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Efficiency of the combined application of silent tyres and silent road surfaces

Gijsjan van Blokland; Michiel van Leeuwen

Affiliation: M+P – consulting engineers, P.O. Box 2094, 5260 CB Vught, The Netherlands
e-mail: GijsjanVanBlokland@mp.nl, MichielvanLeeuwen@mp.nl

Abstract

Control of traffic noise is pursued through laying silent pavements and through regulating and stimulating silent tyres. The evaluation criteria for tyres and roads however are not related to each other: tyre noise is evaluated on an ISO 10844 surface, while road surfaces often are evaluated with specified testing tyres, defined in the CPX method [1] . The combined effect of application of a silent tyre on a silent road surface does not necessarily equal the sum of the separate effect of the tyre and the road.

We have made an inventory of available data from controlled measurement programs on tyre/road combinations performed by M+P in the last 15 years. The database consists of more than 2000 tyre/road combinations, including heavy duty vehicle tyres and experimental surfaces such as flexible pavements.

From that database we extracted the combinations of the performance of a series of tyres on an ISO 10844 road with the performance of these tyres on a range of other surfaces. For each of these combinations we constructed a scatter diagram and from that we calculated the “slope” and the “correlation”.

On base of these data we simulated the effect of scenarios of silencing the tyre fleet on different types of surfaces. We found that the road surface has a very significant effect on the effect of silencing the tyre population. On some surfaces the efficiency of silencing tyres is almost zero, while on other surfaces the efficiency is nearly 100%.

Keywords: road, tyre, interaction

1 Introduction

The noise generated by the rolling vehicle tyre is the main contribution to the noise exposure of living areas in the vicinity of roads. On highways, about 95% of the total emitted energy noise of cars is tyre/road noise. For heavy duty vehicles it is about 70%. Effective reduction of the noise emission of road traffic therefore concentrates on suppressing tyre/road noise. This is in the Netherlands (and other countries also) pursued through two paths:

1. stimulation of the development and application of low noise road surfaces
2. stimulation and regulatory activities for wider application of low noise tyres

It is very relevant to know to what extent these two paths interact with each other. Can it be that a low noise road looses part of its noise suppressing capabilities when driven on by low noise tyres? Or is there a amplification effect, such that the combination of a low noise tyre on a low noise surface results in a stronger effect than the sum of the road and the tyre effect would predict?

This study focuses on the following objectives:

1. to determine the acoustic performance of tyres, especially low noise tyres on regular road surfaces in relation with the performance found on the ISO 10844 [5] test track
2. to evaluate the expected effects of the future tyre population in the Netherlands, including effects of stimulation of low noise tyres, and the increased application of low noise road surfacings.

2 Available data and setup of the study

The study is based on available data of rolling noise levels of several tyres on several road surfaces. Although extensive work is done on this topic, we only used data sets from controlled measurement programs in which at least 8 surfaces and at least 8 different tyres were used. The following three major data sets, meeting these requirements, were available within M+P: the studies on Welschap, Sperenberg and Kloosterzande [2], [3] and [4]. In total, 51 car tyres have been tested on 93 surfaces, and 40 truck tyres on 65 surfaces.

The data from Welschap and Sperenberg are based on pass-by measurements [5]. For Kloosterzande also the near-field sound was measured using the CPX (Close Proximity) method[1]. We used data at 80 km/h for passenger car tyres and for truck tyres.

For each of the test surfaces we have plotted the rolling sound levels of the test tyres against the levels of the same tyres on an ISO test surface. From the resulting scatter diagram we have calculated the best fitting function of the following form using orthogonal analysis:

$$L_{test} = a + b \cdot L_{ISO} \, , \qquad (1)$$

With L_{test} : sound level on the test surface, L_{ISO} : sound level on the ISO surface.

