Proceedings of 20th International Congress on Acoustics, ICA 2010

23-27 August 2010, Sydney, Australia

How to Measure the Effectiveness of Low-noise Pavements in Urban Situations?

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PACS: 43.50.Ba, 43.50.Gf, 43.50.Lj, 43.66.Lj

ABSTRACT

Low-noise pavements have proven to be very effective and efficient reducers of traffic noise. This reduction is normally expressed in (spectral) noise level differences with unit dB(A). However, noise reductions of low-noise pavements can differ significantly from the net noise reductions measured at the adjacent facades. On the other hand, recent research has shown that the subjective impressions of low-noise pavements roads often seem to contradict objectively measured noise level reductions. A criterion derived from psychophysics has been developed to determine the effectiveness of low-noise pavements. In two cities in the Netherlands, (test) tracks with low-noise pavements have been constructed. First, standard SPB and CPX measurements have been carried out along with measurements outside and inside the adjacent dwellings. Second, psychophysical analyses based on the normalised CPX results have been carried out. Third, all inhabitants in this street filled in a questionnaire concerning their impression of the improvement of their situation due to the low-noise pavements. The results of the psychophysical analyses and questionnaire seem to corroborate well, however, in one case the questionnaire has led to biased results due to changed safety conditions and acoustical conditions caused by sources other than road traffic.

INTRRODUCTION

Environmental noise has become an important issue in Western European countries. From numerous questionnaires it was concluded that road traffic noise is the major stress factor of inhabitants in cities. Not only does traffic noise seriously jeopardize the quality of urban live, also the non-urban areas are more and more covered with a blanket of noise [1]. Silence is, therefore, becoming a rare species. Therefore, extended national and international legislation has been implemented to limit the noise emission levels from road systems. This stimulated the development of low-noise pavements. Low-noise pavements have been proven very effective in reducing annoyance [2].

At present, in many cities in the Netherlands Thin Layers are applied. Noise measurements on Thin Layers have proven that acoustical absorption does not play a significant role in noise reduction at low speeds. Therefore, these surfacings do not need additional maintenance against clogging. At this moment, there is a great variety of commercial low-noise pavements available [3].

Most important is that inhabitants greatly appreciate Thin Layers because of the typical nature of their emitted noise. There are several measurement methods to determine, accurately and objectively, the quantity of noise emitted from traffic on a certain road. The usefulness of developing and improving objective, representative, and comparable methods is without doubt. However, the results from these methods correlate poorly with impression of inhabitants living adjacent to this road: road surfaces can be perceived "louder" as well as "softer" than what could be expected from objective measurement results.

In this paper, the first test results of a new method are presented. This method includes acoustical perception into the quantising of the overall effect of low-noise pavements.

SALIENCY

As it has often been suggested, various "subjective" measures, like loudness, correlate better to each other than to the real impression. Therefore, a new measure had to be found. This measure had to include processes that occur at higher levels in the human auditory system. In order to find such a measure we have to look closer at the emission spectrum of low-noise pavements. In figure 1 the unweighted octave band spectrum of a reference road type (AC surf) and a Thin Layer are shown.

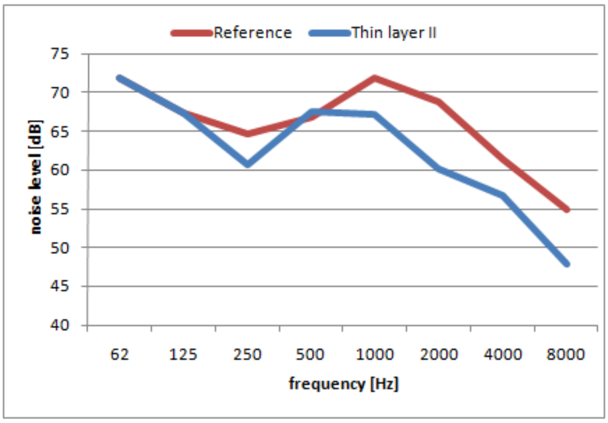

Figure 1: The unweighted octave band spectra of a reference road type and a Thin Layer

From figure 1, it can be seen that the overall shapes of the spectra are quite similar. That is why an on loudness based method does not significantly improve judgement compared to dB or dB(A).

