showed that the use of waste plastic as modifier in bitumen for asphalt concrete offer the potential of durable, longer lasting road

KEY WORDS

Waste Plastic, Modified Bitumen, Asphalt Concrete, Durability

INTRODUCTION

Durability has been defined as the ability of a material to resist changes in its properties due to environment effects. The environment factors affecting the durability of bituminous mixture are temperature, air and water, particularly in tropical country such as in Indonesia which pavement temperature and rainfall intensity are high i.e. 50°C and >2000 mm/year respectively. Terrel et al (1990) summarized that there are two mechanisms on road deterioration induced by moisture: (1) loss of cohesive strength and stiffness bitumen film and (2) the failure of adhesive bond between the aggregate and bitumen. Failure of the adhesive bond leads to a serious reduction in the durability of the mix and possibility of premature failure. In order to prevent damage due to the effect of air and water, numerous studies have been conducted to improve mechanical properties of bitumen and the mixture. Polymer modified bitumen is one way to improve mechanical properties of bitumen and mixture which leads to minimize that problems.

The objectives in this study are to investigate the effect of waste plastic as a modifier in bitumen on the durability of both conventional mix and modified mixes in terms of moisture susceptibility and disintegration of aggregate mix through laboratory experimental

METHOD APPROACH

Waste plastic - bitumen blend

Bitumen used in this study was penetration grade bitumen 60/70, which is widely used in Indonesia for asphalt concrete. Modifier used in this study is waste plastic milk carton, predominantly composed of High Density Polyethylene (HDPE). Waste plastic milk carton was obtained from local household waste. HDPE milk cartons were cut into small pieces of approximately 2 x 2 mm^2 size. The thickness, density, melting point, tensile strength, and elongation at break of waste plastic (HDPE) are 0.5 mm, 0.94 – 0.97 gm/cc, 120 – 130^oC, 31.35 MPa, and 100%, respectively.

The chopped plastic was blended with bitumen at low speed for about 5 minutes until all of plastic quantity required was added. The mixture is heated constantly to 160 - 170^oC and mixed at high speed for 1 hour using a mechanical stirrer. Three types of modified bitumen were prepared by varying content of waste plastic HDPE (0.75%, 1.5% and 3% by weight of binder) in the mixture.

The unmodified and modified bitumen properties have been evaluated using the penetration test at various temperatures (25^oC, 30^oC, 35^oC and 40^oC) and softening point test. A summary of test results can be seen Table 1.

Table 1 Summary of The Penetration Value of Waste Plastic-Bitumen Blend

Test	Waste Plastic HDPE - Bitumen Blended			
Penetration (dmm)	0%	0.75%	1.5%	3%
25^oC	78	72	66	55
30^oC	149	122	103	85
35^oC	239	206	176	133
40^oC	350	319	285	223
Softening Point (°C)	45	47	48.5	54

To determine whether waste plastic dispersed in bitumen or not can be observed using optical micrograph. Figure 1 represents optical micrographs for modified bitumen and unmodified bitumen. It is clear that Figure 1 showed waste plastic dispersed in bitumen.

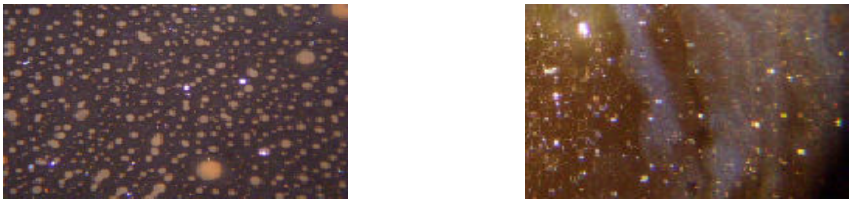


Figure 1 Optical Micrograph for Modified and Unmodified Bitumen

Determination of optimum waste plastic content

The Marshall test method was used to determine the optimum bitumen content for unmodified bitumen. This was found to be 6% by weight of total mix. The selection of the optimum waste plastic content used in bitumen was based on moisture susceptibility and Cantabro test. As shown in Figure 2 and 3 that Asphalt concrete prepared using waste plastic content of 1.5% exhibited the highest of retained stability and the lowest of particle loss (%). This indicated that waste plastic content of 1.5% in binder showed the best to resist moisture susceptibility and disintegration. Further waste plastic content 1.5% (by weight of optimum bitumen content) was selected for more detailed in laboratory durability investigation.

