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THE INFLUENCE OF ENVIRONMENTAL FACTORS AND CURING PERIOD TOWARDS THE PERFORMANCE AND DURABILITY OF ASPHALT MIXTURES

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ABSTRACT

The aim of this study was to provide up-to-date information about the influence of curing period and environmental factors, that are temperature and humidity, towards the performance and durability of asphalt mixtures. To measure the performance of the mixture, several Marshall characteristics, such as Marshall stability, flow, Marshall Quotient (MQ), Void Filled with Asphalt (VFA), Void in the Mix (VIM) and Void in Mineral Aggregate (VMA) are used in this study, whereas Marshall Retained Stability is used to measure the durability characteristic of the mixtures. The mixtures are developed according to two standard specifications, that is, SKBI – 2.4.26.1987 UDC : 625.75 (02), the old specification, on which the mixtures, AC mixture, is compacted as many as 150 blows (75 times per face). Another specification used in this study is the new specification for hot mixture proposed by Department of Public Work (2001), on which asphalt mixture, named HMA-PRD, is compacted in two phases, that is, phase 1 and 2 with total 150 blows and 400 blows, respectively. After the compaction, the mixture then is cured in different curing period and in several conditions, that is, indoor and outdoor conditions with different levels of temperature and humidity. The result indicates that curing period has dominant effect on the mixtures stiffness. Actually, temperature and humidity factors also contribute to the results; however, it depends on the location of the mixtures cured and also the climates. The durability test results that the longer the curing period and the higher the temperature are, the more durable the mixtures will be. Another result of this study is the new-specification mixture, HMA-PRD, is more superior than the old-specification mixture in stiffness and durability parameters.

***Keywords**: Asphalt Mixtures, Curing Period, Environmental Factors, Performance, Durability*

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ABSTRAK

Tujuan dari penelitian ini adalah untuk memberikan informasi terkini mengenai pengaruh periode curing (waktu jeda antara saat sampel selesai dibuat dengan waktu pengujian) dan faktor lingkungan (suhu dan kelembaban) terhadap kinerja dan durabilitas dari campuran beraspal. Dalam studi ini, untuk mengukur kinerja dari campuran beraspal digunakan beberapa parameter Marshall, seperti Marshall stability, flow, Marshall Quotient (MQ), Void Filled with Asphalt (VFA), Void in the Mix (VIM) dan Void in Mineral Aggregate (VMA). Sedangkan untuk mengukur durabilitas campuran beraspal digunakan parameter Marshall Retained Stability. Campuran beraspal dibuat dengan mengacu pada 2 (dua) standard, yaitu yang pertama, SKBI – 2.4.26.1987 UDC : 625.75 (02), dimana campuran beraspal dipadatkan sebanyak 150 kali (75 kali per muka), untuk mendapatkan apa yang dinamakan campuran beton aspal (asphalt concrete/AC). Standard kedua yaitu standard baru Bina Marga (2001), dimana campuran beraspal dipadatkan sebanyak 2 (dua) fase, yaitu fase 1 dengan jumlah pemadatan sebanyak 150 kali dan fase 2 dengan jumlah pemadatan 400 kali. Hasil dari proses pemadatan dua fase ini adalah campuran beraspal hot mixture asphalt – percentage refusal density (HMA – PRD). Sesudah proses pemadatan, campuran beraspal kemudian disimulasikan dengan beberapa periode curing dan dua kondisi curing yang berbeda, yaitu curing di dalam dan di luar ruangan, dengan beberapa tingkatan suhu dan kelembaban. Hasil yang diperoleh dari studi ini mengindikasikan bahwa periode curing mempunyai pengaruh yang dominan terhadap kekuatan campuran. Sebenarnya faktor suhu dan kelembaban juga mempunyai kontribusi terhadap bertambah atau berkurangnya kekuatan campuran, namun hal ini tergantung dari lokasi dimana proses curing dilakukan dan tergantung juga pada pengaruh cuaca, terutama pada saat proses curing dilakukan di luar ruangan. Pengujian durabilitas campuran beraspal memberikan hasil bahwa semakin panjang periode curing dan semakin tinggi suhu di lokasi curing, maka campuran beraspal akan semakin awet (durable). Hasil lain yang diperoleh dari studi ini adalah campuran beraspal HMA-PRD menunjukan kinerja dan durabilitas yang lebih superior dibandingkan dengan kinerja dan durabilitas campuran beton aspal (AC).

