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NOISE CONTROL FOR A BETTER ENVIRONMENT

Time-Integrated Noise Reduction of Low Noise Pavements – Giving Fair Credit to the Most Efficient Pavements in the Long Term

Sandberg, Ulf[1]
Swedish National Road and Transport Research Institute (VTI)
SE-58195 Linköping, Sweden

ABSTRACT

The efficiency in reducing road traffic noise of a pavement is often expressed as "noise reduction" when the pavement is in new condition. Far too often, the longevity of the noise reduction is neglected. But what the noise exposed residents along the road perceive is the noise during its life-cycle.

Especially porous asphalt pavements change its properties substantially with time. Moreover, the speed of this change depends on the construction. For example, single-layer porous pavements mostly get clogged earlier than double-layer porous pavements, given a certain air voids and maximum aggregate size; something which is due to the much greater air voids volume under the surface for the double-layer version. When evaluating overall performance over the life-cycle, therefore, it is important to consider the noise reduction year by year over the lifetime.

The author argues that fair descriptors of the acoustic efficiency of low noise pavements are the "Time-integrated noise reduction (TINR)" and the "Time-averaged noise reduction (TANR)". In the paper, some examples from measurements as well as hypothetical examples are presented. Using this descriptor, it is shown that single-layer porous pavements often come out far less efficient than double-layer pavements; and the latter often offer better cost-benefit ratios.

It is also suggested how one should average noise properties of different wheel tracks, lanes, and directions of highways and motorways.

Keywords: Low noise, pavement, lifetime
I-INCE Classification of Subject Number: 10, 72, 87

1. INTRODUCTION

The efficiency in reducing road traffic noise of a pavement is often expressed as "noise reduction" when the pavement is in new condition. Far too often, the longevity of the noise reduction is neglected; yet this is a crucial parameter. Especially, the low noise pavements that rely on porosity for noise reduction are subject to problems with clogging that give such pavements shorter acoustical life.

But what the noise exposed residents along the road perceive is the noise during its life-cycle. So far, no measure to express the noise reduction with regard to its lifelong function has been suggested. This is what this paper attempts to do.

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[1] ulf.sandberg@vti.se

2. IMPORTANT MEASURES FOR LOW NOISE PAVEMENTS

The measurement methods used to characterize the noise properties of pavements are either the Statistical Pass-By (SPB) method (ISO 11819-1) or the Close-ProXimity (CPX) method (ISO 11819-2); together with the Reference Tyres specification (ISO/TS 11819-3). With these, one can either assign a set of noise levels (Vehicle Noise level or CPX level for the cases of light and heavy vehicles separately) or composite indices based on these (SPB Index, or CPX Index). These are based on A-weighted sound pressure levels, but one can also report (A-weighted) frequency spectra. Further, one may either treat them as "absolute levels" or compare them to some reference measurement, to report a "noise reduction" (versus the noise properties of the reference pavement).

With these methods, one can make measurements at certain times during the lifecycle or (which is probably most common) measure only when the pavement is in new condition. An example is shown in Figure 1, where the author followed a double-layer porous asphalt concrete pavement (DPAC) annually over its lifecycle, which was 7 years. The reference pavement was a mix of various sections of SMA 16 on different roads [1].