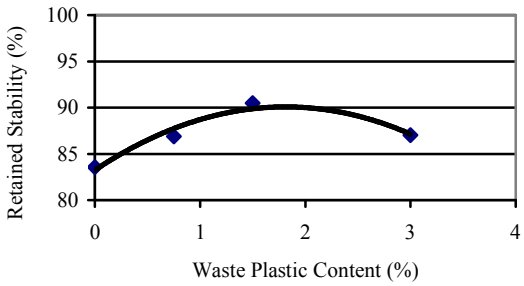
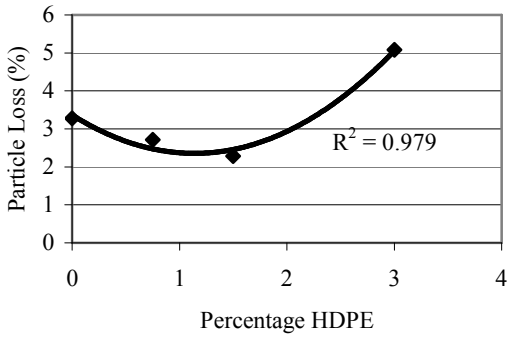


Figure 2 The Effect of Waste Plastic Content (%) on Retained Stability (%)



Figue 3 The Effect of Waste Plastic Content (%) on Particle Loss (%)

Test used

Durability tests used in this research are moisture susceptibility test and Cantabro test. Tests used in evaluation of moisture susceptibility are Marshall stability and Indirect Tension Stiffness Modulus (ITSM) test, while Cantabro test is used to evaluate the resistance to disintegration between aggregate and bitumen.

Moisture susceptibility test using Marshall Stability test

To evaluate the effect of modified bitumen in asphalt concrete mixes on moisture susceptibility, the specimens were prepared using conventional and modified binder. The specimens for moisture susceptibility test are divided into three conditions. The first is unconditioned specimen, which the specimen placed in a water bath at 60°C (140°F) for at least 40 minutes and not longer than 60 minutes, after that the Marshall stability of the samples is determined. The second is conditioned-(1) specimen, which the specimen placed in a water bath at 60°C (140°F) for 24 hours and the last condition is conditioned-(2) specimen placed in water bath at 25°C for 28 days, after that the specimen placed in a water bath at 60°C for at least 40 minutes and not longer than 60 minutes and the Marshall stability also is determined. The retained Marshall stability is calculated and compared to specified minimum values set by governing agencies. The retained stability is ratio Marshall stability of conditioned specimen over unconditioned specimen. A typical requirement for this test is that the retained stability at least 75% of control condition as recommended by Indonesian specification.

Moisture susceptibility test using ITSM

The Indirect Tensile Stiffness Modulus (ITSM) test is used to determine stiffness modulus of bituminous mix using the Nottingham Asphalt Tester (NAT). In moisture susceptibility test using NAT, the specimens are divided into two conditions. The first is unconditioned specimen, which the specimens placed into NAT chamber and conditioned at 20°C for at least 3 hours to 24 hours before ITSM test, after that the mix stiffness of the specimens is determined. The second is conditioned specimen, which the specimen placed in a water bath at 25°C and mix stiffness was determined every 7 days with the total number of days extended to 28 days. Percentage of retained stiffness is calculated, which the retained stiffness is ratio mix stiffness of conditioned specimen over mix stiffness after immersion.

Cantabro test

The Cantabro test is used to assess durability of bituminous mixes in terms of resistance to disintegration between aggregate and bitumen under the effect of traffic. The Cantabro test results also have been used assess a much wide range materials such as HRA, DBM and SMA [11]. The results of Cantabro test are presented as Cantabro loss value. The percentage of Cantabro loss value was recorded every specified rotation with total number of rotation extended to 500.

RESULTS AND DISCUSSION

Moisture susceptibility test results and discussion

A summary of moisture susceptibility test results obtained by Marshall stability test for all mix compositions that interpreted in percentage of retained stability are presented in Table 2. The

results show asphalt concrete mixture prepared using modified bitumen exhibited better resistance to stripping potential than conventional mix. However, the percentage of retained stability of all mix compositions is higher than 75% as recommended by Indonesian specification. The results of moisture susceptibility test obtained from Marshall stability test for conditioned-1 (specimens soaked at 60°C for 1 day) and conditioned-2 (specimens soaked at 25°C for 28 days) show similar rank that asphalt concrete mix prepared using modified bitumen exhibits the higher percentage of retained stability value than conventional mix.

