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Poroelastic Material for Urban Roads Wearing Courses

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Abstract. Conventional road materials used for producing wearing courses of roads are based on mineral aggregate and bituminous or Portland cement binders. The road materials must be optimized for different properties, including skid resistance, durability, rolling resistance and tire/road noise. Unfortunately, it seems that within classic technologies it is very difficult to achieve further reduction of tire/road noise. Innovative porous material PERS that contains considerable amount of crumb rubber seems to have great potential of traffic noise reduction. The paper presents brief history of PERS development, its present stage and unexpected properties, for example, spill fuel fires retardation.

Introduction

"First, a few snapped twigs and bruised blades of grass. Soon, a path, a trail. Then, in surprisingly little time, the way becomes a road. Roads are truly exceptional among human works, in both their mutability and their longevity." So begins a very interesting book [1] documenting the history of our roads. During the centuries different road materials were used, including stones, wooden blocks, different mineral mixes bounded by bituminous or Portland cement binders. All this to fulfill the growing demands of road users and provide requested properties of road surfaces. Most important properties of road wearing courses are:

- Skid resistance (especially in wet conditions).
- Durability.
- Load capacity.
- Rolling resistance.
- Tire/road noise.
- Fire safety (especially in the case of tunnels, fuel stations, parking lots)

Conventional~~,~~ modern road pavements, both based on bituminous and Portland cement binders provide adequate, that is very high, skid resistance, considerable durability and load capacity as well as low rolling resistance. Unfortunately, according to common opinion, they have very limited potential to further decrease tire/road noise, and this noise is one of the greatest environmental issues related to road traffic. Also in the case of spill fuel fires, very often associated with car accidents, conventional road pavements contribute to spread of fire and increase of fire risk, especially in confined spaces like tunnels, park houses, garages.

In the early 70s of the 20th century, a Swedish scientist, Nils - Ake Nilsson [2] invented a road material that is based on crumb rubber aggregate bonded by polyurethane resin. This pavement called Poroelastic Road Surface (PERS) is elastic and porous at the same time, thus it reduces both groups of tire/road noise generating mechanisms – vibration related and aerodynamically related [3].

Development of PERS was carried out in many countries, most notably in Sweden, Norway and Japan. First mixtures contained only rubber aggregate and polyurethane binder but they were not able to provide enough skid resistance so the mixture was enhanced with certain amount of mineral aggregate. This modification resulted in improvement of skid resistance. Tire/road noise on both types of mixtures is much lower than on other, typical road pavements. Most ~~of~~ studies (summarized in [4]) show decrease of noise reaching 10-12 dB in relation to typical road surfaces like Stone Mastic

Asphalts (SMA). The biggest, and partly unsolved problem with PERS is its low longevity and insufficient resistance to debonding from the base layer. Following chapters describe selected results of PERS development performed within 7th Framework Project RESUADE financed by EU and ongoing national Polish project SEPOR.

Construction of poroelastic pavement

Poroelastic road surface is a wearing course for roads with considerable content of interconnecting voids, while at the same time the surface is elastic due to the use of rubber as a main aggregate. The air void content should be at least 20 % by volume and the rubber content should be at least 20 % by weight. Generally, to avoid problems with skid resistance the PERS mixes contain also mineral aggregate of small size (usually below 6 mm). In most of the trials polyurethane resin is used as a binder, but within research project SEPOR another type of binder is tested, namely rubber modified asphalt. PERS material may be prefabricated in form of slabs that are glued to the base course, or it may be prepared in a similar way ~~like~~ to typical bituminous pavements and placed on the road with an ordinary paver. Structure of PERS is presented in Fig. 1 while examples of three different PERS materials are shown in Fig. 2.

Many experiments performed on test sections paved with PERS show that one of the most important issues related to this innovative pavement is its adhesion to the base layer. Due to great difference in stiffness modulus the PERS layers tend to delaminate from the base course creating unacceptable pot holes. Mechanism of the delamination is described in Fig. 3.

