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NOISE CONTROL FOR A BETTER ENVIRONMENT

Further development of the poroelastic road surface within the new Polish project SEPOR

Mioduszewski Piotr ¹
Ejsmont Jerzy ²
Ronowski Grzegorz ³
Taryma Stanisław ⁴

Gdańsk University of Technology
ul. Narutowicza 11/12, 80-233 Gdansk, Poland

ABSTRACT

Road surfaces have a direct impact on noise generated by rolling tyres, the main and dominant source of noise of moving vehicles. Road surface texture, porosity and stiffness/elasticity govern the pavement contribution to tyre/road noise the most. An experimental PoroElastic Road Surface (PERS) is a wearing course with a high content of interconnected voids (pores) and with an elastic behavior due to the use of small particles of rubber as the main aggregate. It was already proved, that using that type of pavement, a road traffic noise reduction up to 12 dB can be achieved.

The new project SEPOR founded by the Polish National Centre for Research and Development has started in 2018 aiming in further development of poroelastic road surface. Its main goal is to enhance durability of PERS by optimization of mix composition, improvement of the production process, increasing the interlayer bonding strength and to optimize noise reduction and skid resistance. Experimental test sections will be constructed within a trafficked road and tested for noise, rolling resistance, skid resistance and fire suppression properties.

The paper presents the results of noise and rolling resistance measurements performed on a pilot small-scale test section of PERS built on a construction yard.

Keywords: Tyre/road noise, Poroelastic road surface, Low-noise pavement

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¹ pmiodusz@pg.edu.pl

² jejsmont@pg.edu.pl

³ gronowski@pg.edu.pl

⁴ staryma@pg.edu.pl

1. INTRODUCTION

Tyre/road noise, the main and dominant source of noise of moving vehicles, depends both on a pavement type and on vehicle tyres. According to the literature [1, 2] the potential for future noise reduction by optimizing vehicle tyres is estimated to be 1 - 2 dB for passenger cars and up to 2 dB for heavy vehicles. A higher potential of noise reduction, up to 8 dB considering the conventional pavements, is predicted for road surfaces: from 4 dB for cars to 2 dB for trucks on dense surfaces, about 6 dB for optimized dense surfaces and correspondingly from 8 dB (cars) to 4 dB (heavies) for porous surfaces. An even higher noise reduction, up to 12 dB, can be obtained when introducing modifications of the effective hardness/stiffness/elasticity of a porous road surface by a significant rubber additive to the mix. The reduction of tyre/road noise itself can be even 1 - 2 dB higher. Such a pavement is called the PoroElastic Road Surface (PERS).

2. THE POROELASTIC ROAD SURFACE

Road surface characterized with noise reduction of 10 - 12 dB is a much better noise abatement solution than most of the low, medium, or even high noise barriers. Additionally to impressive noise reduction properties, the PERS pavement will not obstruct any views (which must be accepted in case of noise barriers) and its efficiency is essentially equally high in all directions from the noise source. There are also no shadow zones.

One should noticed that other features of the poroelastic road surfaces, i.e. wet and dry friction, rolling resistance, drainage properties, resistance to fire, reflexes of headlights, are not significantly worse than for other road surfaces. On the contrary, they are usually even better when compared to non-porous road surfaces. As an example one can observe the better self-cleaning properties of poroelastic pavement due to compression and expansion of the PERS material itself, leading to the blowing out of dirt particles from the interior of the surface. In winter conditions, an invisible layer of ice (black ice) is crushed by rolling tyres so decrease of friction is not so dramatic like in the case of rigid pavement what is another added value for PERS pavement.

From an environmental and ecological point of view, poroelastic surfaces show a great potential for using rubber from used car tyres, which do not have to be anymore stored or incinerated in cement plants, polluting the environment and producing significant amounts of CO₂. Due to the low abrasiveness of these surfaces, the pollution by the lost particles from road pavement may be also significantly reduced.