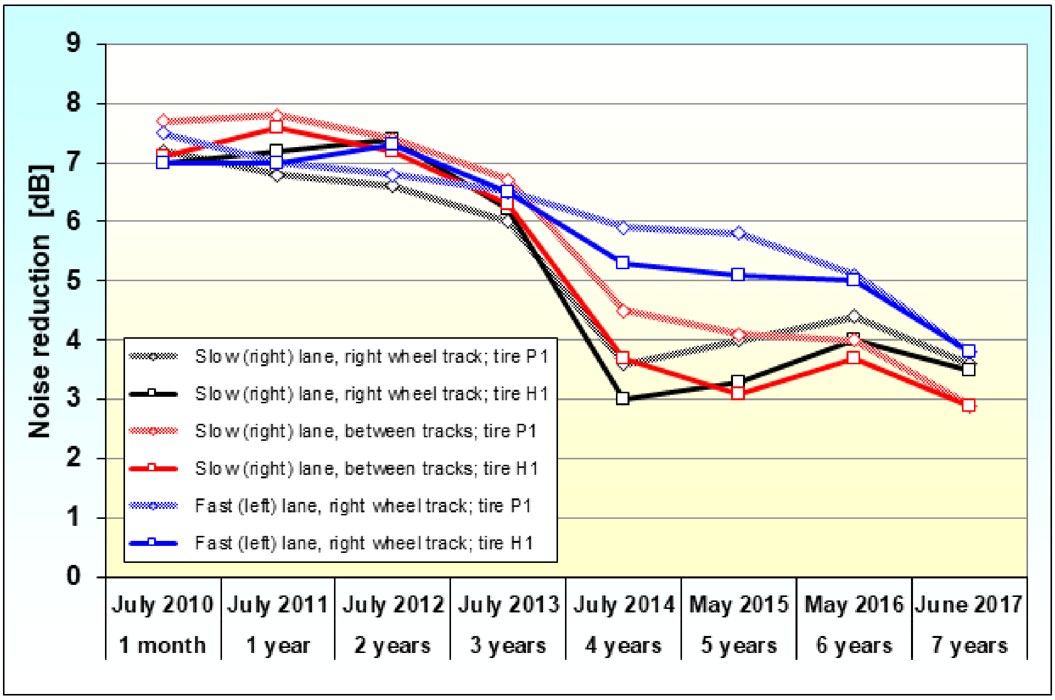

Figure 1 — A-weighted noise reductions over the 7 years of lifecycle (2010-2017), for 80 km/h measured with the CPX method, using tires P1 and H1. Results in the two directions have been averaged. From [1].

Figure 1 raises another question: how to treat the results for the two directions (if applicable) and for more than one lane per direction (if applicable)? Often, by the act of traffic and time, ruts may appear in the wheel tracks, which raises the question of which tracks in the lateral direction that one should measure. The measurements and the analyses may be rather comprehensive if all options shall be covered. If all separate noise levels or noise reductions are reported to the road or environmental authority responsible of the road or its environments, the volume of measures and noise levels may make it very difficult to make an overall assessment which is fair.

This author argues that if the overall acoustical performance of a highway or motorway is assessed, the preferences should be:

- Use the (arithmetic) average levels of the right and left wheel tracks (if both are measured), or the level in the wheel track which is closest to the road environment. It is usually not a big difference between the left and right wheel tracks, so either case will give essentially the same results.
- Use the (arithmetic) average levels of both directions (if both are measured and if noise exposure on both sides are a concern). If noise exposure is a concern only in one of the directions, it may be enough to measure only that direction, unless the pavements are very different in the two directions.
- Use the (arithmetic) average levels of all lanes. The lanes may by time get different noise properties (as in Figure. 1) and they may carry quite different traffic. The author recommends the simplest way: calculate the arithmetic average of all lanes (in both directions).

4. ARITHMETIC AVERAGE OR POWER?

It may be argued that, ideally, all averages should be calculated as sound power rather than arithmetic mean of CPX levels, like in modern noise prediction models. However, in practice, evaluations will not be so much better (fair) in this way that it justifies the more complicated calculations. It is also not very often when traffic data for each lane and each direction are available.

In Table 1, three examples are illustrating the very small difference between calculating averages based on CPX levels and based on power levels. In the examples, it is assumed that a "quiet pavement" has 2+2 lanes for which the lanes have similar noise-reducing properties in the first example (green), while in the second example (blue) the fast lanes have two dB more noise reduction than the slow lanes, and the third example (yellow) there is an additional two dB difference also in the directions. The more different noise reductions there are in the lanes, the more calculations of arithmetic average of CPX levels versus averaging of corresponding power levels differ. Yet, this difference is only 0.3 dB when lanes differ by 4 dB, which may be considered as an unusual extreme case. The author thinks that this does not justify averaging based on power levels.

Table 1 – Three examples of "quiet pavements" with different noise-reducing properties between their lanes, illustrating the difference between calculating averages for all lanes of a highway or motorway based on CPX levels versus based on power levels. Note that the levels (in dB) are arbitrarily chosen as "even" numbers, where only the differences are relevant. See further the text.

