Acoustical and Mechanical Impedance Measurements on PoroElastic Road Surfaces

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Summary
Different test sections of PoroElastic Road Surfaces (PERS) have been constructed in 2013 and 2014 in the frame of the European Project PERSUADE. In this paper measurement results of the acoustical and mechanical impedance of the Belgian test sections will be compared to the results obtained in Denmark, Sweden, Slovenia and Poland, and with measurement results found in literature. A small test section has been in place at the Belgian Road Research Centre since October 2013 and a larger (140 m²) test section was installed at a regional road in Herzele in September 2014.
The acoustical absorption, optimized texture and mechanical impedance (or dynamic stiffness) of the pavement all contribute to the noise reducing capabilities of this experimental pavement type. The high absorption coefficient, compared to conventional pavements, such as dense asphalt concrete or stone mastic asphalt road surfaces, is caused by the high air void content, similar to (two-layer) open porous asphalt. The main noise reducing aspect however is the fact that the stiffness of the road surface is almost equal to the stiffness of standard tyres, drastically reducing tyre vibrations and hence the tyre/road noise. This lower dynamic stiffness is obtained by using rubber particles mixed with stone aggregate, and bound with polyurethane, an elastic polymer.
The acoustical absorption coefficient will be measured on the actual test sections (limited to 1600 Hz – a 100 mm impedance tube), as well as in laboratory conditions on slabs or cores which were produced on site together with the test sections. The mechanical impedance will be measured using an impact hammer, impedance head and accelerometer.

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1. Introduction

With its 67 000 km of roads, Flanders is the region in Europe with the highest road density. It is therefore not surprising that traffic noise is one of the biggest environmental problems of our society. In 2013, 24% of the Flemish people stated to be annoyed by noise [1]. Hereby traffic was indicated as the main source of the nuisance. This problem does not only occur in Flanders. Research commissioned by the European Federation for Transport and Environment (T&E) has shown that 44% of the EU citizens is exposed to sound pressure levels potentially dangerous to their health [2]. This noise pollution can lead to insomnia, learning difficulties, irritability and health problems, such as hearth diseases.
In 2012, the European Directive 2002/49/EC was introduced to tackle these problems. This directive states that all EU member states must draw up strategic noise maps and action plans for all roads with more than 3 million vehicle passages a year. The next step is then to reduce the amount of residents that are exposed to high levels of traffic noise. One of the possible measures is the further development of noise reducing road surfaces.

In 2009 the EU-funded Project PERSUADE, *PoroElastic Road Surface: an innovation to Avoid Damages to the Environment*, was initiated which aims to develop further the experimental concept of poroelastic road surfaces (PERS), based on recycled tyres. If PERS proves to be both quieter and durable, it can be used in areas where traffic nuisance is the highest. The Belgian Road Research Centre (BRRC) is the coordinator of PERSUADE, which consists of 12 members from 8 EU member states[2].

PERS is a top layer, as shown in Figure 1, with a higher elasticity than conventional road surfaces and a large percentage of voids.

Figure 1. Close-up of PERS (1 square = 10x10 mm)

The elasticity is gained through the use of crumb rubber that is held together with the elastic binder polyurethane. The crumb rubber can originate from car and truck tyres. Other components are added to improve the mix, e.g. stones are added to increase the skid resistance and the durability.. To bind the PERS to the sub layer, the same binder is mostly used as in the mixture, although it is also possible to use another polymer, such as epoxy. According to previous Japanese research a noise reduction up to 12 dBA can be achieved by using PERS as the top layer [3]. Preliminary SPB-measurements at the test tracks in Sterrebeek and Herzele showed a reduction of 7-8 dBA compared to a DAC at 50 km/h.

In this paper the focus is not on SPB- or CPX-measurements, but on the main road properties responsible for a high noise reduction: texture, acoustical and mechanical impedance. In Section 2 the different test sections are introduced, followed by the measurement results of texture and acoustical absorption in Section 3. The paper is finalized with some preliminary conclusions in Section 4.

[2] *http://www.persuadeproject.eu*

2. Test sections

In order to further examine the characteristics of the PERS in practice, the BRRC installed two different test sections. A first, small scale test section was constructed on a parking area at the BRRC venue in Sterrebeek and a second one on a public road in Herzele, see Figure 2.

Figure 2. PERS test sections.

