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Investigation on material properties and surface characteristics related to tyre–road noise for thin layer surfacings

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HIGHLIGHTS

- The research focuses on the properties of thin layer road surfacings.
- Surface characteristics related to tyre–road noise are measured and observed.
- Influences of material properties on texture and sound absorption are analyzed.
- Relationship between connected air voids contend and overall porosity is studied.
- Free field technology is introduced to test the sound absorption of road samples.

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ABSTRACT

Thin layer surfacings are very popular to reduce tyre–road noise in the Netherlands and some other European countries. In this study, laboratory measurements were carried out to investigate the mixture composition, surface texture and sound absorption of thin layer surfacings. Both slab samples produced in the lab and the cores drilled from trial sections were used for measurements. Observations were made on the test results, and the influence of different material properties on the texture and sound absorption were investigated. A relationship between the connected air voids content and the overall porosity of the surface is also analyzed.

1. Introduction

Road traffic noise has become an important consideration for well-being and health of citizens living in and around urban area. In European Union countries, it is estimated that around 50% of the population is regularly exposed to over 55 dB of road traffic noise, a level potentially dangerous to health. Research has revealed that the noise generated from the interaction between the rolling tyre and the road surface is one of the most important contributions in the overall traffic noise [1,2]. If one wants to reduce traffic noise, solutions have to be found in that interface. A noise reducing pavement is therefore considered as an effective way to reduce tyre–road noise from the source. To develop noise reduction pavements further, it is important to determine the relationship between the road material properties, surface characteristics and the noise levels.

Much work has been undertaken to understand the generation of tyre–road noise and related influencing parameters [3,4]. From existing research, it is known that the surface texture [5] and sound absorption [6,7] are two of the most important parameters which influence the tyre–road generation. On the other hand, they are also determined by basic material properties, such as aggregate gradation, binder content and air voids. In existing studies, most of the work concentrates on studying the relationship between the surface characteristics and the noise levels [8–10]. Models were also developed to deduce the tyre–road noise from the surface characteristics [11–13]. In road engineering, it is quite important

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to observe the influence of the basic materials on the surface characteristics which are related with the tyre–road noise generation. This will help the road designers to develop noise reducing surfaces and improve existing materials.

Existing studies show that decrease of macro- and megatexture and increase of the sound absorption generally lead to a reduction of tyre–road noise. The principles of noise reducing surface design are based on these findings correspondingly. Porous asphalt, the most popular used noise reducing pavement, provides pronounced sound absorption ability by its high air voids content, and it has already been regularly studied [14,15]. Most of the research also took into account materials with large difference in material properties [16,17]. From the existing road surfaces, the thin layer surfacing became very popular for urban and provincial roads in recent years in the Netherlands and some other European countries. The thin layer surfacing generally has a thickness between 20 mm and 30 mm. The typical thickness in the Netherlands is 25 mm. In comparison with dense surfaces, the noise reduction is considered to be achieved through the small surface texture and the high sound absorption [18]. Replacing porous asphalt with thin layer surfacings on highways is also considered an option in the Netherlands [19]. This requires a better understanding of the noise reduction possibilities of such type of surface. This paper will focus on the mixture compositions and the surface characteristics in relation with the tyre–road noise. Small changes of the material properties are made between different surfacings, and the influence of these changes in materials on the noise related properties is investigated.

Laboratory measurements are performed to determine the material properties and surface characteristics. Thin layer surfacing samples produced in the lab and extracted from the road sections are included in the test program. The mixture composition, surface texture and sound absorption are measured. Besides the standard methods for testing the surface texture, X-ray Computerized Tomography (CT) scanning was employed to determine the mixture composition of the samples. The sound absorption was measured by using the surface impedance technology. These are all new methods for testing noise related parameters of a road surface. The influence of the material properties on the surface characteristics is then determined by using the measurement results on mixture composition, texture and absorption. Besides, a relationship between the connected air voids and the overall porosity of the surface is also developed.

2. Materials and measurement methods

2.1. Materials and samples

2.1.1. Slab samples

The thin layer surfacing was the main object of the study. Different thin layer surface mixtures were designed based on adjustments from the reference surface called Micro-Top, which is a noise reducing thin layer surfacing developed by Ballast Nedam contracting company in the Netherlands. Table 1 gives the design parameters for each type of mixture. Cells with a italicized indicate the properties which are varied. Different mixtures were made to investigate the influence of mixture composition on different surface characteristics.