***Kata Kunci** : Campuran Aspal, Periode Curing, Faktor Lingkungan, Kinerja Aspal, Durabilitas*

INTRODUCTION

Nowadays, many researches related with pavement material and designs are conducted so that it is expected that the result of the researches can improve the efficiency of construction process and lengthen the service life of the pavement.

However, the field condition often does not reflect what the pavement design and research result expected of which there are many pavements in Indonesia tend to be easy to deteriorate. Several factors are considered as the causes of this condition, such as low quality material used, construction process that does not follow the procedures and the influence of unpredicted environmental factors. Actually, the first two aforementioned factors can be solved by obeying the appropriate specification and procedures. And the last factor, to date, is still in active research and interesting to be analyzed. Two environmental factors that are considered as important factors to be researched in this study are moisture content (in term of humidity) and temperature. In this study, the influence of those two factors will be analyzed especially at the time when the pavement mixture has already been compacted and the road is ready to open to traffic.

Besides the two factors, the length of curing period of the road pavement before it is ready to open to traffic is also an interesting topic to be researched. Setiadji (2000) considered that the environmental factors and length of curing period had a significant influence on pavement performance and durability. And the inappropriate treatment of these factors cannot optimize the performance of the pavement mixture.

In this study, a comprehensive analysis of the influence of environmental factors and length of curing period was conducted. Two types of mixture were employed, that is, Asphalt Concrete (AC) and new hot mixture asphalt (HMA) used in Indonesia, named as HMA tested following percentage refusal density (PRD) test or HMA-PRD.

Objectives Of The Study

Three objectives defined in this study were:

a. To derive the optimum curing period conducted throughout a series of laboratory works
b. To obtain a correlation factor between environmental factors specified in the specification, especially temperature, and the environmental factors commonly encountered in Indonesia
c. To compare the characteristics of AC and HMA-PRD.

The Related Topic Of Curing Period In Previous Studies

Curing period is an interesting topic to be researched since during this period, the influence of environmental factors can affect the stiffness of the pavement to resist towards the traffic load. However, how much the influence of this factor that has to be considered during curing period is still questionable. Because the influence of two components of environmental factor, that is temperature and humidity (in the term of relative humidity), is often considered not significant enough, compared with the influence of water (in the form of rain or flood), to affect the strength of pavement in achieving its optimum strength during the curing period.

Before achieving the optimum strength, the performance of the mixture can drop fast if it is exposed to the traffic. How long the curing period needed by the mixture to achieve the optimum strength required further research. Setiadji (2000) and Crause et al (1981) indicated that asphalt mixtures tend to have certain period to achieve its optimum strength. Based on Setiadji work, the curing period between one to three days was needed to achieve its optimum strength. After this period, the mixture was predicted more durable to resist to load and environmental influence. However, before this optimum strength achieved, the mixture was more fragile.

Horan (2001) mentioned that the period of oven curing at 120° C was about 2 hours for mixture having water absorption less than 2.5%. For mixture with water absorption more than 2.5%, the period of oven curing was about four hours. North Central Superpave Center (NCSC) in 1999 also conducted a research about superpave mixture and summarized that the period of oven curing for superpave mixture was about 4 hours.

RESEARCH METHODOLOGY

a. Preparing and testing material
   The aggregate and filler (stone dust) used in this study came from Mangkang - Semarang quarry, while the asphalt used was Esso-type with penetration 60/70. All material used has been tested and fulfilled Indonesia material standard specification (SNI). Regarding to the material requirements, HMA-PRD has higher requirements than that of AC, such as flakiness and elongation indices that equal to 10%. The value of the same parameter for AC is 25%.

b. Mixing and treating samples
   Asphalt mixture in the form of briquettes was prepared using aggregate gradation according to SKBI – 2.4.26 1987 UCD : 625.75 (02) (Department of Public Works, 1987) for AC and HMA-PRD standard specification (Department of Public Works, 2001). The specification used by both mixtures has major differences, especially in mixture requirements and test procedures. The differences in mixture requirements are depicted in Table 1. The procedure of mixing is similar for both methods; however, the procedure of compaction is quite different. AC mixture is compacted only once with 75 blows per face (total 150 blows). Meanwhile, HMA-PRD is compacted in two phases. The first compaction is conducted with 75 blows per face. The samples for the second compaction are made using the asphalt content of the samples of the first compaction at void in the mix (VIM) = 4.9 – 5.9%. This mixture then is compacted with 400 blows per face (total 800 blows). In this study, before being compacted, the samples were treated towards the influencing factors researched as follows.
   - Treatment towards curing periods (12, 24, 36, 48, 60 and 72 hours) at ambient temperature
   - Treatment towards temperatures (21, 23, 25, 27, and 29°C) and humidity (outdoor condition, indoor at ambient temperature and air-conditioned indoor condition) at one-day curing period.