We are interested in the slope and the correlation for each of the test section for the following reasons. The slope represents the ratio of the sound level difference between two tyres on the given road surface, compared to the ISO surface. A slope of 0.5 means two tyres with a difference in sound level of 3 dB on ISO will on average exhibit a difference of 1.5 dB on the test surface.

The correlation indicates the amount of which the ranking of tyres on the test surface matches the ranking on the ISO surface. This is expressed as a number between -1 and 1. In practical terms the correlation indicates whether a tyre that is low noise on an ISO surface is also low noise on the test surface.

We also calculated the average difference between the two sound levels. This value represents the sound reducing property of the road surface. Two examples of scatter diagrams and the resulting values for slopes and correlation are given below.

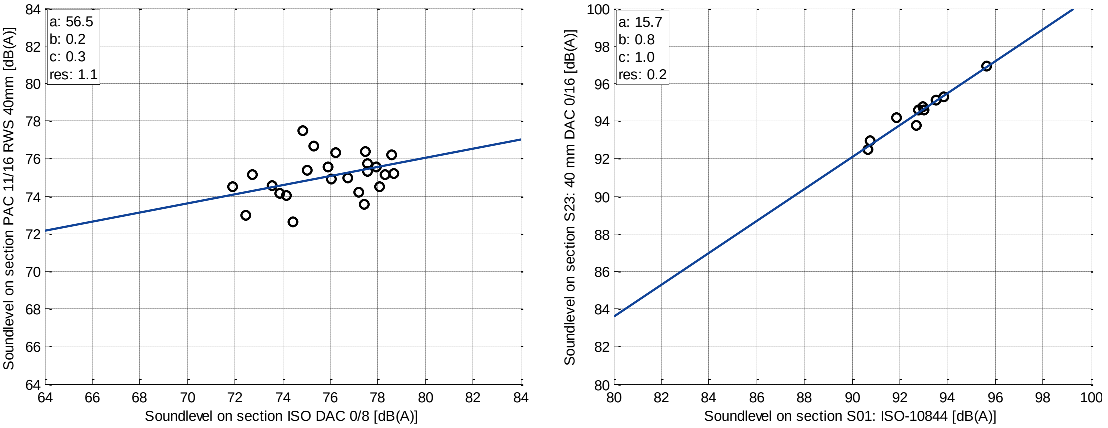

Figure 1 – Examples of the regression analysis of the rolling noise levels of a set of tyres on Porous Asphalt Concrete (PAC) 6/16 (left) and Dense Asphalt Concrete (DAC) 0/16 (right). The *b* represents the slope, *c* gives the correlation coefficient and *res*: the residual variance. The graph on the left is an example of a low correlation and a low slope, while the graph on the right illustrates a high correlation and a high slope.

3 Results

3.1 General

The analysis has been done for each of the 93 road surface for car tyres and 65 for truck tyres. The values for the slopes varied between 0 and about 1.2 and for the correlation values ranging from 0,0 to 1,0 were found for general surfaces. We only found values outside this range for experimental surfaces, such as very coarse surface dressings and very smooth rubberized surfaces.

The range of slopes we found means that the differences in sound levels are in general largest on the ISO surface. Only few surfaces exhibit larger variation.

The complete results are reported in [7], [8] and [9], which are available at the authors. As an example the results for Kloosterzande test area are given below. The data are grouped by surface type.

