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THE IMPACT OF THIN NOISE REDUCING ASPHALT LAYERS ON THE QUALITY OF LIFE IN AN URBAN ENVIRONMENT

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Abstract
In October 2015 the city of Antwerp has, as part of their traffic noise action plan, constructed two test sites in an urban environment where five different thin noise reducing asphalt layers (TAL) and a poroelastic road surface (PERS) are compared to the standard Stone Mastic Asphalt 10 (SMA 10). The mechanical and acoustical characteristics of all these test tracks will be monitored twice a year for at least three years. Furthermore, the objective noise reduction is compared to the subjective perception of the residents living nearby. A survey was taken before the actual installation of the test tracks in April 2015 and was repeated in November 2015. Differences in the answers of the respondents can then be linked to the installation of a noise reducing road surface.
In this paper the objective noise reduction, measured using the Statistical Pass-By method is compared with self-reported physical complaints, which were assessed in the pre- and post-survey. From the objective results a noticeable reduction in road traffic noise can be observed, ranging from 3.8 to 5.2 dB(A). No clear changes could be found in the self-reported physical complaints, although the overall disturbance from road traffic noise has been reduced.

Keywords: SPB; acoustic surveys; thin asphalt layers; low noise surfaces.

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1 Introduction

As a consequence of the European Noise Directive 2002/49/EC, all EU member states are forced to not only analyze the situation by producing noise maps, but also to act against the problems by drafting noise action plans. Besides the national governments, also larger cities, e.g. Rotterdam in the Netherlands and recently Antwerp in Flanders, have drawn up noise action plans with actual implementation. According to [1], one of the most interesting and cost effective measures that can be taken is the use of noise reducing road surfaces.

Some recent studies have investigated the relationship between objective noise reductions and noise annoyance levels using surveys. In [2] it was shown that noise-related characteristics were less significant predictors of noise annoyance than personal, social and housing characteristics. The noise sensitivity was found to play an important role on the noise-health relationship [3]. No strong correlations were found between road traffic noise or noise annoyance and self-reported health problems such as hypertension, heart problems, tiredness and headaches.
Recently listening tests are being used as well to determine the impact of loudness and road traffic noise spectrum on the annoyance level [4,5]. These type of listening tests will be part of future research and are not discussed in this paper.

The structure of the paper is the following: Section two gives a description of the test tracks and the measurement methods which were used for this research. In Section three an overview is given of the SPB-results, traffic counts and pre- and post-surveys. The paper is finalized with some conclusions in Section 4.

2 Test tracks and measurement methods

This section includes a description of the test tracks which were discussed briefly in the introduction, followed by a listing of the measurement methods which were used in this research.

2.1 Description of the test tracks

As the main goal of the project is to evaluate the effect of TAL in an urban environment two locations were selected in the city of Antwerp and its nine districts. Different streets were selected in a first list with a minimum length of 600m, already equipped with asphalt, preferably as straight as possible with a limited number of side streets. As surveys will be used to evaluate the effect of TAL it is important that the situation before the installation of TAL is not leading to a high amount of noise related complaints. This means that the present road surface should be in a moderate to good state, and that the street should not be close to other noise sources such as an airport, railway, industry or highway. Some of these factors were on the “wish-list” in order to be able to perform the necessary acoustic measurements such as Close ProXimity (CPX) and Statistical Pass-By (SPB – according to ISO 11819-1 [6] & ISO 11819-4 [7]). The street should also have a speed limit of 50 km/h, with no schools or other areas with a reduced speed limit, and preferably no round-abouts or speed humps. For budgettary reasons it would be beneficial if the base layer is still in good condition.

After a long selection process with the occasional setbacks, such as the presence of cobble stones or tar in the base layer, or a political refusal to cooperate, two suitable locations were eventually selected. The first test site (denominated further as test location *A*) is located at the Zandvlietse Dorpstraat in Zandvliet, one of the districts north of the city center. It is a calm street with mostly detached houses, see Figure 1, and a maximum of 500 vehicles passing through the street on a single day (both directions as a whole). Only a very limited number of heavy vehicles passes through this street. It is located about two kilometers away from the Antwerp harbour, with all its industry, the A12 highway and a railway.

Figure 1 – Zandvlietse Dorpstraat in Zandvliet [*Google Streetview*].