c. Marshall test and determining optimum asphalt content
   After being treated towards influencing factors and compacted, each sample was tested to determine its Marshall properties. Seven properties used to determine the performance of each sample and the optimum asphalt content; that were, unit weight, stability, flow, void in the mix (VIM), void in mineral aggregate (VMA), void filled

with asphalt (VFA) and Marshall Quotient (MQ) (see Table 1).

d. Determining the durability characteristic of the mixture
To find out the durability characteristic of the mixture, the samples at optimum asphalt content were immersed in water at 60° C for different periods, that were, 1, 4 and 7 days. The capability of the mixture to withstand towards deterioration after immersion in water at 60° C for a certain period was measured in a parameter named Marshall Retained Stability (%). The mixture with minimum 75% of Marshall Retained Stability is categorized as the mixture with high durability.

RESULTS OF THE STUDY

The results of this study are depicted in Fig. 1 to 5 and Tables 1 and 2. All figures in the following section are based on the results produced by AC and HMA-PRD mixtures at optimum asphalt content. For HMA-PRD, because of several factors, such as the difficulty to find out high-quality composing material, especially aggregate, that can fulfill the requirements and the strict procedure that must be followed, many samples failed to fulfill the mixture requirements and only the rest of them can be displayed. The testing results of HMA-PRD that can fulfill the material and mixture requirements (after second phase of compaction) are showed as solid markers in Fig. 1 and 3.

The Influence of Curing Periods towards Mixture Performance

A significant result in Marshall Stability parameter are exhibited by both types of mixture for which at increasing curing period, the stability value of the mixture trends to increase (see Fig. 1). Meanwhile, other Marshall properties increased or decreased in non-significant values.

The stability value of HMA-PRD was seemed to be higher than that of AC and the flow was lower than that of AC. This is caused by more compaction efforts applied on this mixture rather than that of AC.

The void properties (VMA, VIM and VFA) of the mixtures did not show any significant improvement by lengthening the curing period. Among the three void parameters, VIM parameter changed in the highest rate. It was also noted that VIM and VFA value of HMA-PRD were extremely different compared with AC's. Again, this was caused by high compaction effort applied and only occurred after 72-hour curing period since only at this period, all Marshall properties can fulfill the requirements. Two properties commonly failed to be fulfilled by mixtures at other curing period, that were, VIM and VMA. With low VIM requirement after the first phase of compaction, it was difficult for the mixtures to fulfill the minimum VIM and VMA requirements specified for the second compaction. Even, several mixtures had negative value of VIM indicating that the mixture was proceed to bleeding.

The Influence of Temperature towards Mixture Performance

The correlation between temperature and humidity at outdoor and indoor condition can be seen in Fig. 2. The different correlation of temperature and humidity at indoor, as depicted in Fig. 2b, can be occurred since the treatment towards each temperature was not conducted in continuous period. So, the addition of water vapour into the room at the period between two treatments could be the reason why high humidity can be occurred at high temperature at AC room.

The largest effect of temperature towards mixture performance was actually the effect of temperature towards asphalt; therefore the analysis conducted was always related to viscosity characteristic of asphalt. Whereas, the effect of humidity towards mixture performance analyzed how much this moisture that is infiltrated into the mixture can deteriorate the mixture.

The combination of temperature and humidity can reduce sharply the Marshall Stability value of the mixture (see Fig.3). The decreasing of stability value was followed by the increasing of flow of the mixture until it reached certain temperature (as extreme point) and then the flow line was curved down. One reason of this result was at high temperature; the asphalt was liquid enough to flow in into the voids and it yielded a more-compacted mixture. This reason was supported by the facts that VIM and VMA values decreased and VFA increased after that temperature. It was interesting to know that in this study this extreme point was occurred around 25° C. It means that based on Fig. 3, the temperature before 25° C is better to cure the mixture than the temperature after 25° C. However, this summary still needed further research to know the influence of humidity on the continuous period at increasing temperature.

