VOL. 11, NO. 20, OCTOBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EFFECTS OF AIR VOIDS CONTENT ON THE PERFORMANCE OF POROUS ASPHALT MIXTURES

Norhidayah Abdul Hassan, Mohd Zul Hanif Mahmud, Nurainaa Adi, Noraziela Rahmat, Mohd Rosli Hainin and Ramadhansyah Putra Jaya
Faculty of Civil Engineering and Transportation Research Alliance, Universiti Teknologi Malaysia, Skudai, Malaysia
E-mail: mohdzulhanif@gmail.com

ABSTRACT

This study evaluates the effects of different air voids content on the resilient modulus, abrasion loss and permeability of porous asphalt mixture. One of the main issues with porous asphalt mixture is having an adequate amount of air voids content for its performance. High air voids content will increase the infiltration rate but reduces its durability and vice versa. Gyratory compacted samples were fabricated at various air void contents i.e. 17.5%, 20% and 22.5% using aggregate gradations adopted from Australian and Singaporean specifications. The samples were tested for permeability, resilient modulus and abrasion loss. From the analysis, it was found that the increase in the voids content improves the permeability but adversely affects the resilient modulus and the mixture's performance under abrasion. The resilient modulus and abrasion loss show similar pattern at low air voids content where no significant difference between both mixture types but at high voids content, finer compositions shows to be more durable. Therefore, it can be concluded that the air voids content influences the performance of porous asphalt mixtures.

Keywords: porous Asphalt, air voids, durability, abrasion loss, resilient modulus

INTRODUCTION

Porous asphalt is an open graded mixture. This mixture type is designed to provide the optimum functional and structural performance particularly the mixture's permeability, modulus and durability. However, these properties are not proportional. High air void content provided in the mixture will improve the permeability but reduces its modulus and durability [1-2]. Too much air voids also can cause the mixture having excessive aging and stripping problems. On the other hand, inadequacy of air void within the mixture will lead to the loss in permeability and clogging problem. Normally porous asphalt is designed to achieve the desired air voids content typically between 18 and 25% [2-3]. To use low fines and optimum bitumen content in the mixture is critical in order to provide adequate interconnected voids and enable water to infiltrate through the surface layer [3-4]. Therefore, this study was undertaken to investigate the effect of various air voids content on the performance of porous asphalt mixture i.e. permeability, resilient modulus and abrasion loss.

MATERIALS AND METHODS

Mixture design

The laboratory samples of the porous asphalt were fabricated based on mixture design adopted from Australia and Singapore specifications [5-6]. The mixtures were prepared to achieve the middle range envelope as plotted in Figure 1. Details of the aggregate composition for both gradations are presented in Table 1. The materials used for mixing the samples were crushed granite, performance grade bitumen (PG 76) and hydrated lime. The samples were mixed at their respective optimum bitumen content i.e. 5.25% for Australian mixture and 4.75% for Singaporean mixture.

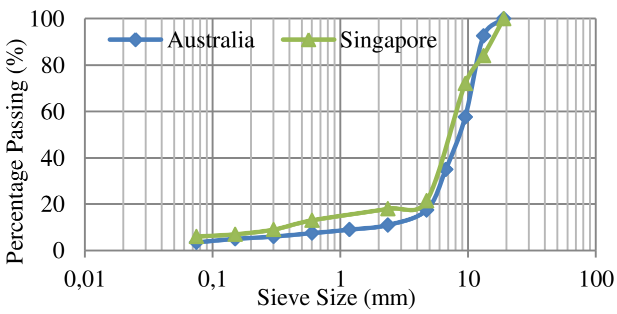


Figure-1. Aggregate gradations for porous asphalt mixtures.

Table-1. Aggregate composition for different porous asphalt mixtures.

Criteria	Mixture type	
	Australia	**Singapore**
Coarse Aggregates, %	82.5	78.5
Fine Aggregates, %	14.0	15.5
Filler, % (passing 75μm)	3.5	6.0

The blended mixtures were prepared according to ASTM D 6925 specification. The materials were mixed and compacted at 180 °C and 170 °C respectively with short-term conditioning period of 2 hours prior compaction [7]. The samples were compacted using

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Superpave gyratory compactor to achieve the desired air voids content i.e. 17.5, 20 and 22.5 % with the tolerance of ± 0.5%. A few trial samples were prepared to obtain the number of gyration required to achieve the target air voids content as shown in Figure 2. It shows that the Australian mixture (coarser gradation) requires higher number of gyration compared to Singaporean mixture (finer gradation). After the samples were compacted at the targeted number of gyration, the air voids content of the samples were determined according to ASTM D 3202 [8].

