CAN A POROELASTIC BLOCK PAVEMENT BE A SOLUTION FOR LOW TYRE/ROAD NOISE CITIES?

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Abstract
The recently finished large European project PERSUADE has focused its research on development of special type of low-noise road pavement - the poroelastic road surface (PERS). The research in such pavement is at least in assuring high noise reduction capability and maintaining wet skid resistance at an acceptable level. When glued to paving blocks it makes a quiet and at the same time aesthetically pleasing surface, a perfect solution to be used in cities, especially in their historic centers.
Noise measurements on such pavement show lower emitted noise for PERS compared to the reference surface: the noise reduction for passenger cars at 50 km/h and at 80 km/h is between 7 dB(A) and 8.5 dB(A). The overall noise levels have just slightly changed during the monitoring period. The spectrum shows a slight increase of noise levels by time in the middle frequency region, which could be explained with the reduction of the sound absorption capability of the poroelastic road surface.

Keywords: poroelastic road surface; low noise pavement; tyre/road noise; PERS block pavement; tyre recycling.

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1 Introduction

The EU funded project PERSUADE (www.persuadeproject.eu) has been testing the poroelastic road surface on trafficked roads. Such a road pavement surface is made of poroelastic material (PERS), and shows excellent noise reducing qualities. The noise reduction, compared to the most common road pavements, could reach 10 dB(A) or more [1], what was shown at test tracks in Japan and Sweden.
The basic material consists of rubber granules or fibres and it is equivalent to aggregate in asphalt concrete mixtures. Rubber aggregate is often supplemented by stone aggregates to enhance the friction capability of the surface. Finally, PERS includes a binder to hold the mix together. The design void content is usually above 20% and it can reach 30%.
The first half of the project was dedicated to the laboratory development of promising mixes which were tested on small scale "pilot" test tracks. At the next stage, full scale test tracks were built from June to September 2014 in Denmark, Belgium, Sweden (two) and Poland, with lengths varying between 24 m and 75 m.
While the PERS materials of these five full scale test tracks consist of partly different mixes, there was a specific application tried at the test track in Slovenia.
The specificity of this application is that when glued to cement concrete paving blocks it makes a quiet and at the same time aesthetically pleasing surface; a perfect solution to be used in cities,

especially in their historic centers. Such pavement is being tested on currently last full scale test track which was built in Slovenia in December 2014.
The aim of the research is to solve durability issues of poroelastic mixture, to maintain stability of the system of blocks for a reasonable operating (life) time and to keep wet skid resistance at acceptable levels.

2 Block pavement structure

At first, two promising mixtures have been developed in the laboratory and have been tested in several European countries, including Slovenia. In September 2013, the first PERS block pavement was tried with a small test track in town of Nova Gorica, 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.
A year later (in December 2014) the second and larger test track was constructed nearby with improved mixture for the surface.
The PERS pavement structure is formed almost as usual block pavement (Figure 1), with unbound layer as a base. A cement concrete layer was built over the base layer, on top of which a layer of sand was spread.
The pavement surface was prepared indoors in a construction hall, and consists of poroelastic blocks: poroelastic tiles, manufactured in the same shape as blocks, were glued to usual cement concrete blocks. Such PERS blocks were finally laid into the sand.

