PAPER

Effect of compaction temperature on porous asphalt performance

To cite this article: N N Luxman *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **244** 012011

Effect of compaction temperature on porous asphalt performance

N N Luxman[1], N A Hassan[1, 3], R P Jaya[2], M N Mohd Warid[1], N Mohd Azahar[1], M Z H Mahmud[1] and S Ismail[1]

[1]School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor

[2]Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

Corresponding author: hnorhidayah@utm.my

Abstract. Porous asphalt is an open-graded aggregate mixed with polymer modified binder that contains relatively high air voids after compaction to allow for water infiltration. The performance of porous asphalt, particularly the strength and durability are highly influenced by compaction temperature. Higher compaction temperature may decrease the mixture air voids, thus failed to achieve required mixture densities and reduce its ability to perform as designed. Meanwhile, lower compaction temperature could potentially increase the viscosity of polymer modified asphalt and decrease the adhesion between aggregates, hence promoted stripping problem on pavement. Therefore, this study investigates the performance of porous asphalt compacted at various temperatures. The samples were prepared by using polymer modified asphalt PG76, granite aggregates and hydrated lime as mineral filler. The materials were mixed and compacted using gyratory compactor at different temperatures. The samples were then tested for volumetric properties, Abrasion loss, Resilient Modulus, Creep and Moisture Susceptibility. Based on the results, it can be concluded that compacting the porous asphalt at low temperature will reduce its performance.

1. Introduction

Porous asphalt is designed with higher air void percentage to allow water to infiltrate through surfaces faster than conventional asphalt pavement. Normally, the recommended air voids content is between 18 and 25% to provide adequate drainability during heavy rainfall [1]. On the other hand, temperature is an important factor in asphalt pavement construction [2]. The effect of temperature is very significant particularly during the mixing, laying and compaction operations in making strong and durable pavement [3]. This is because asphalt needs to be heated to achieve the required viscosity for better adhesion. However, prolonged heating will oxidize and harden the asphalt binder that can cause severe damage to the pavement.

Willoughby et al. [4] described the material temperature plays a role in achieving overall density. The finding showed that samples compacted at 93℃ possessed double amount of air voids contained in a sample compacted at 135℃, with the air void discrepancy quadrupling when the sample was compacted at 70℃. As the HMA cools, the asphalt binder eventually becomes stiff enough to prevent any further reduction in air voids regardless of the applied compressive force [5]. One must be aware of how long it takes to cool from lay down to preserve a minimum compaction temperature. However, further attempts to compact the asphalt mixture at low temperature will not be effective. Further compaction may fracture the aggregate in the mix, decrease pavement density and frustrate the purpose of compacting [6]. If asphalt mixtures are cooler than desirable temperature, a variation in mix temperature can cause poor mix compaction leading to non-uniform densities [7]. The severe decrease in density leads to a loss of fatigue life and serviceability of the pavement [8]. One of the major problems of insufficient compaction temperature is the non-uniformity of the existing pavement surface texture.

During the compaction of porous asphalt, there is a certain limit of temperature to ensure a good performance of the pavement [9]. Maintaining temperature is the crucial part during compaction process to produce porous asphalt pavement with high air voids connectivity and good in terms of strength and durability. Low compaction temperature will affect the adhesion between aggregate and asphalt binder as well as the density due to high viscosity of the asphalt that resists compaction effort [10]. The improper compaction will result in problems such as cracking, porthole, stripping etc. that could reduce its design life. Renken [11] stated that it is strictly unacceptable to obtain a high void content by the reduction of the compaction degree. This is because a high compaction degree is decisive for the resistance against deformation and particle loss (raveling). On the other hand, Poulikakos et al. [12] stated that the Cantabro test is a special test for porous asphalt that is widely used to determine mixture resistance to particle loss by impact and abrasion from traffic as well as stripping resistance. Rodriguez-Hernandez et al. [13] stated that the air void content and permeability of porous asphalt mixtures influence the resistance to abrasion loss. This is due to the high surface area exposed to air resulting in particle loss in the porous asphalt. Porous asphalt is also subjected to more moisture damage than conventional dense mixes due to its high exposure to moisture. Previous research has studied the effect of mixing and compaction temperature on the indirect tensile strength using Polymer Modified asphalt by varying the temperature [14]. The indirect tensile strength can be used to determine the tensile properties of the asphalt mixture which can further be related to the cracking properties of the pavement [15]. The study found that the indirect tensile strength gradually increases with the increase in the compaction temperature. A higher tensile strength corresponds to a stronger cracking resistance. Mixtures that can tolerate higher strain prior to failure are more likely to resist cracking than those unable to tolerate high strains [16]. Therefore, this study aims to evaluate the effect of different compaction temperatures on the performance of porous asphalt.

