Poroelastic Block Pavement as a Low Tyre/Road Noise Solution for Cities

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Summary
A special type of low-noise road pavement is being developed in the ongoing large European project PERSUADE. It is made of poroelastic material (PERS) and it shows excellent noise reducing qualities. The research in such pavement is focused on assuring noise reduction capability while solving wet skid resistance, which must be maintained at an acceptable level. The specific application of this new type of road surfacing is that when glued to paving blocks it makes a quiet and at the same time aesthetically pleasing surface, thus perfect solution to be used in cities, especially in their historic centres.
In the first half of the project, two promising poroelastic mixes have been developed in the laboratory. Both mixes were used to build block pavements in test tracks in town of Nova Gorica. The first tyre/road noise measurements have been performed in early January 2015. The results show lower emitted noise for the poroelastic road surface compared to the dense AC road surface typical for that area. At 50 km/h and at 80 km/h the noise reduction is between 7 dB(A) and 8.5 dB(A) and is very similar for all passenger cars. An electric passenger car took part in controlled pass-by measurements but surprisingly, the noise reduction at 80 km/h was only around 4 dB. The reason could be in the specific car construction, for which the contribution of the tyre/road noise to the overall noise is smaller than in the case of gasoline passenger cars.

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1. Introduction

The EU funded project PERSUADE (www.persuadeproject.eu) has been scheduled for a duration of six years, with twelve partners from seven European countries cooperating, including research institutes, universities and companies representing the sectors of industry involved. PERSUADE is testing the poroelastic road surface on trafficked roads.

A road pavement surface, made of poroelastic material (PERS), shows excellent noise reducing qualities. In the forms we currently know, PERS material consists of an aggregate of rubber granules or fibres, often supplemented by friction-enhancing stone aggregates and a binder to hold the mix together. The design void content is usually above 20% and it can be even 30%. Early stage tests in Japan and Sweden show that noise reduction compared to the most common road pavements could reach 10 dB(A) or more [1].

In the first half of the project, two promising mixes have been developed in the laboratory. This phase has been followed by testing of the mixtures on small scale “pilot” test tracks (typically 10–50 m²) and in the current phase on full scale test tracks. In June-September 2014 five full scale test tracks have been built in Denmark, Belgium, Sweden (two) and Poland, with a length varying between 24 m up to 75 m. These consist of partly different mixes, are constructed in different ways and are laid on roads carrying different traffic volumes.

The specific application of this new type of road surfacing (poroelastic) is that when glued to paving blocks it makes a quiet and at the same time aesthetically pleasing surface. Such a block pavement forms a perfect low tyre/road noise solution to be used in cities, especially in their historic centres. Such pavement is being tested on currently last full scale test track which was built in December 2014 in Slovenia.

The aim of the research is to transform the experimental concept into a feasible noise abating solution. This requires solving some issues while assuring noise reduction capability: durability of poroelastic mixture, maintaining wet skid resistance at acceptable levels, and in case of block pavement, stability of the system of blocks, which must be sufficient for a reasonable operating (life) time.

2. Test site and construction

Since the start, the European project PERSUADE has made good progress. Two promising mixtures have been developed in the laboratory. These have been first tested in several European countries, including Slovenia. A poroelastic block pavement has been tested in town of Nova Gorica with a small test track already since September 2013. The second and improved mixture forms a surface of the pavement constructed in December 2014 nearby in a larger test track.
The pavement structure practically reflects usual block pavement (Figure 1). Its surface consists of poroelastic blocks: poroelastic tiles, which are manufactured in the same shape as blocks, have been glued to usual cement concrete blocks. Blocks were laid into a sand layer which in turn was built over a cement concrete layer (Figure 2).

Figure 1. Poroelastic block pavement.

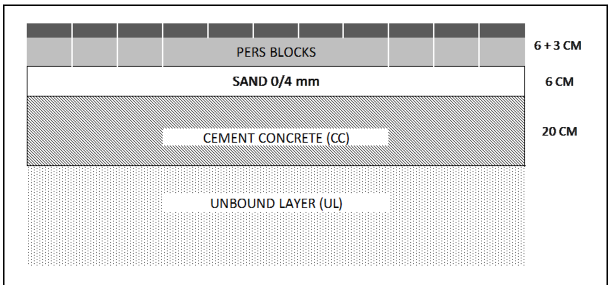

Figure 2. Pavement structure.