The pattern of increasing or decreasing of Marshall properties was also occurred on HMA-PRD in the similar way (see solid markers in Fig. 3). However, from the figures, it can be summarized that HMA-PRD is more superior than AC in the performance.

The Influence of Humidity towards Mixture Performance

As shown in Table 2, the stability value of the mixture at indoor condition generally is higher than that of the mixture at outdoor condition and the flow value exhibits the opposite. It seemed obvious that humidity also influenced the void, on which the mixture treated towards humidity at outdoor condition had VIM relatively high and VFA relatively low than that of the mixture treated towards humidity at indoor condition. It is noted at outdoor condition the relative humidity can be higher than the relative humidity at indoor condition, especially when the temperature is drop at night until dawn. At that temperature, the probability of the humidity to achieve dew point (the temperature at which the air becomes saturated and produces dew) is higher. The content of water vapour in the air at outdoor condition then will be the dominant effect on the decreasing of stiffness of the mixture. This could be the reason why the stability value of the mixture at outdoor condition was generally lower than the stability value at indoor condition. Another interesting finding based on Table 2 is that HMA-PRD is less stiffness than AC. One reason of this finding was the mixture has not achieved its optimum strength when the treatment was conducted (the mixture was treated towards humidity directly after it has finished to be compacted).

Analysis of Durability Test

Fig. 4 shows that the longer the mixture is cured, the more durable the mixture will be. All samples still can fulfill the minimum requirement for durability characteristic; that was minimum 75% of Marshall Retained Stability, after 3-day immersion in water at 60° C. However, after 7-day immersion, almost all samples were failed to retain their durability and felt under the minimum requirements, except 2 samples; that were, two 72-day curing samples for both mixtures, AC and HRA-PRD. Surprisingly, although the decreasing rate of the Marshall stability was higher on HMA-PRD than that of AC (6.4% and 4.5%, for HMA-PRD and AC, respectively), Marshall Retained Stability of HMA-PRD after immersion was still higher than that of AC, that was, 94.8% and 78.1.8%, respectively. The HMA-PRD samples also exhibited their superiority compared with AC samples in durability characteristic after they were treated towards temperature, as shown in Fig. 5. The Marshall Retained Stability for all HMA-PRD samples were higher than that of AC's after 7-day immersion in water at 60° C, even HMA-PRD samples treated towards temperature 29° C still can fulfill the minimum requirement of the durability test after the end of the test. Therefore, it can be summarized that HMA-PRD mixture is more durable than AC mixture.

CONCLUSIONS

1. The longer the curing period is, the higher the stability value of the mixture will be. Regarding to test result, the mixture cured for a certain period will have maximum stability value and then starting to decrease. However, no curing period recommended in this study since there still is an increasing on the stability value even after 7-day curing period.
2. Temperature and humidity contribute an important effect on the mixture performance. However, no temperature can be recommen-ded as curing temperature at indoor condition for the mixture after compaction. At outdoor condition, humidity has significant influence towards the decreasing of the mixture stiffness, especially at night until dawn when the relative humidity is relatively high.
3. In durability test, the longer the curing period is, the more durable the mixture will be. Based on the test result in this study, the mixtures treated towards 7-day curing period and high temperature (in this case, 29° C) are more durable than mixture with other types of treatment.
4. The performance of HMA-PRD was still better than AC in terms of stiffness and durability characte-ristics.

