Analysis of moisture susceptibility of hot mix asphalt (HMA)

Adelia Dwidarma Nataadmadja*, Eduardi Prahara, and Oki Setyandito

Civil Engineering Department, Faculty of Engineering, Bina Nusantara University Jakarta, Indonesia 11480

Corresponding author: anataadmadja@binus.edu

Abstract. Indonesia has been extensively expanding its road networks to support the economic and the population growth. It is very important to ensure that the road networks perform well and last to their designed life. However, it is very common to find roads with asphaltic surfaces with some pavement failures not long after the construction finished. The most commonly pavement failures found are potholes and stripping, which are related to water intrusion to the hot mix asphalt. Indonesia is a tropical country and its soil has a high groundwater level in general. Therefore, it is very important to study the effect of moisture in asphaltic surfaces. This research aims to provide a preliminary analysis on the moisture susceptibility of hot mix asphalt. It was found that there were a few of Marshall test results that did not satisfy the requirements, which could be caused by human variation and the angularity of aggregates. The Cantabro Loss test results show that the HMA specimens lost around 11% and 15% of material after being exposed to water and abraded. From the research results, it was found that there is a strong relationship between the flow and the Cantabro Loss of the prepared HMA specimens.

Keywords: hot mix asphalt, moisture, aggregate, Cantabro, Marshall

1. Introduction

Indonesia is one of the countries with a high population density and a high population growth rate. Therefore, the infrastructure, especially the road and highway networks, must be continuously improved and maintained. It is crucial to correctly design the road pavement from the beginning to ensure that the asset lasts. However, it is very common to find pavement failures not long after the roads were constructed, especially after the monsoon season [1].

The presence of moisture or water in hot mix asphalt pavement could lead to the loss of strength and durability of the pavement because the adhesion bond between the asphalt and aggregate is broken and the cohesive bond in the bitumen (asphalt) is lost [2]. The most commonly pavement failures in flexible pavement (with asphaltic road surface) due to the presence of water are stripping, potholes, and rutting [3]. There are a number of factors that affect the susceptibility of hot mix asphalt (HMA) surfaces, such as the aggregates properties (minerals, source of aggregate, angularity, dust, and moisture content), the asphalt binder properties (stiffness, chemical composition, and refining process) [4], [5].

Usually the moisture damage starts at the bottom of the asphaltic surface or at the interface between asphalt layers, continued to become localized potholes, and then, cracking developed [6], [7]. The combination between water intrusion to this localized pavement failure and traffic loading will lead to further degradation of the pavement layer [7]. Ravelling or loss of aggregate can occur, especially in chip seal surfaces and binder from pavement could be flushed or turned into surface bleeding [4].

There are a number of research projects worldwide hat have studied the effect of moisture in hot mix asphalt (HMA)[8], [9]. Indonesia is a tropical country and most places have a high groundwater level, and hence, it is very important to study the effect of moisture in the HMA layers to ensure that the pavement layers could serve their functions throughout their service age. This research aims to provide a preliminary analysis on the moisture susceptibility of HMA as designed according to Indonesian standard.

2. Experimental design

2.1. Materials

HMA consists of aggregates, binder (asphalt), and filler (optional). In this research, a natural aggregate was used, as shown in Figure 1. These aggregates were crushed into four sizes, as shown in Table 1. The coarsest aggregates are denoted as Aggregate I and the finest aggregates are denoted as Aggregate IV. A Laser Induced Breakdown Spectroscopy was performed on this aggregate to determine the dominant chemical elements of this aggregate.

Figure 1. Natural Aggregates

Table 1. Aggregates grading

Aggregate	Passed Sieve No.	Retained by Sieve No.
I	¾” (19.1 mm)	3/8” (9.6 mm)
II	3/8” (9.6 mm)	#8 (2.4 mm)
III	#8 (2.4 mm)	#16 (1.2 mm)
IV	#16 (1.2 mm)	#200 (0.075 mm)

There were two types of asphalt used herein. They were both 60/70 asphalt (as stated in the product specifications) but sourced from different companies. There was no filler used in the HMA used for this research. The asphalt samples were then constructed by using the asphalt mix design used in [10] with 5.5% asphalt content, and the details are shown in Table 2. There were four samples constructed for each variation. Two samples were used for the Marshall tests and the other two samples were used for the Cantabro Loss tests.

