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Ageing Behavior of Porous and Dense Asphalt Mixtures in the Field

Ruxin Jing, Aikaterini Varveri, Xueyan Liu, Athanasios Scarpas, and Sandra Erkens

Abstract Bitumen ageing is one of the principal factors causing the deterioration of asphalt pavements. As bitumen ages, the pavement loses its ability to relax stresses during loading/unloading and thermal cooling process, thus the risk of cracking increases. Oxidation and ultraviolet (UV) radiation are believed to be the main factors that can cause bitumen ageing during pavement service life. The aim of this study is to evaluate the mechanical behavior of porous and dense asphalt pavements during field ageing. Pavement test sections were constructed in 2014 and are being exposed to actual environmental conditions since then. To investigate the effect of UV radiation on ageing, UV reflective glass-plates were utilized to cover part of the pavement surface. To study the evolution of the pavements' mechanical properties, asphalt cores were collected from the test sections periodically (at one-year intervals). The changes in the stiffness modulus of the mixtures were determined via cyclic indirect tensile tests. The results show that the effect of mineral aggregate packing, and hence of air-void distribution and connectivity, on the ageing sensitivity (both thermal and UV ageing sensitivity) of the pavements with time was found to be significant, as the changes of the stiffness of the porous mixtures were greater than that of dense mixtures.

Keywords Field ageing · Porous mixture · Dense mixture · Stiffness · UV radiation

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1 Introduction

Ageing of asphalt mixtures occurs during production and construction and continues throughout the service life of the pavement. Because of ageing, asphalt becomes stiffer and loses its ability to relax stresses under repeated traffic loading and during the cooling process, thus the risk of fatigue and cracking increases [1].

Depending on their mechanisms, different types of ageing can be distinguished such as thermal ageing and UV ageing [2]. Thermal ageing is considered to be the primary asphalt ageing mechanism and is highly dependent on the climate conditions, i.e. temperature. On the other hand, UV ageing only takes place within first micrometers of the top pavement layer; however it should not be ignored because of its relation with raveling, which is a surface pavement distress [3]. Past studies show a clear relationship between the air voids content and the ageing sensitivity of asphalt mixtures [4]. Porous asphalt shows a higher degree of ageing than dense asphalt [5]. Although some investigations have been carried out, field data for different types of asphalt mixtures under diverse climatic conditions are still needed to understand better field ageing and to further develop a proper laboratory ageing protocol.

The goal of this study is to evaluate the ageing behavior of porous and dense asphalt mixture in the field. The main objectives of this study are to (i) investigate the effect of field ageing on asphalt stiffness on the basis of Cyclic Indirect Tensile Test, (ii) correlate the changes of the stiffness with climate temperature data, (iii) determine the effect of the UV radiation on the resulting of asphalt stiffness.

2 Test Section and Experimental Method

2.1 Asphalt Mixture Design

One Porous Asphalt (PA) and one Stone Mastic Asphalt (SMA) mixtures were designed using the aggregate gradations shown in Fig. 1. For both mixtures, the same type of aggregate, i.e. Norwegian sandstone, with a nominal maximum size of 16 mm was used. Norwegian sandstone is a type of crushed stone with density 2740 kg/m^3. The target air void content was 16% and 5% for the PA and SMA mixtures, respectively. The same type of PEN 70/100 bitumen was used for both mixtures. The binder content was 5.0% and 6.4% for the PA and the SMA mixtures, respectively. A factory filler which contents limestone and 25% of calcium hydroxide, i.e. Wigro 60 K filler, with density 2780 kg/m^3 was used for both mixtures.

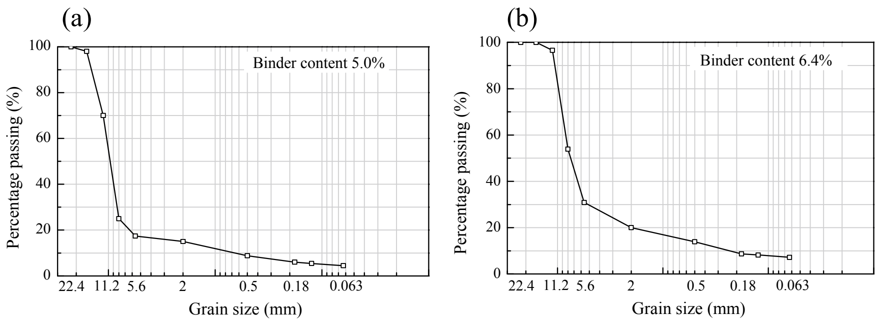

Fig. 1 Aggregate gradation of asphalt mixtures **a** PA mixture **b** SMA mixture