Motorway lanes and direction	CPX levels Ref. pvmt	Pow. levels Ref. pvmt	CPX levels Quiet pvmt	Pow. levels Quiet pvmt	CPX levels Quiet pvmt	Pow. levels Quiet pvmt	CPX levels Quiet pvmt	Pow. levels Quiet pvmt
Slow lane ←	100	100	94	94	95	95	96	96
Fast lane ←	100	100	94	94	93	93	94	94
Median								
Fast lane →	100	100	94	94	93	93	92	92
Slow lane →	100	100	94	94	95	95	94	94
CPX level average Noise reduction	100		94 **6.0**		94 **6.0**		94 **6.0**	
Power, overall Noise reduction		106.0		100.0 **6.0**		100.1 **5.9**		100.3 **5.7**

Nevertheless, sometimes there are substantial differences not only in noise properties of the lanes and/or directions, but also different traffic in them. The number of vehicles/hour may differ substantially, and so may the proportions of light and heavy vehicles do as, usually, there are more heavy vehicles in the slow lanes than in the fast lanes. But the speeds may also be different in the slow and fast lanes. To calculate a fair "noise reduction" for such a case, one should use a traffic noise model that takes into account such differences in the source model.

4. TIME-INTEGRATED NOISE REDUCTION

In Figure 2, the area under the two curves (red for P1 and black for H1) shows the time-integrated A-weighted noise reduction. For P1 it is the yellow and for H1 it is the blue areas, with green area as the blend of the blue and yellow. Table 2 shows the same in table format, where it appears that the time-averaged noise reduction for the 7-years lifecycle is 5.7 dB for the P1 tire and 5.5 dB for the H1 tire (A-weighted levels). The reference pavement was a mix of various sections of SMA 16 on different roads [1].

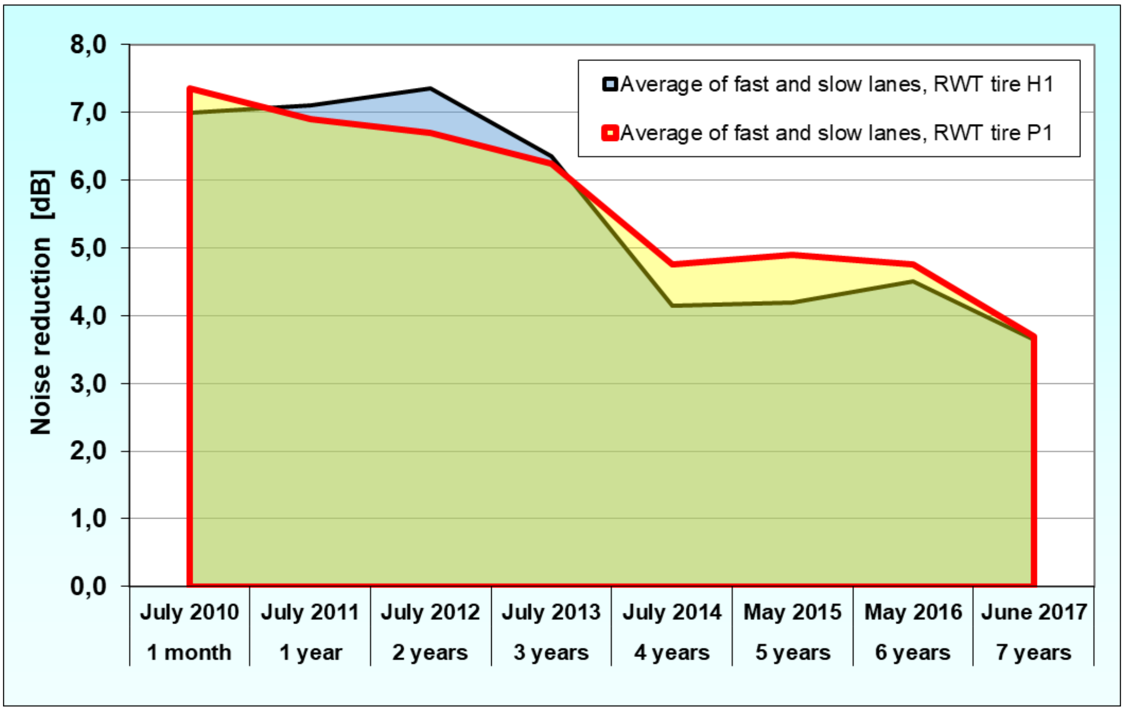

Figure 2 — A-weighted noise reductions over the 7 years of lifecycle (2010-2017), measured with the CPX method, using tires P1 and H1. Results in the two directions and for both lanes have been averaged. Red curve is for tire P1 and black curve is for tire H1.