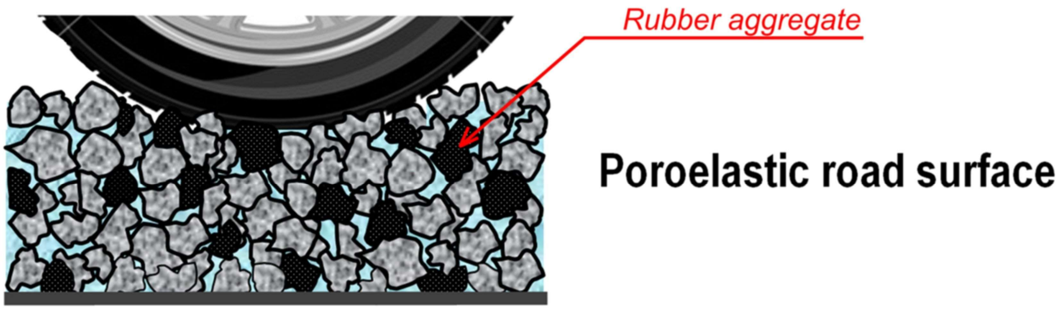

Fig. 1. Structure of PERS.

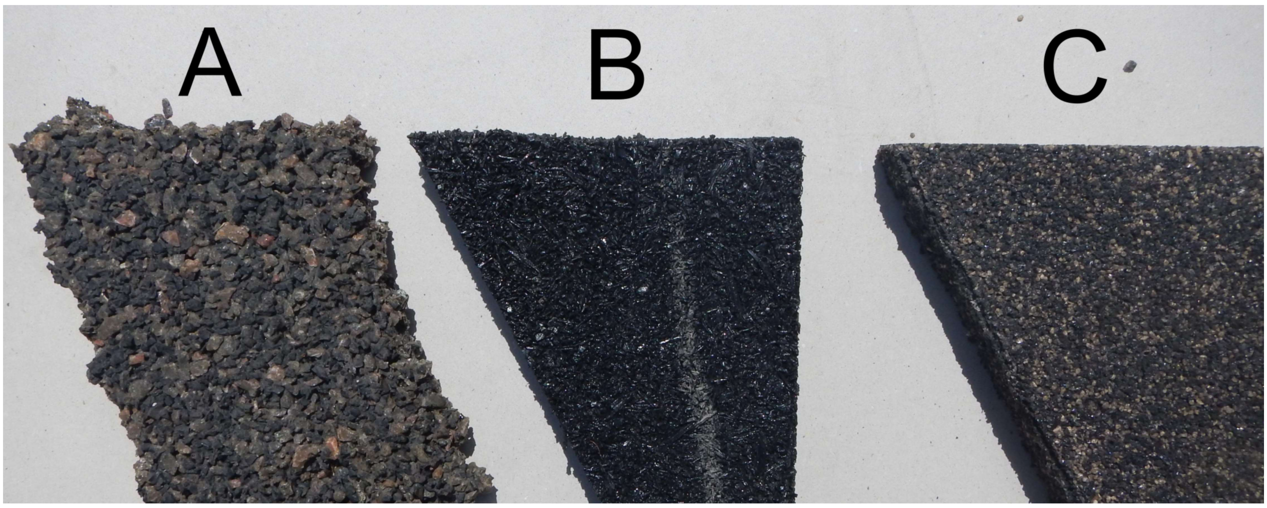

Fig. 2. Three different samples of PERS; A – material with mineral aggregate laid by the paver, B- material without mineral aggregate prefabricated as a slab, C- prefabricated material with mineral aggregate.

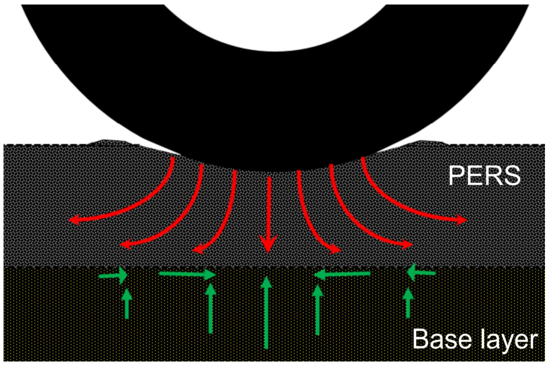

Fig. 3. Shear forces generated at the interface of flexible and rigid layers.