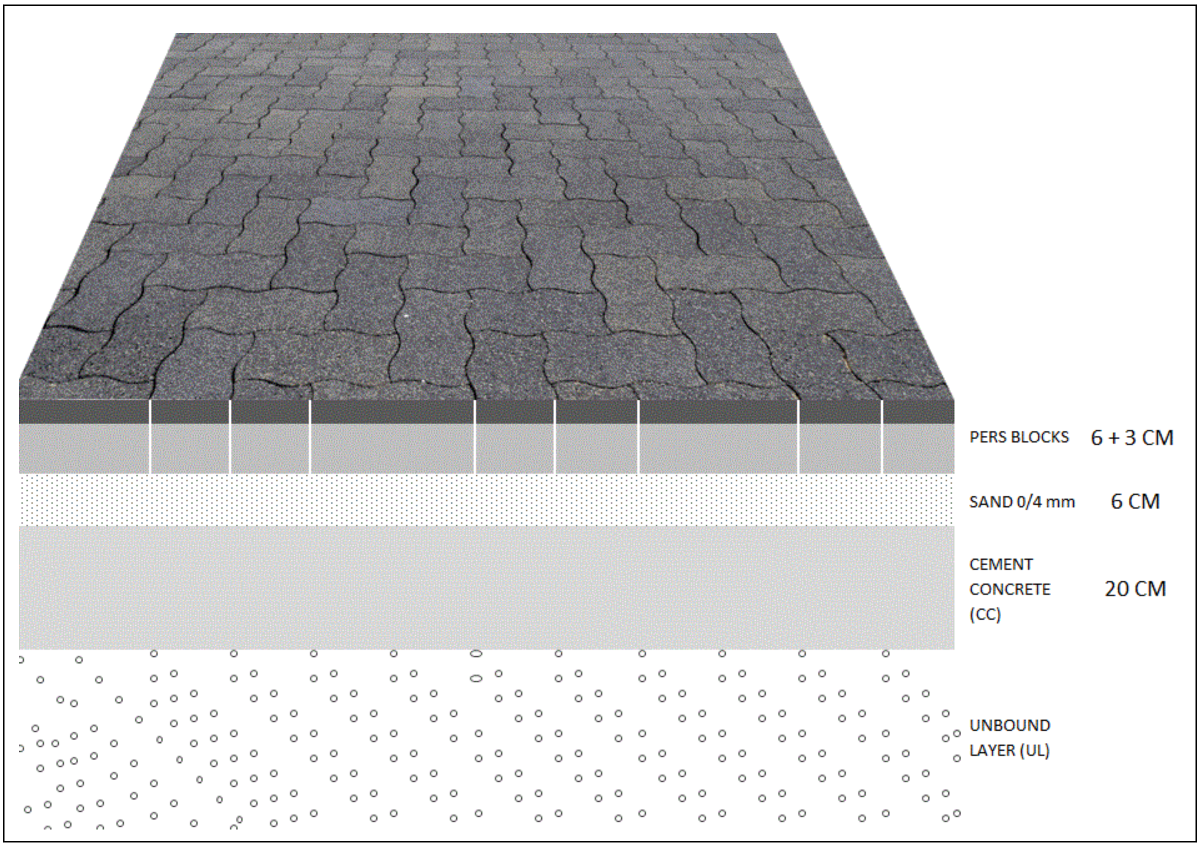

Figure 1 - Poroelastic block pavement and its structure.

3 Noise measurements

Pass-by measurements (Figure 2) according to the ISO 11819-1 standard [2] were performed at this test track during the first half of the year 2015 and in March 2016 (15 month after opening of the test track to the normal traffic).
The measurement procedure complied with the requirements of the standard: 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 maximum A-weighted sound pressure level of each individual vehicle passed-by was measured together with the vehicle's speed.
The length of the test track is due to some objective reasons somehow shorter than prescribed (app. 18 m), but long enough to be able to perform the measurements correctly.

Figure 2 – During the measurements.

The traffic on this city road is dominated by the passenger cars, therefore measurements were primarily focused on those. The noise measurements methods performed were:
- Statistical pass-by measurements (SPB) of the passenger cars in the normal traffic flow,
- Controlled pass-by measurements (CPB). These measurements were performed with the institute' passenger car (hereinafter called passenger car ZAG), and dual-axle heavy vehicle.

Additionally to the two above mentioned passenger car and heavy vehicle the controlled pass-by measurements were on one occasion performed with an electric passenger car as well. To this aim, a two seats and "open" chassis passenger car model Renault Twizy joined the measurements.
At initial rounds of measurements were all vehicles equipped with winter tires.

4 The results and analyses

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 logaritem of speed was calculated for each vehicle category.

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

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

Where $L_{\text{Amax,m,v}}$ is the maximum A-weighted sound pressure level for the vehicle category m at a speed v, and b_{m} and a_{m} are 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 3.
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].