These test sections are used to optimize the construction procedure, to test the durability of the material in real conditions and to conduct in situ (acoustical) tests.

Before moving the project to a public road, a first small PERS test section was constructed on the parking area of the BRRC (Sterrebeek) in

September 2013. Because the PERS cured too quickly, the test track was installed in 5 parts. At each transition there was an unevenness which caused extra noise production, see Figure 2 at the top. Therefore, the PERS was milled off and a new PERS mixture was applied in November 2013 in one batch, see Figure 2 in the middle.

In September 2014, a third test section, a larger one, measuring 40 m by 3,5 m, was constructed on a public road. The road, shown in Figure 2 at the bottom, is located in Herzele in Flanders and has a speed limit of 50 km/h.

3. Measurement results

In this paper unfortunately not all the measurement results are available. The in situ determination of the absorption coefficient in Herzele and the measurements of the mechanical impedance should be finished however at the time of the conference presentation.

3.1. Texture

By using a laser profilometer, see Figure 3, the texture of a road surface can be determined.

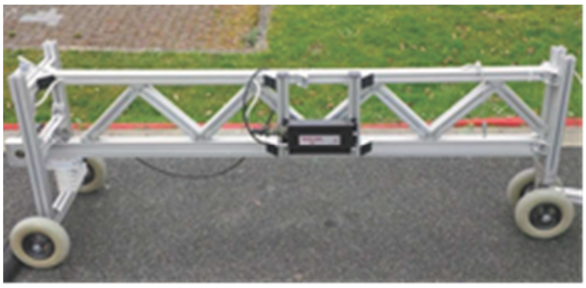

Figure 3. Static laser profilometer.

The texture spectra were obtained on the first and the second PERS test sections in Sterrebeek, as well as on the test section in Herzele and a dense asphalt concrete (DAC) texture spectrum is shown for comparison. The same laser profilometer was used in Herzele as in Sterrebeek but in Herzele it was mounted on a car to be used as a dynamic laser profilometer.

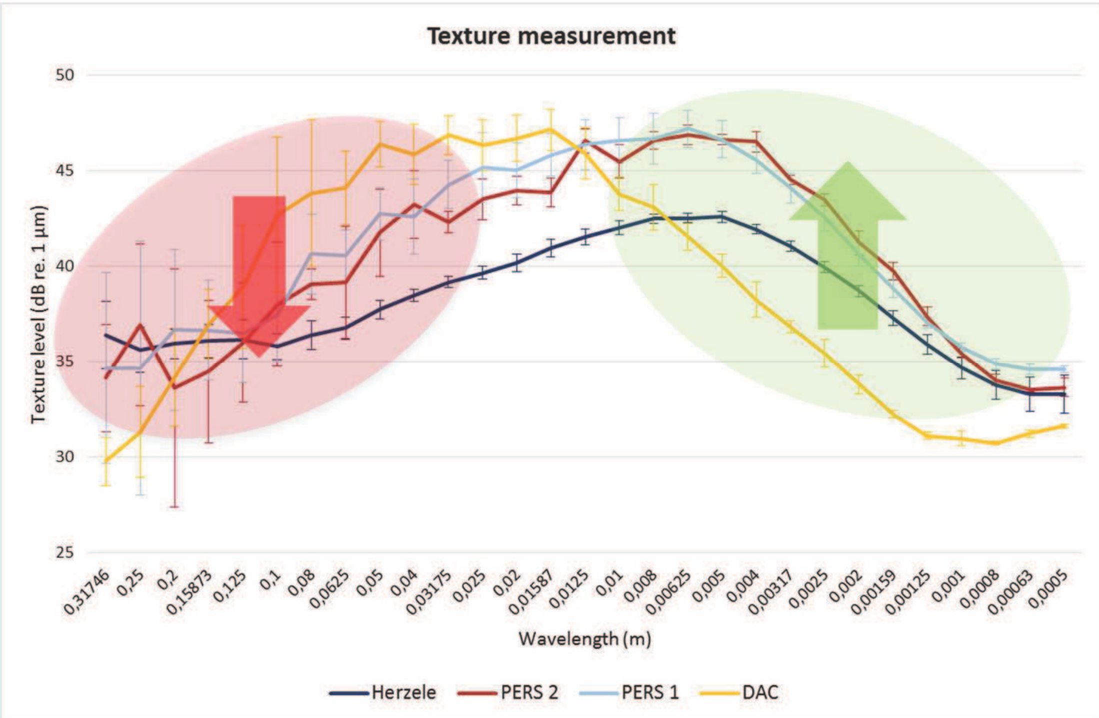

Figure 4. Comparison of the texture levels determined by laser profilometry on the PERS test sections and one dense asphalt concrete section (DAC)

Figure 4 shows the average of the texture measurements. From this graph, the higher macrotexture (0,5-50 mm) levels (indicated in green) of the PERS test sections can be noticed, which has a positive effect by reducing so-called air pumping. The DAC has the highest megatexture (50-500 mm) levels (indicated in red), which is increasing tyre/road noise.