Table 2
Binder properties of the investigated thin layer surfacings.

Items	Cariphalte DA	Sealoflex Color
Penetration, at 25 °C, unit: 0.1 mm	85–130	70–100
Ring and ball softening point, unit: °C	⩾80	50–56

Three aggregate sources were used in the study. Bestone is employed in most of the mixtures and considered as a reference aggregate type. It is a sandstone mined from a quarry in Norway. The other two stone types were Tillred and Irish Greywacke, used in mixture P06 and P07 respectively. Tillred is a red color chipping from the UK, and Irish Greywacke is a sandstone obtained from Ireland. The binder used in all mixtures except P06 was Cariphalte DA. P06 is made with the colorless bitumen Sealoflex Color with addition of Bayferrox synthetic iron oxide pigments. Properties of the two bitumen types, Cariphalte DA and Sealoflex Color are given in Table 2.

For testing the surface characteristics, samples with a large surface area are preferred. Large samples facilitate the measurement procedure and provide more accurate results. Use of small samples, such as drilled cores has its limitations because of all kinds of undesired side effects.

Because of the above mentioned considerations, slab samples were produced for the thin layer surfacing materials. The length and width of the slabs were 700 mm and 500 mm respectively. This size ensured that the surface area was large enough for any test on the surface characteristics, including surface texture and sound absorption. The overall thickness of the slabs was 70 mm, with a 30 mm thin top layer and a 40 mm dense asphalt concrete bottom layer. The setting can be considered as a simulation of a practical road surface structure. The mixtures and the samples were produced with the mixing and compaction unit available in the lab of Ballast Nedam. Nine slabs were made based on each of the mixture design in Table 1. The 40 mm bottom layer was first laid and compacted. The thin surfacing was then compacted on top of the bottom layer.

2.1.2. Core samples

In addition to slab samples, cores were also taken from road sections with different materials. In this study, core samples were used to extend the investigations and they were mainly used for the statistical analysis. Cores were drilled on trial sections in Kloosterzande in the Netherlands. Material properties of each surface layer for each section are summarized in Table 3. The trial section number is following the original ones given in a previous project [20]. In this study, four thin layer surfacings (Sections No. 2–5) and seven porous asphalt surfacings (Sections No. 6–9, 15, 24 and 31) are taken into account. Sections No. 9, 15 and 24 have a 25 mm thick surface, and can also be treated as porous type thin layer surfacings. Two lanes were paved corresponding to each surface type as shown in Table 3. From each lane one core was extracted.

2.2. Measurement methods

2.2.1. CT scanning

The mixture composition of the sample was investigated by using CT scanning technology. This is a non-destructive three dimensional imaging tool originally developed for medical diagnosis. In recent years, the CT method has gained increasing application in research of civil engineering materials [21,22]. The scanner used in this study was the Siemens SOMATOM Plus4 Volume Zoom medical scanner available at the Delft University of Technology. The samples used in the test are cores with a diameter of 100 mm. The scanning was done in slices of 1 mm apart. For a 30 mm thick sample, a total of 30 slices are scanned.

The distinction between air voids, mortar and coarse aggregate (⩾2 mm) is made by the choice of the Hounsfield units (HU). As the scanner is only able to separate compositions on difference in densities, it is clear that the air voids have the

Table 1
Designs of the investigated thin layer surfacings.

	Coarse aggregate content, % by mass	Max. Aggregate size, mm	Air voids content, % by volume	Binder content, % by mass of mixture	Aggregate type
Ref.	78	2/6	12	6.1	Bestone
P01	78	2/6	*8*	6.1	Bestone
P02	*78*	2/6	*18*	6.1	Bestone
P03	*72*	2/6	*8*	6.1	Bestone
P04	68	2/6	*8*	6.1	Bestone
P05	78	*4/8*	12	6.1	Bestone
P06	78	2/6	12	6.1	Tillred
P07	78	2/6	12	6.1	*Irish Greywacke*
P08	78	2/6	12	*7*	Bestone