Tire/road noise reduction

Measurements performed by the Technical University of Gdańsk (TUG) on 6 road test sections constructed within PERSUADE project in Poland, Slovenia, Denmark and Sweden shown that poroelastic pavements provide tire/road noise reduction of about 10 dB in relation to typical (reference) road surfaces like SMA11 or SMA16. In Fig. 4 results of noise tests performed on the drum facility of TUG are presented. Eight tires were tested on PERS slabs as well as on replicas of DAC11 and Surface Dressing (APS4). Noise reduction provided by PERS increased for higher speeds from initial level of 8 dB at speed of 30 km/h to 12 dB at 100 km/h.

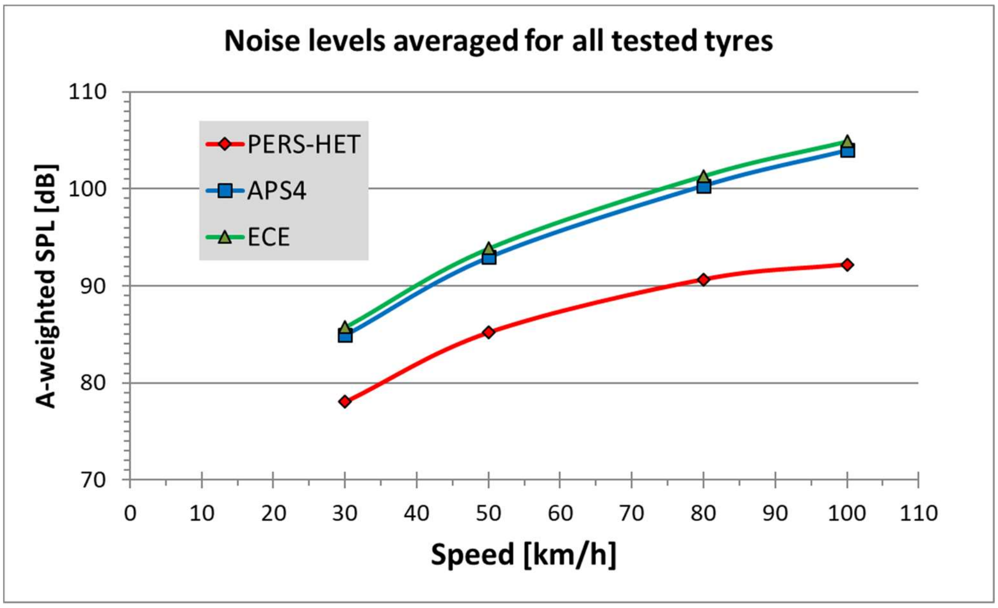

Fig. 4. Tire/road noise levels as tested on drum facility; PERS-HET – poroelastic pavement manufactured by HET Germany, APS4 – replica of Surface Dressing SD11, ECE – replica of Dense Asphalt Concrete DAC 11.

Tire/road noise reduction of 8-12 dB must be considered as of very high value, making PERS the most quiet road pavement so far. What is important, considerable noise reduction is obtained also for wet conditions as PERS belongs to the drainage type of pavements, thus vastly reduces splash and spray problems that are also responsible for excessive noise on dense pavements and significant limitation of visibility. Elasticity of PERS promotes self-cleaning properties so high noise reduction is preserved for a long time contrary to conventional drainage pavements that get clogged quickly, especially if vehicles' speed is low or moderate.

Tire rolling resistance

Rolling resistance of car tires is presently one of the most important concerns due to climate changes that are associated with CO_2 emission. Evaluation of rolling resistance on PERS pavements was performed both on road test sections and in laboratory. For road test innovative test trailer R^2 Mk.2 was used (see Fig. 5) while in laboratory, special roadwheel facility equipped with replicas of road surfaces was used (see Fig. 6).

Fig. 5. Test trailer R2 Mk.2.

Fig.6. Roadwheel facility.

