

Evaluation of Binder Absorption in Asphalt Mixture with Various Aging Conditions Using Rice Method

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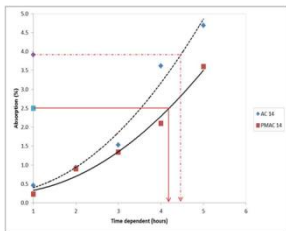
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Graphical abstract



Abstract

This study evaluated the effect of time dependent on the binder absorption of asphaltic concrete by comparing between Asphaltic Concrete 14 (AC14) and Polymer Modified Asphaltic Concrete14 (PMAC14) through rice method and subjected to aging. The stability of the samples was also examined. Two asphalt cements (60/70 and PG76) were used in this study. The result shows that the stability and binder absorption under long term aging is highest than that of short term and un-aged. In addition, the binder absorption has been found to follow a polynomial relationship with time-dependent.

Keywords: Asphaltic concrete; polymer; aging; absorption; stability

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1.0 INTRODUCTION

Absorption is a very complex subject. Although some absorption may lead to improved strength in compacted mixtures due to mechanical interlocking, the portion of the asphalt which is absorbed is not available for binding the aggregate particles together in the asphalt paving mix [1]. In addition the time dependence of absorption can lead to incorrect estimation of air voids, an important parameter in asphalt mix design. Furthermore, if selective absorption occurs, then the non-absorbed asphalt may have different physical, rheological, and chemical properties than the original asphalt to such an extent that the non-absorbed asphalt would behave much differently than the original asphalt as a binder. Little is known about selective absorption [2]. Study in the time-dependent phenomenon of asphalt absorption especially in a view of the storage of Hot Mix Asphalt (HMA) in silos or transportation over long distances to the paving site is very important [3]. Asphalt absorption is an important property of asphalt mixture. However the absorption of asphalt by mineral aggregates can occur over a long period of time in hours, days or months after the pavement is placed [4]. Previously, Panda and Mazumdar [5] and Murphy et al. [6] stated that if the absorption is fast enough and essentially completed during the mix design procedure, this is adequate. However, if the absorption rate is slow, the need for additional asphalt content cannot be determined

during the mix design, resulting in the mixes will eventually have too little asphalt content [7]. Adding extra asphalt to the slow absorbing aggregate also causes problems because the mix is over-asphalted when placed and will be tender and difficult to compact. The mix may also flush initially in the pavement. Some absorption may lead to improved strength in a compacted mixture through particle interlocking; the portion of the asphalt that is absorbed is no longer available as binder [8]. The situation is further aggravated because of the time-dependent nature of the absorption phenomenon. In view of the above consequences, the absorption of asphalt by mineral aggregates in the pavement mixture needs to be further studied. Hence, this study was conducted to investigate the effect of time dependent on the absorption of asphaltic concrete.

2.0 MATERIALS AND EXPERIMENTAL PROCEDURES

2.1 Binder And Aggregate

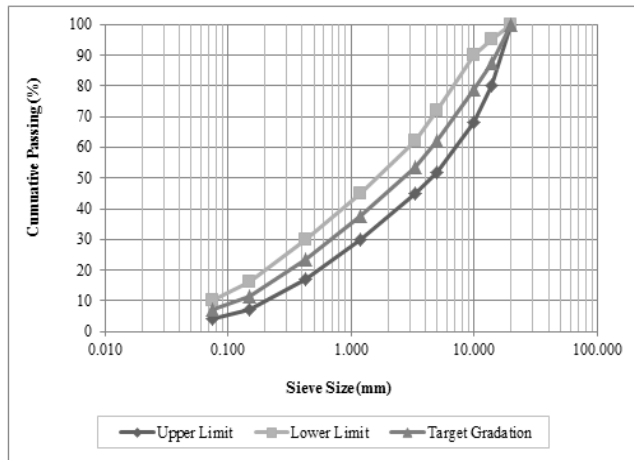
The binder used in this study was a conventional penetration grade 60/70 and polymer modified binder, PMB (PG76) supplied by Shell Malaysia. Both grade 60/70 and PG70 bitumen was heated at 100°C for a period of 1 hour before adding to the

aggregate mixes. Aggregates (granite type) were supplied by Kim Seng Quarry Sdn. Bhd. with the average density is 2.75 g/cm³.

2.2 Gradation

In this study, the gradation of the aggregates met the requirements for the median gradation of the Malaysian Public Works Department, AC14 [9] as shown in Figure 1.