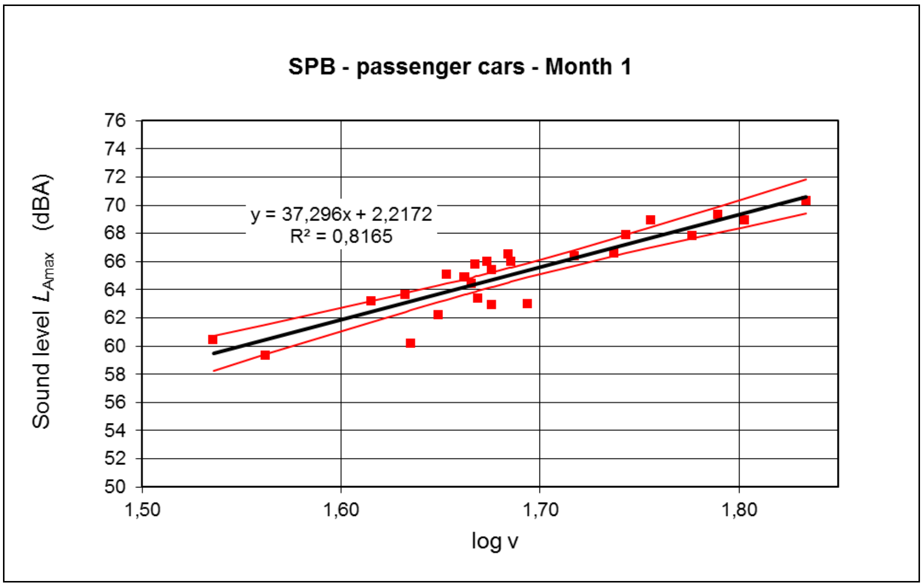

Figure 3 – Example of results, regression line for passenger car.

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

$$L_{corr} = L(t) + K.(t_{ref} - t) \ . \quad (2)$$

Where L_{corr} is a temperature corrected sound level, dB(A), L is a measured sound level, dB(A), t is a measured air temperature, t_{ref} is a reference temperature 20^0C, and K is a temperature coefficient.

Temperature correction K = −0,07 dB(A) / °C has been applied for passenger cars but not for heavy vehicle. In the following diagrams the temperature corrected sound levels are shown. The SPB

measurement results, obtained for passenger cars at characteristic time intervals after opening the test track to normal traffic, are shown in Figure 5.
The measured sound levels vary between 64,2 dB(A) and 65,6 dB(A) for driving speed 50 km/h and between 66,9 dB(A) and 73,2 dB(A) for driving speed 80 km/h.
Due to the fact that the speed of the majority of passenger cars was around 50 km/h, the results for driving speed 80 km/h are much less accurate than for driving speed 50 km/h.
The results of the CPB measurements of passenger car ZAG, obtained at characteristic time intervals after opening the test track to normal traffic, are shown in Figure 6. Within the measurement uncertainty the results do not differ much from that for the SPB measurements. The measured sound levels in this case vary between 65,1 dB(A) and 66 dB(A) for driving speed 50 km/h and between 70,8 dB(A) and 72,1 dB(A) for driving speed 80 km/h.
From Figure 5 it can be seen that the change in the noise emission for the consecutive measurements is rather small and is within the measurement uncertainty.