Table 2 — A-weighted noise reductions over a 7 years lifecycle, measured with the CPX method, using tires P1 and H1. Results in the two directions and the two lanes per direction have been averaged. Values in A-weighted dB, except the rightmost column which is in dB-years.

Reference tire	30 days 07-2010	1 year 07-2011	2 years 07-2012	3 years 07-2013	4 years 07-2014	5 years 07-2015	6 years 07-2016	7 years 06-2017	Average for all years	Time-integrated reduction
P1	7.4	6.9	6.7	6.3	4.8	4.9	4.8	3.7	**5.7**	**39.9**
H1	7.0	7.1	7.4	6.4	4.2	4.2	4.5	3.7	**5.5**	**38.5**

5. EXAMPLE OF COMPARISON OF TWO POROUS PAVEMENTS

Figure 3 and Table 3 show a comparison of two low noise pavements (averaged for all directions, lanes and tires), where one is one of the best available (called "premium") and the other one is a much less expensive one (called "budget"). These are just examples, but the first one could be a double-layer porous asphalt (30+50 mm thick), with an average loss of noise reduction of 0.5 dB/year, repaved after 7 years, while the second one could be a 50 mm thick single-layer porous asphalt, with an average loss of noise reduction of 0.7 dB/year repaved after 5 years.

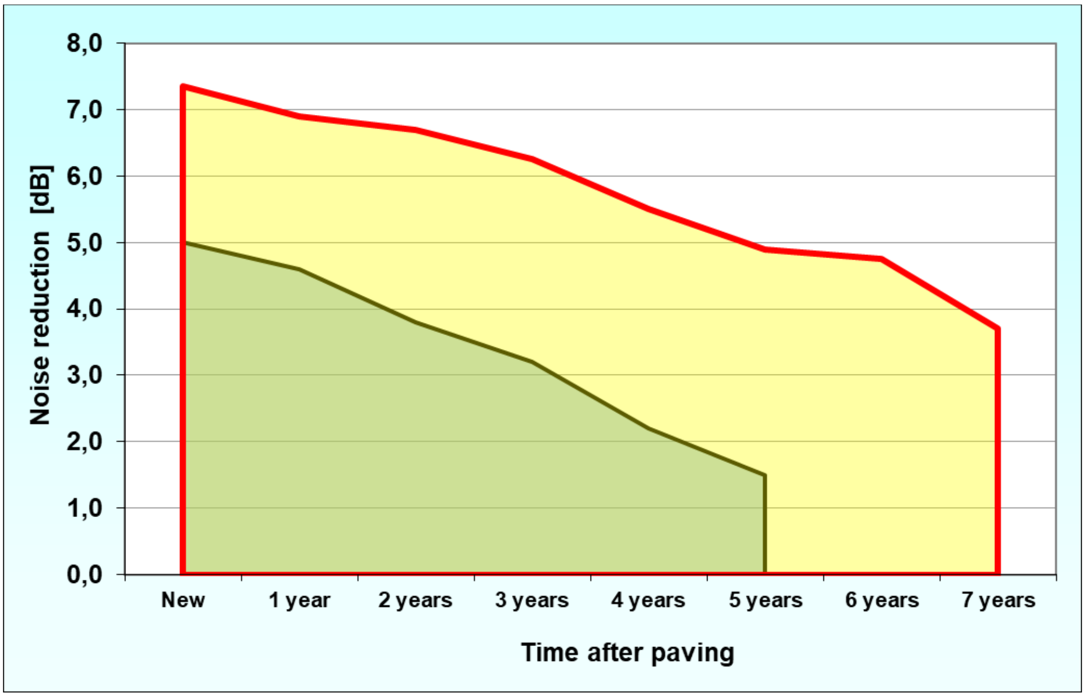

Figure 3 — Noise reductions over 7 years of lifecycle for a "premium low noise pavement" (red curve over yellow and green area), and over 5 years lifecycle for a "budget low noise pavement".