2.2 Overview of the Test Section

The construction phase of the test sections started with the removal of the existing old pavement surface. After the milling process, a bitumen emulsion tack coat layer was sprayed on the surface. Then the new stone asphalt concrete (STAC) layer of 6 cm thickness was laid first, and the 5 cm thickness top porous (PA) and dense (SMA) asphalt layers were placed on the left and right lanes separately, as shown in Fig. 2 (left). STAC is commonly used as base layer of pavements in the Netherlands. The layers were compacted using a roller compactor. The construction of the test sections was done in October 2014. The profile of the new pavement structures is shown in Fig. 2 (right), in which the old STAC (17 cm thickness) and cement bound asphalt granulate base layers (AGRAC, 25 cm thickness) exist more than 10 years.

Fig. 2 Profile of test section

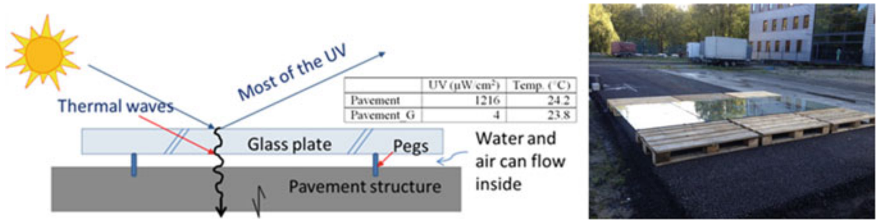

Fig. 3 Schematic representing the use of UV reflective glass-plate

2.3 UV Reflective Glass-Plate

UV reflective glass-plates were utilized to cover part of the pavement surface. The glass plates were capable of reflecting most of the UV radiation but they allowed thermal waves to penetrate and heat the pavement. This capability of the glass plates was verified by the UV and temperature measurement results. One measurement is given in the table in Fig. 3. The values in the table represent the temperature and UV intensity on the pavements without (Pavement) and with (Pavement_G) glass plates covered. The glass plates have been lifted up by pegs to allow for ageing of the pavement due to other factors such as water and air (oxygen), Fig. 3. The glass plates were installed on March 2016.

2.4 Cyclic Indirect Tensile Test

Samples (with and without the UV effect) with a diameter of 100 mm and a thickness of 50 mm were cored from the PA and SMA layers on an annual basis since 2014. The dynamic modulus of the cores were determined by means of Cyclic Indirect Tensile Test (IT-CY) according to NEN-EN 12697-26. The tests were performed using the Universal Testing Machine (UTM) at five frequencies i.e. 0.5, 1, 2, 5 and 10 Hz and four testing temperature i.e. 0, 10, 20 and 30 °C. The conditioning time before testing was set to be 4 h to equilibrate sample's temperature and three replicates were tested.

3 Results and Discussion

3.1 Field Ageing Behavior

According to the Time-Temperature Superposition principle, the master curve of the dynamic modulus was generated at a reference temperature of 20 °C. Figure 4 shows the evolution of stiffness for the porous (PA) and dense (SMA) mixtures from 2014 to 2018. Unfortunately, no cores were taken from the SMA section right after laying.

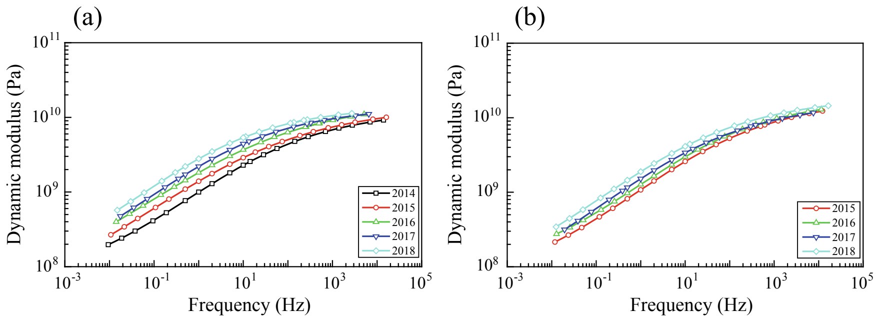

Fig. 4 Master curve of asphalt mixtures at reference temperature 20 °C **a** PA mixture **b** SMA mixture