Per frequency band, however, the differences can be more than 5 dB. Based on psychophysics a theory has been developed that predicts the so-called Auditory Saliency A0 [4]. This A0 criterion determines the saliency of differences in sounds as detected by the human ear. The A0 criterion is determined by comparing the differences per frequency band between the spectra of a certain road surface and AC surf, respectively.

PROJECT OF THE HAGUE

Introduction

In the city of The Hague, three test tracks and a reference track (Test track 1) have been put. In table 1, an overview of the various surface types can be seen. All concerned so-called gap graded mixtures with various open void contents. The respective open voids contents are also presented in the table.

Table 1. Overview of the applied surface types

	Test track 1	Test track 2	Test track 3	Test track 4
surface type	"Zaans"	Thin Layer I	SMA 0/6	Thin Layer II
void contents	low	middle	low	high

In figure 1 a photo of the test location can be seen.

Figure 1. Photo of the test location (Laan van Nieuw Oost-Indië)

On these tracks various noise measurements have been performed. The results have been correlated to results of a questionnaire. This questionnaire was developed by the city of Copenhagen [5].

Noise measurements

On the test tracks standard SPB and CPX measurements according ISO 11819 1/2 have been performed. In table 2, the average noise reductions are presented. The averages follow from the Conformity of Production (COP) procedure which is standard in the Netherlands. In addition, the respective noise labels have been presented in this table.

Table 2. Average noise reduction for passenger cars at 50 km/h

test track		noise reduction [dB(A)]	
no	surface type	COP	noise label
1	"Zaans"	2.1	0*
2	Thin Layer I	3.3	3.4
3	SMA 0/6	1.8	1.1
4	Thin layer II	4.1	4.6

*expected value, no noise label

From table 2 it follows that most measured noise reductions are within 1 dB(A) equal to the noise labels. Only the noise reduction of test track 1 ("Zaans") is quite higher than the expected 0 dB(A).

The noise measurements have been repeated in 2009 (CPX only) and 2010 (CPX and SPB). In figure 2 the measured average noise reductions are presented graphically. The accuracy of these data is almost equal to that of SPB measurements.

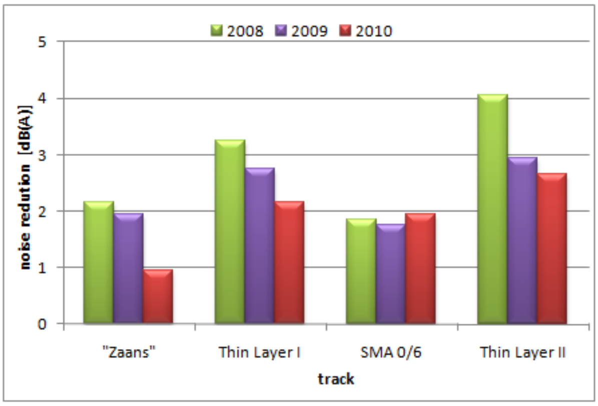

Figure 2. The measured average noise reductions measured in 2008, 2009, and 2010 for passenger cars at 50 km/h

From figure 2 it can be seen that the loss of noise reduction is more or less proportional to the initial value of the noise reduction. This is a well-known fact found in practice. It implies that always the minimal noise reduction should be chosen. Secondly, another familiar effect can be seen which is the drastic loss of reduction of silent Thin Layers after one year (winter). Thirdly, it can be seen that the noise reduction for "Zaans" has dropped dramatically to a value that could be expected from such a pavement. SMA 0/6, on the other hand, shows no decline at all and remains at its remarkable high value.

Psychophysical judgement

Based on the results of the noise measurements in 2008 and 2010, the A0 criterion for saliency has been calculated for each track separately. For 2009, there are no results since only CPX measurements have been performed. The transformation from CPX spectra into the required SPB spectra turned out to be too inaccurate. In table 3, the results of the psychophysical analysis have been presented.

