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Tire/Road Noise On Poroelastic Road Surfaces - Results Of Laboratory Measurements

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Summary
Tire/road noise is the most important part of traffic noise for medium and high speed driving both in the case of passenger cars and trucks. The potential to make modification of tires that significantly reduce tire/road noise in nearly over, at least for conventional tires so the only promising action is to improve road pavements. One of the innovative solutions is poroelastic road pavement (PERS) that reduces airflow related noise mechanisms due to its porosity and impact related mechanisms owing to its elasticity. Although the existing PERS test sections are still struggling with certain problems most notably non satisfactory durability and somewhat low friction, the experiments show that substantial progress is possible and the acoustic performance of PERS is very good making it the most quiet road pavements so far. The paper presents results of laboratory tests of PERS performed at the Technical University of Gdańsk both for car and truck tires.

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1. Introduction

Generally, tire/road noise depends on tire and road pavement construction as well as operating parameters including environmental conditions. Environmental conditions like temperature or road wetness are out of control by road users so it is not possible to reduce traffic noise by changing them. Although operating parameters, and most notably vehicle speed, may be controlled in such a way that traffic noise is reduced but all regulations like speed limits or restrictions imposed on heavy vehicles are in contradiction to free and uninterrupted traffic. Most probably there is still seriously limited potential of making tires less noisy, but probably without unconventional designs (like for example composite wheel [1]) it is not possible to reduce tire/road noise by more than just a few decibels. All attempts to manufacture non-pneumatic, unconventional tire/wheels failed so far especially in durability respect. This means that the most promising way to reduce tire/road noise and what follows also traffic noise is to develop "quiet" road surfaces that reduce noise in relation to conventional solutions like dense asphalt concrete or SMA and at the same time ascertain good traction, durability and low rolling resistance. One of such pavements is Poroelastic Road Surface (PERS) that may provide noise reduction up to 11-12 dB(A) in relation to the most common road surfaces nowadays.

According to common definition [2]: "*A poroelastic road surface is a wearing course for roads with a very high content of interconnecting voids so as to facilitate the passage of air and water through it, while at the same time the surface is elastic due to the use of rubber (or other elastic products) as a main aggregate. The design air void content is at least 20 % by volume and the design rubber content is at least 20 % by weight.*"

The concept of Poroelastic Road Surface was invented at the end of 1970s by Mr Nils-Åke Nilsson who also manufactured the first samples of this pavement. Few years later the Technical University of Gdańsk (TUG) performed noise measurements on a small scale test section built on Torslanda Airport - see Fig. 1.

Figure 1. Tire/road noise measurements on PERS section located on Torslanda Airport.

PERS may be constructed in-situ or it may be pre-casted as slabs or plates that must be glued to the road basecourse. Material that is constructed in-situ is not fit for laboratory testing on roadwheel facilities as it is extremely difficult to lay it on the outer drum. On the other hand pre-casted slabs may be cut to small parallelogram segments, joined together to form a ribbon (see Fig. 2). When the ribbon is placed on the drum it bends and may be bonded to the steel outer surface of the drum - see Fig. 3.

Figure 2. Ribbon formed by joined PERS segments before placing on the drum

Figure 3. Bonding PERS ribbon to the drum

2. Mechanical properties of PERS

Tire/road noise generation mechanisms may be divided into two basic groups: aerodynamically releated mechanisms as well as mechanisms related to impacts of tread elements interfacing road pavement. Airflow mechanisms are less efficient if road pavement is porous. Porosity reduces compression of air within tread grooves in tire footprint area, damps air resonances and makes Helmholtz resonance less efficient, so all drainage (porous) pavements decrease tire/road noise considerably. Typical void content of PERS materials is at about 30% with corresponding permeability (tested according to EN 12697-40) of 60 s or less [1]. This levels drainage properties of PERS with typical drainage asphalt or drainage concrere pavements. Howeve, despite being porous PERS is also elastic so impacts of tread elements hitting pavement are less violent and some energy of the impacts is dissipating in the pavement that has certain damping properties.

Both effects acting together make poroelastic road surfaces extremally quiet. TUG tested mechanical properties of two different samples of PERS and compared them with typical, "conventional" road pavements [4]. One of the poroelastic pavements designated as "PERS - A" was manufactured as prefabricated slabs and the mix contained rubber granulate as well as mineral aggregate bonded together with polyurethane resin (see Fig. 4). Second sample designated as "PERS - B" was also prefabricated as a slab but contained only rubber aggregate bonded with polyurethane resin.