Another beneficial feature of PERS pavement is a great reduction of fire spread under the car when spilled fuel ignites. This opens unexpected field of application for this surface e.g. in tunnels, on bridges, at fuel stations, fuel terminals, car parks etc.

But it should be stated that poroelastic road surfaces are still in the experimental phase and their longevity is the main issue. Actually the cost of PERS is relatively high, but even now it can be compared to the cost of an acoustic barrier. When, after further development, a product that can be used on a large scale is obtained, the cost of its implementation should be significantly reduced.

3. DEVELOPMENT OF PERS

The state-of-the-art and historical review of the poroelastic road surface was presented in [3, 4]. More detailed information especially regarding the developed and used PERS material properties and characteristics as well as test program and test conditions at certain test sections can be also found there.

Since the invention of PERS at the end of 1970's in Sweden a numerous projects were conducted mainly in Europe and Japan. The latest significant European project dealing with the PERS pavement, finished in 2015, was PERSUADE "PoroElastic Road Surface: an innovation to Avoid Damages to the Environment" [5, 6]. This project was founded by the European Commission under the Seventh Framework Programme, started in 2009 with the aim to develop durable, cost-effective poroelastic road surface using recycled tyres, into a feasible noise-abatement measure as an alternative to, for example, noise barriers. The PERSUADE project lead to great progress related to PERS but still many problems, especially with insufficient durability and paving procedures, remain to be solved before this type of pavement will be widely used.

In May 2018, a new project SEPOR founded by the Polish National Centre for Research and Development (NCBiR) started aiming in further development of the poroelastic road surface.

4. PERS DEVELOPMENT WITHIN THE SEPOR PROJECT

The main goals of SEPOR project is to improve durability of the poroelastic road surface by optimization of PERS mix composition, improvement of the production process and increasing the interlayer bonding strength. The project also aims to optimize noise reduction and skid resistance. Experimental test sections of poroelastic pavements will be constructed in Poland within a trafficked road and tested for noise, rolling resistance, skid resistance and fire suppression properties. The project will run for 3 years. Gdansk University of Technology is the coordinator and main research partner in this project.

To achieve the goals a comprehensive research program was drafted, consisting of the following tasks:

1. Optimization of the composition of the PERS mix
2. Optimization of the interlayer adhesion of the PERS mix to the base layer
3. Construction of small scale test sections of PERS within a trafficked road and testing for noise, rolling resistance, skid resistance and flammability
4. Construction of full scale PERS test sections within a trafficked road
5. Testing of the full scale PERS test sections
6. Verification of obtained solutions and environmental impact evaluation
7. Dissemination of results and patents

At the time of writing this paper the first 3 tasks of project are in progress.

5. PILOT SMALL SCALE TEST SECTIONS OF PERS

Within the 1st task five different PERS mix types were prepared. The maximum stone aggregate size was 5 or 8 mm depending on mix type, asphalt amount was 10 or 11 %. The amount of added rubber aggregate was the same in all mixtures (15 % by mass) but differed in the proportions of used rubber grit fractions. The air voids content was 22 or 30 % by volume depending on mix.

A pilot small scale test sections of those mixes were paved at the project partner company yard and pre-tested for noise and rolling resistance. The test sections were paved in three lanes. They were designated *PERS 1* to *PERS 5* and, to distinguish the lateral position of each section, the lane number was added to these designations.

Photos showing the layout of test sections with marked distances and designations are presented in Fig. 1, 2 and 3. It should be mentioned here that the paved PERS wearing courses were NOT bonded in any way to the base layer which was an old dense road surface in this case.



