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Investigation of microstructure characteristics of porous asphalt with relevance to acoustic pavement performance

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A B S T R A C T

Both spatial characteristics and the structure of air voids have certain impacts on the acoustic properties of porous asphalt, with regard to sound absorption behavior. Aside from global parameters of the microstructure, like porosity, certain geometrical characteristics of air voids also have an effect on sound absorption and acoustic parameters. Spatial parameters of the microstructure like 3D fractal dimension or pore diameter distributions are determined from X-ray CT scans, using methods of digital image processing. Geometrical parameters of different porous asphalt samples are compared, and the relationship between the geometry and the acoustic behavior is studied in great detail. In particular, an evolution of the microstructure caused by long-term soiling processes – changes which usually materialize during porous asphalt's service life – and their effects on spatial and acoustic parameters are analyzed. A defined laboratory procedure for artificial soiling has been used to study soiling mechanisms, enabling the correlation to certain soiling states to be drawn. The design of the study shows how more basic analyses of the acoustic deterioration of porous asphalt due to soiling effects during its service life are possible, with the consideration of changes in the air void microstructure.

1. Introduction

Porous asphalt (PA) mixtures have a very high void content of above 20% (for example in Germany, it is 24% to 28% regarding Marshall samples (FGSV, 2013)). A very high percentage of the pores are interconnected and thus accessible from the surface, for example that which is shown in Varveri et al. (2016). The porous structure is based on an extremely gap-graded mix design. The design of porous asphalt is favored for having good drainage and acoustic noise-reducing properties. Water is able to infiltrate into the porous layer, thus aquaplaning, road spray and light reflection at night is all reduced, to a certain extent. Due to the high air void content (air voids which are inter-connected and easily accessible), it is a porous absorber in an acoustic sense and can therefore decrease road traffic noise. In addition, aerodynamic

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sound-generating effects between the tire and the road surface, like air-pumping, may be reduced by the open-graded or porous surface (e.g. Sandberg and Eysmont, 2002).

While asphalt technology would normally aim to prevent water from entering into the pavement by having a comparably low air void content, the high void content of porous asphalt is not only needed but intentionally designed as such, for its functional properties. The problems caused by the high air void content consist of increased material deterioration, for example raveling effects (e.g. Zhang et al., 2016), and increased physical ageing effects of bitumen due to water and air infiltration (for example causing moisture damages, stripping effects or embrittlement of the aggregate skeleton). Acoustic properties, like the characteristic wave velocities, decrease as well over a certain period of time through soiling of the porous structure (e.g. reported in Bendtsen and Raaberg, 2007 or Alber, 2013). Due to these factors, porous asphalt has a shorter structural service life than conventional asphalt pavements. A shortening of the acoustic service life can also be attributed to deterioration and soiling effects.

Regarding these benefits and drawbacks of porous asphalt (with its high air void content), studies should aim to optimize the service life of porous asphalt with regard to both structural and acoustic aspects. Therefore, it is necessary to gather detailed information about the porous structure, for example via imaging techniques, the measurement of important parameters and asphalt structure models, in order to deal with problems which shall arise. In this paper mainly the acoustic properties are addressed, using some of the above-mentioned methodological techniques.

The porous structure is analyzed using X-Ray (micro) Computed Tomography (XRCT) and certain digital imaging processing techniques in order to determine describing parameters of the air void and skeleton structures of the porous asphalt. Measurements of flow resistivity and sound absorption as important acoustic properties have been undertaken to study certain impacts caused by grading (at the design stage), or by soiling (during the service life).

As an initial investigation in this new research field, this paper aims to show principal methodological approaches and only exemplary results.

2. Material

For this paper 5 drillcores with a diameter of 8 cm or 10 cm have been considered:

- 2 drillcores PA8 in a new/unsoiled state
- 1 drillcore PA8 soiled with 480 g/m^2 (artificial dirt)
- 1 drillcore PA8 soiled with 1440 g/m^2 (artificial dirt)
- 1 drillcore PA 11 in a new/unsoiled state

The drillcores specified as “soiled” have been artificially soiled with laboratory experiments on 2.5 m^2 specimens in combined raining/soiling events, flushing a certain amount of (artificial) dirt into the porous structure by artificial rainfall in several steps in accordance with the test procedure described in Alber (2013) and Alber et al. (2018). The measured data of the artificial soiling tests has comprised (time-dependent) drainage and retention of water applied to the specimen and amount of dirt flushed out by artificial rain. Moreover the evolution of properties which are important to the acoustic and sound-absorbing behavior have been analyzed by measuring flow resistivity and sound absorption.

Table 1 shows the mix design (according to Alber, 2013 respectively Alber et al., 2018) and the volumetric properties of the specimen. The binder is polymer-modified bitumen, granite is used as coarse aggregate and the filler consists of limestone.

Table 1
Volumetric properties of the different PA types used in the study.

Mix type	PA 8	PA 11
Layer thickness [cm]	4.0	4.0
Void content [Vol.-%]	25.3	27.2
Binder content PmB 45 A [M.-%]	6.3	6.3
Mix design/gradation [M.-%]		
0–0.09 mm	3.7	3.7
0.09–0.25 mm	0.3	0.3
0.25–2.0 mm		
2.0–5.6 mm	4.5	
5.6–8.0 mm	87.3	5.5
8.0–11.2 mm	4.2	87.4
11.2–16.0 mm		3.1
16.0–22.4 mm		

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