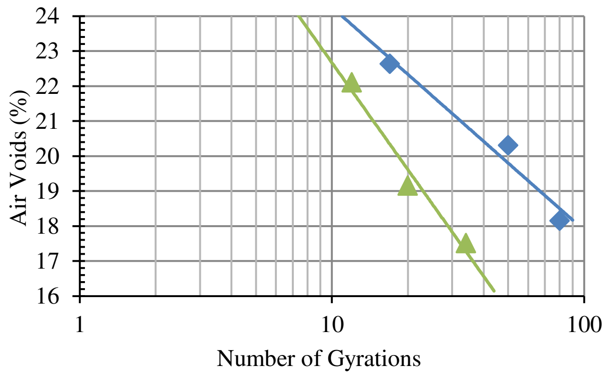


Figure-2. Air voids content against number of gyrations.

Permeability test

The permeability was measured based on falling-head method using flexible wall permeameter at room temperature of 25 °C. Permeability test was conducted to determine the rate of water transmitted through a saturated sample in accordance to ASTM PS 129 specification [9]. The discharge time of the samples were recorded once the water started to flow at a specific marked interval on the standpipe. The discharge time was used to determine the coefficient of permeability based on Darcy's Law. The measurement of the discharge time was recorded four times for each of the samples. The permeability coefficient, k (cm/s) was calculated using Equation. 1 where *A* (cross section area of sample, cm^2), *a* (cross section area of standpipe, cm^2), *l* (height of sample, cm), h_1 (initial height of water above the sample, cm), h_2 (height of the water after time, cm), and *t* (time taken for the water to fall from h_1 to h_2, second).

$$k = \frac{al}{At} \ In \left(\frac{h_1}{h_2}\right) \quad (1)$$

Cantabro test

Cantabro test concerns the determination of the particle loss under abrasion for porous asphalt mixture. The purpose of this test is to evaluate the cohesion, bonding and sustainability towards traffic abrasion for the laboratory fabricated samples [6]. This test was conducted using Los Angeles abrasion machine with the number of revolutions were fixed to 300 at 30 revolutions per minute as stated in ASTM D 7064 specification [10]. This test was conducted on unaged samples at the temperature of 25 ± 1 °C. Three samples were fabricated to the desired air voids content for each mixture type. The Cantabro abrasion loss, C_L (%) was calculated using Equation. 2 where W_1 (initial mass of the sample, g) and W_2 (final mass of the sample, g).

$$C_L = \frac{W_1 - W_2}{W_1} \times 100 \quad (2)$$

Resilient modulus test

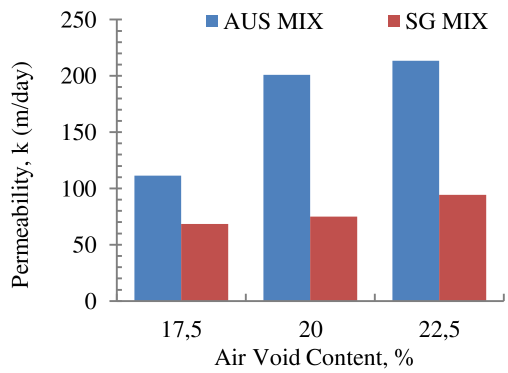
Resilient modulus test was conducted to determine the elastic properties of the materials using Universal Testing Machine (UTM) at the temperature of 25°C according to ASTM D 4123 specification [11]. Resilient modulus of the sample was measured based on the repeated-load for indirect tension test. The UTM machine was set to apply repeated peak load of 1kN to the sample in a form of haversine waveform at the frequency of 1Hz. The load duration was 0.25 s and the resting period was set to 0.75 s. A total of five repeated loading cycles were subjected to the sample at two different orientations of 0° and 90°. The estimated Poisson's ratio, μ was 0.35 [12]. The total resilient modulus, M_R (MPa) was calculated using Equation. 3 where *P* (repeated load, N), *H* (recoverable horizontal deformation, mm), *t* (thickness of the sample, mm), and *μ* (Poisson's ratio).