Fig. 1. Pilot small scale test sections of PERS mix – part 1

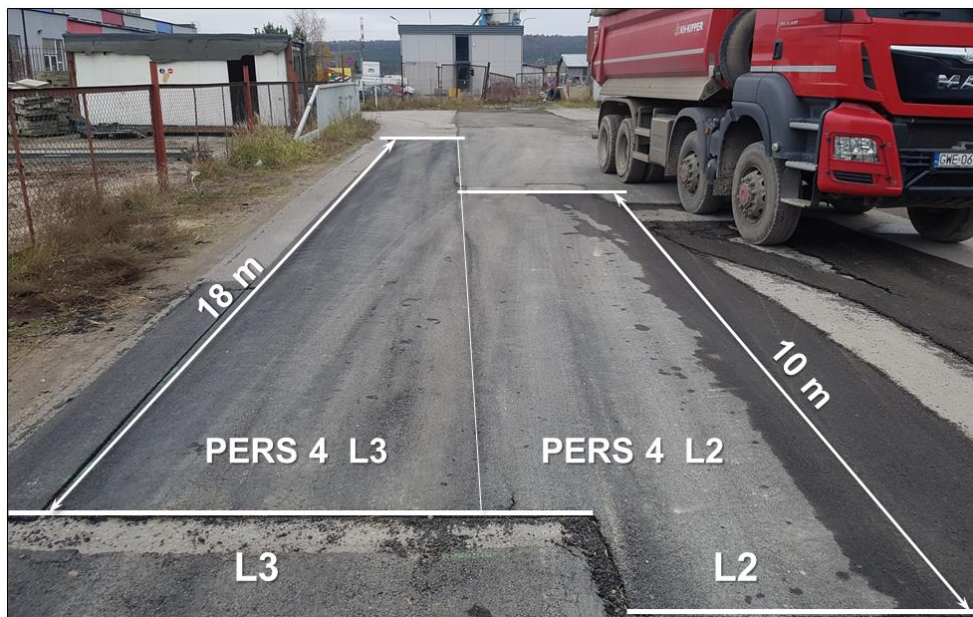


Fig. 2. Pilot small scale test sections of PERS mix – part 2



Fig. 3. Pilot small scale test sections of PERS mix – part 3

The main purpose of producing the pilot small test sections within the partner company yard was to identify the possibility of producing the selected PERS mixtures in a standard factory and the possibility of paving the produced mixtures with conventional equipment used for building conventional mineral-asphalt mixtures.

The location of the paved PERS test sections on a closed small factory yard made it very difficult to carry out any road tests. Nevertheless noise and rolling resistance measurements using the trailer methods were performed on them with a low speed of 30 km/h.

6. NOISE TESTS

Additionally to the main purpose of producing the small scale PERS test sections, to find out the potential noise reduction of the selected different mix types of PERS, tire/road noise measurements using the CPX method (according to the ISO 11819-2:2017 [7] and ISO/TS 11819-3:2017 [8]) were performed on them. Noise tests were conducted when all other tests had been finished, almost at the end of life of the test sections. The sections technical condition at the time of noise testing was rather poor. Due to the absence of a binding layer with the base layer the PERS pavements were deteriorated, detached and shifted, partly ravelled. Also the sections paved in lane 1 were most probably wet although there were no rain falls within the last 24 hours before measurements. Most probably the transportation trucks used to park there were cleaned and washed in this place and used dirty water was flowing on the ground. The condition and damages of test sections are shown in Fig. 4.



Fig. 4. *Technical condition and damages of PERS test sections*

Noise tests on those test sections were performed in November 2018, when the ambient air temperature was within the range of 1.5 - 2.5 °C. Later on the same day noise measurements were also conducted on a SMA8 reference pavement in similar conditions at the air temperature of 1 °C. The measured A-weighted sound pressure levels for both reference tyres and the calculated CPX Index values for all tested sections are presented in Tab. 1. The obtained results are also shown in Fig. 5 and 6.