Table 2. Composition of HMA design

Asphalt Content		**Weight of Aggregate (gr)**			
%	**gr**	**I**	**II**	**III**	**IV**
5.5	66	242	193	181	476

2.2. Aggregate and Asphalt Preliminary Check

To ensure the suitability of the materials to be used in HMA design, there were several standard tests for coarse and fine aggregates and asphalt, as listed in Table 3, before the HMA samples were prepared.

Table 3. Aggregate and Asphalt Tests

	Test	Standard
Aggregate Tests	Bulk Specific Gravity	
	SSD Specific Gravity	SNI 1969:2008
	Apparent Specific Gravity	
Asphalt Tests	Penetration Test at 25ºC	SNI 06-2456-1991
	Softening Point Test	SNI 2434-2011
	Specific Gravity	SNI 2441-2011
	Ductility at 25ºC	SNI 2432-2011
	Flash and Fire Point Test	SNI 06-2433-1991

2.3. Marshall Tests

The Marshall tests were conducted for the prepared asphalt samples according to *Standar Nasional Indonesia* (SNI) 06-2489-1991 [11] to determine the characteristics of the asphalt mixes. From the test results, the stability and the flow parameters of the samples could be determined. There were also other parameters that were calculated, such as Void in Mix (VIM), Void in Mineral Aggregate (VMA), Void Filled with Asphalt (VFA), and density. There were two samples constructed for each HMA variation.

2.4. Cantabro Loss Tests

The Cantabro Loss test is a test used to determine the loss of abrasion of compacted HMA samples as stated in [12]. This test involves measuring the breakdown of the prepared HMA specimens with Los Angeles Abrasion machine. The Cantabro Loss was calculated by finding the difference between initial and final weight of the HMA specimens after the specimen being rotated in Los Angeles machine for 300 revolutions at a speed of 30 revolutions per minute (rpm). The result was presented in percentage and it shows the durability and the quality of the asphalt binder.

For this research, due to the equipment limitation, there was procedure for this test was slightly modified. The HMA specimens were prepared with a diameter of 10.2 cm and a height of 6.35 cm. This is smaller than the specimen size specified in [12], but it does not hinder in achieving the goal of this test as this test is looking at the percentage lost after the specimens being abraded. Moreover, the prepared specimen was immersed in water bath at 60ºC for one hour to simulate the HMA surfaces being flooded, and hence, the ability of the specimen to resist disintegration action after contact with water can be assessed. This procedure is similar to the research project described in [13], although they immersed the specimen for 24 hours in the water at 60ºC.

3. Results and Discussion

3.1. Materials Description

Table 4 shows the results of the tests conducted on the coarse and fine aggregates. It was found that the natural aggregate used in this research satisfy the requirements. Moreover, the mineral analysis was also performed on the aggregate and it was found that the aggregate is dominated by Calcite, Manganese, Sodium, and Aluminium, as seen in Figure 2.

Table 4. Aggregate tests results

Tests	Results	Requirement
Bulk Specific Gravity	2.51	≥ 2,5 gr/cc

SSD Specific Gravity	2.58	
Apparent Specific Gravity	2.65	
Absorption (%)	2.17	≤ 3