$$M_R = \frac{P}{Ht}(0.27 + \mu) \quad (3)$$

RESULT AND DISCUSSION

Permeability, abrasion loss and resilient modulus

Figure 3 shows the relationship of air voids content with permeability, abrasion loss and resilient modulus. Overall, it can be seen that both permeability and abrasion loss values increase with the void content while the resilient modulus reduces with the void content. As reference, the value for abrasion loss for porous asphalt mixtures was recommended not to exceed 15% [6, 10].



(a)

ARPN Journal of Engineering and Applied Sciences

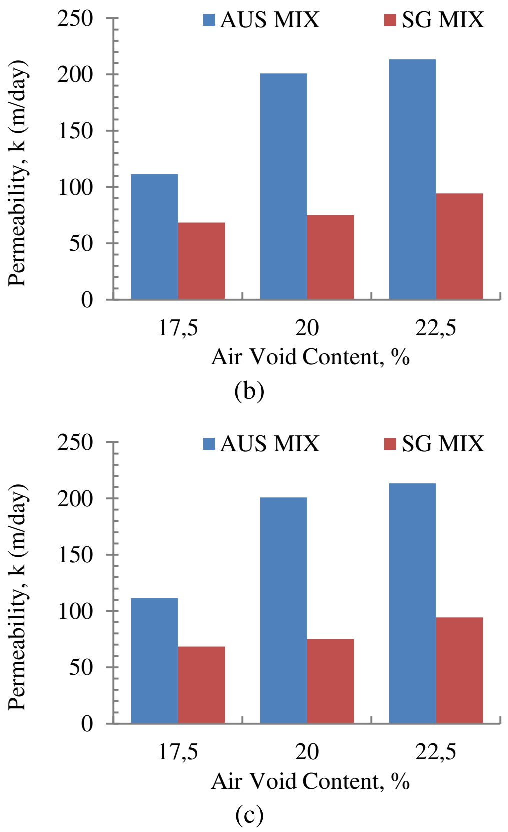


Figure-3. Relationship of air void content with (a) Permeability (b) Abrasion loss (c) Resilient modulus for Australian and Singaporean mixtures.

When comparing the mixtures, Australian mixture seems to have higher permeability rate and abrasion loss than Singaporean mixture with the increase in air voids content. This is likely due to the coarser aggregate compositions of Australian mixture compared to Singaporean gradation. High fines content in Singaporean mixture tends to cause more void spaces of being filled up thus reduces the interconnected voids that permit water to flow through the mixture. Additionally, high fines content also creates more mastic regions within the mixture that enhance the bonding strength between the aggregates. As a result, the Singaporean mixture has better resistance against particle loss under abrasion and higher resilient modulus compared to Australian mixture even at high voids content. Figure 4 compares the measured parameters of permeability and resilient modulus at different void contents for both mixtures. This relationship is significant in determining the design voids content that will optimise the mixtures' functional and structural properties. Based on the intersection point, it shows that the optimum voids content for both Australian and Singaporean mixtures are approximately 20% and 22% respectively. To achieve their best performance, Australian mixture requires less air voids content with greater permeability rate compared to Singaporean mixture due to its coarser gradation that creates better interconnectivity of the air voids. As a result, Singaporean mixture needs more voids content to compromise the permeability with excessive dust or fine materials within the mixture.