2. Experimental

2.1. Materials

The materials used include granite aggregate, polymer modified asphalt (PG76) and hydrated lime as mineral filler. The physical properties of the modified asphalt and aggregate used in this study were listed in tables 1 and 2, respectively. All the material properties were in accordance to Malaysian Public Works Department Standard [17]. Figure 1 shows the grading of the combined aggregate selected from the standard, particularly grading Type B.

Table 1. Properties of performance grade PG76.

Properties	Test standard	Requirement [17]	Result
Penetration at 25℃ (dmm)	ASTM D5	-	40.6
Softening point (℃)	ASTM D36	60 (min)	70
Viscosity at 135˚C (Pa.s)	ASTM D4402	3 (max)	2.8
Specific gravity	ASTM D70	-	1.030

Table 2. Properties of granite aggregate.

Test	Standard	Requirement [11]	Result
Los Angeles Abrasion	ASTM C131	< 25%	23%
Polish Stone Value	BS 812-114	>40	53
Flakiness	BS 812-105	< 25%	19%
Soundness	ASTM C88	<18%	6.8%
Water Absorption	ASTM C127	<2%	0.9%

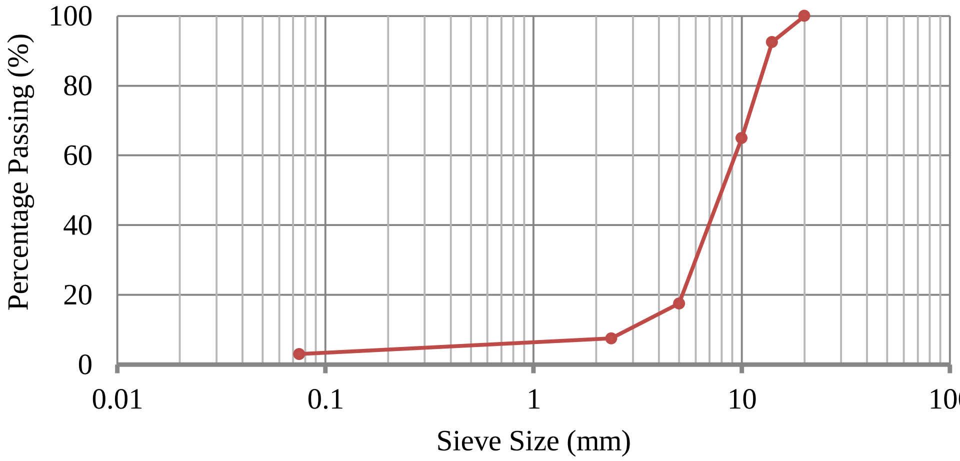

Figure 1. Grading of the combined aggregates.

2.2. Sample preparation and laboratory performance test

The samples of porous asphalt mixture were prepared using a Superpave Gyratory Compactor (SGC) with 5% design binder content. The aggregates were dry sieved and mixed with asphalt binder (PG76) at 185℃ mixing temperature. Four different compaction temperatures were selected in this study for comparison i.e. 140℃, 150℃, 160℃, and 170℃ and compacted at 40 gyrations. The compacted samples were then tested for volumetric properties (in terms of density and air void content) and mechanical performance i.e. Cantabro test, resilient modulus, dynamic creep and moisture susceptibility. The Cantabro test was conducted to determine the particles loss of porous asphalt mixtures, which indicates the durability of the samples as specified in ASTM D7064. On the other hand, resilient modulus test was conducted to determine the elastic properties of porous asphalt at temperatures of 25℃ and 40℃ in compliance to ASTM D4123. The dynamic creep test assessed the permanent deformation characteristics of porous asphalt mixture at 40℃ as stated in BS EN12697-25. Moisture susceptibility test was also evaluated using indirect tensile strength ratio (ITSR) in accordance to ASTM D6931. Measuring tensile strength before and after water conditioning gives indication of asphalt mixture moisture susceptibility.

3. Results and discussion

3.1. Air voids content

Based on figure 2, the lowest air void percentage is 21.7% obtained from the sample compacted at 170℃ followed by 22.2% at temperature of 160℃. At 150℃ compaction temperature, the air void is 24.2%, slightly higher than 140^{o}C of compaction, which is 24%. Even though it fluctuated, the trend shows the air void percentage increases with the decrease in compaction temperature. This shows that compaction temperature influences the void content during the mix design. Once the temperature reduced, it becomes difficult to achieve the required density as the mix was hardened. Along with the decrease in density, the air void of porous asphalt mixture increases but not more than 25%.