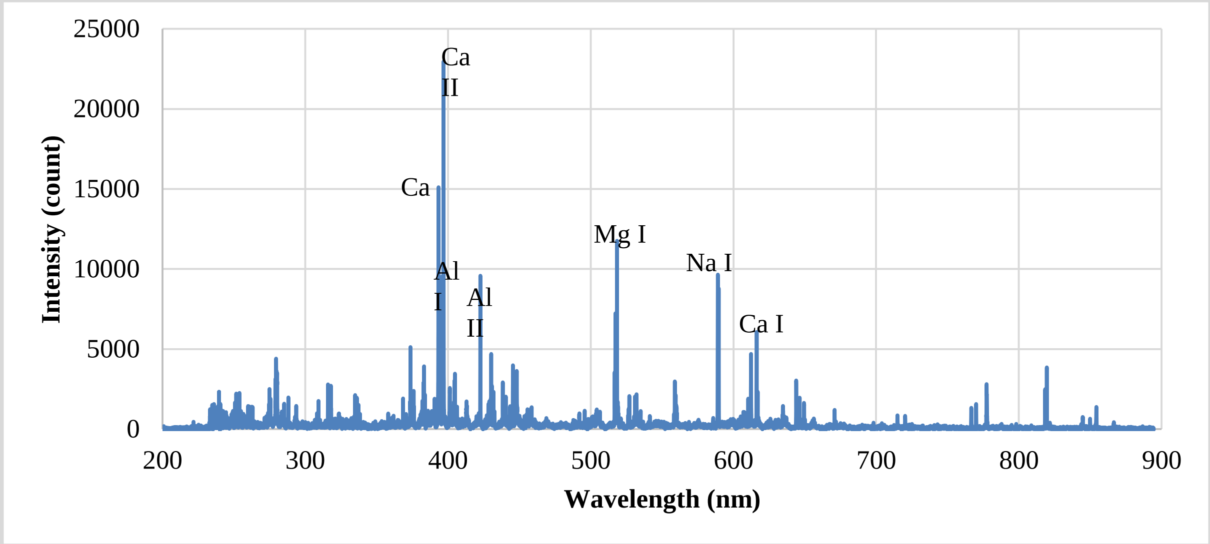

Figure 2. Chemical content of the aggregate

Table 5 shows the results of the tests conducted on the asphalt. It can be seen that the binder passed all the requirements, except for the flash and fire point tests for Asphalt 1. In general, Asphalt 1 seemed to be more rigid than the Asphalt 2 as it has lower ductility value and penetration test. Both asphalts were used as the binder for the HMA designed in this research as both are commercially available and have been used in a number of road construction projects.

Table 5. Asphalt test results

Tests	Unit	Asphalt 1	Asphalt 2	Requirement
Penetration Test at 25ºC	0,1 mm	64	69	60-70
Specific Gravity	gr/cc	1.074	1.114	≥ 1.0
Ductility at 25ºC	cm	126	160	≥ 100
Softening Point Test	ºC	50	50	≥ 48
Flash Point Test	ºC	200	306	≥ 232
Fire Point Test	ºC	255	338	≥ 288

3.2. Marshall Test Results

Table 6 shows the parameters of the HMA samples tested, which were obtained from the Marshall test and further calculations. The results for every samples and the average values of the two samples were shown. It can be seen that the HMA designed satisfy most of the requirements and the values that do not satisfy the requirement were given an asterisk mark (*) next to them.

The flow of HMA samples made by using the Asphalt 2 exceeded the requirement, which suggests that the HMA samples were too soft. Moreover, both the VIM and density values of both samples did not fall between the allowable values. These values show that the samples were not compact enough. This could be due to the HMA sample compaction method, which was done manually, and hence, variations in the samples were expected. This can be observed by the relatively significant difference between the results of each pair of samples. For example, the stability parameter values for Asphalt 1, which are 1545.21 kg and 2393.03 kg.

Table 6. Marshall Test results

Parameter	Unit	Asphalt 1			Asphalt 2			Requirement
		Sample 1	Sample 2	Average	Sample 1	Sample 2	Average	
Stability	kg	1545.21	2393.03	**1969.12**	1887.07	1394.79	**1640.93**	>800
Flow	mm	4.1	5.05	**4.58**	8.05	5.33	**6.69***	2-5
VIM	%	5.45	5.47	**5.46***	5.45	5.47	**5.46***	3 - 5
VMA	%	20.33	21.94	**21.14**	21.17	22.19	**21.68**	> 15
VFA	%	73.22	75.19	**74.21**	74.30	75.48	**74.89**	65 -75
Density	gr/cm^3	2.12	2.07	**2.10***	2.09	2.07	**2.08***	≥ 2,2

3.3. Cantabro Loss Test Results

Table 7 shows the results of Cantabro Loss tests, which were conducted to see the effect of water on the ability of the prepared HMA specimens to resist abrasion. It can be seen from Table 7 that the HMA samples prepared with Asphalt 1 has lower percentage of material lost than the HMA samples prepared with Asphalt 2. It seems that the HMA samples prepared with Asphalt 2 are slightly more sensitive to abrasion than the HMA samples prepared with Asphalt 1. However, it is important to note that there were only two samples prepared and there were a number of factors that could cause variation on the results. For Sample 1 prepared with Asphalt 2, the percentage of material loss was higher than its pair. This could be due to many factors, such as uneven compaction force and the angularity of coarse aggregates. If the data for Sample 1 prepared with Asphalt 2 is removed, it can be seen that the percentages of Cantabro Loss between Asphalt 1 and Asphalt 2 are similar, which is approximately 11%. These results suggest that there might not be any relationship between the asphalt and the resistance to abrasion of the prepared samples