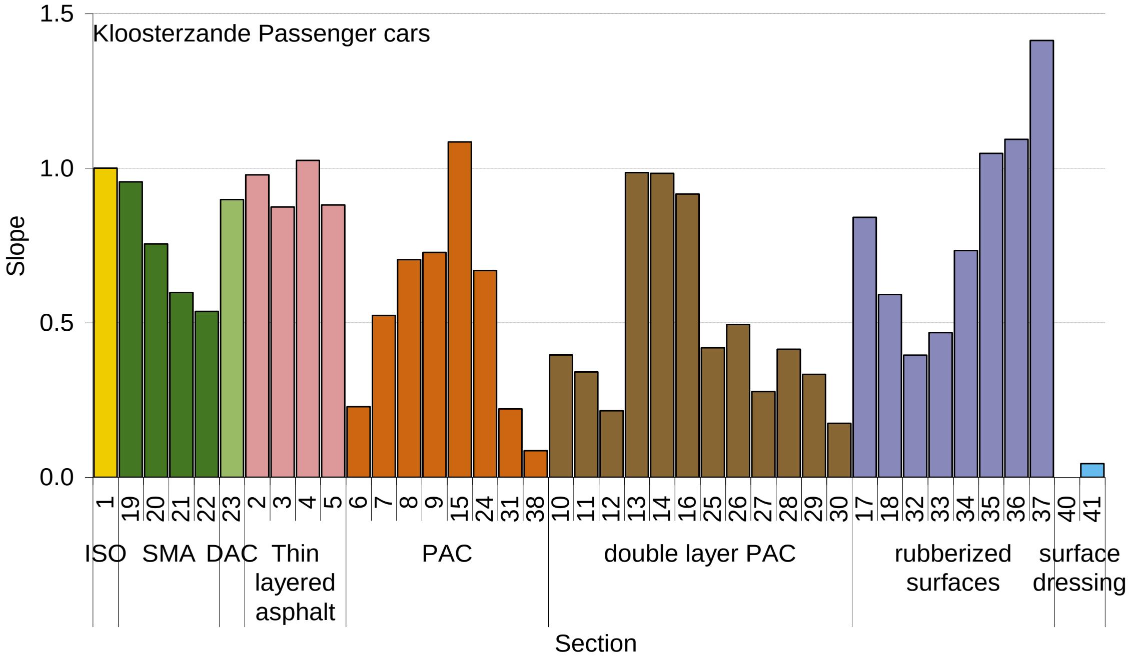

Figure 2 – Value of the “slope” for the Kloosterzande sections for passenger car tyres, grouped by surface type. Section 1 is the ISO 10844 surface