Figure 1 Asphaltic concrete gradation for AC14



2.3 Marshall Stability

Marshall Stability was carried out on compacted samples according to ASTM D5581-07 [10]. The stability test is an empirical test in which cylindrical compacted samples, 100mm diameter by approximately 63.5 mm height are immersed in water at 60°C for 30 to 40 minutes. The Marshall stability value is the maximum force recorded under compression.

2.4 Absorption By Rice Method

Rice Method is used to determine the theoretical maximum density, also called the void free density of asphalt mixes using loose mix. The theoretical maximum density is used to calculate the void content of asphalt mixes. The equipment and procedures for conducting this test were referred to ASTM D2041 [11]. On the other hand, to determine the binder absorption, the total volume of the aggregates (bulk density) and binder used were measured.

2.5 Aging Of Bitumen Mixtures

Short term aging (STA) simulates the pre-compaction of the construction phase while long term aging (LTA) simulates aging over the service life of the pavement from 10 to 15 years. In the laboratory, aging of samples was conducted according to AASHTO R30-02 [12]. For STA, laboratory prepared sample of loose mix asphalt was placed in a tray and conditioned in a forced draft oven for 4 hours at the mix compaction temperature. For LTA samples, the loose mix was aged in a forced draft oven at 85°C for 120 hours. Both samples type will be subjected to rice method after conditioning.

3.0 RESULTS AND DISCUSSION

3.1 Stability

The results of the Marshall Stability test at various aging conditions are presented in Figure 2. Generally, the stability of asphaltic concrete AC14 (added with 60/70 PEN bitumen) and PMAC14 (added with polymer modified bitumen) increases after every aging stage. For instance, the stability of AC14 increases by almost 12.3% after STA and 16.1% after LTA. On the other hand, the stability of PMAC14 increases by 21% and 22% after STA and LTA respectively. It shows that aging process causes oxidation and increases the hardening rate of the bitumen, thus resulting in an increment in stability. This phenomenon is usually termed as age-hardening [13].

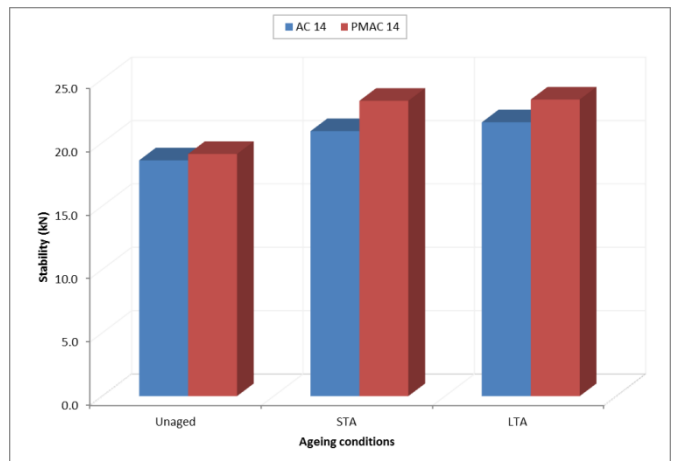


Figure 2 Stability of asphaltic concrete AC14 and PMAC14 at different aging

3.2. Voids of Mixture

Voids in Total Mix (VTM) are the volume of pockets of air voids between the aggregate particles of a compacted mix. The VTM of the specimens tested increases after every aging session as show in Table 1. For instance, for AC14, the VTM of un-aged specimens was 4.2%. However, when subjected to different aging period, the VTM was increased approximately 4.5% and 4.8%, respectively for STA and LTA. According to JKR specification [9], the VTM should range between 3% to 5%. Thus, the results meet the JKR specification. From the results of the investigation summarized in Table 1, the Voids filled with Bitumen (VFB) increase after short and long term aging. Generally, the VFB should be in range of 70% to 80%. Therefore, the VFB results in this study meet the JKR requirement. Generally, it can be concluded that the hardening of bitumen appears to increase the VTM and VFB.

Table 1 VTM and VFB mixture before and after aging session

Properties	Un-aged		Short Term Aging		Long Term Aging	
	AC14	PMAC14	AC14	PMAC14	AC14	PMAC14
VTM	4.2	3.0	4.5	3.6	4.8	4.6
VFB	71	73	75	77	78	80

3.3 Determination Of Binder Absorption Before Aging

The binder absorption of asphaltic concrete AC14 and PMAC14 was analysed using rice method and the results are summarized in Table 2. The values reported in Table 2 are averaged from three samples which were tested without aging the samples. The corresponding comparisons for test results show that the percentage binder absorption for AC14 is 3.91% and 2.5% for PMAC14.