Table 7. Cantabro Loss Test results

Parameter	Unit	Asphalt 1			Asphalt 2		
		Sample 1	Sample 2	**Average**	Sample 1	Sample 2	**Average**
Initial weight	gr	1270	1300		1290	1300	
Final weight	gr	1132	1144		1043	1156	
Cantabro Loss	%	10.87	12.00	**11.44**	19.15	11.08	**15.12**

3.4. Relationship between Marshall Test and Cantabro Loss Test Results

Figure 3 shows the relationship between the Cantabro Loss and stability, flow, VIM, VMA, VFA,and density as listed in Table 6 and Table 7. The dashed black lines show the allowable limit for each parameter. It was found that there is a strong relationship between the Cantabro Loss and the flow of the prepared HMA samples with coefficient of determination (R^2) of 0.92, while there is almost no relationship between the Cantabro Loss and the other parameters.

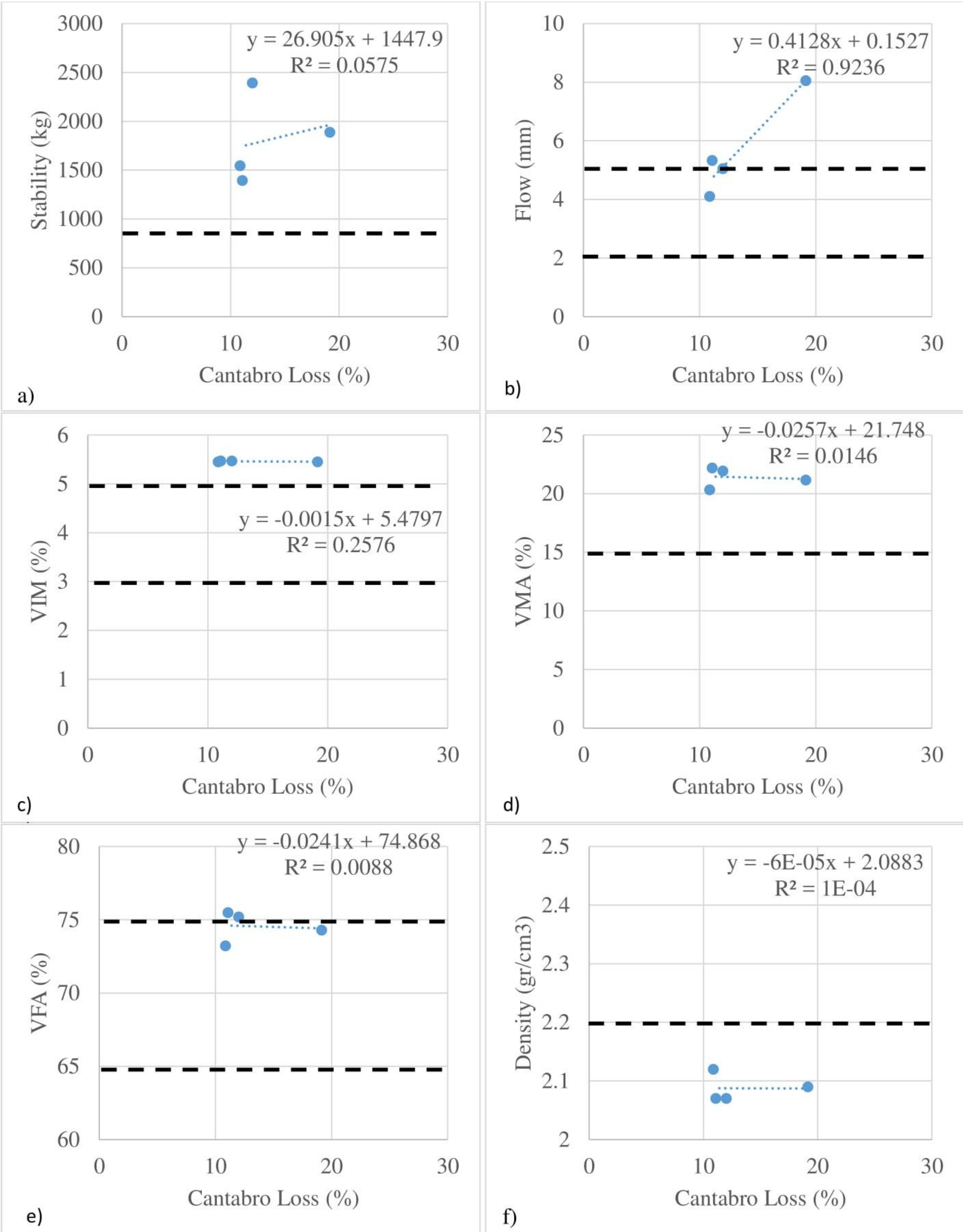

Figure 3. The relationship between Cantabro Loss and Stability (a), Flow (b), VIM (c), VMA (d), VFA (e), and Density (f)