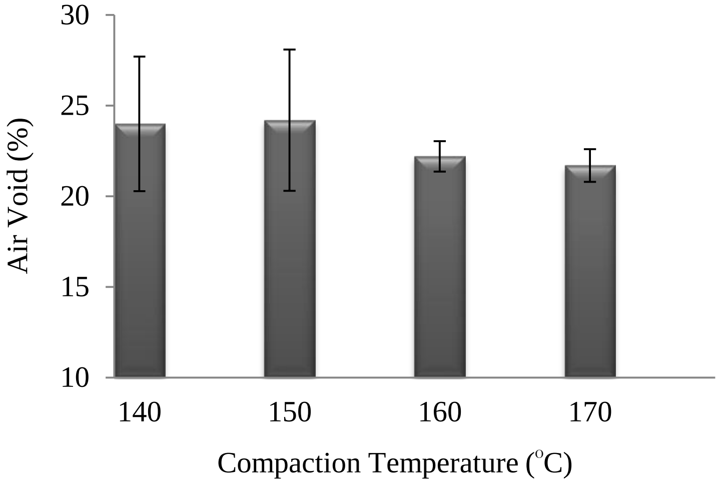

Figure 2. Air Void Percentage.

3.2. Abrasion loss

The Cantabro test was conducted to determine the abrasion loss, which indicates the durability of the samples and resistance against raveling. The result is given in figure 3. According to PWD [11], the abrasion loss for porous asphalt must not more than 15%. All the samples with various compaction temperatures have successfully achieved the specification limit. The lowest abrasion loss percentage is 6.1 % at 170℃ of compaction followed by 6.4% at 160℃ of compaction. The results slightly fluctuated at 150℃ of compaction with the abrasion loss of 9.8% while at 140℃ of compaction, the abrasion loss is 6.9%. However, the trend shows that as the compaction temperature is decreased, the abrasion loss is increased. Abrasion loss and air void are obviously related to each other. The low abrasion loss indicates that the mix has high resistance towards raveling. As the air void percentage increases due to low compaction temperature, the density decreases, thus the samples are vulnerable to stone loss under abrasion.

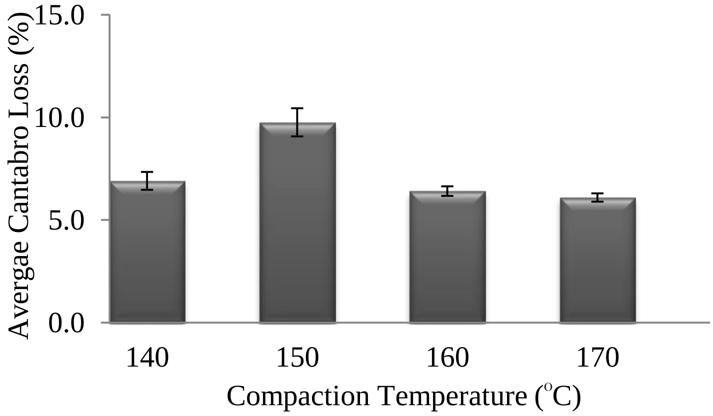

Figure 3. Abrasion Loss Percentage.

3.3. Resilient Modulus

Resilient Modulus test was carried out to evaluate the stiffness of porous asphalt mixtures, which refers to the ability of a mixture to recover after releasing a load. The higher the resilient modulus, the stiffer the asphalt mixture. Figure 4 shows the results of the test conducted at 25°C. The data tested at 40°C cannot be obtained as the samples broke during the initial stage of the testing. Overall, the resilient modulus of the samples compacted at lower temperature is slightly lower compared to those compacted at high temperature due to high air void percentage in the mixture. Based on the result, the highest resilient modulus is found at 170°C, which indicates the samples have better resistance to deformation.

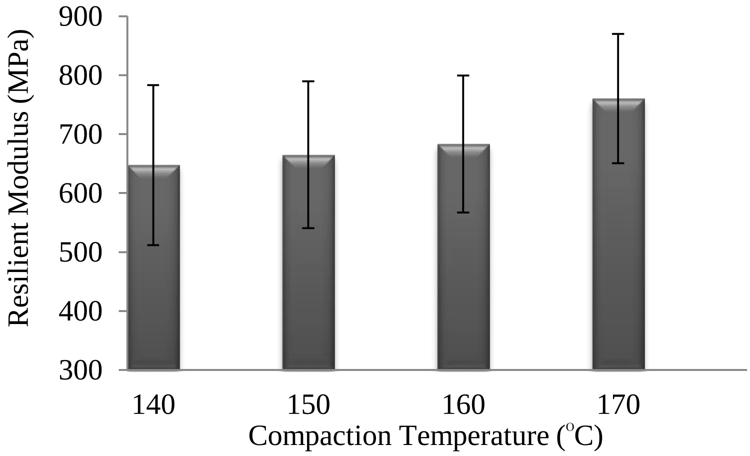

Figure 4. Resilient modulus test at 25°C.