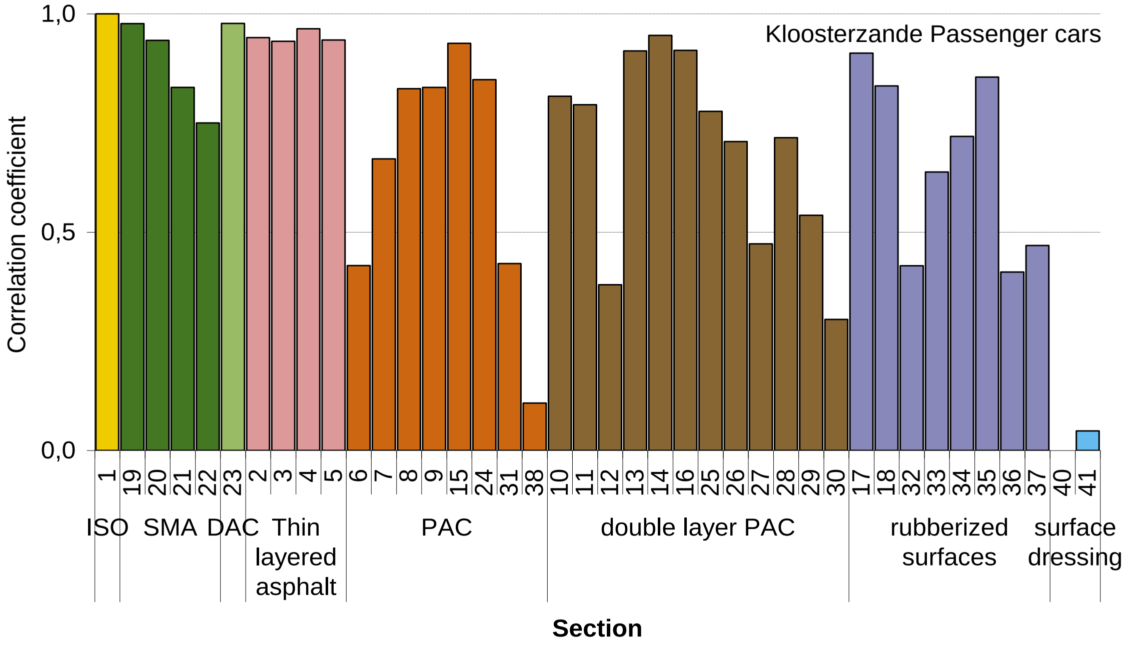

Figure 3 – Value of the “correlation” for the Kloosterzande sections for passenger car tyres, grouped by surface type. Section 1 is the ISO 10844 surface

This graph illustrates the large variation in values for the slope and the correlation coefficient. The ISO 10844 section and the Thin layered asphalt surfaces have values around 1.0, while some single and double layered PAC section have values below 0.2. The sections with a surface dressing exhibit even lower values for the slope. The highest slope value is observed for surface nr. 37 which is an extreme smooth flexible surface.

3.2 Relevant surface parameter

There are strong indications that the value of the slope is affected by the surface texture. An example of this can be found in the Stone Mastic Asphalt (SMA) surfaces in Kloosterzande. There are four SMA surfaces with increasing stone grading: 0/6[1], 0/8, 0/11 and 0/16. The slopes found on these surfaces are shown in figure 3.

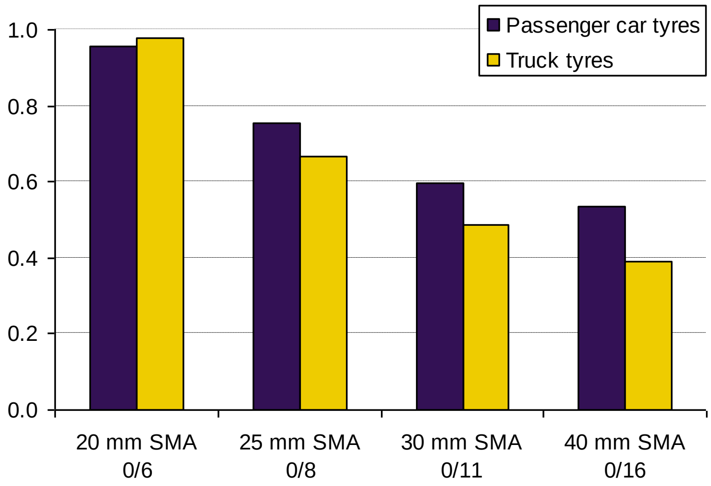

Figure 4 –

Slopes found on Kloosterzande SMA surfaces

From the graph, it is clear that a smaller grading size leads to a higher slope. It is noteworthy that this also applies for truck tyres.

The same trend can be seen across different surface types. For example, as shown in figure 1, all thin layered asphalt have slopes near 1.0. Those surfaces have a smooth surface texture, due to their asphalt grading of 2/6 and 4/8. On the other hand, some PAC surfaces have a very low slope. Those sections have a grading of 11/16, and thus a very rough surface texture.

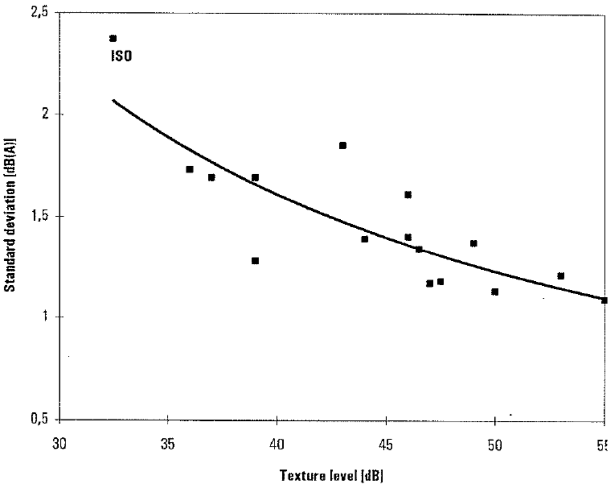

Figure 5 –

Relation between the standard deviation in the rolling noise levels of a series of passenger car tyres and the texture level of the 80 mm octave band (Source: [10])