The lower megatexture and higher macrotexture of PERS partly explains why PERS has a high noise reduction compared to DAC. It should be noted, however, that the noise reduction is not solely because of the texture.

One other interesting remark can be made. Although the PERS mixtures in Sterrebeek and Herzele are exactly the same and installed by the same contractor, and the texture levels have been measured by the same person and using the same equipment, the texture levels are much lower for the test section in Herzele compared to both test sections in Sterrebeek. Possible explanations are differences in the compaction procedure and a possible higher curing degree of the mix in Herzele before it was spread.

3.2. Acoustical impedance

The measurement of the acoustical impedance or acoustical absorption coefficient has been performed using an impedance tube (inside diam. 100 mm, working frequency range 250-1600 Hz), as shown in Figure 5. It has been designed specifically for in situ measurements of sound absorption properties of road surfaces according to [4]. In the laboratory measurements are performed on rectangular slabs.

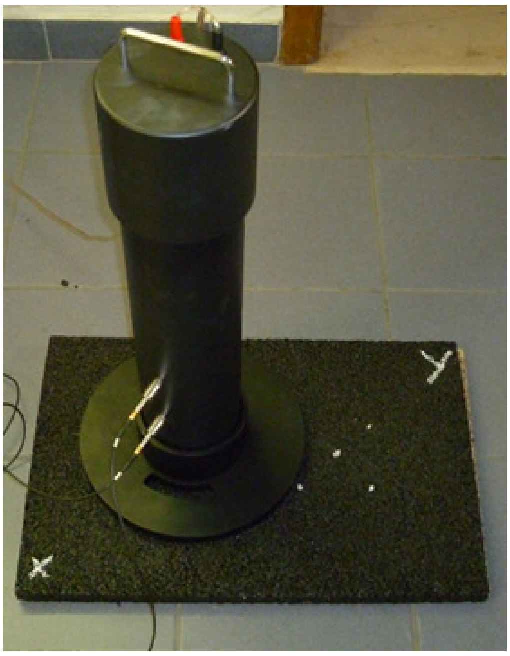

Figure 5. a BSWA-tech SW420R impedance tube

Two different PERS test slabs which were manufactured on the test site in Herzele were tested under varying circumstances: on the floor, on a steel plate and on an asphalt layer. Test slabs from Sterrebeek were no longer available as they were tested destructively to determine their raveling resistance.