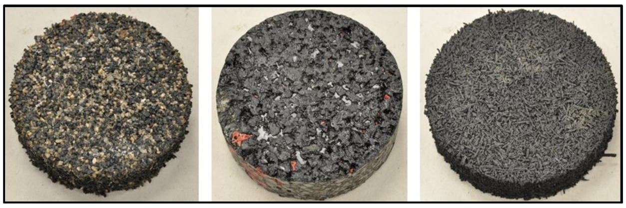

Figure 4. Selected samples used for stiffness evaluation; from the left: PERS - A, low noise asphalt pavement COLSOFT, PERS - B

Dynamic Shear Rheometer used for dynamic stiffness testing is presented in Fig. 5. Tests were performed for frequency range from 0.01 Hz to 25 Hz. Tests were performed for temperature +4ºC, +20ºC and +40ºC. To get broader view on the subject typical porous asphalt and Stone Mastic Asphalt SMA8 were also included for comparison of mechanical properties of PERS.

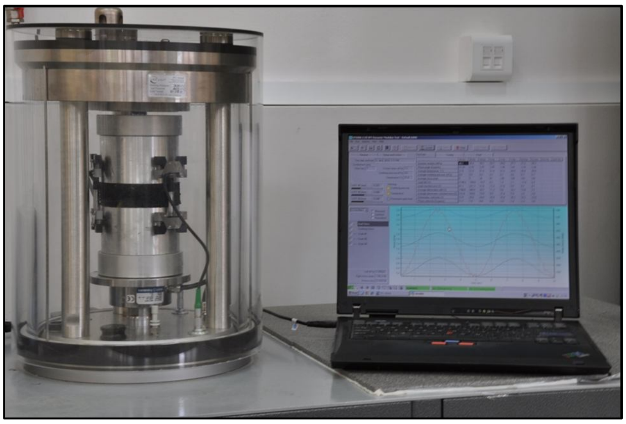

Figure 5. Instruments used for evaluation of dynamic stiffness of road pavements

The results of measurements are presented in Fig. 6 as Black Diagrams. The diagram indicates that PERS materials for all test temperatures reveals fairly constant phase shift of 4º for poroelastic material without mineral aggregate (PERS - B) and 7º for material with mineral aggregate (PERS - A). Such behaviour is typical for elastic materials. Three "conventional" road pavements reveal characteristics typical for viscoelastic materials (bent curve of parabola shape). In Fig. 7 Master Curves evaluated according to [5] are presented.

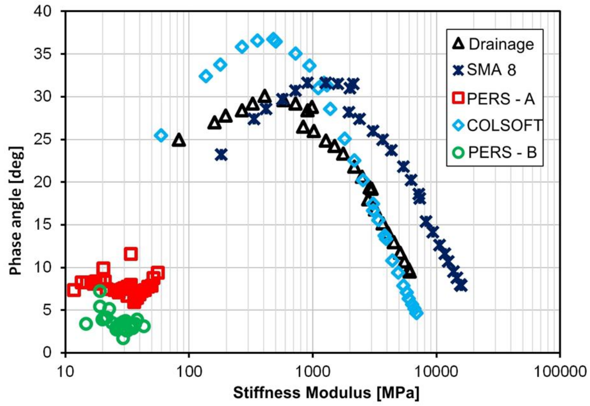

Figure 6. Black diagrams for selected road pavements

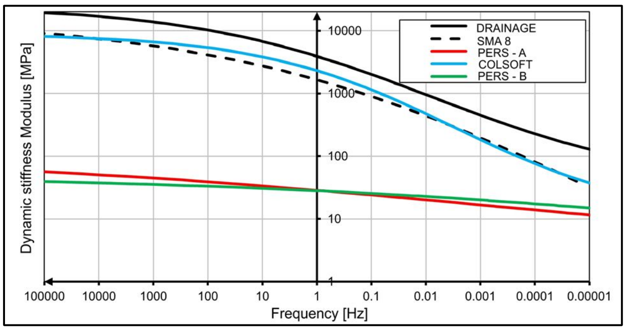

Figure 7. Master Curves

Results presented in Fig. 6 and Fig. 7 indicate that mechanical properties of poroelastic road pavements containing mineral aggregate are very similar to properties of mixes containing only rubber aggregate and binder. This is a very important finding as it shows that moderate contain of mineral aggregate does not impair elasticity of PERS, thus should not spoil noise reduction properties. On the other hand mineral aggregate increases slip resistance of the pavement thus has very positive effect on safety. Similar results may be also obtained by adding sand to the mix.

Typical noise reduction of porous pavements according to Gardziejczyk [6] is 6-9 dB in relation to traditional pavements. At the same time noise reduction of porous and elastic PERS is 10-12 dB. This shows that stiffness of pavements plays a very important role in tire/road noise generation. The following chapter summarizes some of laboratory measurements performed at the Technical University of Gdańsk.