4. Conclusions

Indonesia has been experiencing a massive development on its infrastructure, especially on the road network. It is important to ensure that the road constructed will last until the end of its designed age, while it is very common to find roads with many surface defects and failures, such as stripping and potholes. These defects are caused by the presence of water on the road surfaces as the water will interrupts the cohesive bonding between the binder (asphalt) and the aggregates on the road wearing surfaces. In this research, a preliminary analysis on the moisture susceptibility of HMA as designed according to Indonesian standard was conducted. A natural aggregate and asphalt (60/70 penetration) sourced from two different companies were used to construct several HMA specimens. Both Marshall and Cantabro Loss tests were conducted to assess the prepared HMA specimens for its stability and flow and its resistance to abrasion after being exposed to water, respectively. It was found that some Marshall test results did not fall in the allowable range. This could be due to the human variation that could potentially occur in the sample making process, such as during the compaction process. Moreover, the Cantabro Loss test results show that the HMA specimens lost around 11% and 15% of material for the samples prepared with Asphalt 1 and Asphalt 2, respectively, after being exposed to water and abraded. These results suggest that there might not be any relationship between the asphalt and the resistance to abrasion of the prepared samples. It was also found that there is a strong relationship between the flow and the Cantabro Loss of the prepared HMA specimens.

This research was able to provide a preliminary analysis on the effect of moisture on asphaltic surfaces that was conducted on limited samples. Therefore, for further research, it is important to perform this research study on more samples and more variation in aggregate types.

5. Acknowledgement

The authors would like to thank Ministry of Higher Education in Indonesia for the research grant provided to conduct this research.

References

[1] P. S. Kandhal and I. J. Rickards, "Premature Failure Of Asphalt Overlays From Stripping: Case Histories," 2001.

[2] N. D. Little and R. D. Jones, "Chemical and Mechanical Processes of Moisture Damage in HotMix Asphalt Pavements. Moisture Sensitivity of Asphalt Pavements," 2003.

[3] E. Rmeili and T. Scullion, "Detecting Stripping in Asphalt Concrete Layers Using Ground Penetrating Radar," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 1568, pp. 165–174, Jan. 1997.

[4] S. K.D, "Moisture Damage in Asphalt Mixtures- A State-of-Art Report," Washington, D.C., 1990.

[5] R. . Hicks, "Moisture Damage in Asphalt Concrete," Washington, D.C., 1991.

[6] N. P. Khosla, G. B. Birdsall, and S. Kawaguchi, "An In-Depth Evaluation of Moisture Sensitivity of Asphalt Mixtures," 1999.

[7] T. . Scholz, "Durability of Bituminous Paving Mixtures," University of Nottingham, 1995.

[8] B. M. Kiggundu and F. L. Roberts, "Stripping in HMA Mixtures: State-of-the-art and Critical Review Of Test Methods," 1988.

[9] J. Grenfell, N. Ahmad, Y. Liu, A. Apeagyei, D. Large, and G. Airey, "Assessing asphalt mixture moisture susceptibility through intrinsic adhesion, bitumen stripping and mechanical damage," *Road Mater. Pavement Des.*, vol. 15, no. 1, pp. 131–152, Jan. 2014.

[10] W. Wati, "Pengaruh Penambahan Bahan Alami Lateks (Getah Karet) Terhadap Karakteristik Campuran Hot Rolled Sheet Wearing Course (HRS-WC)," Bina Nusantara University, 2015.

[11] Badan Standardisasi Nasional, *Campuran beraspal, Metode pengujian dengan alat Marshall*. 1991.

[12] TxDOT, "Test Procedure for Cantabro Loss." 2014.

[13] V. S. Arrieta and J. E. C. Maquilón, "Resistance to Degradation or Cohesion Loss in Cantabro

Test on Specimens of Porous Asphalt Friction Courses," *Procedia - Soc. Behav. Sci.*, vol. 162, pp. 290–299, 2014.