The second test site (denominated further as test location *B*) is located at the Kleine Doornstraat in Wilrijk, the most southern of the Antwerp districts. This street contains mostly row houses, or semi-detached houses, and has a higher traffic intensity with a maximum of up to 5000 vehicles passing through the street on a single day in one direction. As can be seen on Figure 2, the street consists of two seperate lanes. A larger number of heavy vehicles and busses pass on this location. The street is located less than one kilometer from the E19 and A12 highways and about five kilometers from Antwerp airport.

Figure 2 – Kleine Doornstraat in Wilrijk [*Google Streetview*].

At both test locations five different test tracks are installed, see Figure 3 and Figure 4. At test location *B* the original road surface, a Dense Asphalt Concrete 0/10 (DAC 10), installed in 2012 by Aswebo, was still in a good shape so it was kept as a reference surface. The SPB-locations are marked here with small purple dots.

Figure 3 – Test tracks installed at test location *A*.

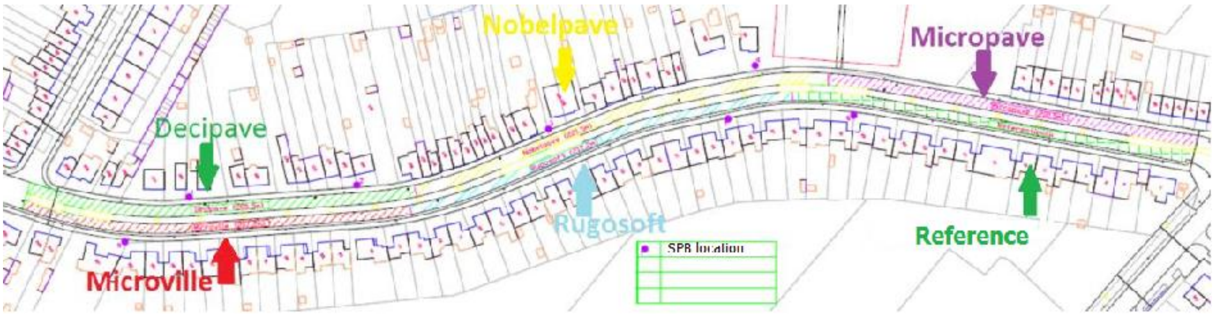

Figure 4 – Test tracks installed at test location *B*.

In Table 1 an overview is given of the different test tracks at both locations. Three contractors, one from Belgium (VBG – Colas Group) and two from the Netherlands (Dura Vermeer and Rasenberg Infra), were responsible for the installation of all test tracks. VBG was also responsible for the removal of the original road surface, the installation of a base course (where required) and additional works such as the replacement of gullies and the adaptation of existing manholes. On test location *A* a new base course of min. 6 cm (type APO-B 0/14) was placed while on test location *B* only a part of the existing base course was replaced in order to reduce the costs and to obtain two different scenarios.

Table 1 – General properties of the test tracks.

Test location A	**Contractor**	**Length [m]**	**Width [m]**
Microville	VBG	164	5.0
SMA 10	VBG	147	
Micropave	Dura Vermeer	167	
Decipave	Rasenberg	153	
PERS	VBG	100	
Test location B	**Contractor**	**Length [m]**	**Width [m]**
Microville	VBG	207	4.0
Rugosoft	VBG	212	4.0
Reference	Aswebo	212	4.0
Micropave	Dura Vermeer	201	5.8
Nobelpave	Dura Vermeer	222	5.8
Decipave	Rasenberg	206	5.8

The thickness for all TAL and PERS is max. 3 cm, while the SMA 10 is placed at a thickness of 4 cm.

Both the acoustical and the mechanical properties of these test tracks will be monitored for at least three years. The acoustical quality of the TAL is the main focus of this trial, but also other characteristics like rolling resistance, durability (resistance against raveling) and skid resistance will be studied. The first results of texture and CPX measurements will be discussed at Inter-Noise 2016.
Besides the measurement campaigns, which are repeated every six months, the impact on the quality of life of the residents living at the two test locations is examined using surveys, as explained further in Sec. 2.3.