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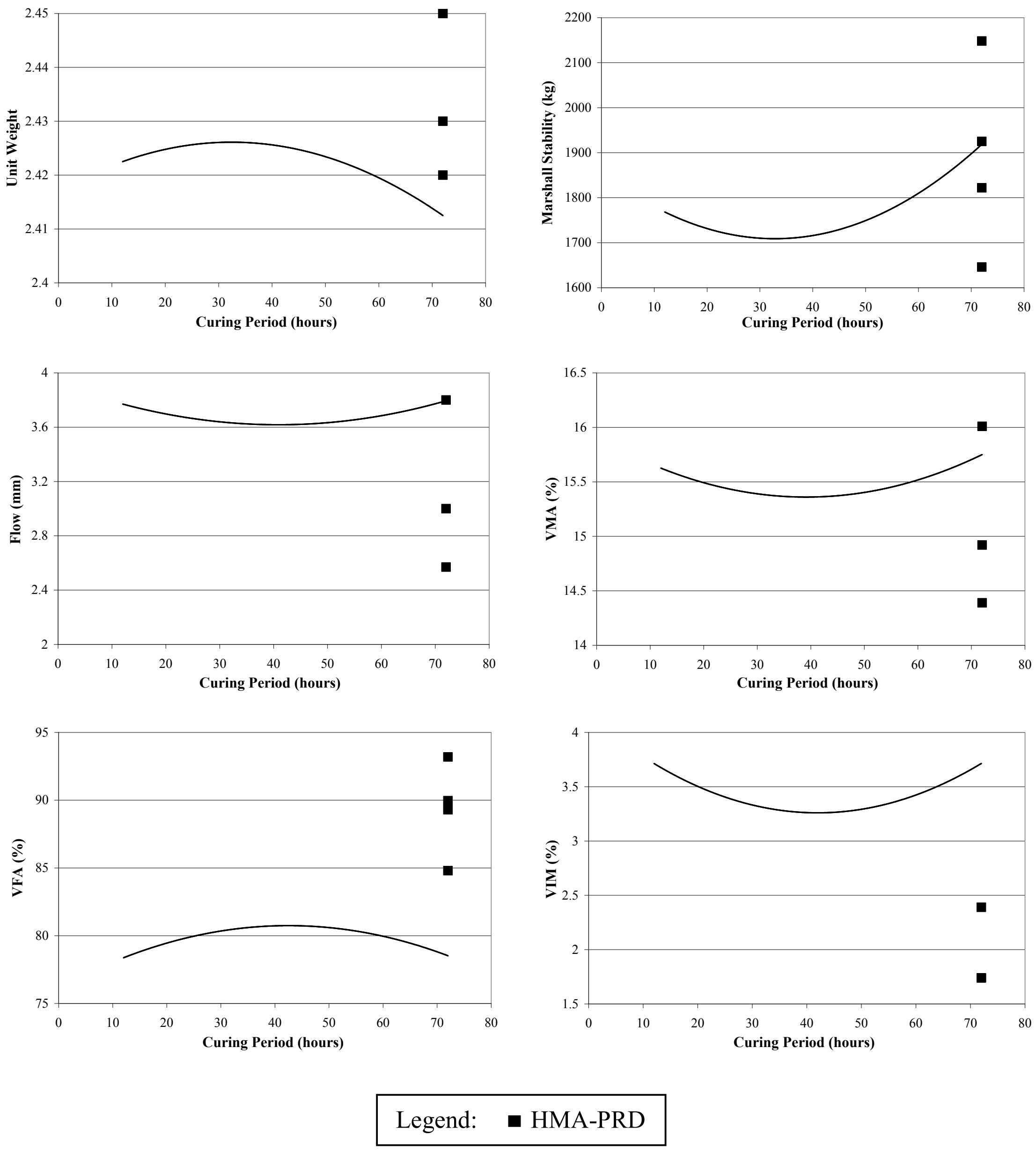