3. Acoustical properties of PERS

Generally, laboratory (drum) methods are not very well suited for making tire/road noise measurements as there are serious problems with fitting road pavements to the outer surface of drums. Replica road surfaces that may substitute real road pavements are difficult to manufacture and they have different stiffness than original road materials not to mention their curvature. TUG uses several replica road surfaces (see Fig. 8) that have very similar texture like road pavements but they are made using different materials (polyester laminates or polyurethane).

In this respect PERS is very different as in most cases the same material may be laid on the road and bonded to the drum. To evaluate PERS influence on tire/road noise tests of 12 passenger car tires were performed on PERS-A, replica of Dense Asphalt Concrete (DAC12) and replica of Surface Dressing (SD11).

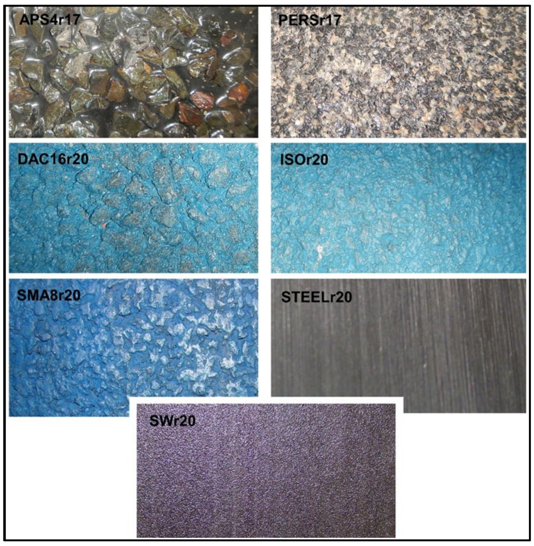

Figure 8. Replica Road Surfaces used for tire testing at TUG

Results of measurements performed for speed range 30 - 100 km/h indicate that noise reduction due to use of poroelastic road surfaces increases for higher speeds. In Figures 9-12 overall noise levels at speeds 30, 50, 80 and 100 km/h are compared between PERS-A and two conventional road pavements, or to be precise, their replicas (SD11 and DAC12). Fig. 13 presents average noise reduction for each speed.