Overall, the dynamic modulus of both PA and SMA mixtures increases with time. The rate of modulus change is higher for the PA than for SMA mixture. This is mainly because of the high void content of PA, which leads to an inherently high sensitivity to oxidative ageing. More interestingly though, it can be observed that the change in the dynamic modulus for both mixtures is significantly higher for two periods, namely from 2015 to 2016 and from 2017 to 2018. The weather data that were collected from a weather station close to the test sections show the fluctuations in the yearly mean temperature and the number of days with high temperatures (more than 20 °C) over the years from 2015 to 2018. Figure 5a shows that the yearly mean temperature in 2016 and 2018 was about 1 °C higher than in 2015 and 2017. Also Fig. 5b demonstrates that daily mean temperature exceeded 20 °C for 23 days in 2016 and 31 days in 2018, while 20 and 19 days were recorded in 2015 and 2017. In addition, 2016 and 2018 were in general warmer than 2015 and 2017 as shown by the number of days that the daily mean temperature was above 10 °C.

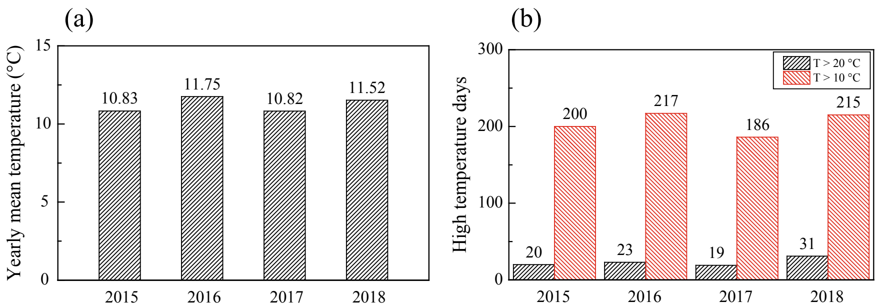

Fig. 5 Temperature information from 2015 to 2018 **a** Yearly mean temperature, **b** high temperature days

3.2 UV Ageing Behavior

The effect of UV radiation on ageing is demonstrated through the ITT results plotted in Fig. 6 for the PA and SMA mixtures with and without the UV reflective plates. The UV reflecting plates were installed on 2016, therefore by 2018 the test sections were covered by glass only for a period of two and half years. In Fig. 6, the PA/SMA labels denote the samples with UV effect (not covered by glass), while the PAG/SMAG labels denote the sample from the section covered by glass (without UV effect).

It is observed that UV radiation has a greater effect on PA than SMA mixtures. The difference in modulus for the PA and PAG samples increases with time. In contrast, there is no significant changes in stiffness for the SMA samples with and without the