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[1] In this paper, we indicate the stone grading of asphalt with two numbers separated by a slash. The first indicates the minimum diameter of the stones in millimetres, the second number the maximum size. 0/6 therefore means stones with a diameter between 0 and 6 mm are part of the mixture.

This illustrated relation with surface texture is corroborated by data of rolling noise levels of several tyres obtained on different types of surfaces (see figure 4). Here we have displayed the standard deviation of the rolling sound levels in a population of passenger car tyres as a function of the texture level at the 80 mm wavelength band. If a surface shows a low slope value, the variation in sound levels are low. The relation between deviation (and thus slope) with the surface texture is clearly visible from this graph. In the graph are combined dense and porous surfaces, indicating that porosity or acoustic absorption is not so important.

3.3 Results grouped per surface type

We are aware that the calculated value of the slope exhibits a rather high uncertainty. We have improved the accuracy of the slope values by averaging over several surfaces of the same type obtained from different data sets. We concentrated on the following five types of surfaces that are commonly used in the Netherlands:

- dense asphalt concrete (DAC) 0/16;
- porous asphalt concrete (PAC) with a single layer of grading 6/16;
- two layered porous asphalt concrete with a top layer of 4/8 on a bottom layer of 11/16;
- Improved two layered porous asphalt concrete with a top layer of 2/4 grading on a bottom layer of 8/11;
- Thin surface layer with grading of 3/6.

In this part of the study, we only looked at passenger car tyres. The values we found for the reduction, slope and correlation are listed in table 1.

Table 1 – Average reduction, slope and correlation for car tyres on a limited number of surface types at 80 km/h.

	DAC 0/16	**PAC 6/16**	**two layered PAC 4/8 – 11/16**	**two layered PAC 2/4 – 11/16**	**thin surface layer**
Reduction	-1.1	2.6	4.7	6.0	3.6
Slope	0.75	0.35	0.5	1.0	1.0
Correlation	0.9	0.5	0.7	0.9	1.0

4 Scenario study

With the results of the regression analysis, we predicted the influence of the stimulation of silent tyres on the average noise levels. We looked at three scenarios:

1. Current situation, so no shift towards more silent tyres
2. 50% of the tyres that are louder then average are replaced by a silent tyre
3. 100% of the tyres that are louder then average are replaced by a silent tyre.

The last scenario is based on the expected effect of more stringent European regulation on sound levels from tyres that becomes in place around 2016. The limit values lie around the current average sound level. Therefore, about half the currently used tyres will exceed the limit and will have to be replaced. The expected distribution of sound levels will now be largely asymmetric: most tyres will just below the threshold, while only few will be very silent.

As input data, the current distribution of noise levels over the existing tyre population is used. We estimated that this distribution follows a normal distribution. The standard deviation is based on the measurements done by the Dutch Rijksdienst voor het Wegverkeer (RDW) for the list of silent tyres.

4.1 Example analysis

Based on the input data, we get a distribution for the current tyres on the different surfaces. An example is given below, where the distribution of sound levels on DAC en PAC is given.