Figure 1. Marshall Properties of Asphalt Mixtures Treated towards Curing Period

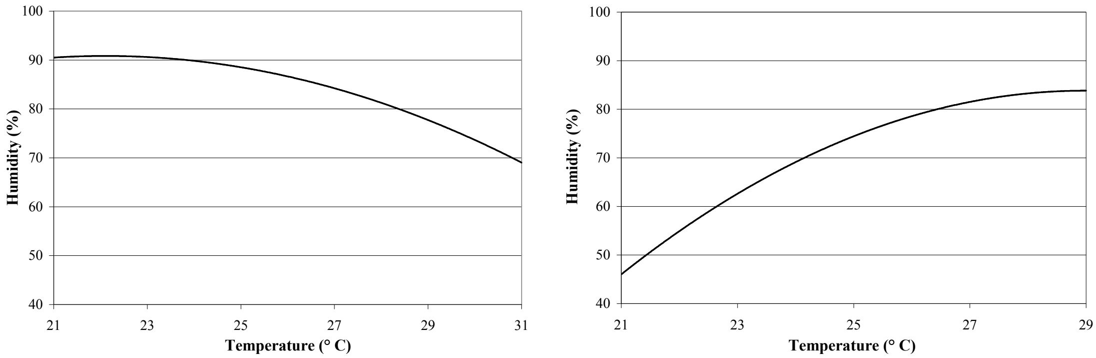
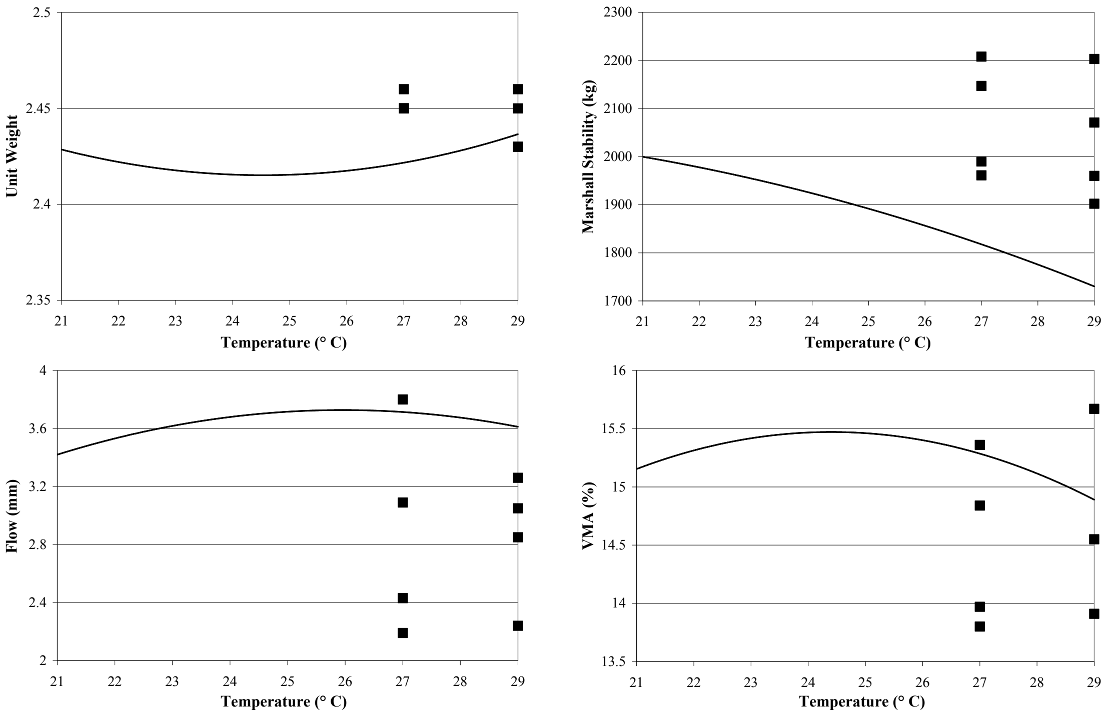


Figure 2. Correlation between Temperature and Humidity:
(a) outdoor and (b) indoor condition