Test track is located on a road that can be classified into a »low« speed road category with the traffic operating at an average speed of around 50 km/h.

3. Noise measurement method

The first group of pass-by measurements (Figure 3) according to the ISO 11819-1 standard [2] were performed at this test track in January 2015 (30 days after opening of the test track to the normal traffic and then repeated on days 35 and 43) allowing authors to present the preliminary results.

Figure 3. Pass-by measurements.

The measurement procedure that was used complied with the requirements of the standard, except for the length of the test track. Due to some objective reasons this was shorter than prescribed (app. 18 m), but still long enough to be able to perform measurements correctly. The horizontal distance from the microphone position to the centre of the test track was 7.5 m. Microphone was located 1.2 m above the plane of the road lane.
The city road with the test track is trafficked predominantly by the passenger cars therefore measurements were primarily focused on those. The maximum A-weighted sound pressure level of each individual vehicle passed-by was measured together with the vehicle's speed.
Statistical pass-by measurements (SPB) of the passenger cars in the normal traffic flow were performed. Controlled pass-by measurements (CPB) were also performed, by means of driving over the test track with the passenger car model Renault Kangoo, hereinafter called passenger car ZAG, and dual-axle heavy vehicle model Renault Manager. Beside the two aforementioned gasoline and diesel-powered vehicles the controlled pass-by measurements of an electric passenger car were also performed (Figure 3). To this aim, a two seats and “open” chassis passenger car model Renault Twizy was used. All vehicles collaborating in measurements were equipped with winter tyres.

4. Evaluation of results

Individual maximum pass-by noise levels together with the speed of vehicles were recorded and a regression line of the maximum A-weighted sound pressure level versus the logharitem of speed was calculated for each vehicle category.

The regression line may be expressed in a form [1, 3]:

$$L_{Amax,m,v} = a_m + b_m . log_{10}(v) \qquad (1)$$

where:

$L_{Amax,m,v}$ maximum A-weighted sound pressure level for the vehicle category m at a speed v

b_m and a_m the slope and the intercept of the regression line.

Maximum A-weighted sound pressure level L_{veh} at the reference speed can be determined from the regression line for each vehicle category. An example of measurement results for passenger cars in the normal traffic flow is shown in Figure 4.
As an indication of the error in estimating the true average maximum pass-by level at a particular speed the 95% confidence curves have been applied [4].

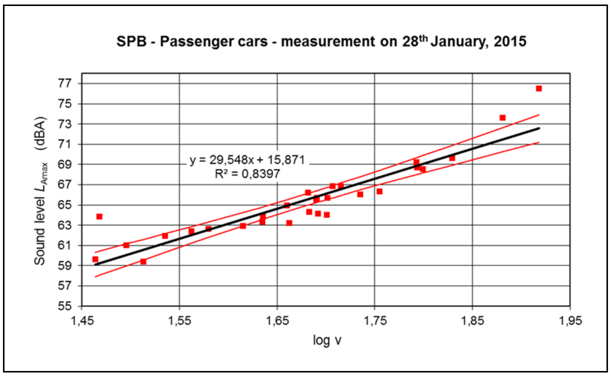

Figure 4. Example of SPB measurement results for poroelastic road surface.

In order to take into account the influence of road surface temperature on the measurement results the temperature correction has been applied according to the equation 2 [5]:

$$L_{corr} = L(\theta) + K \cdot (\theta_{ref} - \theta) \qquad (2)$$

where:

L_{corr} temperature corrected sound level, dB(A)

L measured sound level, dB(A)

θ measured road surface temperature,

θ_{ref} reference temperature 20^0C,

K temperature coefficient.

For passenger cars correction $K = -0,04$ dB(A) / °C has been applied. For heavy vehicle no temperature correction has been applied. In the following diagrams the temperature corrected sound levels are shown.
The SPB measurement results for passenger cars on days 30, 35 and 43 after opening the test track to normal traffic are shown in Figure 5.