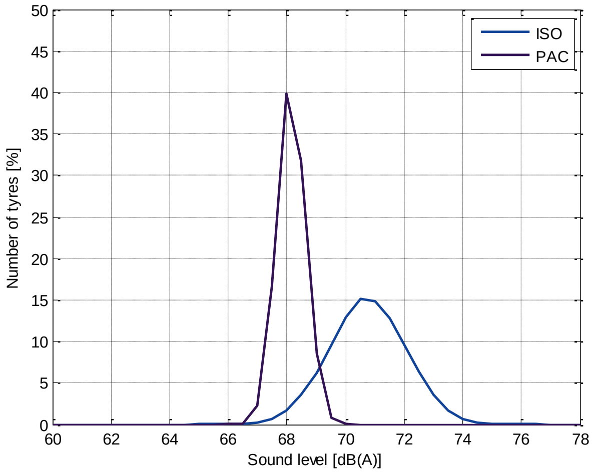

Figure 5 –

Distribution of sound levels at 80 km/h on ISO and PAC. The distribution in PAC is narrow, due to the effect of the slope being around 0,3

The two populations are shifted with respect to each other due to the noise reducing properties of the PAC surface. The distribution on PAC is smaller due to the slope being less then 1. No effect of the correlation is visible, because no selection of tyres has been made.

We can now predict what the sound level distribution will be after a scenario is applied. This will lead to different results for all surfaces. Again, we use ISO and PAC surfaces as example. In the example, we looked at scenario 3 where all loud tyres has been replaced with silent tyres.

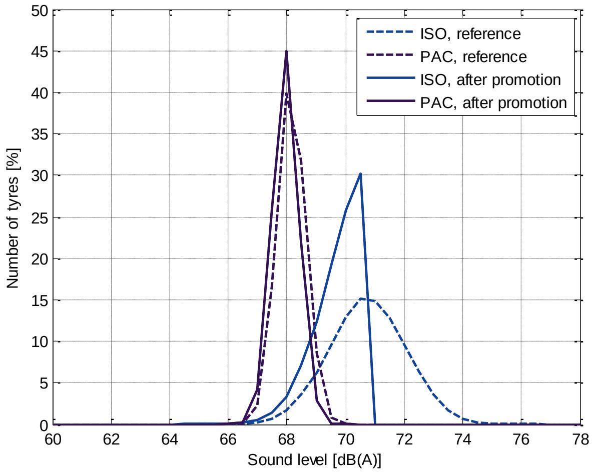

Figure 6 –

Distribution of sound levels at 80 km/h on ISO and PAC after replacing all the loud tyres with silent tyres

The populations have now changed. The distribution on the ISO surface has only half the original width. The original average sound level is now the maximum sound level. The distribution has become asymmetric, where most tyres have a sound level of only just below the maximum value.

On the PAC surface, the situation is different. The correlation of less then 1 causes the shape of the distribution to change. Some tyres are measured as silent on the ISO surface, but as loud on the PAC surface. Other tyres are silent on both surfaces. This leads to a less pronounced change in the shape of the distribution.

4.2 All surfaces

The populations for all surface groups has been calculated for each scenario, and from that the average sound level.

The total sound reduction is the difference between the average sound level of the current tyre fleet on an ISO surface and the average sound level on a test surface in a certain scenario. Those sound reductions are given in the table below.

Table 2 –sound reduction of the combined application of low noise tyres and surfaces. The figures are relative to the current tyre fleet on an ISO surface.

Description	ISO	DAC 0/16	PAC 6/16	two layered PAC 4/8 - 11/16	two layered PAC 2/4 - 11/16	thin surface layer
Reference	0	-1.1	2.6	4.7	6.0	3.6
50% replaced	0.5	-0.8	2.7	4.9	6.5	4.1
100% replaced	1.0	-0.4	2.8	5.1	6.9	4.6

From this table, we can see that silencing the tyre fleet causes an additional effect on the reduction of the road surface. Also it is shown that the additional effect on some surfaces is smaller than on other surfaces.

In the next table (table 2) we have extracted the effect of application of low noise tyres. The left column presents the results of the scenarios on an ISO test track. A 100% shift leads to a 1,0 dB effect. On a standard DAC 0/16 surface the effect is 0,7 dB and on a coarse PAC 6/16 surface only 0,3 dB remains. Full effects are found on the smooth surfaces with 2/4 or 3/6 top layers.