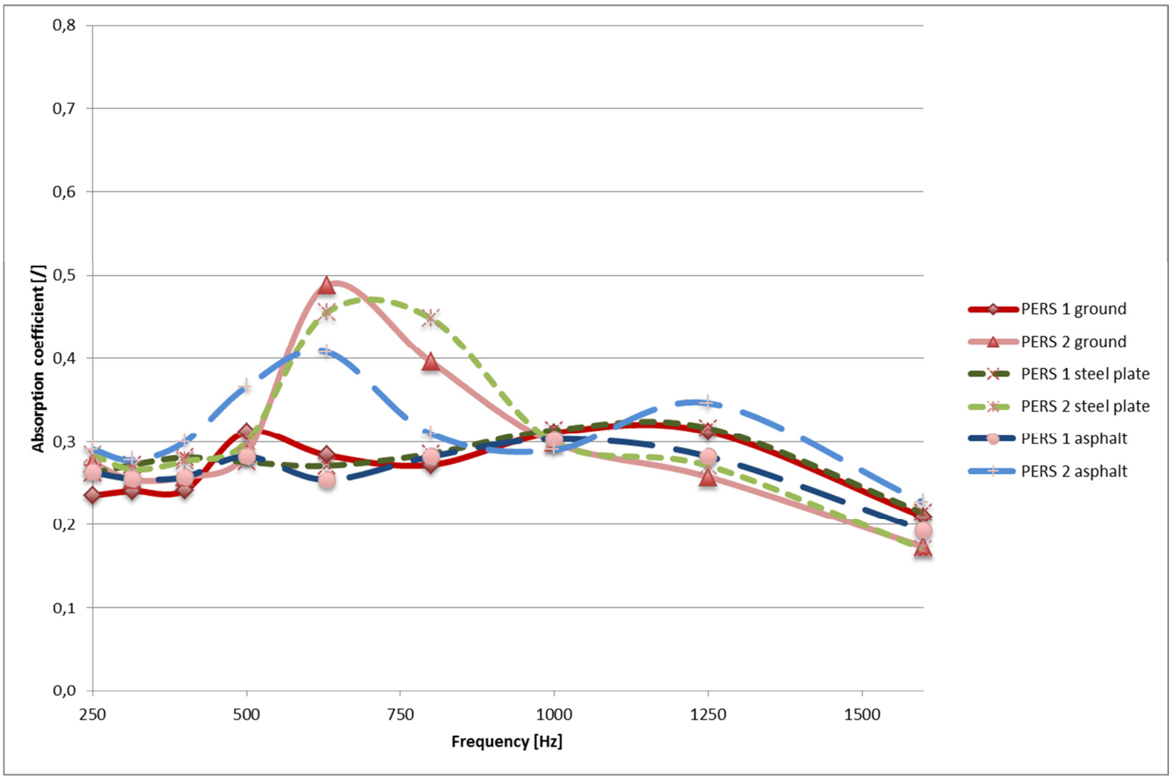

Figure 6. Third octave band results for two PERS test slabs

The differences between the two test plates, as shown in Figure 6, are much larger than expected, with especially PERS 1 showing a much lower than expected absorption behaviour when comparing these results with the results reported in [5], as shown in Figure 7 (a peak of up to 0.9 at 1000 Hz for drilled cylindrical samples from the test track in Sterrebeek).

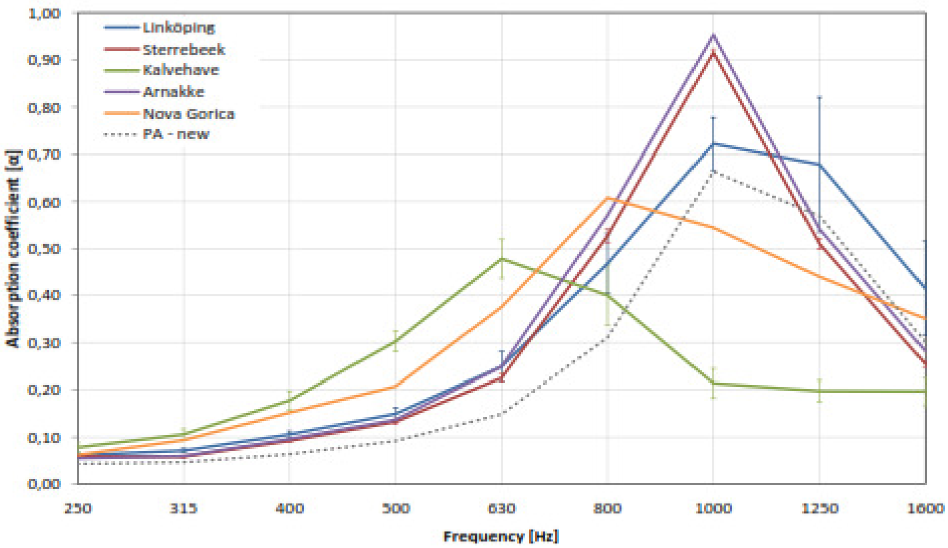

Figure 7. Third octave band results for cylindrical samples drilled from the different test sites in the PERSUADE project (taken from [5]

This might be caused by the different method of compaction used when creating these test slabs, different thickness or measurement procedure and equipment, but needs to be further investigated.

It is clear however that the under layer below the test slab influences the absorption results as well. Since both the floor and a steel plate are reflective surfaces, the absorption results are similar. Placing an asphalt under layer beneath the test slab has a larger influence. Ideally the top layer should be completely in contact with an asphalt under layer, as it is in reality, but this is difficult to achieve in the laboratory as the surface of these thin test slabs is more uneven than the road surface itself due to the method of compaction. As air leaks between the bottom of the impedance tube and the test slab will severely influence the measurement results, most measurements were executed on the bottom of the compacted test slabs which were in contact with the casting during compaction.