2.2 Statistical Pass-By

Standard ISO 11819-1 [6] describes the “Statistical Pass-By” (SPB) method. According to [6] the speed and the maximum sound pressure level of minimum 100 cars and 80 heavy vehicles should be measured. The measurement is performed during their passage in front of a microphone which is

placed at a height of 1.2 m and a distance of 7.5 m from the center of the first lane of which the acoustical quality has to be assessed. A graph with the maximum sound pressure level in function of log(*v*), with *v* the vehicle speed, is plotted and the average value of the maximum sound pressure level is calculated at a reference speed (L_{veh}). In this study the reference speed v_0 is 50 km/h and no heavy vehicles are taken into account as not enough single heavy vehicles pass at the test location.
At test location *A* it is not possible to meet the requirements for the measurement location as specified in [6], not even with a backing board as described in [7]. Therefore only at test location *B* modified SPB-measurements have been performed, using a backing board to eliminate the possible influence from acoustic reflections from the rear of the measurement position. However, it should be noted that the results will be less accurate compared to measurements in true free-field conditions. All SPB-measurements were performed by a master student from UAntwerp with the equipment from and under the guidance of a researcher from the Belgian Road Research Centre (BRRC). Table 2 gives an overview of the equipment used for the SPB measurements.

Table 2 – SPB measurement equipment.

Measurement	BRRC
Vehicle speed	Kustom Signals KR10SP
Sound pressure level	B&K 4189 Microphone B&K 2260 Investigator

2.3 Surveys

A large cohort-study in Flanders called the Survey on the Living Environment (SLE) is repeated every 3-5 years. Over 20.000 surveys are distributed in Flanders in order to obtain at least 5.000 valid responses. In the lastest survey of 2013 it is shown that 24.1% of inhabitants is bothered at least reasonably by noise in and around their house [8]. The main cause of nuisances was traffic noise, with 26% of inhabitants being reasonably to extremely bothered.
An Experimental Study Design (ESD) was developed in order to investigate the possible self-reported health benefits after the installation of TAL compared to a conventional asphalt pavement. A customized survey, based on the SLE questionnaire, was developed for this study, containing 26 closed questions and room for additional remarks. The first ten questions are used to gather the necessary socio-demographic data. These questions are followed by five general questions about the quality of life and nuisance by noise, smell and light, taken from SLE. The last eleven questions are related to symptoms (e.g. headache, sleep quality, …) and activities (phone conversation, working/studying, relaxing, …) indoors and outdoors which could be influenced by traffic noise. The survey was delivered to the residents in written form, including an accompanying letter and a prepaid return envelope. It was also possible for the residents to fill out the survey online, created using Qualtrics. The statistical analysis afterwards was performed using SPSS 23.0 (*Statistical Package for the Social Sciences by IBM©*).
The pre-survey was conducted in April 2015, before the installation of the TAL which was initially planned for May 2015. The first post-survey was conducted in November 2015, one month after the actual installation of the noise reducing asphalt layers. A second post-survey is conducted in April 2016. During the same period of the survey traffic counts are performed at both locations.

Table 3 gives an overview of the number of respondents at both locations. The overall response rate is about 30%. The total number of respondents is 57 in the pre-survey and 44 in the first post-survey. In the first post-survey only the parts of the streets with a new road surface have been selected, explaining the lower numbers. To increase the response rate for the first post-survey three gift vouchers were raffled among the participants. This seemed to work at test location *B* (increase from 31 % to 43 %), but failed at test location *A* (decrease from 25 % to only 14 %). This might be related to the fact that the PERS test track was not yet installed in October 2015, due to the very stringent weather conditions, which caused a lot of complaints from the local residents.

Table 3 – Number of respondents of the pre- and first post-survey.

Location	Pre-survey	First post-survey
A	19/77 (25 %)	10/74 (14 %)
B	38/121 (31 %)	34/80 (43 %)
A+B	*57/198 (29 %)*	*44/154 (29 %)*

3 Results and discussion

In this section the results from both the SPB-measurements, traffic counts as the surveys are discussed.

3.1 SPB measurements

All results have been corrected using a semi-generic approach for the temperature correction coefficient of -0.10 dB(A)/°C for dense road surfaces and a reference temperature of 20 °C, as suggested in [9]. The different test tracks have been anonimized and given a number which is not related to the order in which they are installed at the test locations.

Table 4 – SPB-results @ 50 km/h and noise level reductions compared to the reference.

Test track	SPB (@50 km/h) [dB(A)]	Reduction [dB(A)]
REF	71.0	---
TAL 1	67.2	3.8
TAL 2	66.2	4.8
TAL 3	67.2	3.8
TAL 4	67.1	3.9
TAL 5	65,8	5.2

All measurement results were diminished with 6 dB(A) to take into account the added reflections from the backing board. Only the results of passing cars were used to calculate the SPB-value. The noise reduction compared to the reference surface (DAC 10) reaches a maximum value of 5.2 dBA and a minimum value of 3.8 dBA. From these objective measurements it is clear that the residents should be able to distinguish cleary the difference in noise levels before and after the installation of the TAL.

