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THE ULTRA LOW NOISE POROELASTIC ROAD SURFACE: A REAL LIFE DEMONSTRATION IN THE LIFE PROJECT NEREIDE

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A poroelastic road surface (PERS) consists of rubber granulates and stone aggregates bound with an elastic resin, such as polyurethane and does not contain bitumen. Thanks to its elasticity, porosity and texture, it is capable of yielding an unequalled noise reduction.

In 2015 the six year EU funded project PERSUADE ended, which has aimed to develop a highly noise reducing, safe and affordable PERS with an acceptable durability. The holistic approach of the PERSUADE consortium resulted in some interesting findings and a possible solution of the problems blocking the general use of this type of pavement, mainly cohesion problems (ravelling) and adhesion to the sub layer. One specific type of poroelastic surface performed quite well and seems to have an acceptable durability and to combine this with an extreme noise reduction.

In the NEREiDE project one will build further on this concept and after some further adaptations, a short test track will be built on a trafficked road in Belgium still in 2017. A long test track (500 m) is planned in Tuscany in the course of 2018. This paper will give a state of the art after the PERSUADE project and report of the completed and ongoing activities about poroelastic pavements in the NEREiDE project.

Keywords: poroelastic road surface, rubber, noise reduction

1. Introduction

Tyre/road noise is for cars already at low speeds (typically as low as 30 – 40 km/h) the dominant noise source. Abating traffic noise is hence mainly reducing tyre/road noise. One can (and should) work on the tyre properties to reduce noise but also on the pavement. To reduce the tyre/road noise, one can only “turn on three buttons”: the pavement texture (minimum of megatexture and maximum of macrotexture), the absorption by the pavement (high accessible void content and a proper shape and length of the “channels” formed by the voids) and the elasticity of the pavement. Low noise pavements based on an optimized texture or a high void content do exist and are even widespread in some countries, such as the Netherlands. However, the third possibility to reduce noise, making the pavement elastic, is hardly exploited so far in the commercially available pavements. Some extra noise reduction is gained in some countries by adding rubber to bituminous pavements, but these pavements are still quite “hard” and the gain is limited, typically 1 up to 2 dB(A). One can suppress tyre/road noise much more by making the pavement much more elastic, and this idea is exploited with PERS.

2. PERS: opportunities and challenges

2.1 What is PERS?

PERS is a porous (at least 20 % of voids) and elastic pavement containing rubber granulates (at least 20 % by weight, virgin material or recycled) and an elastic polymer as binder, such as polyurethane. It may contain other ingredients, such as natural or artificial stone aggregate, certain chemicals or certain types of fibres. Each of these ingredients may have a specific function: enhancing skid resistance, durability, homogeneity of the wet mix etc.

2.2 Why do we (still) want it?

PERS is in fact not a new idea: it has been invented at the end of the 1970ties by the Swedish consultant Nils-Åke Nilsson and some tests have been done in Sweden, Norway and from mid 1990ties also in Japan, demonstrating its huge and unequalled noise reduction potential: 8 up to 12 dB(A). The low noise pavements with the highest noise reduction which are in use today, two-layer porous asphalt, yield "only" 5 – 7 dB(A). Some further testing has been done in a national project in Sweden and in the national project "Noise Innovation Program" and in the subsequent project "Ultra Silent Pavement" in the Netherlands. A comprehensive overview of the history of PERS can be found in [1].

This huge noise reduction potential makes PERS very attractive. PERS reduces – at least for cars – as much noise as typical noise barriers, opening interesting perspectives for noise abatement, as noise screens do have a lot of disadvantages: they are expensive, their effectiveness depends on the local weather conditions, they are vulnerable to vandalism, intrusive and last but not least: there are a lot of situations where they cannot be used, e.g. in most city streets.