Table 3 – Sound reduction from only the silent tyres on different surfaces, relatively to the reference situation of the current tyre fleet on the given surface.

Description	ISO	DAC 0/16	PAC 6/16	two layered PAC 4/8 - 11/16	two layered PAC 2/4 - 11/16	thin surface layer
Reference	0	0	0	0	0	0
50% replaced	0.5	0.3	0.1	0.2	0.5	0.5
100% replaced	1.0	0.7	0.2	0.4	0.9	1.0

5 Conclusions

The road surface type plays in important role in the effectiveness of stimulating silent tyres. This has two reasons:

1. The difference in sound levels betweens tyres is smaller on rougher textures;
2. The correlation between the sound levels on an ISO surface and on a test surface is, in almost all cases, between 0 and 1. This means that a silent tyre on ISO is not necessarily silent on another surface.

As result of this, the sound reduction due to the combination of silent surfaces and silent tyres is smaller then the numeric sum of both. Mathematically, this can be expressed as:

$$\Delta L_{tyre+surface} \leq \Delta L_{tyre} + \Delta L_{surface} \tag{2}$$

Improving the road surface by making the surface smoother will make the total sound reduction being more close to the sum of both parts.

An important factor in the low additional gain from improving tyres lies in the low representativity of the ISO surface. This surface is smooth, in comparison to commonly used surfaces. It is therefore an exceptional surface, instead of a more average. A more representative, and thus rougher, test surface would be beneficial since this will lead to more realistic results of tyre testing.

An advantage of the current ISO testing surface is that the difference between tyres are more pronounced that on a rough surface. This improves the accuracy of measurements of the sound level class of a tyres.

5.1 Recommendations

Based on this research, we have the following recommendations:

1. Start of an ISO program to get to a more representative test surface.
2. The ranking of tyres should be based on measurements on a more rougher surface.
3. In calculating the future effects of silent traffic, the effect of combining roads and tyres should be taken into account more explicitly. Future roads with a smooth texture have an additional positive effect because of the reduced disturbance from the silent tyres simulation.

Acknowledgements

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References

[1] ISO TC43/WG33, "*working draft of 11819-2, Method for measuring the influence of road surfaces on traffic noise-Part 2: The Close Proximity method*", April 2009

[2] A. von Meier and G.J. van Blokland , *"Effect of road surfaces on tyre noise , data from Welschap"*, report M+P.MVM. 89.2.7, 1991;

[3] D.F. de Graaf, A.A.A. Peeters, H.M. Peeters, "Tyre/road noise measurements of truck tyres", M+P report DWW.03.7.1, 9 February 2005;

[4] W. Schwanen, H.M. van Leeuwen, A.A.A. Peeters *et al*, "Acoustic optimization tool, RE3: Measurement data Kloosterzande test track", M+P report DWW.06.04.8, 31 August 2008;

[5] ISO 13325, "Tyres – Coast-by methods for measuring the influence of tyre-to-road sounds emission", 22-01-2003;

[6] ISO 10844: 1994, " Acoustics- Specification of test tracks for the purpose of measuring noise emitted by road vehicles";

[7] G.J. van Blokland, H.M. van Leeuwen, "Noise levels of tyres on a regular road surfaces compared to noise levels on the ISO 10844 test surface", M+P report DVS.09.08.1, July 3, 2009;

[8] G.J. van Blokland, "Invloed van het wegdek op het effect van stille banden", M+P report DVS.09.10.2, november 26, 2009 (in Dutch);

[9] G.J. van Blokland, H.M. van Leeuwen, "Geluidtechnische eigenschappen van 10 banden uit de stille banden lijst op verschillende wegdekken", M+P report DVS.09.10.2; november 26, 2009 (in Dutch);

[10] G.J.van Blokland and D.F.de Graaff, "Effect of tyre noise limits on traffic noise", report M+P.MVM.99.4.1 June 1995.