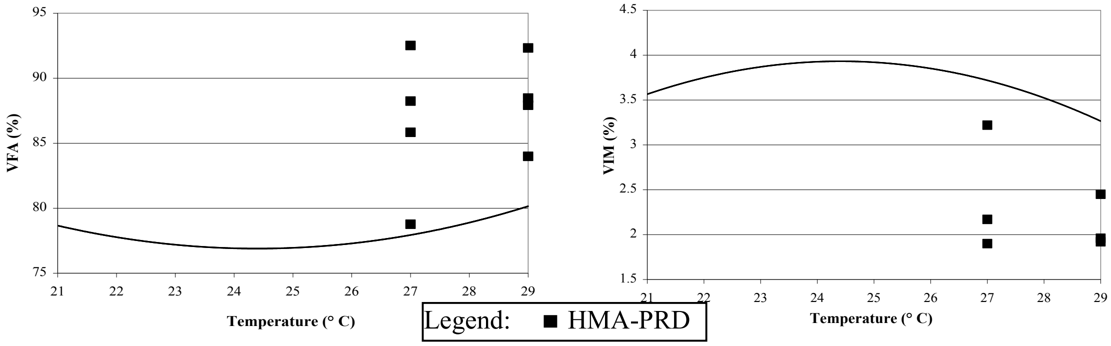


Figure 3. Marshall Properties of Asphalt Mixtures Treated towards Temperature

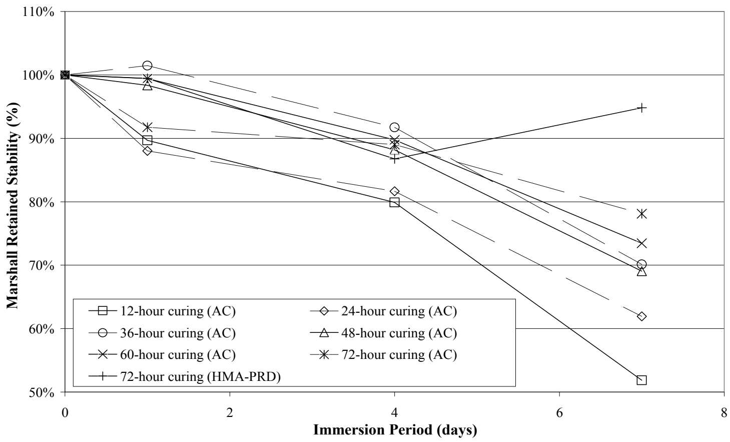


Figure 4. Durability Characteristics of Asphalt Mixtures Treated towards Curing Period

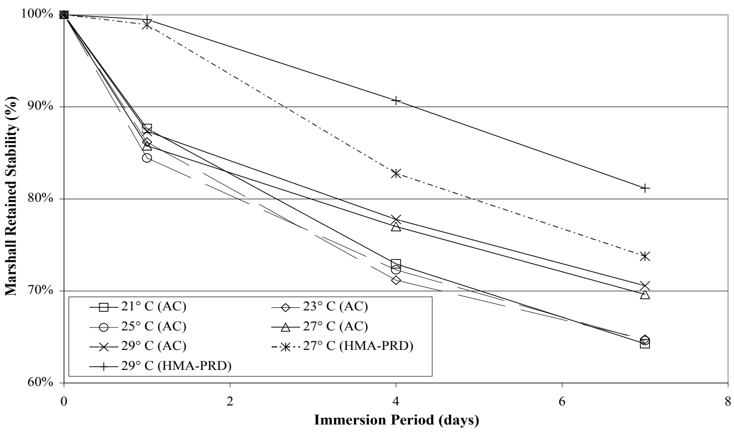


Figure 5. Durability Characteristics of Asphalt Mixtures Treated towards Temperature

Table 1. The Mixture Requirements for AC and HMA-PRD

Parameter	Mixture requirements		
	HMA-PRD		AC
Asphalt absorption (%)	Traffic > 1 million ESAL[1] Traffic < 1 million ESAL	Max. 1,2 Max. 1,7	N/A
No. of compaction blows per face		75	75
Void in the Mix (VIM, %)	Traffic > 1 million ESAL 0,5 million ESA < Traffic < 1 million ESAL Traffic < 0,5 million ESAL	Max. 5,9 Min. 4,9 Max. 4,9 Min. 3,9 Max. 6,0 Min. 3,0	Max. 5 Min. 3
Void in Mineral Aggregate (VMA, %)		Min. 15	Min. 15[2]
Void Filled with Asphalt (VFA, %)	Traffic > 1 million ESAL 0,5 million ESA < Traffic < 1 million ESAL Traffic < 0,5 million ESAL	Min. 65 Min. 68 Min. 75	N/A
Marshall Stability (kg)		Min. 800	Min. 550
Flow (mm)		Min. 2	Max. 4 Min. 2
Marshall Quotient (kg/mm)		Min. 200	Max. 350 Min. 200
VIM at PRD (%) (with 400-blow compaction)	Traffic > 1 million ESAL 0,5 million ESA < Traffic < 1 million ESAL Traffic < 0,5 million ESAL	Min. 2,5 Min. 2 Min. 1	N/A

Keterangan : [1] ESA = Equivalent Standard Axle
[2] This research used aggregate with maximum nominal size ½ inch and VMA min. 15%

Table 2. Average Marshall Property Values on Several Humidity Conditions

Humidity	Unit Weight	VIM	VMA	VFA	Stability	Flow	Marshall Quotient
	gr/cm3	%	%	%	kg	mm	kg/mm
			AC Mixture				
Outdoor	2.41	4.09	15.83	76.46	1764	3.44	506
Outdoor	2.42	3.67	15.46	78.40	1600	3.49	477
Outdoor	2.42	3.62	15.43	78.70	1778	3.78	460
Indoor	2.42	3.56	15.36	78.98	1779	3.57	519
Indoor	2.42	3.71	15.50	78.23	1835	3.15	578
			HMA – PRD Mixture				
Outdoor	2.39	5.07	16.45	71.56	1473	4.46	340
Outdoor	2.37	5.76	17.05	68.76	1386	4.35	325
Outdoor	2.35	6.51	17.72	65.72	1377	4.79	287