Results of measurements indicate that for passenger car tires the Rolling Resistance Coefficient on PERS is higher than on smooth surfaces like ISO or DAC16 but lower than on very coarse surfaces like Surface Dressing APS4 (see Fig. 7). Unfortunately for truck tires the rolling resistance on PERS is much higher than on conventional pavements due to dissipation of energy in elastic surface that deflects very much under load imposed by truck tire (see Fig. 8). The authors believe that it is not a big problem as PERS surfaces are intended for use in urban areas where heavy vehicles traffic is restricted or prohibited.

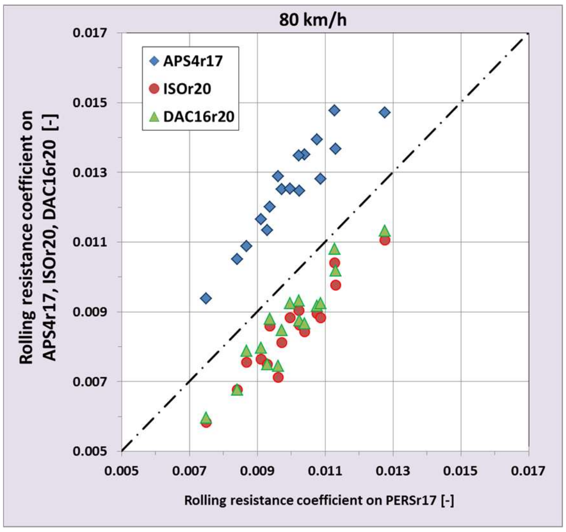

Fig. 7. Rolling resistance for passenger car tires.

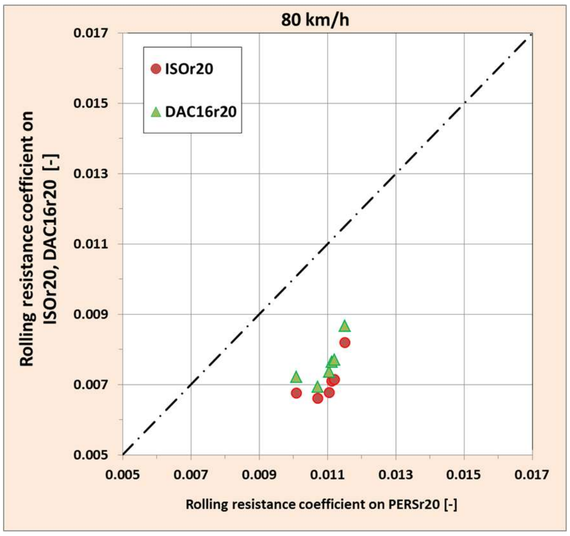

Fig.8. Rolling resistance for passenger truck tires

Fire risk

At the early stage of PERS development there were serious concerns related to the fire risk associated with this surface, namely possible emission of hydrogen cyanide (HCN) and violent spread of fire in case of accident and fuel spill. Numerous tests performed both on small samples of PERS and on real cars subjected to fire on PERS surfaces proved that HCN emission is negligible and that the surface actually **prevents** fire spread [5].

In Fig. 9 an example of 20 liters fuel spill fire on conventional road surface photographed 10 second after ignition is presented. For comparison, in Fig. 10 similar fire on PERS (but this time with car) is presented after 10 seconds of burning. Due to limited size of PERS sample some fuel seeped through PERS and flowed on dense pavement. This is visible as intensive fire at the back of car. Drainage properties of PERS help retardation of fire and give time for evacuation of the driver and passengers.

Fig. 9. Fuel fire on dens surface (after 10 s).

Fig. 10. Fuel fire on PERS (after 10 s).

Summary

At the present stage of development poroelastic road surfaces exhibit very high tire/road noise reduction, acceptable skid resistance and rolling resistance and excellent fire properties (especially PERS based on polyurethane binder). The biggest problem that still must be solved is unsatisfactory durability (delamination from the base layer and rutting). Consortium SEPOR makes experiments with different binders, that may solve those problems. First tests with rubber modified asphalt give promising results so in the near future full scale road test sections using new PERS mix will be constructed in Poland. In order to improve bonding between the poroelastic pavement and the base layer, an intermediate layer reinforced with fabric will be introduced.

Acknowledgements

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