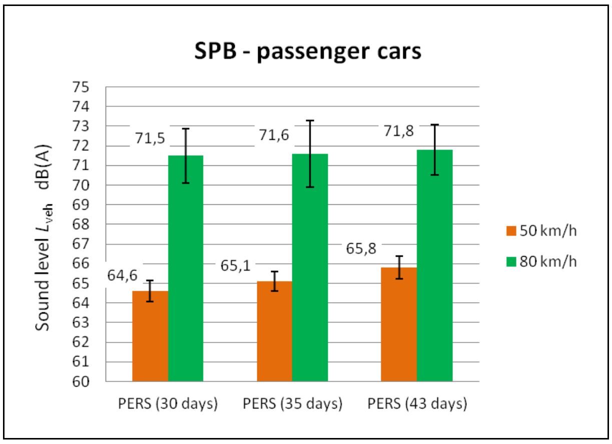

Figure 5. Sound levels of passenger cars in the normal traffic flow.

The measured sound levels vary between 64,6 dB(A) and 65,8 dB(A) for speed 50 km/h and a little around 71,5 dB(A) for driving speed 80 km/h.
The results of the CPB measurements of passenger car ZAG, performed on days 30, 35 and 43 after opening the test track to normal traffic are shown in Figure 6.

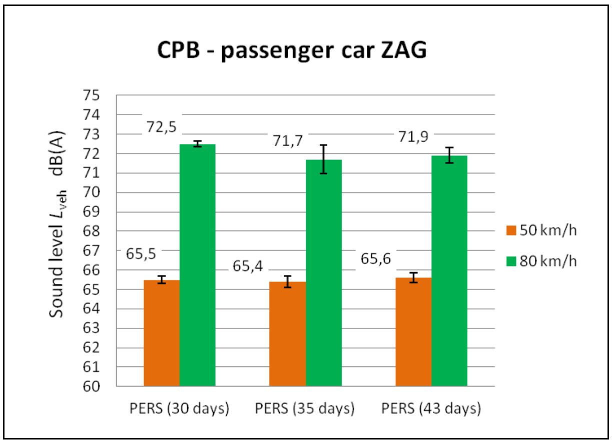

Figure 6. Controlled pass-by levels of passenger car ZAG.

The results differ just slightly from the SPB measurements. The measured sound levels in this case vary a little around 65.5 dB(A) for driving speed 50 km/h and between 71.7 dB(A) and 72.5 dB(A) for speed 80 km/h.
From Figures 5 and 6 can be seen that due to the small time interval between two consecutive measurements the change in the noise emission is small and is within the measurement uncertainty.
Comparison of pass-by levels for measurements on poroelastic road surface, 43 days after opening of the test track to traffic, is shown in Figure 7.
While SPB and CPB measurements show very similar results for gasoline driven passenger cars, CPB measurements for electric car show 5 dB(A) and 3 dB(A) lower sound levels for driving speeds 50 km/h and 80 km/h respectively.

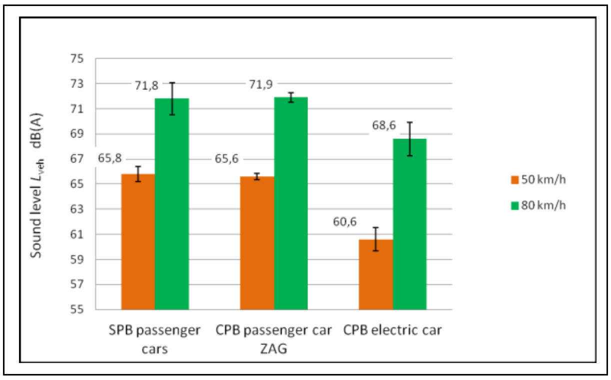

Figure 7. Pass-by levels of different passenger cars at characteristic velocities.

Comparison of controlled pass-by levels for measurements on poroelastic road surface, 43 days after opening of the test track to normal traffic, is shown in Figure 8.

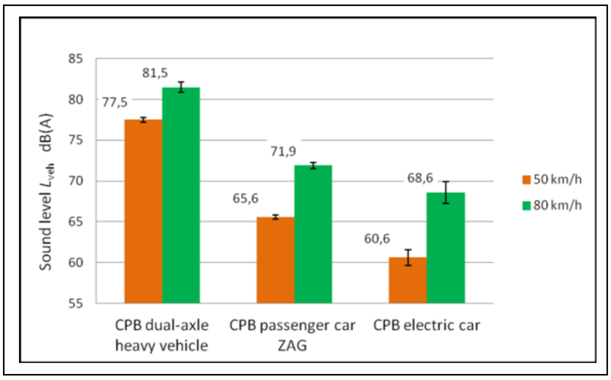

Figure 8. Controlled pass-by levels of dual-axle heavy vehicle and passenger cars at characteristic velocities.