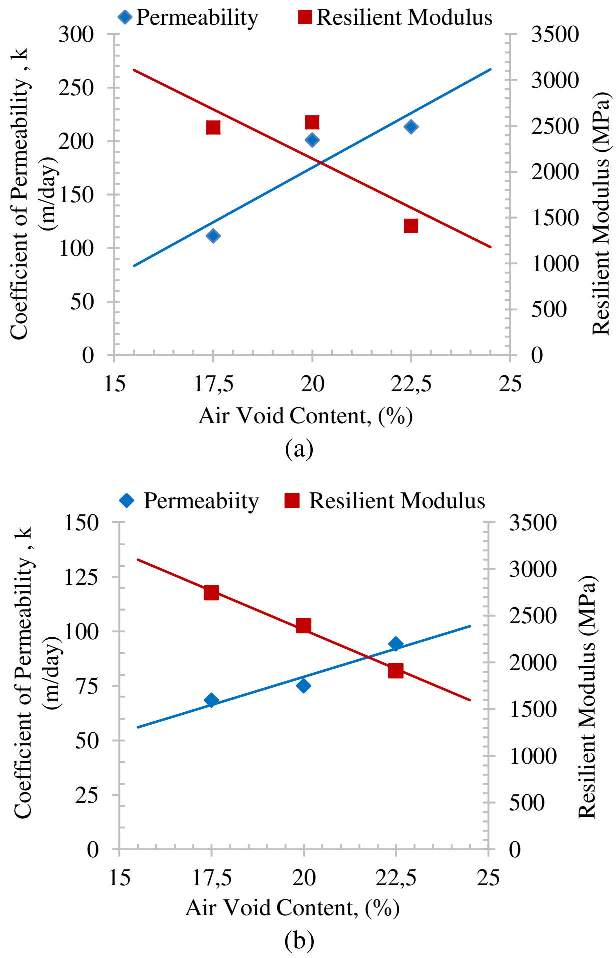


Figure-4. Relationship of air void content with permeability and resilient modulus for (a) Australian Mixture (b) Singaporean mixture

CONCLUSION

It can be concluded from the results that the air voids content affects the performance of porous asphalt mixtures in terms of permeability, abrasion loss and resilient modulus. Least fine materials in the Australian mixture has caused the mixture to become sensitive towards the changes in voids content as shown by the sudden drop in resilient modulus and large increase in permeability and abrasion loss at high voids content. Apart from that, fine aggregate mixture indicates it is more durable and resilient to deformation but produces low coefficient of permeability. Therefore, any combination of materials (aggregate composition and binder) used should possess strong cohesion and adhesion properties so that a stabilized mixture can be achieved but simultaneously maintaining an open structure of the porous mixture.

ACKNOWLEDGEMENT

The authors wish to acknowledge support from Ministry of Education Malaysia (MOE) and Universiti Teknologi Malaysia for funding this study under the research grant of GUP 09J89.

REFERENCES

[1] Hainin, Mohd Rosli, L. Allen Cooley Jr, and Brian D. Prowell. An investigation of factors influencing permeability of Superpave mixes. International Journal of Pavements 2.2 (2003): 41-52.

[2] Abdul Hassan, Norhidayah , Mohd Zul Hanif Mahmud, and Ramadhansyah Putra Jaya. Air Void Characterisation in Porous Asphalt Using X-Ray Computed Tomography. Advanced Materials Research 911 (2014): 443-448.

[3] Putman, Bradley J., and Laura C. Kline. Comparison of mix design methods for porous asphalt mixtures. Journal of Materials in Civil Engineering. 24.11 (2012): 1359-1367.

[4] Hamzah, M.O. , M. M. Samat, and R. Muniandy. Modification of aggregate grading for porous asphalt. Proceedings Of The 3rd Eurasphalt And Eurobitume Congress Held Vienna, May 2004. Vol. 1. 2004.

[5] Australian Asphalt Pavement Association. National asphalt specification. AAPA, Melbourne, (2004).

[6] Singapore, Land Traffic Authority. Materials and workmanship specification for civil and structural works. LTA, Singapore, (2010).

[7] ASTM D6925. Standard test method for preparation and determination of the relative density of Hot Mix Asphalt (HMA) samples by means of the Superpave gyratory compactor. ASTM International. (2009).

[8] ASTM D3203. Standard test method for percent air voids in compacted dense and open bituminous paving mixtures. ASTM International. (2011).

[9] ASTM PS 129. Standard provisional test method for measurement of permeability of bituminous paving mixtures using a flexible wall permeameter, ASTM International. (2001).

[10] ASTM D7064 / D7064M-08. Standard practice for open-graded friction course (OGFC) mix design. ASTM International. (2013).

[11] ASTM D4123-82. Standard test method for indirect tension test for resilient modulus of bituminous mixtures. ASTM International. (1995).

[12] Roberts, F. L., *et al*. Hot Mix Asphalt Materials, Mixture Design, and Construction. National Asphalt Pavement Association, NAPA Education Foundation, Lanham, Md., 2009.