Table 3 — Data as of Figure 3 for the two pavements. Values in A-weighted dB, except the rightmost column which is in (A-weighted) dB-years.

Pave-ment	30 days 07-2010	1 year 07-2011	2 years 07-2012	3 years 07-2013	4 years 07-2014	5 years 07-2015	6 years 07-2016	7 years 06-2017	Average for all years	Time-integrated reduction
Prem	7.4	6.9	6.7	6.3	5.5	4.9	4.8	3.7	5.8	40.6
Budg	5.0	4.6	3.8	3.2	2.2	1.5	-	-	3.4	17

In this example, the initial noise reduction would be 7.4 vs 5.0 dB; and the average for the life-cycle would be 5.8 vs 3.4 dB. It may not be seen as a very dramatic difference, but when considering the length of the lifecycles; the time-integrated noise reduction is 40.6 vs 17.0, which is really a dramatic difference. Even if the single-layer pavement maybe costs only half of the double-layer one (in this particular example), the time-integrated noise reduction would not suggest that its cost-benefit ratio would be favorable. The case for the budget pavement would be even worse if one would assume that the two pavements should be replaced by newer ones after they have fell short of the same noise reduction value (for example 3 dB).

A third example appears in Figure 4. In this case, the pavement represented by the black curve is assumed to be a dense asphalt concrete with 11 mm maximum aggregate size (DAC 11); a very common pavement worldwide. It could also be a thin-layer asphalt. The noise reduction is again referenced to a “medium-aged” SMA 16. When new, this pavement may offer sigificant reduction but this will quickly fade away with time. However, it may remain in service for a few more years than the porous pavements (unless winter tyres with studs are used, such as in Sweden) and it is a relatively inexpensive pavement. Nevertheless, noise reductions of this example would generally be too low to be of interest.

These examples suggest that it is important to look at both the service life and the annual noise reduction when selecting the type of low noise pavement and often the most expensive option may be the most cost-effective.

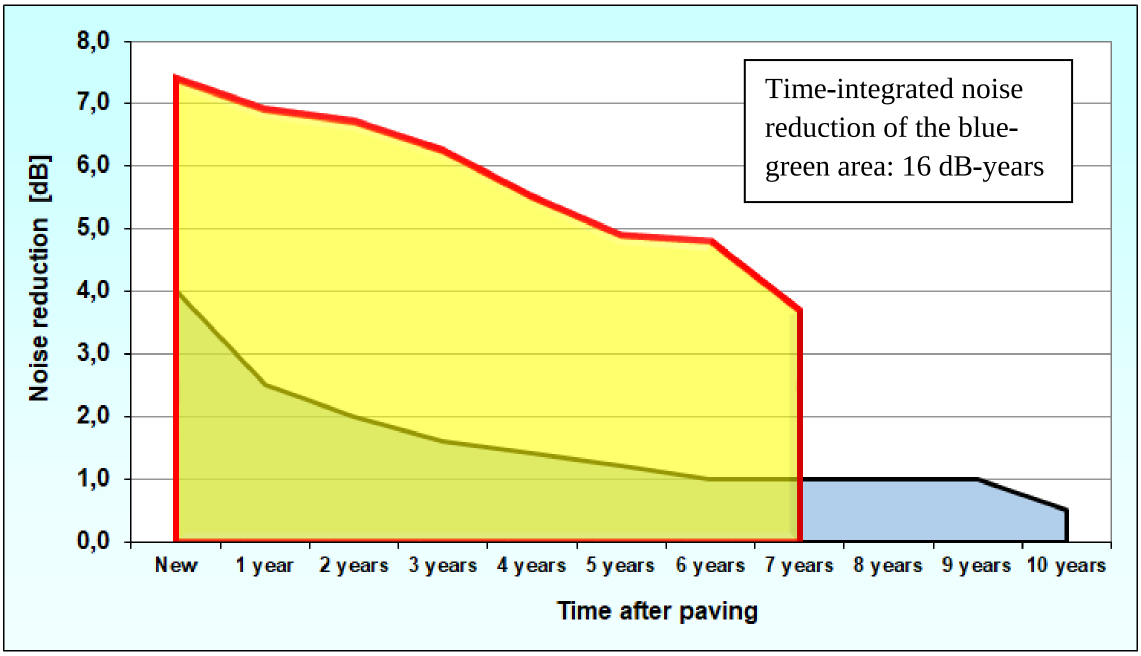

Figure 4 — Noise reductions over 7 years of lifecycle for a “premium low noise pavement” (red curve over yellow and green area), and over a 10 years lifecycle for a “regular dense pavement” which could be a DAC 11 or a thin asphalt layer. Note that it is only an example.