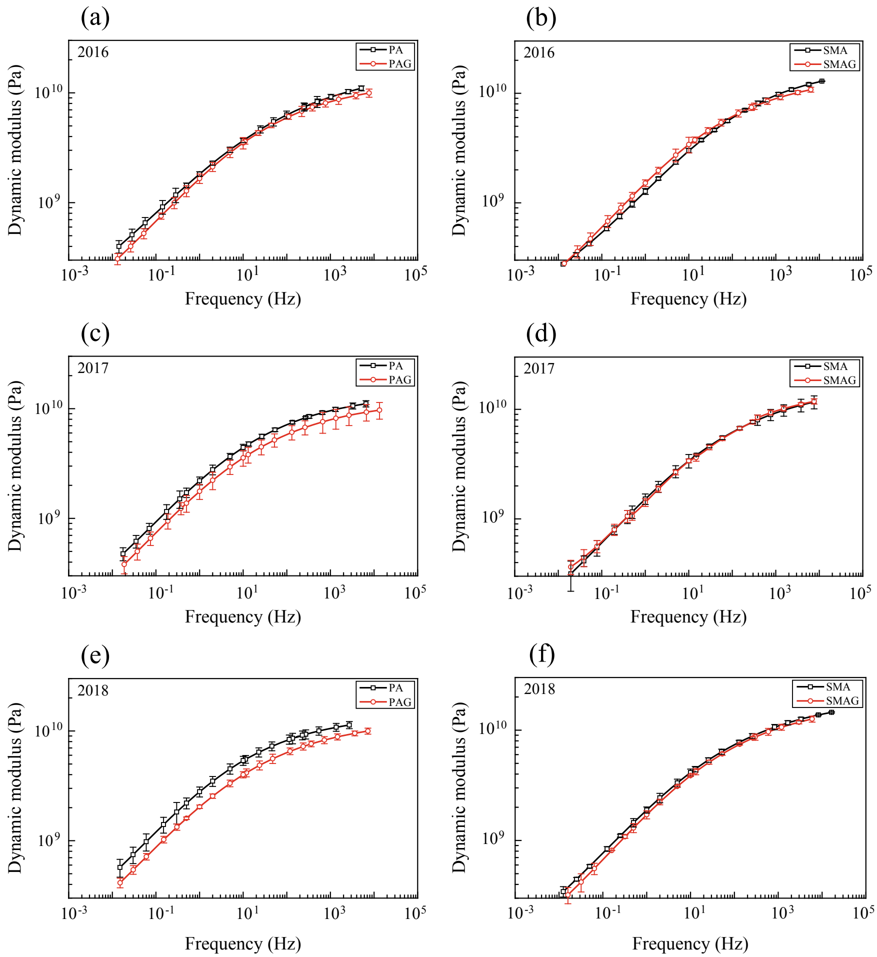

Fig. 6 Effect of UV radiation on stiffness master curve of asphalt mixtures

UV radiation effect. Generally, it has been found that UV ageing takes place within the top 5 μm of the exposed binder film [3]. Therefore, it is anticipated that the high void content of the PA mixture, will allow for larger surface areas of asphalt binder to be exposed to UV radiation. In addition, the high interconnected air voids in PA may allow for UV radiation to penetrate deeper in the PA layer, which is not the case for the SMA layer as the mixture is a quite dense. Because the data represent a short time period, the effect of UV radiation on dense asphalt (SMA mixture) may be more significant in the next years.

4 Conclusions

Identifying the ageing behavior of asphalt mixtures in the field is important on the development of artificial laboratory ageing methods for mixture ageing that allow for reliable predictions of long-term mixture performance. For this reason, asphalt pavement sections with one open and one dense mixtures were constructed in 2014 and continuously exposed to environmental conditions. A series of stiffness tests were conducted on asphalt cores, which were yearly taken from the pavement sections.

The results show that field ageing have more influence on porous mixture than dense mixture, because of the high void content of the porous mixture, which leads larger binder area directly exposed to the air and temperature variations. High temperature and the number of warm days play an important role on the evolution of field ageing. UV radiation has a substantial effect on the field ageing sensitivity of porous asphalt, but not on dense asphalt. This is probably because of the high interconnected air voids network in porous mixtures, which allows UV radiation to easily penetrate into the asphalt layer.

As a continuation of this research, asphalt cores (both porous and dense asphalt) will be taken from the pavement sections on an yearly basis to monitor the changes in their stiffness. In the meantime, an experimental testing program is currently undertaken on asphalt mixture and (extracted) bitumen with the aim to develop a proper ageing protocol to simulate long-term ageing of porous and dense asphalt mixtures.

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References

1. Isacsson, U., Zeng, H.: Relationships between bitumen chemistry and low temperature behavior of asphalt. Constr. Build. Mater. **11**(2), 83–91 (1997)
2. Petersen, J., Glaser, R.: Asphalt oxidation mechanisms and the role of oxidation products on age hardening revisited. Road Mater. Pavement Des. **12**(4), 795–819 (2011)

3. Durrieu, F., Farcas, F., Mouillet, V.: The influence of UV ageing of a SBS modified bitumen: comparison between laboratory and on site ageing. Fuel **86**(10), 1446–1451 (2007)
4. Lu, X., Redelius, P., Soenen, H., Thau, M.: Material characteristics of long lasting asphalt pavement. Road Mater. Pavement Des. **12**(3), 567–585 (2011)
5. Jemere, Y. Development of a laboratory ageing method for bitumen in porous asphalt. Constr. Build. Mater. 204–210 (2010)