3.4. Dynamic creep

Figure 5 and 6 show the result from creep test. Based on figure 5, the value of creep strain slope increased as the compaction temperature decreased. On the other hand, the creep stiffness modulus decreased as the temperature decreased as shown in figure 6. This shows that, as the compaction temperature increases, the air void percentage decreases making it more durable under the loading and less strain measured. However, at 140˚C compaction temperature, one of the samples failed earlier before it reached 3600 cycles. Overall, the creep performance decrease with the decrease in the compaction temperature.

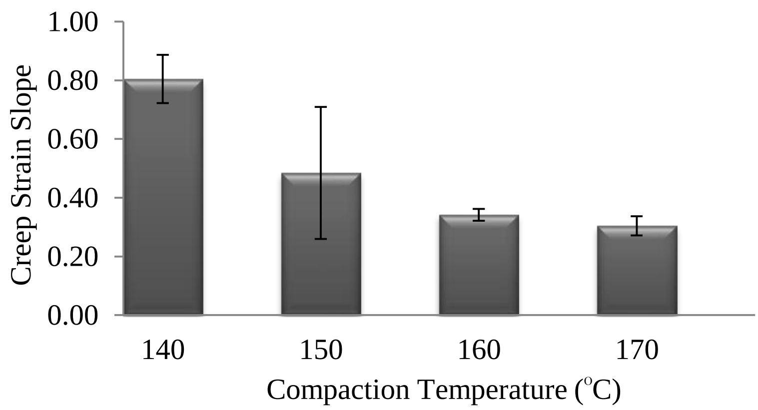

Figure 5. Creep Strain Slope.

IOP Conf. Series: Earth and Environmental Science **244** (2019) 012011 doi:10.1088/1755-1315/244/1/012011

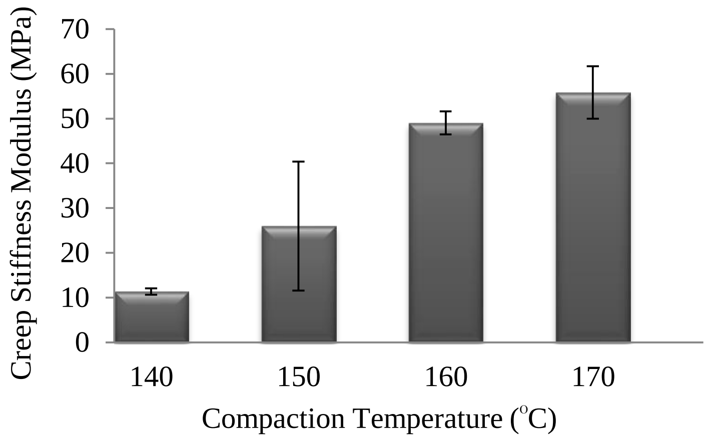

Figure 6. Creep Stiffness Modulus.

3.5. Moisture Susceptibility

Figure 7 shows the result of the Moisture Susceptibility Test. The figure presents the data of indirect tensile strength for both unconditioned (dry) and conditioned (wet) as well as the tensile strength ratio, TSR for the different compaction temperatures. The highest value of the indirect tensile strength is obtained at 170˚C for both unconditioned and conditioned and the value consistently decreases with the decrease in compaction temperature. This shows that lower compaction temperature affects the performance of porous asphalt because of the ineffective compaction that causes high air void corresponding to low density of mixture. This could reduce its resistance to cracking or having low durability. On the other hand, the value of TSR also gradually decreases as the temperature decreases. High TSR indicates that the mixture will perform well to provide better resistance against moisture damage. This is because, when the compaction temperature decreases, the air voids percentages increases making it more susceptible to moisture, therefore, less durable. However, according to BS EN 12697-12 procedure, the minimum acceptable ITSR is 77%. Therefore, as shown by the plot, the tested samples comply with the minimum standard for all compaction temperatures which describe that the samples have good resistance against moisture damage.