2.3 Requirements and challenges

There are a few reasons why PERS is still a concept and not yet a widespread tool for noise abatement, in spite of the fact that the concept was invented almost 40 years ago. The history of PERS is up to now mainly a list of failures [1]. The main reasons of the failures where insufficient ravelling resistance, insufficient bonding to the sub layer and insufficient skid resistance. In some cases the failures were due to reasons which were "external" to the PERS, such as disintegration or rutting of the sub layer(s) or accidental destruction of the PERS by a snow plough. The lifetime of the PERS varied from a few weeks up to a few years with some relatively successful Japanese experiments (and now a quite successful PERSUADE test track, see further). There were also questions about the fire safety and the safety of the workers, the economic feasibility and the sustainability of the product.

2.4 The PERSUADE project [2]

Between 2009 and 2015 an FP7 project "PERSUADE" was conducted in order to develop PERS from a yet experimental concept to a usable noise abatement measure.

The problems to be solved and questions to be answered about PERS at the beginning of the project were numerous: how to produce a mix which would yield a durable, highly noise reducing pavement with a sufficient skid resistance? How to avoid the PERS to ravel or to loosen from the sub layer? What in the case of a fuel spill? Or in the case of an accidental vehicle fire on a PERS section? How to build PERS without increasing rolling resistance? Which precautions should be taken to protect road workers and people living around from hazardous fumes? What to do with PERS at the end of its lifetime? What about economic aspects?

In order to find an answer to all relevant questions a comprehensive research program was drafted, consisting of the following work packages (WP):

- WP1: Project management

- WP2: Mix design
- WP3: Structural design
- WP4: Test tracks
- WP5: Monitoring of the test tracks
- WP6: Environmental issues
- WP7: Cost-Benefit Assessment
- WP8: Dissemination

The PERSUADE project was at least a partial success: achievements are the demonstration that PERS can be quite ravelling resistant (comparable to thin asphalt layers), it is not toxic and there is no fire risk. On the contrary, PERS can be used for better fire protection in, for example, tunnels. Obtaining a good friction is not a major problem and its noise reduction is comparable to a 4 m high noise screen on both sides of the road. Application techniques have been developed, tested and well documented. PERS can dramatically reduce the production of fine dust from studded tyres. Winter behaviour is an issue but, as for porous asphalt, this can be overcome with an adapted winter strategy. The product can be beneficial from an economic point of view in some cases. And when the noise reduction is taken into account it is a sustainable solution.

The project team was less successful in demonstrating the long term durability: the monitoring time of the full scale test sections became shorter than planned due to some delays with finding and testing durable mixes, but also the construction was delayed, and some of the test sections failed prematurely. The team learned that PERS on an asphalt sublayer combined with a significant volume of trucks is not a good combination as it leads to delamination within about one year. If water is not properly evacuated from the PERS after rainfall, this might speed-up the delamination. However, on a road without trucks, or a low proportion of trucks, PERS may work. The consortium had at the end of the project (August 2015) indications however, based on the observations on the Swedish and Slovenian test sections and the test in the wheel tracking device, that a PERS glued on a semi-flexible or cement concrete sub-layer will be much more durable, even under the action of truck tyres.

2.5 The best performing solution so far: PERS slabs on a semi-flexible under layer [3,4]

2.5.1 Mix formulation and production of the slabs

PERSUADE partner VTI[1] constructed three PERS test tracks on the road E 363 about 15 km west of the town Linköping in central Sweden. AADT[2] is there about 4700 vehicles with 6 % heavy vehicles. The speed on the location is about 70 km/h (also posted speed).

PERSUADE partner Heidelberger Elastomertechnik GmbH (HET) in Germany, produced slabs for the Sjögestad test track in the size of 1.0 m by 0.5 m (see Figure **1**). The thickness was decided to be 30 mm, as a compromise between cost and expected acoustic performance. For covering the 60 m^2 area, this required 120 plates. In order to have a few plates as spares, 140 plates were ordered from HET.

The PERS material had the following composition by weight:

- 53 % hard aggregate, made of basalt (čedič from Libochovany in Czech Republic)[3]. The hard aggregate was a mix of 10 % of fraction 0/4 and 90 % of fraction 2/4.