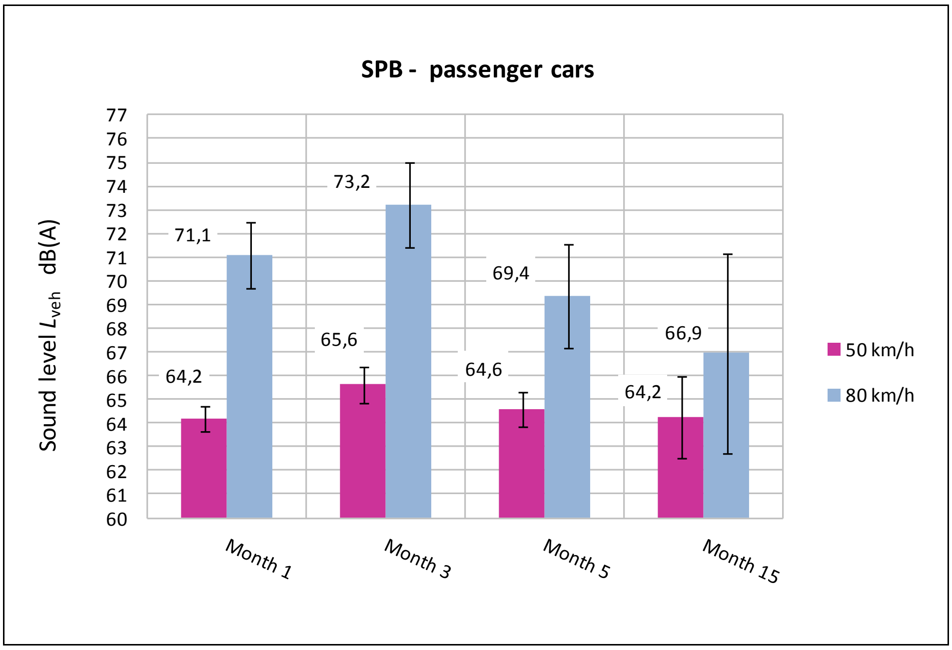

Figure 4 - Sound levels in the normal traffic flow, SPB, passenger cars.

The noise spectra of passenger car ZAG at characteristic time intervals, measured during CPB measurements, are shown in Figure 6. A slight increase of noise levels with time can be noticed in the middle frequency region, namely around 2 dB, for the complete observation period of 15 months, from the opening of the test track to normal traffic. This behaviour can be explained with the reduction of the sound absorption capability of the poroelastic road surface with time.

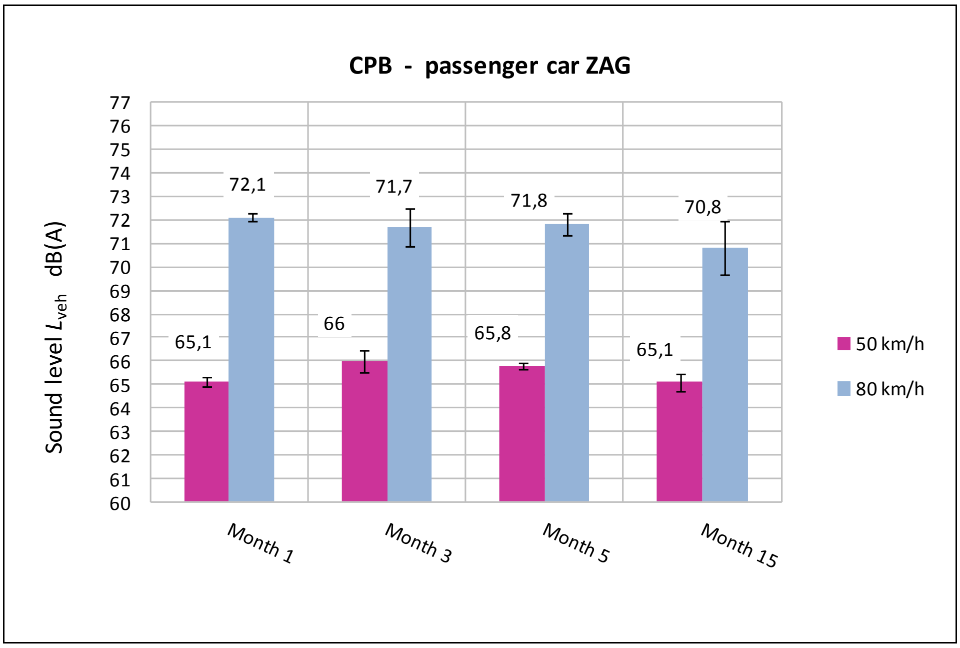

Figure 5. Sound levels, CPB, passenger car ZAG.