3.2 Traffic counts

Traffic counts were performed by the police of Antwerp in order to evaluate the possible influence of the traffic density during the period of the pre- and post-survey. In Figure 5 and Figure 6 the results of these traffic counts (during one week each) have been summarized.

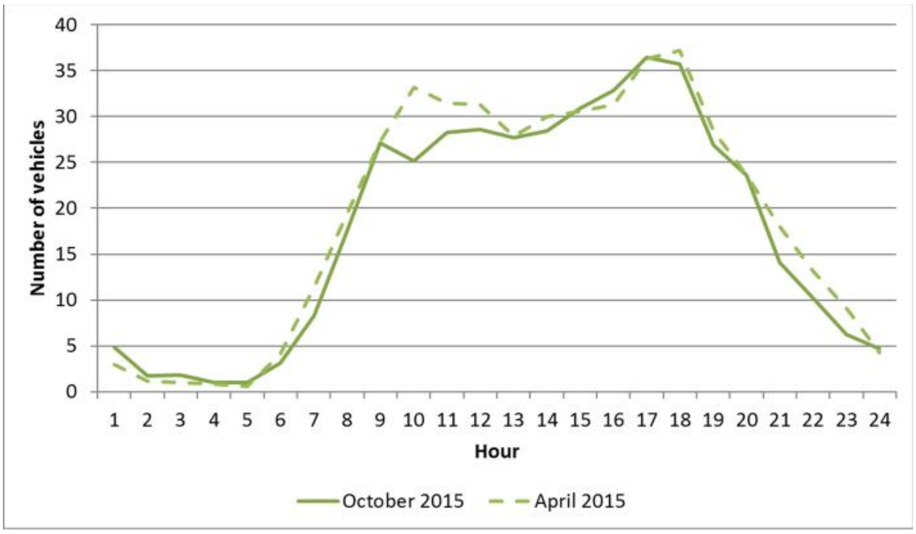

Figure 5 – Average traffic densities per hour at test location *A*

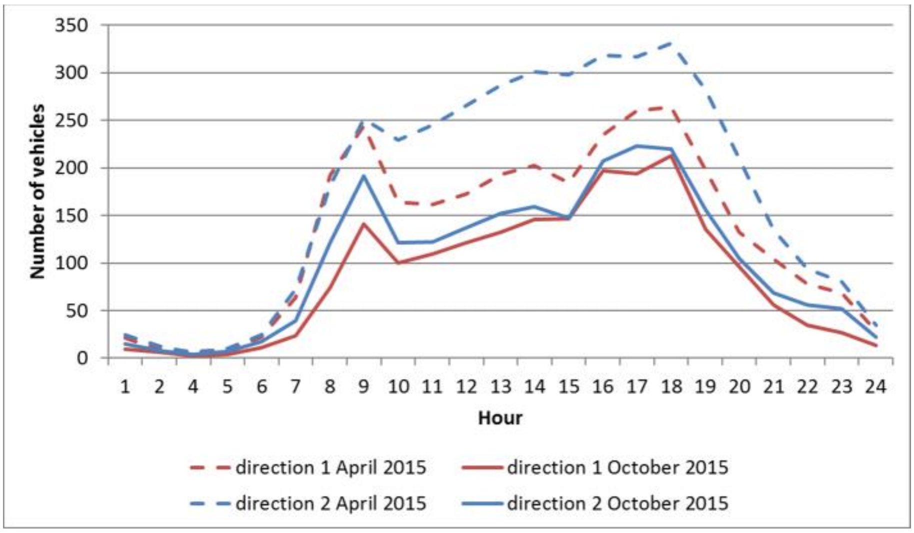

Figure 6 – Average traffic densities per hour at test location *B*

The results from these traffic counts match the description of the test locations in Sec. 2.1. At test location *A* there are no noticeable differences in traffic density between April and October 2015. However, at test location *B* differences up to 100 vehicles per hour in each direction (towards Doornstraat and Laaglandweg) can be found. A lot more traffic passed through test location *B* in April 2015 compared to October 2015. A possible clarification for these differences could be nearby roadworks causing traffic to follow a detour. These roadworks or the detour have not been found unfortunately. This means that the outcome of the surveys may have been influenced by the change in traffic density and that this should be considered in the discussion and analysis of the results.