Table 2 A Summary of Moisture Susceptibility Test Results

Mix Compositions	Stability (kN)		Retained Stability (%)
	Unconditioned	Conditioned (1)	
Unmodified	8.967	7.489	83.511
Modified	10.143	9.174	90.446
	Stability (kN)		Retained Stability (%)
	Unconditioned	Conditioned (2)	
Unmodified	8.967	7.030	78.394
Modified	10.143	8.317	81.995

Note: Conditioned (1) : Specimens soaked at 60°C for 1 day
Conditioned (2): Specimens soaked at 25°C for 28 days

The stiffness modulus and retained mix stiffness of asphalt concrete mixes obtained by NAT under varying days soak is summarized in Table 3. These results indicate that stiffness modulus of asphalt concrete tend to decrease with an increase in days soak. To examine the effect of modified bitumen in asphalt concrete mixes on moisture susceptibility, percentage of retained mix stiffness is used as indicator whether the mix has low or high moisture susceptibility. Previous research indicated that moisture damage of mix could occur when the percentage of retained mix stiffness is below 70% to 75% [9]. The asphalt concrete mix prepared using modified bitumen has higher in mix stiffness and retained mix stiffness than conventional mix, this indicated that the some improvement in strength was obtained. This finding is consistent with findings obtained from Marshall stability test.

Compared to the conventional mix, the results showed that asphalt concrete mixes prepared using modified bitumen at retained mix stiffness of 70% exhibit an improvement in reducing moisture susceptibility about 30%.

Table 3 Mix Stiffness Modulus (MPa)

Soaked (Days)	Stiffness Modulus (MPa)		Retained Mix Stiffness (%)	
	Unmodified (UM)	Modified (M)	Unmodified (UM)	Modified (M)
0	3890.50	4839.5	100	100
7	3053.25	3819.00	78.48	78.91
14	2832.50	3608.00	72.81	74.55
21	2149.50	3281.75	55.25	67.81
28	1838.50	2762.50	47.26	57.08

Cantabro test results and discussion

Cantabro was originally developed to assess the resistance to particle loss by abrasion and impact for porous asphalt but this method may also be used to rank other types of bituminous material [11]. Typical specimen before and after tested in Los Angeles machine without steel ball is presented in Figure 4.

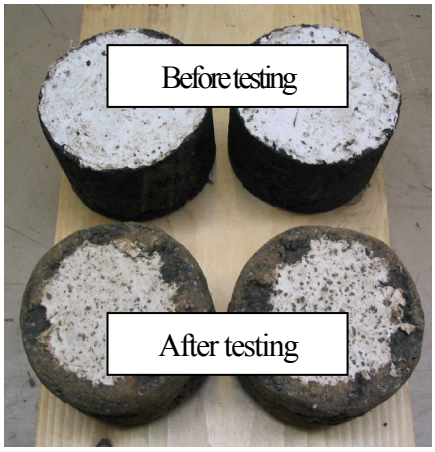


Figure 4 Typical Cantabro Test Results

Cantabro test results represented as percentage of Cantabro loss at specified number of drum cycles is shown in Figure 5. This result shows that asphalt concrete mix prepared using modified bitumen has lower percentage of Cantabro loss than conventional mix, however all mix compositions have low percentage Cantabro loss at 500 cycles about 5.83% and 3.91% for conventional mix and modified mix respectively. As seen in Figure 5 that asphalt concrete prepared using modified bitumen has lower percentage of Cantabro loss indicates better durability in terms of resistance to disintegration between aggregate and bitumen or improvement in adhesive bond leads to premature failure reduction. It is clear that the use of modified bitumen using waste plastic in asphalt concrete mix give significance effect improving durability of mix approximately 33%.

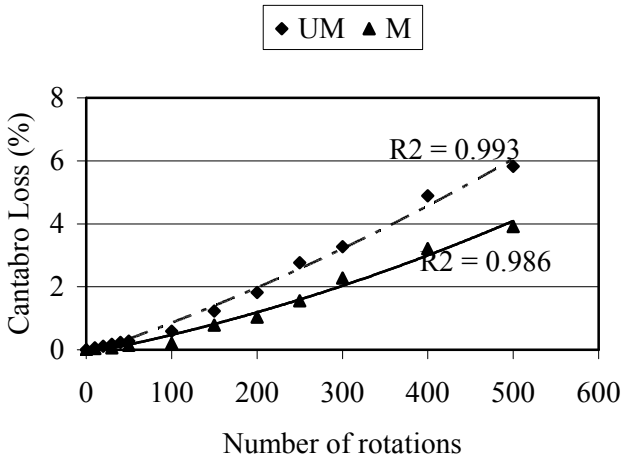


Figure 5 Cantabro Loss (%) Results

CONCLUSIONS

The following summaries have been drawn:

(1) The optimum bitumen content of the asphalt concrete mix used in the investigations was determined to be 6% containing 1.5% by weight of waste HDPE plastic.
(2) Increasing the soaked days in water bath caused reduction in mix stiffness modulus and Marshall stability, which mean it reduced resistance to moisture susceptibility.
(3) The addition of waste plastic in binder caused improving approximately 30% and 33% in moisture susceptible and particle loss due to disintegration respectively.
(4) In general the durability of asphalt concrete mixes prepared using waste plastic was better than conventional mixes.

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