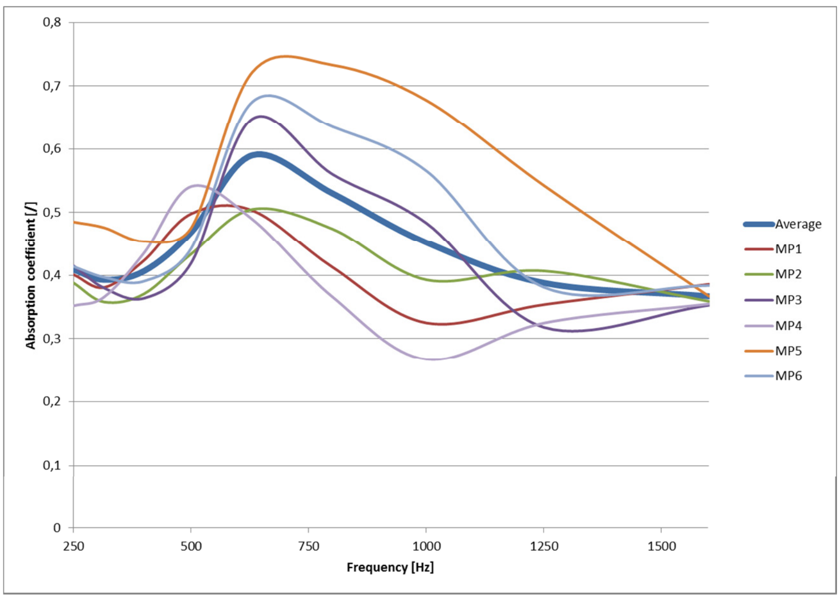

Figure 8. Third octave band results for the in situ measurements in Sterrebeek (MP = measuring point)

In Figure 8 the results are shown for in situ measurements on the second test track in Sterrebeek. Both the measurement results on 6 different measurement locations and the average absorption coefficient are given. It is clear that the variation is large between different measurement locations.

The absorption values measured in situ are considerably higher than measured on the test slabs from Herzele. This can be caused by the different compaction method, but also by leaking.

3.3. Mechanical impedance

The measurement procedure which has been used to measure the mechanical impedance in situ is thoroughly described in [5] and shown in Figure 9. A PCB Piezotronics high sensitivity, ceramic shear ICP accelerometer type 352C33 (upper frequency limit 10 kHz), a PCB Piezotronics Modally Tuned® Impulse Hammer type 086D05 and a PCB Piezotronics ICP Impedance Head type 288D01 will be used for these measurements. Measurement results will be available at the conference presentation.

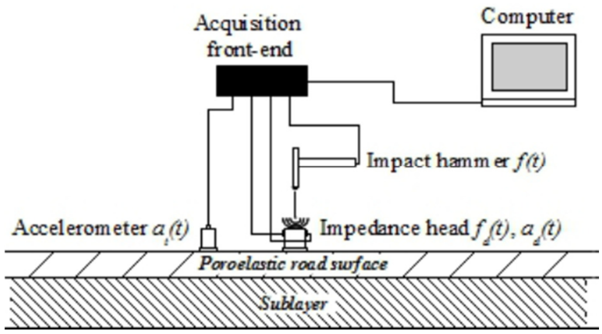

Figure 9. Experimental set-up for the determination of the mechanical impedance in situ (taken from [5])

It is shown in [5] that the PERS has an elasticity comparable to a tyre, while a normal asphalt road is approx. 200 times stiffer. This elasticity drastically reduces the tyre vibrations contributing to the noise production.

4. Conclusions

From previously reported SPB- and CPX-measurements it is clear that PERS shows promising acoustical results. The influence of the acoustical impedance on these results is not clear yet as the measurement results presented in this paper are fluctuating too much between measurement locations or between measurements in situ and on test slabs. These differences can be found between the different test tracks as well. It is clear however that the homogeneity needs to be improved as well during the installation of the PERS mixture.

These preliminary results need to be compared further with more in situ measurements and measurements on cylindrical samples. The test setup itself will be validated using different well-known absorption materials, including checking the influence of an under layer and possible unevenness of the test locations, leading to air leaks and an excessive acoustical absorption.

Acknowledgements

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