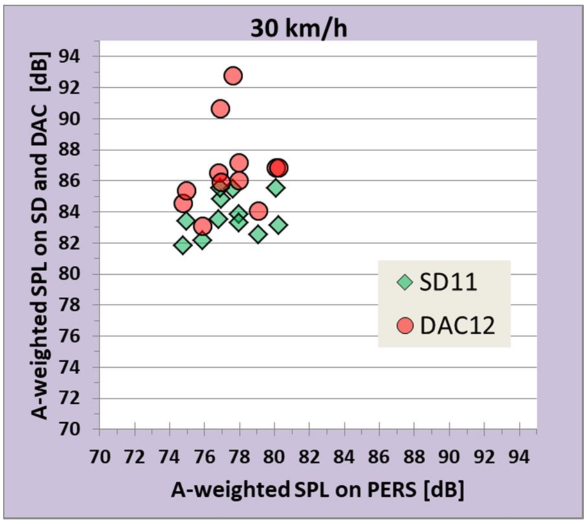

Figure 9. Noise comparison for speed 30 km/h

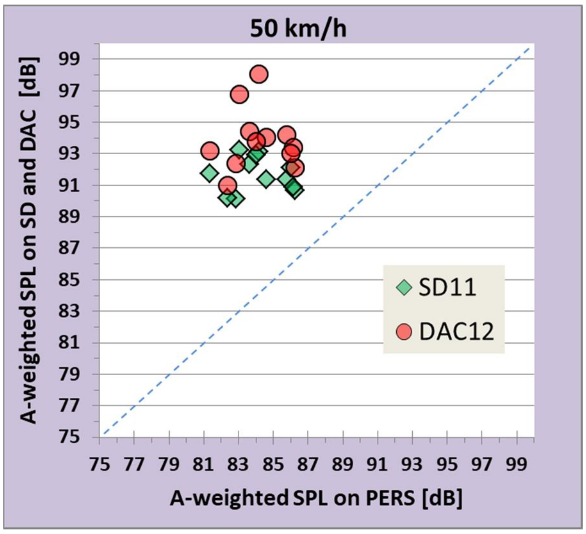

Figure 10. Noise comparison for speed 50 km/h

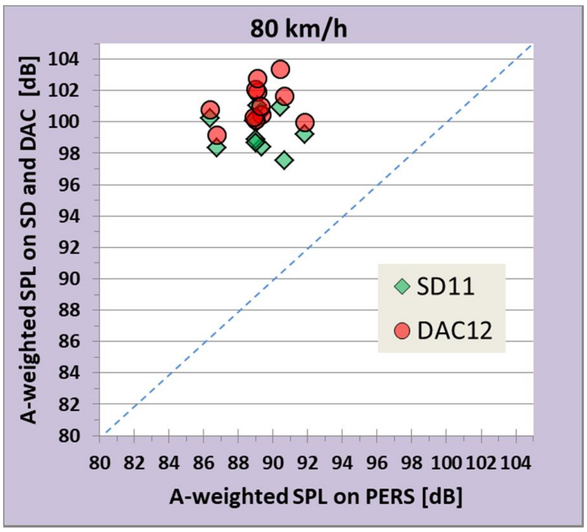

Figure 11. Noise comparison for speed 80 km/h

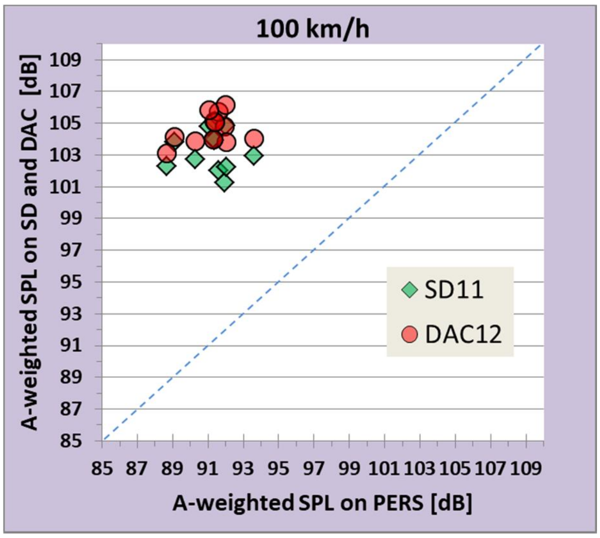

Figure 12. Noise comparison for speed 100 km/h

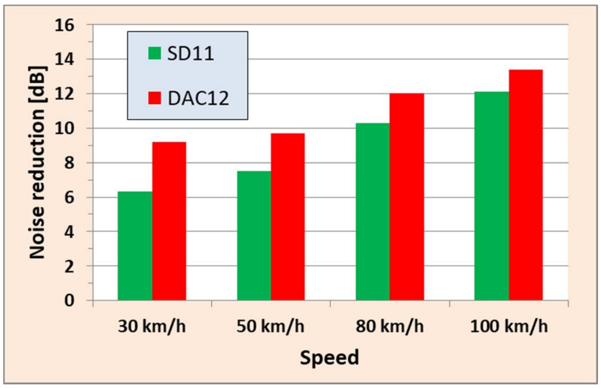

Figure 13. Noise reduction as a function of speed

The comparison of noise spectra (Fig. 14) shows that noise reduction is especially high in the frequency range 800 - 2000 Hz. This range is very important as for the majority of tire/pavement combinations maximal third-octave band noise levels occure within this frequency range.

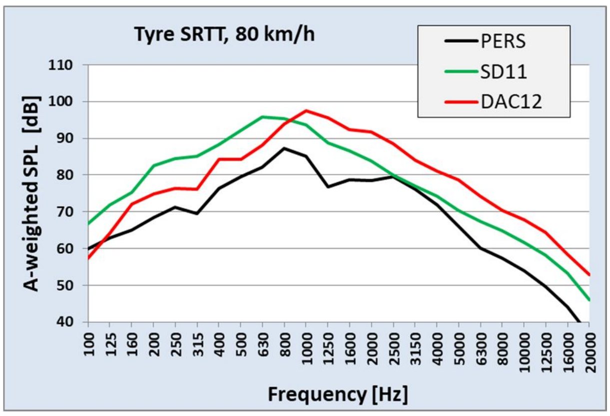

Figure 14. Noise spectra comparison for tire SRTT

4. Conclusions

Poroelastic road surfaces have very favourable noise reduction properties and in comparison to typical conventional pavements like Dense Asphalt Concrete or SMA the reduction may be as high as 12 dB and this makes them the most silent road surfaces that can presently be constructed. The reduction (although not documented in this paper) may be even higher for studded tires. The noise reducing potential of PERS cannot be fully utilized as present PERS materials have insufficient durability. The authors believe that it is possible to develope PERS to such a state that its durability will be in line with other commonly used road pavements. Further improvement of PERS is the main goal of the project SEPOR that started in Poland this spring.

Acknowledgement

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