Tab. 1. The measured A-weighted sound pressure levels for both reference tyres and the calculated CPX Index values for all tested sections

Test section	Tyre P1 [dB(A)]	Tyre H1 [dB(A)]	CPXI [dB(A)]
	30 km/h		
PERS 1 L3	76,8	77,1	76,9
PERS 2 L2	75,6	76,6	76,1
PERS 3 L1	77,0	77,2	77,1
PERS 4 L2	76,5	77,2	76,9
PERS 4 L3	76,9	77,5	77,2
PERS 5 L1	76,7	77,7	77,2
PERS 5 L2	77,8	79,2	78,5
SMA8 - reference	81,3	81,8	81,6
Difference: SMA8 - PERS (average)	4,6	4,3	4,4
<i>Difference: SMA8 - PERS 2 L2 (the quietest)</i>	<i>5,7</i>	<i>5,2</i>	<i>5,5</i>
<i>Difference: SMA8 - PERS 5 L2 (the loudest)</i>	<i>3,5</i>	<i>2,6</i>	<i>3,1</i>

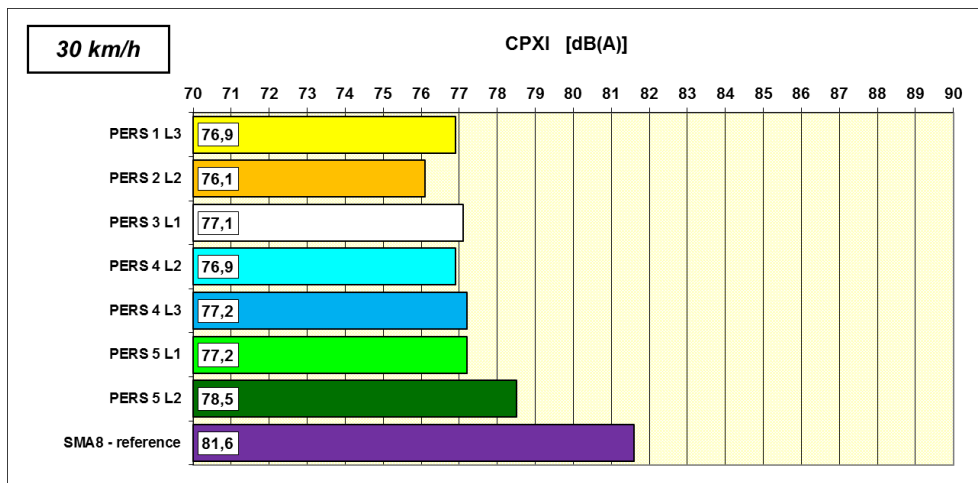


Fig. 5. The calculated CPX Index values for all tested sections

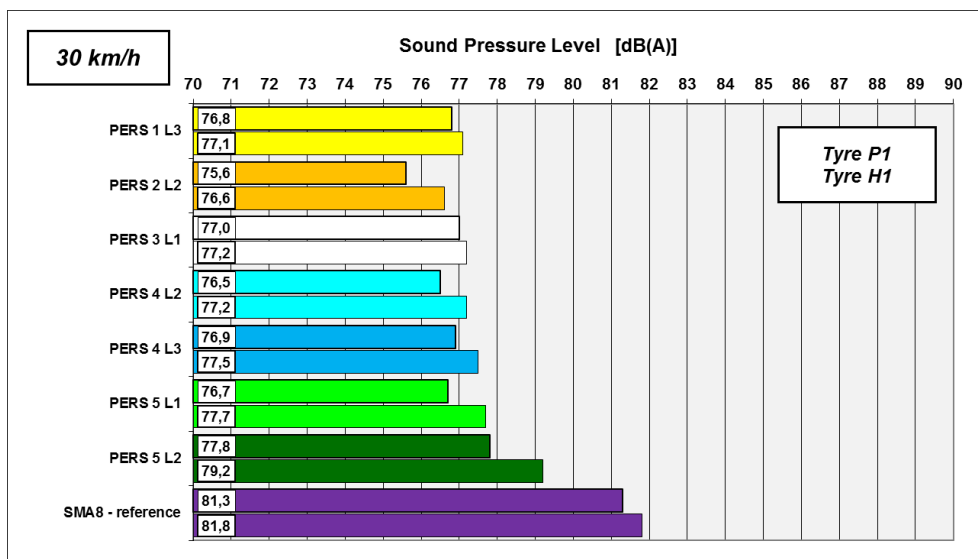


Fig. 6. The measured A-weighted sound pressure levels for both reference tyres for all tested sections