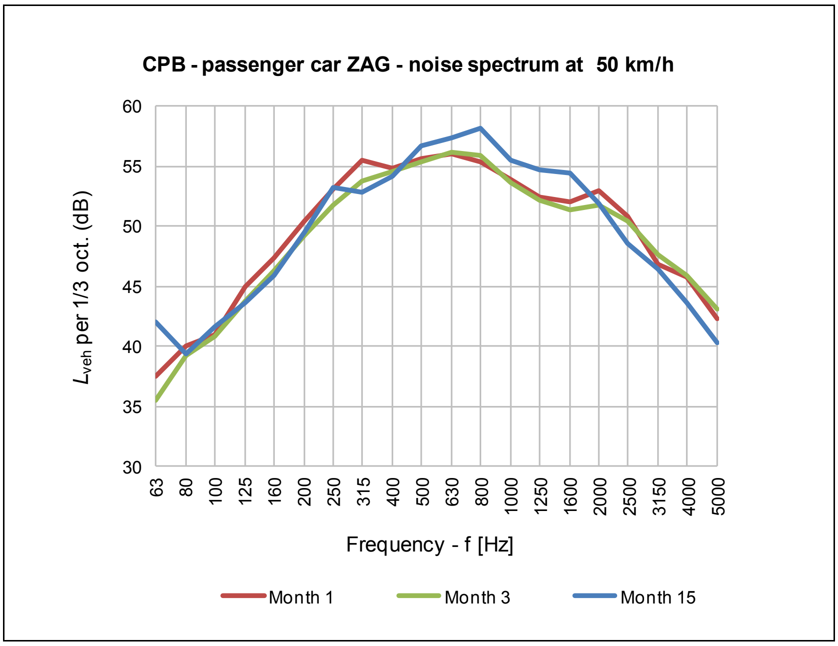

Figure 6 – The noise spectra for passenger car ZAG.

The pass-by levels for vehicles involved in pass-by measurements on poroelastic road surface, one and half months after opening of the test track to traffic, were already compared and reported [6] in the second half of the project duration. At the time, a temperature correction was chosen, which was replaced with the correction explained above at the end of the project. Basically the same pass-by levels, this time with the new temperature correction applied, can be seen in Figure 7.

While SPB and CPB measurements show 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.

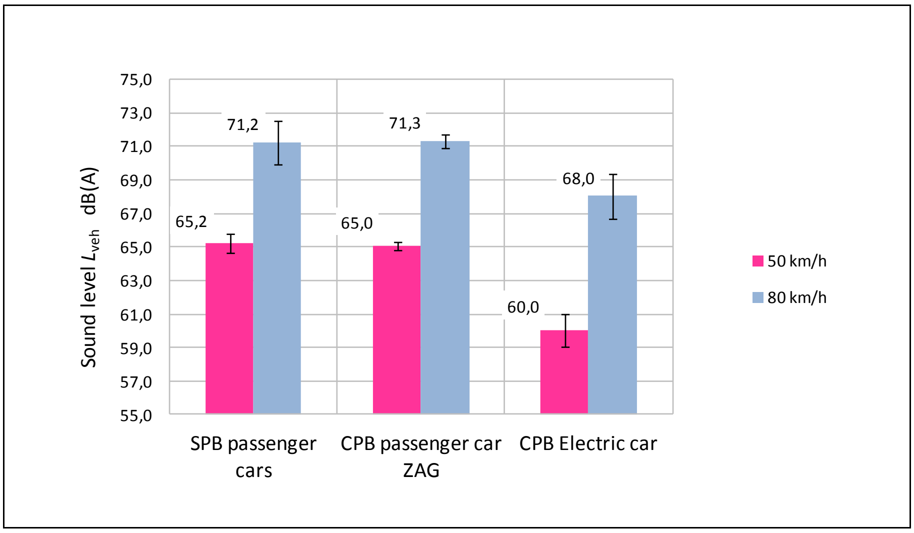

Figure 7 - Sound levels, SPB and CPB, passenger cars at characteristic velocities.

Comparison of controlled pass-by levels for vehicles involved in pass-by measurements on poroelastic road surface, one and half months after opening of the test track to normal traffic, is shown in Figure 8. Here, the measured sound levels for the involved passenger car were about 10 dB(A) to 12 dB(A) lower than sound levels for the involved heavy vehicle. As expected, the lowest levels were measured for the involved electric car. These were for 3 dB(A) to 5 dB(A) lower than the levels for the passenger car, depending on the driving speed.