6. TIME-AVERAGED NOISE REDUCTION ALSO IMPORTANT

The time-integrated noise reduction (TINR) is an important parameter for description of the acoustical performance over the lifecycle of a pavement. However, imagine a cement concrete pavement that has a noise reduction of 1 dB and maintains this over (say) 30 years; which is not impossible for an exposed aggregate cement concrete pavement [2]. This would give a TINR of 30 dB-years, which sounds like fairly good performance. But when applying noise-reducing pavements, obtaining only 1 dB of noise reduction is generally far from enough. There should be a value supplementing TINR which gives a representative value of the noise reduction. This is suggested to be the Time-Average Noise Reduction (TANR). In Tables 2-3 this is shown in the second column from the right.

7. APPLYING THE MEASURES TO A REAL CASE

Returning to Figure 1, which was part of a paper for Inter-Noise 2018 [1], describing a real case, the following data would cover that project over the pavement's lifecycle:

Type of pavement: Double-layer porous asphalt concrete, maximum aggregate size 11 mm in the 30 mm thick top layer, and 16 mm in the 50 mm thick bottom layer

Reference pavement: Average of several SMA 16 measured in average condition and age

Measurement methods: ISO 11819-2, ISO/TS11819-3, ISO13471-1

Road and location: Motorway E4, in Huskvarna, Sweden, 2 lanes per direction

Lifecycle: Pavement repaved after 7 years of operation (2010-2017)

TANR: 5.7 dB for ref. tyre P1 (light vehicles) and 5.5 dB for tyre H1 (heavy vehicles)

TINR: 39.9 dB-years for tyre P1 and 38.5 dB-years for tyre H1

8. DISCUSSION

So far, the most common characterization of the acoustical properties of low-noise pavements is to report the noise reduction compared to a reference pavement or its noise level measured by some defined method when the pavement is in new condition. However, pavements change the properties with time and due to traffic, and especially the most common type of low-noise pavements, the porous asphalts, are getting more and more clogged with time and wear. It may well happen that a new pavement with high noise reduction loses its noise-reducing properties considerably faster than a pavement with more moderate noise reduction in new condition.

Therefore, it may be highly misleading just to report the acoustical properties in new condition; it is necessary to study the pavement over a longer time; preferably over its lifecycle.

For estimating cost-benefit ratios of various low-noise pavements it is absolutely necessary to monitor the acoustic properties over the lifecycle. The averaging measures proposed here will aid in such calculations.

8. CONCLUSIONS

In this paper, some new measures are proposed for characterizing the acoustical properties of pavements. The intention is to get (1) a measure which shows the time average noise reduction (TANR) over the lifetime, useful for deciding if the pavement provides sufficiently low traffic noise emission for the exposed people, and (2) a measure which describes the time-integrated noise reduction (TINR) over the lifecycle. The latter helps in determining how long the pavement may fulfil its purpose and how efficient it is in comparison to other pavements. The values used are assumed to be A-weighted CPX levels in dB.

Further, the paper argues that the best way to characterize the acoustical properties of roads with two or more lanes, in both directions, and maybe with different noise properties in the different wheel tracks, is to arithmetically average the CPX levels or the noise reductions in the various wheel tracks, lanes, and directions. To average power levels instead, may give a closer relation with noise emission from the road, as calculated with noise prediction methods, but the difference to CPX level averaging is marginal and does not justify the more complex calculations.

When one is interested in frequency spectral properties too, it is suggested that averaging is made in similar ways as for the overall A-weighted noise levels.

The author suggests that the pavement testing community starts to implement the new measures.

9. ACKNOWLEDGEMENTS

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10. REFERENCES

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