Analysing the obtained results, when looking at the calculated CPX Index values, it can be observed that in comparison to the relatively quiet SMA8 reference surface, noise reduction for the PERS mixtures was achieved at the level of 3.1 ÷ 5.5 dB (4.4 dB on the average) depending on the section. The quietest PERS test section was "PERS 2 L2", the loudest "PERS 5 L2". Differences were observed between nominally the same PERS mixture types but paved in different lines: 0.3 dB for the mixture "PERS 4" and 1.3 dB for "PERS 5". But please remember that the sections in line 1 - "PERS 3 L1" and "PERS 5 L1" were most probably wet.

When looking at the overall noise levels measured for reference tyres P1 and H1, it can be observed that noise reduction on PERS for passenger cars (3.5 ÷ 5.7 dB with the average of 4.6 dB) is slightly higher than for heavy trucks (2.6 ÷ 5.2 dB with the average of 4.3 dB) in comparison to the reference SMA8 pavement. Regardless of the tested reference tyre, the quietest test section of the poroelastic pavement is "PERS 2 L2", while the loudest is "PERS 5 L2".

The averaged third-octave-band noise frequency spectra for both tested tyres (P1 and H1) are presented in Fig. 7.

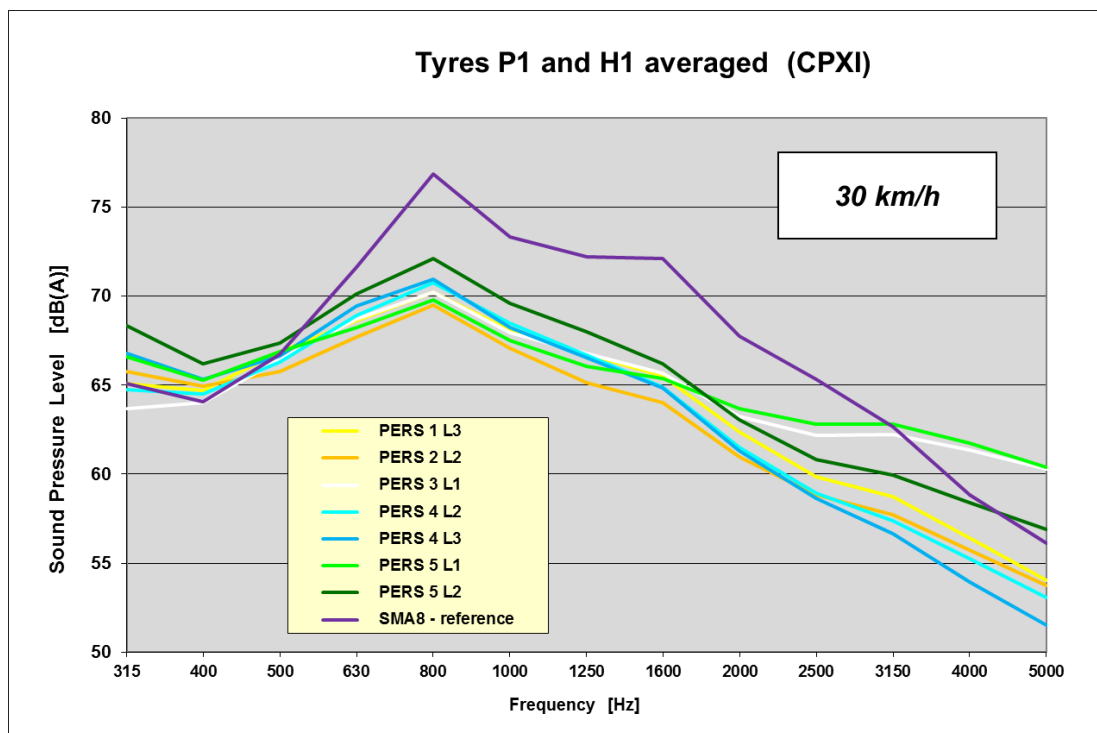


Fig. 7. The averaged third-octave-band noise frequency spectra for both tested tyres (P1 and H1)