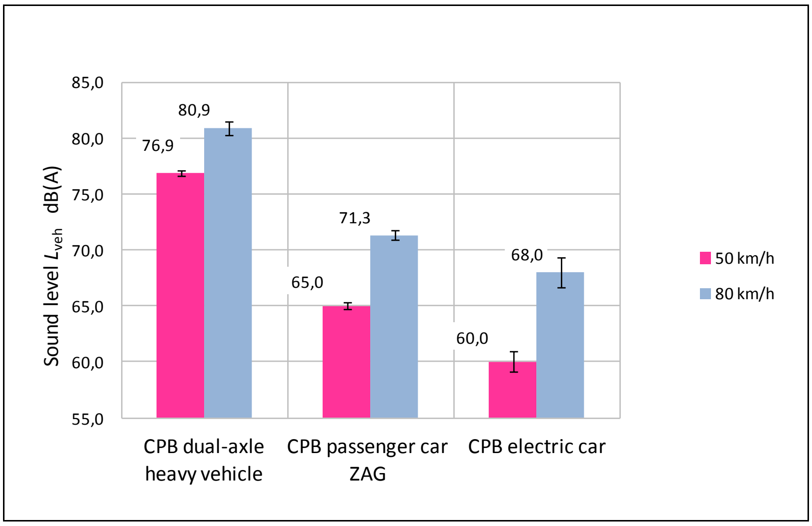

Figure 8 - Sound levels, CPB, heavy vehicle and passenger cars at characteristic velocities.

The maximum A-weighted noise levels for measured vehicles as a function of vehicle speed are shown in Figure 9 [5].

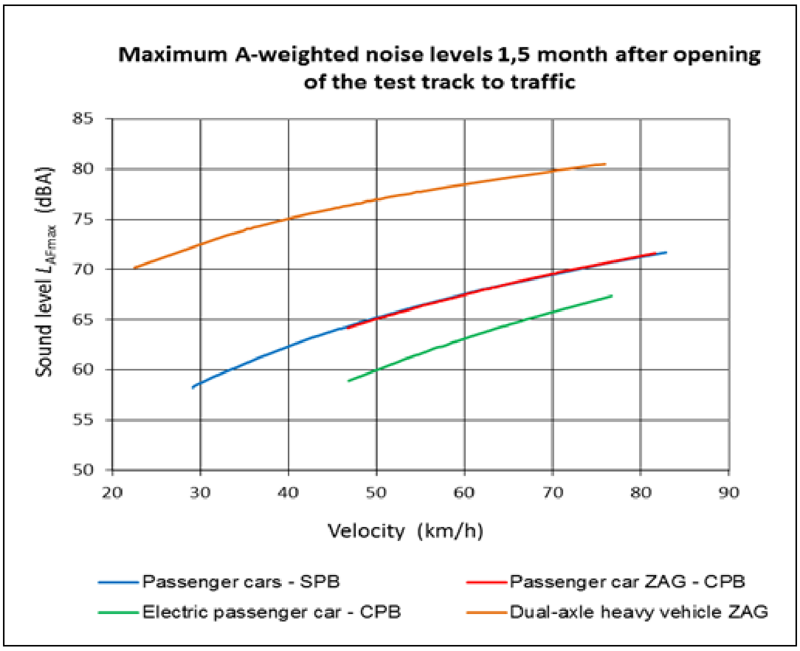

Figure 9 - Maximum A-weighted noise levels for measured vehicles as a function of vehicle speed.

The pass-by noise levels of passenger cars included in the measurements are almost identical to the controlled pass-by noise levels of passenger car ZAG. There is a notable difference between the pass-by noise levels of passenger cars and levels of electric passenger car with the increasing speed. This can be explained by the specific construction of electric car (see Figure 11) which produces higher levels of aerodynamic noise compared to other passenger cars.
To what extent is the PERS reducing noise if it is built-in the pavement structure instead of an asphalt concrete? To find this out, pass-by measurements were performed on the road section, adjacent to the PERS test track, with asphalt concrete (AC) as a surface layer. The reduction of the emitted noise is shown in Figure 10 [6].