Here, the measured sound levels for the involved passenger car were about 10 dB(A) to 12 dB(A) lower than those for the involved heavy vehicle. Sound levels were lower for another 3 dB(A) to 5 dB(A) for the involved electric car, depending on the driving speed.
To find out to what extend the emitted noise is reduced if the poroelastic road surface is built in the pavement structure instead of dense asphalt concrete, pass-by measurements were also performed for the dense asphalt concrete (DAC) on the road section, adjacent to the test track with the poroelastic road surface. The reduction of the emitted noise is shown in Figure 9.
Substantial reduction in noise emissions were measured for passenger cars, in both cases, SPB and CPB measurements (above 7 dB(A) and depending on driving speed). Different situation was found for the electric vehicle (Figure 10), where reduction at driving speed 80 km/h was much lower (4.3 dB(A)) than for driving speed 50 km/h (8.2 dB(A)). The reason could be in the specific car construction, for which the contribution of the tyre/road noise to the overall noise is smaller than in the case of gasoline passenger cars.

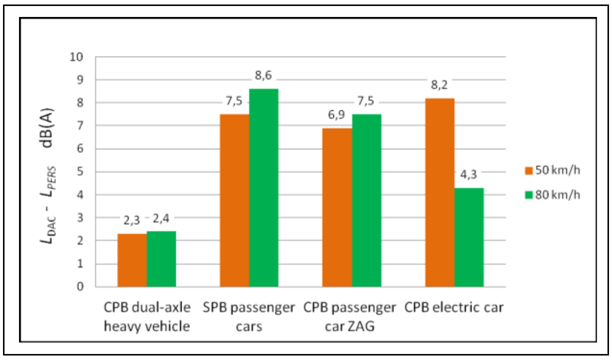

Figure 9. Noise reduction for poroelastic road surface (PERS) compared to the dense asphalt concrete section (DAC).

Figure 10. Electric vehicle involved in measurements.

5. Conclusions

A poroelastic block pavement is being tested in town of Nova Gorica in Slovenia with a test track which was constructed in December 2014.
The pavement structure practically reflects usual block pavement: its surface consists of poroelastic blocks that were laid into a sand layer which in turn was built over a cement concrete layer. The specific feature here is that poroelastic tiles have been glued to usual cement concrete blocks. To make the process easier these tiles were manufactured in the same shape as cement concrete blocks.
Since there was only short time available from construction of the test track, it was possible to perform only limited number of noise measurements.
The following conclusions can be drawn upon the measurements performed:
1. Within the uncertainty of the measurements no evident changes in the noise levels can be noticed in the period between the first and the last pass-by measurement.
2. The emitted noise by car driving over the poroelastic road section is significantly lower than when driving over the dense asphalt concrete (DAC) section.
3. It can be seen from the measurements results that the noise reduction in the case of poroelastic road surface compared to DAC is far more pronounced for passenger cars than for heavy vehicle. At driving speed 50 km/h the noise reduction is of about 7 dB(A) to 8 dB(A) and is very similar for all passenger cars. Surprisingly, for the specific electric passenger car that was involved in measurements, the noise reduction at 80 km/h is only around 4 dB, which is much less than for passenger cars, powered by gasoline. The reason could be in the specific car construction, for which the contribution of the tyre/road noise to the overall noise is smaller than in the case of gasoline passenger cars.

As part of the PERSUADE project we will monitor further the impact of aging of the poroelastic road surface on the noise emissions of passenger cars in the normal traffic flow and on the vehicles which had been used in the so far performed controlled pass-by measurements.

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References

[1] SILVIA-Sustainable road surfaces for traffic noise control, Guidance manual for the implementation of low-noise road surfaces, FEHRL Report 2006/02.

[2] Standard ISO 11819-1 Acoustics- Measurement of the influence of road surfaces on traffic noise, Part 1: Statistical Pass-By method, 1997.

[3] Sandberg U., Ejsmont J.A., Tyre/Road noise reference book, INFORMEX, Kisa, 2002.

[4] Roovers M.S., SPB Study, SILVIA project report, 2005.

[5] SPENS- Sustainable pavements for European new member states, Guidelines for the environmental assessment of various pavement types including recommendations to road authorities in NMS, final report, 2009.