3.3 Surveys

Some results from the surveys are shown in this section. In Table 5 an overview is given of the socio-demographic characteristics of the respondents in the ESD. No significant differences in socio-demographic characteristics occur between the pre- and post-survey.

Table 5 – Characteristics of the respondents in the Experimental Study Design.

	Pre-survey (n=57)	**First post-survey (n=44)**
Gender		
Male	30 (52.5 %)	20 (45 %)
Female	26 (45.5 %)	24 (55 %)
Missing	1 (2 %)	
Age (Min – Max – Avg)	20 – 81 - 55	19 – 84 - 53
Highest degree		
None/primary education	4 (7 %)	2 (4 %)
Secondary/Advanced secondary	25 (44 %)	18 (41 %)
Higher education/University	27 (47 %)	24 (55 %)
Missing	1 (2 %)	
Marital status		
Single	10 (18 %)	6 (14 %)
Married	38 (67 %)	34 (77 %)
Divorced	6 (10 %)	3 (7 %)
Widowed	3 (5 %)	1 (2 %)
Current living situation		
Together with partner	24 (42 %)	19 (43 %)
Together with partner and children	20 (35 %)	20 (46 %)
Alone	9 (16 %)	3 (7 %)
Alone with children	2 (3.5 %)	1 (2 %)
With parents	2 (3.5 %)	1 (2 %)
Present work situation		
Management function	6 (10.5 %)	5 (11.5 %)
(public) Servant	15 (26 %)	17 (39 %)
(un)Skilled worker	2 (3.5 %)	1 (2 %)
Self-employed	7 (12 %)	1 (2 %)
Retired	22 (39 %)	16 (36.5 %)
Unemployed but looking for work	1 (2 %)	1 (2 %)
Unemployed but NOT looking for work	4 (7 %)	3 (7 %)
Type of residence		
Studio or apartment	4 (7 %)	0 (0 %)
Terraced house	11 (19 %)	13 (29.5 %)
Semi-terraced house	33 (58 %)	22 (50 %)
Detached house	9 (16 %)	9 (20.5 %)

In Table 6 the level of annoyance caused by noise, odor and light, observed during the last year, is listed.

Table 6 – The level of annoyance caused by noise, odor and light (%) – pre- and post-survey.

Source of annoyance	**Not bothered at all**		**Slightly bothered**		**Reasonably bothered**		**Seriously bothered**		**Extremely bothered**	
Noise	16	11	25	50	31	25	25	7	3	7
Odor	34	32	43	50	17	16	6	2	0	0
Light	74	68	23	25	0	2	3	5	0	0

In general the changes between pre- and post-survey for annoyance by odor and light are negligable. A definite change in response can be observed for noise where a large portion of the respondents who were seriously bothered are now only slightly bothered. These changes can be observed in both streets so it can be assumed that the change in road surface has effectively reduced the level of annonyance. However, the change in traffic density at test location *B* can also have a positive effect on the level of nuisance by noise. The level of annoyance from reasonably up to extremely bothered (39 %) still remains higher than the average value for Flanders (24 %) as reported in [8], which could be expected in an urban environment (especially at test location *B*).

No clear changes in self-reported physical complaints were visible, but this could be related to the short period between installation of the test tracks and first post-survey. Therefore a second post-survey is planned in April-May 2016.

4 Conclusions

It is shown from the SPB-results that after the installation of TAL a noise reduction was obtained between 3.8 and 5.2 dB(A) compared to the original road surface (DAC 10). In theory this should have a significant effect on the perceived nuisance as a reduction with 4-5 dB(A) is a noticeable difference. From the surveys a shift in the level of annoyance can be observed from seriously and reasonably bothered to slightly bothered. A change in self-reported physical complaints could not be perceived which might be related to the short period between installation of the test tracks and the post-survey.
Unfortunately, a change in traffic density at one of the test locations occurred at the times of the surveys which might have influenced the outcome of the experimental study design as well. Therefore, a second post-survey is planned. Furthermore, listening tests as in [4,5] will be used in future research to investigate if certain TAL cause less annoyance even if they generate the same objective noise level. Finally, the test tracks will be further monitored acoustically during the next 2-3 years.

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