[1] The Swedish National Road and Transport Research Institute
[2] Average Annual Daily Traffic
[3] Although one could also think of using granite, as excellent ravelling resistance results were booked with the Belgian test track in Herzele, were granite was used of the Norwegian Jelsa quarry

- 38 % soft aggregate (rubber granules) with a size distribution of 1/3.
- 9 % PUR (MDI-type)
- 1 % polyol mixture (Z962.02)

From the compact densities of the components (basalt 2.941 g/cm3; rubber granules 1.168 g/cm3; MDI 1.10 g/cm3; polyol mixture Z962.02 1.01 g/cm3), the composition in volume could be calculated to be:

- 30 % hard aggregate
- 55 % soft aggregate
- 15 % binder (PUR + polyol mixture)

From the bulk volume of the panels (1000 mm x 500 mm x 30 mm), their weight (17.5 kg) and the calculated maximum density of the mix (1.684 g/cm3), the air void content in the plates can be calculated to be 31 %.

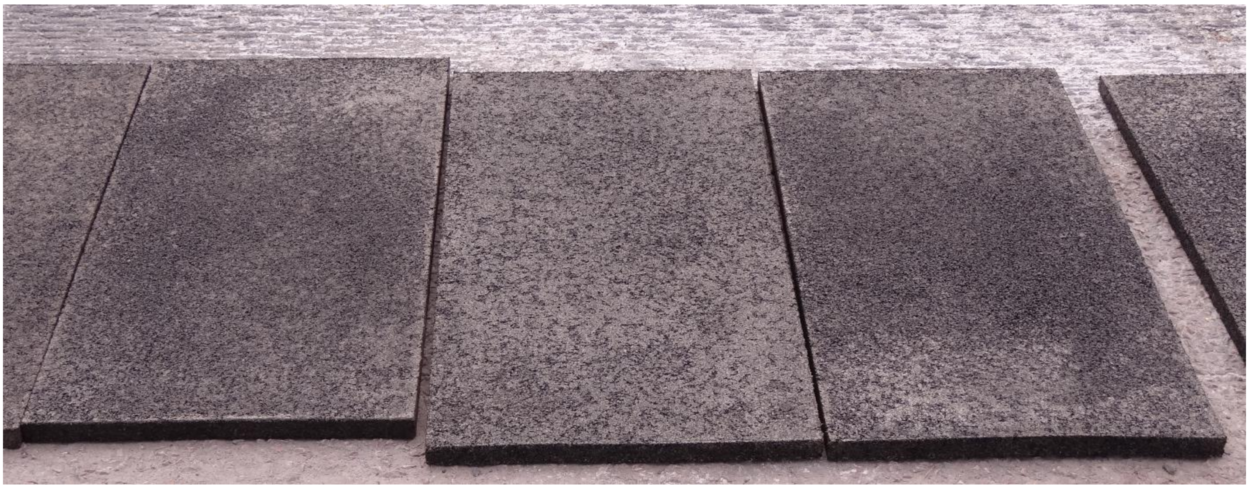

Figure 1 Prefabricated PERS slabs

Upon delivery in Sjögestad it was noticed that some slabs showed inhomogeneity and showed spots with a rather closed texture versus spots with an open texture, which can also be noticed on the slabs shown in Figure **1**. Care should be taken to ensure a homogeneous mixing of the ingredients (sufficiently long mixing time). A system of (e.g. visual) quality control of the slabs which will be produced for the NEREiDE test tracks should be foreseen and the homogeneity should already be checked before they leave the production site.

2.5.2 Under layer and the preparation of it

Earlier work, notably the work on PERS by PWRI in Japan, see [1], had indicated that the success of PERS relies on having a base course to which the PERS can have a very strong bond. For a number of reasons, it was decided to use in the PERSUADE Sjögestad test section design a so-called semi-flexible base layer.