Table 2 Binder absorption of AC14 and PMAC14 before aging

Time dependent	Absorption (%)	
	AC 14	PMAC 14
0 hour (no aging)	3.91	2.50

3.4 Determination Of Binder Absorption Under Short Term Aging

Most asphalt mixes contain both coarse and fine aggregates, and the binder presents in a form of thin films which coats the aggregate surface. In this investigation, the results of binder absorption were plotted versus time as shown in Figure 3. The result for all samples indicates that binder absorption increases with the aging time. The binder absorption values of AC14 for one-hour of aging in the oven are generally quite close to the values of PMAC14, as can be seen in Figure 3. However, the 5 hours Rice absorption is somewhat higher than the 1 hour immersion method. This indicates that one-hour immersion method indeed gives considerably less binder absorption. Based on these observations, determination of the effective time dependent for binder absorption was calculated when the line for un-aged and short term aging is intersecting between each other. Therefore, based on Figure 3, the effective time-dependent for binder absorption of AC14 can be found at 4.3 hours. On the other hand, the effective time dependent for binder absorption of PMAC14 is found at 4.1 hours.

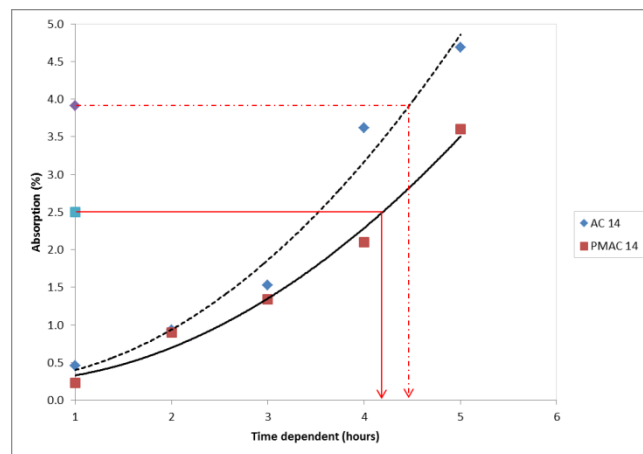


Figure 3 Relationship between binder absorption and time after short term aging

3.5 Determination Of Binder Absorption Under Long Term Aging

The results of the binder absorption versus time for long-term aging are graphically illustrated in Figure 4. Generally, the results show that the binder absorption increases as time-dependent also increased. After 5 days of aging, the absorption values are significantly higher than 1 day absorption values. This again indicates the time-dependent nature of the absorption phenomenon [14]. As shown in Figure 4, the average binder absorption values follow almost a polynomial curve when plotted against aging time. The coefficients of the correlation (R^2) for the curves are 0.98 and 0.94 for AC14 and PMAC14 respectively. This shows that the binder absorption at anytime can be predicted if the absorption is determined at 0 time and two other times initially [15, 16, 17]. This was further confirmed by plotting the binder absorption data reported by Hamzah et al. [18] for geometrically cubical aggregates mixes. Based on the figure it is found that the effective time-dependent for binder absorption of AC14 and PMAC14 is about 4.1 days and 3.8 days accordingly.

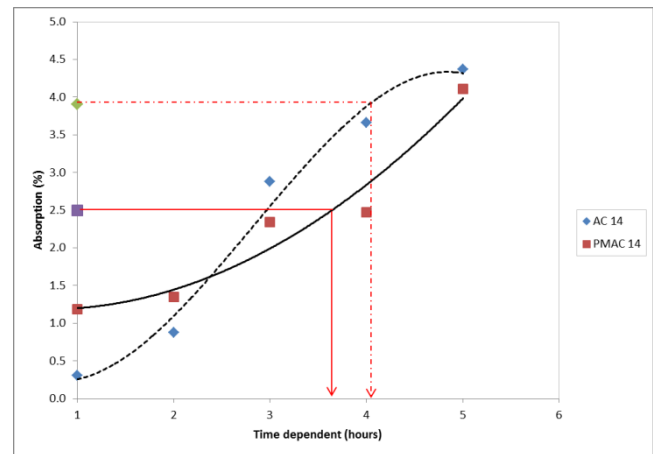


Figure 4 Relationship between binder absorption and time after long term aging

4.0 CONCLUSION

Based on the data obtained for the three different aging techniques with two bitumen types, the following conclusions can be made:

- The stability of samples for AC14 and PMAC14 increases after every aging period where PMAC14 shows the highest increase. Long term aging is found to increase higher stability compared to others due to age hardening.
- The binder absorption is found to follow a polynomial relationship with time-dependent. Based on this relationship, the whole course of binder absorption with time-dependent can be determined.

Acknowledgement

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