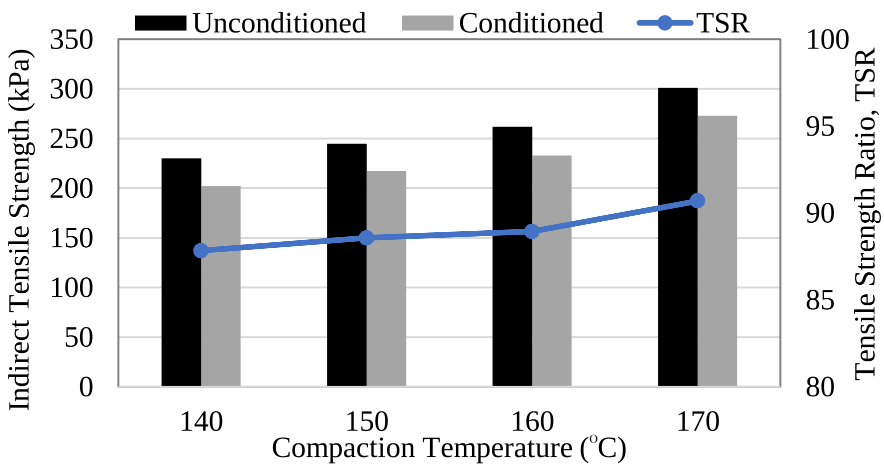

Figure 7. Indirect tensile strength and TSR.

4. Conclusions

This study evaluates the performance of porous asphalt compacted at different temperatures. Based on the results, it can be concluded that the different compaction temperature has consequences for the resulting density and mechanical properties. The reduction in compaction temperature has increased the air void content and reduced the density. The decrease in compaction temperature has also decreased the resistance of the porous asphalt against abrasion loss, permanent deformation and moisture susceptibility.

References

[1] Kamar F H A and Sarif J N 2009 *Proc. of 13th Conf. of the Road Eng. Ass. of Asia and Australasia (REAAA)* p 9-07
[2] Capitão S D, Picado-Santos L G, and Martinho F 2012 *Const. Build. Mater* **36** 1016-1024
[3] Vasconcelos K L, Bernucci L B and Chaves J M 2012. *Proc. 5 th Euras.t and Eurobit. Congr.*
[4] Willoughby K A, Mahoney J P, Pierce L M, Uhlmeyer J S, Anderson K W, Read S A and Moore R 2001 *Construction-related asphalt concrete pavement temperature differentials and the corresponding density differentials* University of Washington
[5] Kristjansdottir O 2006 *Warm mix asphalt for cold weather paving* University of Washington
[6] Hassan Y A 2005 Methodology for determining most suitable compaction temperatures for hot mix asphalt *J. Eng. Sci*. **33**
[7] Lee S J, Amirkhanian S N, Putman B J and Kim K W 2007 *J. of Mater. in Civil Eng.* **19(12)** 1079-1089
[8] Nurul Athma 2017 *Effect of Mineral Fillers on Mastic and Mixture for Porous Asphalt*. Faculty of Civil Engineering, University Technology of Malaysia
[9] McDaniel R S, Thornton W D and Dominguez J G 2004 *Field evaluation of porous asphalt pavement* North Central Superpave Center, Purdue University. West Lafayette, Indiana
[10] Hassan N A, Mahmud M Z H, Adi N, Rahmat N, Hainin M R and Jaya R P 2006 Effects of air voids content on the performance of porous asphalt mixtures
[11] Renken P 2000 *Perspective on optimisation of porous asphalt surface course 2nd Eurasphalt & Eurobitume* Congress Barcelona
[12] Poulikakos L D, Takahashi S and Partl M N 2006 *Evaluation of improved porous asphalt by various test methods* Dübendorf
[13] Rodriguez-Hernandez J, Andrés-Valeri V C, Calzada-Pérez M A, Vega-Zamanillo Á and Castro-Fresno D 2015 *Sustainability* **7** 16226-16236
[14] Tayfur S, Ozen H and Aksoy A 2007 Investigation of rutting performance of asphalt mixtures containing polymer modifiers *J. Constr. Build. Mater* **21** 328-337
[15] Harish L 2014 *The Permeability and Indirect Tensile Strength Characteristics of Porous Asphalt Mixes* Department of Civil Engineering REVA ITM Bengaluru
[16] Taylor R 2007 *Surface interactions between bitumen and mineral fillers and their effects on the rheology of bitumen-filler* PhD Thesis University of Nottingham, UK.
[17] Public Works Department (PWD) 2008 Standard Specification for Road Works – Section 4: Flexible Pavement. Public Works Department, Ministry of Works Malaysia. Kuala Lumpur. JKR/SPJ/2008

Acknowledgements

The support provided by Malaysian Ministry of Higher Education (MOHE), Universiti Teknologi Malaysia (UTM) in the form of a research grant number Q.J130000.2522.19H82 for this study is very much appreciated.