Semi-flexible means that it is a hybrid of a flexible pavement (asphalt concrete) and a rigid pavement (cement slurry). To make room for not only a layer of 30 mm thick PERS, but also a 40 mm semi-flexible base course, the existing pavement had to milled-off down to a depth of 70 mm over the relevant area.

The semi-flexible layer was constructed by first laying a porous asphalt concrete layer, in this case having air voids of approximately 20 %, being 40 mm thick and with a maximum aggregate size of 16 mm (some are even larger) (see Figure **2**).

Figure 2 Porous asphalt 0/16 under layer (coin on the right hand side has a diameter of 25 mm)

Figure 3 Filling of the voids of the porous asphalt with the fine-graded cement slurry and the polished surface of the under layer

When this had hardened reasonably (some four hours later), a fine-graded cement slurry was poured out on the porous surface, thus filling the pores and raked out manually with the aim of just covering the texture of the porous surface by the slurry. This is illustrated in Figure **3**.

On the next day, the semi-flexible surface was polished by a polishing machine. The polishing aimed at removing any laitance and creating a smooth surface where the peaks of the large aggregate had been polished off to expose the flattened stones and with the cement slurry making the surface between the stones exactly even with the stone surface. The result was a rigid and stiff surface of extra high evenness, looking like a cement concrete pavement, which had been polished to expose the aggregate; see also Figure 3.

2.5.3 Construction of the PERS pavement

The PERS on the test track in Sjögestad was only laid in two 1 m wide and 30 m long strips in the wheel tracks and were afterwards surrounded with porous asphalt for the sake of protecting the PERS against the influence of the numerous passages of snow ploughs, which is quite common on secondary roads in central Sweden (Figure 4). The idea is however to cover the whole lane with PERS when this pavement type will be used in the future, certainly in regions with less harsh winter conditions.

The glue used to fasten these HET2 plates to the semi-flexible base course was an epoxy product; NM 62F and NM 62F Tix. The epoxy glue was delivered from Nils Malmgren AB in Sweden. The first product, NM 62F, was used as primer and the second as glue. Since the semi-flexible base course was rather smooth, only 25 litres of the primer was applied on the base course, which approximately equals a 0.5 mm layer of epoxy primer. While the primer still was sticky, 80 litres of the glue was used to fasten the 120 panels. As the amount of epoxy is higher than what is needed to fill the base course texture, some epoxy glue penetrated 1-2 mm into the PERS panels.

Figure 4 The PERS track in Sjögestad (two strips in wheel tracks) under construction

2.5.4 Observations

During the first winter after its construction (winter 2014/2015), a snow plough with steel blades passed about 100 times over it and damaged the test track in spite of the precautions to protect it by surrounding it with porous asphalt. The blad carved in it and caused some ravelling. During the subsequent summer, the test track remained stable and it survived without problems a second winter (2015/2016) and in April 2016 it still looked quite nice (see Figure 5). The Swedish National Road Administration however regrettably removed the test track in the autumn of 2016 as the two other PERS test tracks on the location were failing and they wanted to repave the area in one time for budget reasons.**Error! Reference source not found.** [5] shows the results of some CPX measurements at 80 km/h with the SRTT tyre on some PERSUADE PERS test tracks in the first year after their construction. The Sjögestad test track with panels on semi-flexible under layer appears to be among the best performing with noise reductions between 10 and 12 dB, depending on which reference is used. Moreover, this noise reduction seems stable in the time.