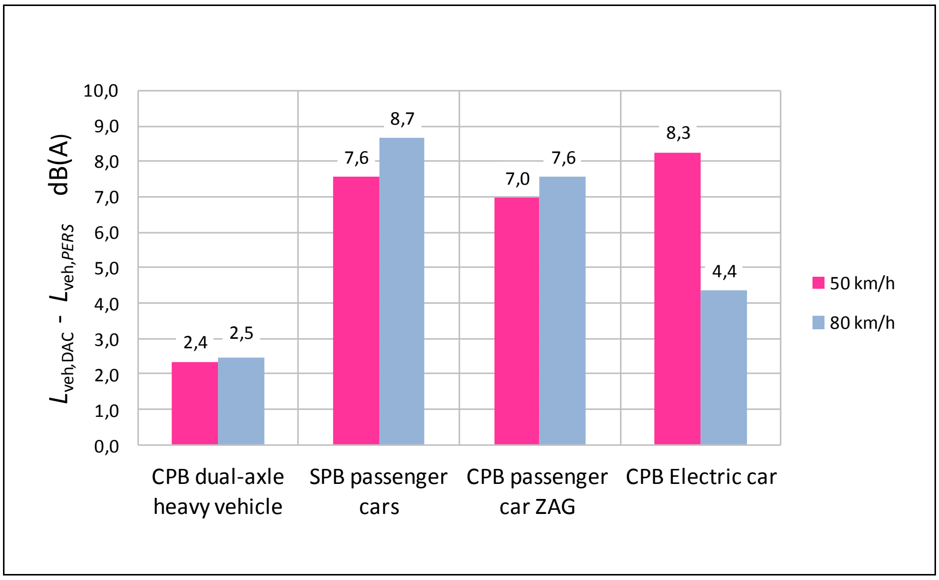

Figure 10 – Differences in sound levels between poroelastic road surface (PERS) and the asphalt concrete section (AC).

With SPB and CPB measurements a substantial reductions in noise emissions were observed for passenger cars (more than 7 dB(A) and depending on the driving speed).
A peculiar situation is related to the measurements with electric vehicle (Figure 11): a reduction at speed 80 km/h is much lower (4,4 dB(A)) than at speed 50 km/h (8,3 dB(A)). As already pointed out above, the reason is most probably 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 other passenger cars.

Figure 11 - Electric vehicle during the measurements.

5 Conclusions

In December 2014, a poroelastic (PERS) block pavement was constructed in a test track in town of Nova Gorica in Slovenia. The PERS pavement structure is built as usual block pavement, starting with unbound layer as a base. A cement concrete layer was built over the base layer, on top of which a layer of sand was spread. The pavement surface consists of poroelastic blocks: poroelastic tiles, were glued to usual cement concrete blocks of the same shape.

Statistical pass-by measurements of the passenger cars in the normal traffic flow and controlled pass-by measurements by means of a passenger car and dual-axle heavy vehicle were performed at several occasions. The outcome of the measurements so far is as follows:
1. The emitted noise by car driving over the poroelastic road section is significantly lower than when driving over the asphalt concrete (AC) section.
2. Within the uncertainty of the measurements no evident changes in the overall noise levels can be noticed in the period between the first and the last pass-by measurement. From the spectrum of the passenger car (CPB measurements) a slight increase of noise levels with time can be noticed in the middle frequency region. This behaviour can be explained with the reduction of the sound absorption capability of the poroelastic road surface with time.
3. When comparing the results on PERS and adjacent road section with AC as a surface layer, the noise reduction is far higher for passenger cars than for heavy vehicle. At the driving speed 50 km/h the noise reduction is about 7 dB(A) to 8 dB(A) and is very similar for all passenger cars. For the specific electric passenger car a reduction at speed 80 km/h is much lower (4,4 dB(A)) than at speed

50 km/h (8,3 dB(A)), and is much smaller than for other passenger cars. The reason for this peculiar situation is to be sought in the specific car construction.

Acknowledgements

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