Analysing the obtained frequency spectra characteristics - comparing particular PERS test section to the SMA8 reference pavement – one can observe noise reduction in the range of medium frequencies 630-1250 Hz as a result of elasticity of the PERS pavement. Unfortunately, no significant real porosity was obtained or the PERS test sections were contaminated with dirt, dust or there were water remaining in the air voids. This is expressed by the lack of expected noise reduction in the high frequency range of 1250-5000 Hz. Nevertheless, a noise reduction of about 5 dB was obtained for the majority of PERS sections within this frequency range. Significantly smaller noise reductions occur for the "PERS 3 L1" and "PERS 5 L1" sections, which were most probably wet – please observe the significantly increased sound levels for frequencies above 2000 Hz.

7. ROLLING RESISTANCE TESTS

Although the test sections were very short and placed in very test-unfriendly location, it was decided to perform also rolling resistance measurements using R² Mk.2 test trailer. The measurements were performed only at 30 km/h, during sunny day with air temperature of 15°C. Following rolling resistance coefficients (CRR) corrected to 25°C were obtained for P1 tyre:

- section "PERS 3 L1" – CRR = 0.018
- section "PERS 2 L2" – CRR = 0.012
- section "PERS 1 L3" – CRR = 0.016
- reference section paved with dense asphalt concrete – CRR = 0.009

As indicated above, rolling resistance measured on all PERS test sections is considerably higher than measured on conventional road pavements. Definitely quality of measurements was not satisfactory due to local conditions but there is no doubt that tested PERS samples exhibited higher energy losses than desired. Possibly part of the losses was due to relative micro-movements between PERS wearing course and base layer, as there was no adhesion between them. Future test sections will be constructed in a way to promote trailer measurements of tyre/road noise and rolling resistance, both layers will be bonded by bituminous glue, thus results will be more reliable.

8. CONCLUSIONS

The performed noise test on the pilot small scale test sections made of different PERS mixture types showed a noise reduction up to 5.5 dB in comparison to a relatively quiet SMA8 reference pavement at a test speed of 30 km/h. When compared to a typical SMA11 reference pavement (measured previously at 50 km/h and extrapolated to 30 km/h) the noise reduction is much higher: from 7.3 dB for the loudest "PERS 5 L2" test section up to 9.7 dB for the quietest "PERS 2 L2". Thus this looks very promising for the future as the paved test sections are a "pilot" study of the SEPOR project.

Unfortunately it is obvious that low rolling resistance is not associated with present design of PERS developed within SEPOR project. The goal in respect of rolling resistance would be to ascertain that rolling resistance coefficient is not more than 25 - 30 % higher than for corresponding conventional pavement. If this goal is achieved the increase of fuel consumption while driving with low or medium speed on poroelastic road pavement would be less than 10 %.

Actually there is no doubt that the poroelastic pavement, although it is still in a development phase, should be considered as one of the major potential road traffic noise abatement measure. It was already proved in the previous projects dealing with poroelastic road surface [9] that PERS has enormous potential in traffic noise reduction (up to 12 dB in relation to conventional road pavements what corresponds to the effect of sixteen-fold decrease in the number of vehicles!) making it the most silent road surface produced so far. On top of this, PERS surface greatly reduces risk of car fire due to fuel spill, has very good slip resistance in winter conditions (reduces danger of the black ice), provides very good visibility during rainy weather due to vast reduction of water splash. PERS is also very ecological friendly as it utilizes rubber aggregate recycled from worn car tyres, so PERS helps to solve problem of scrap tyres. The SEPOR project is the next step towards improving this poroelastic surface and finally implementing it for mass production.

9. ACKNOWLEDGEMENTS

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