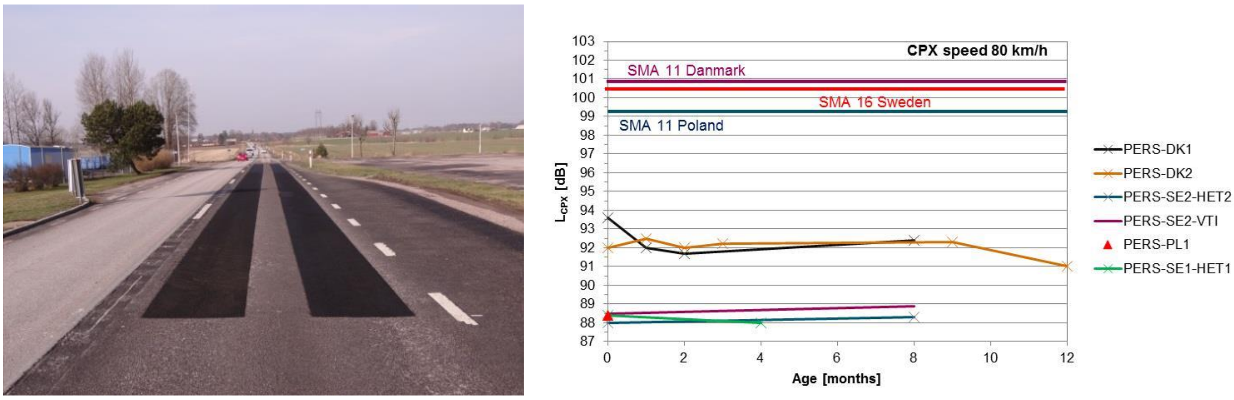

Figure 5 The PERS track in Sjögestad in April 2016 (after two winters, left hand side) and results of noise measurements with the CPX at 80 km/h on some PERSUADE PERS test tracks, compared to references used in some countries. The Sjögestad test track with PERS panels on semiflexible is indicated with "PERS-SE2-HET2"

3. PERS and the LIFE NEREiDE project

The LIFE NEREiDE project aims to demonstrate the use of new porous asphalt pavements and low noise surfaces composed by recycled asphalt pavements and crumb rubber from scrap tyres.

Although the main body of the project deals with rubber asphalt, hence bituminous pavements, a part of the project is dedicated to the demonstration of bitumen-free PERS. The project comprises the following technical tasks regarding PERS:

- PERS mixture design: laboratory development of the PERS mix aiming at an improved cohesion/ravelling resistance
- Demonstration of the enhanced PERS on a small test track in Belgium on a real trafficked road and monitoring of relevant properties
- Construction of a large scale test track on a trafficked road in Italy and monitoring

3.1 PERS mix design

This tasks aims at an enhancement of the PERSUADE PERS mix as mentioned above and which has been chosen as starting point and is carried out with the help of subcontractor TECTERO. One will investigate by means of laboratory research if and how the cohesion and the ravelling resistance can be improved. This could be achieved by providing the rubber and stone particles in the mix with a surface treatment, allowing a much better chemical binding of these particles with the binder (PUR).

At the moment of the drafting of this paper, this task is still ongoing (should be finished by May 2017). The process involves a trial-and-error procedure and the mixtures are assessed by means of the Aachener Ravelling Tester (ARTe) at RWTH, the technical university of Aachen (Germany) (Figure 6). The used machine and testing conditions are identical as those used during the PERSUADE project, allowing direct comparison of the results and a proper assessment of the progress.

Figure 6 Test slab of the first NEREiDE PERS mix (left hand side) and testing on the ARTe (the result was not yet satisfactory)

3.2 Small test track in Belgium

A small scale test track will be built in Gent, Belgium in September 2017. The track will be 50 m long, 3,5 m wide and 3 cm thick. It will consist of prefabricated slabs glued on a semi-flexible under layer, as described in 2.5. A monitoring programme will start immediately after the construction and relevant parameters, such as noise emission, skid resistance, rolling resistance, mechanical impedance, drainability, texture, evenness and sound absorption will periodically be measured, even beyond the end of the NEREiDE project in March 2020.

3.3 Large test track in Italy

Following the smaller scale test in Belgium, a large demonstration track will be built in Tuscany, Italy in the course of 2018. This test track will be 500 m long and 7 m wide and will have the same structure as mentioned above. There will be a monitoring programme on the Italian PERS section as well.

Acknowledgements

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