Table 3. Saliency A0 for passenger cars at 50 km/h

test track		saliency A0 [dB]	
no	surface type	2008	2010
1	"Zaans"	5.5	4.6
2	Thin Layer I	7.8	4.4
3	SMA 0/6	6.0	3.3
4	Thin Layer II	8.0	5.0

From table 3 it follows that the new Thin Layers are most salient, similar as found in the previous global study [4]. In this case, it means that they sound more "pleasant". In addition, it can be noticed that the two other more standard pavement types are also qualified as "silent". Especially, the results of SMA 0/6 are significantly better than those found in the earlier study [4].

In figure 3 the results from the analysis have been presented graphically.

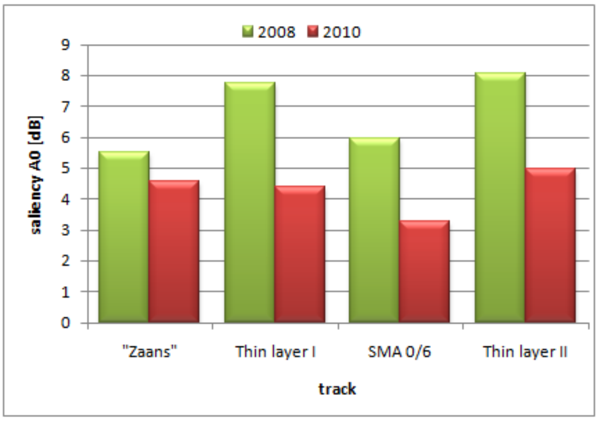

Figure 3. The saliency A0 for the test tracks

From figure 3 it can be seen that in 2010 the saliency of the two Thin Layers are comparable to "Zaans". Both are now indistinguishable from the two standard road types meaning that there is no extra positive effect anymore.

Very remarkable is that the measured noise reduction of "Zaans" dropped significantly but its saliency did not. The opposite results have been found for SMA 0/6. Until now, there is no explanation for this strange phenomenon.

Questionnaire

The results from the questionnaire proved to be very difficult to interpret. As can be seen in figure 1 there are also trams present at the test location. Furthermore, the layout of the road was changed and respondents replied not for the better. The data from the questionnaire was therefore biased. However, respondents adjacent to the silent test tracks were more positive than those adjacent to the less silent tracks were. The results showed no significant difference between Thin Layer I and Thin Layer II. These results corroborate very well the results from the psychophysical analyses. All road types were considered much "better" than a standard road type. However, one must consider that replacing a pavement always leads to positive reactions.

PROJECT OF LELYSTAD

In the city of Lelystad, an existing block pavement road had to be reconstructed. Here a limited test with the psychophysical analysis has been performed. Before reconstruction, the inhabitants could fill in a questionnaire. The results of this questionnaire could assist the road authorities in their choice for a low-noise block pavement, which is more expensive and less durable. From the questionnaire, it followed that besides noise from traffic; its high speed is annoying. This relates to a general feeling of unsafety rather than to noise. In addition, vibrations of busses were classified as annoying.

The new pavement is much smoother; therefore, vibrations are well under the respective limits. Speed of traffic, however, did increase. Surprisingly, this did not lead to more annoyance. Probably the significant reduction of noise and vibrations dominate the overall perception and, therefore, the annoyance.

The noise emission of the standard block pavement and the low-noise block pavement is almost 7 dB(A). The Saliency A0 yielded a improvement of 10 dB. So, in the case of block pavements the A0 criterion differs significantly from the dB(A). This is probably due to the low-frequency behaviour of these two types of pavements.

CONCLUSIONS

Low-noise pavements have been proven to contribute to more acceptable noise situations in cities. However, their effectiveness is hardly proven until now. In earlier projects, it has been shown that de (A weighted) noise level correlates very poorly to the subjective impression of people living adjacent to the road. The new A0 criterion for saliency seems to correlate better since it incorporates psychophysical knowledge. However, improvements are necessary to increase its reliability. These improvements are subject of ongoing study. Furthermore, questionnaires are very difficult to interpret, especially when other factors like safety are important.

In The Hague, the noise measurements and analysis will be repeated annually. From the presented and future results, the analysis for Saliency will be refined. At present, a limited number frequency bands are taken into account. This choice has been based on the ISO 11819/2 draft standard. Present research is carried out to the optimal number of frequency bands to be included.

First results show that the positive subjective effect of thin layer compared to standard road type is fading during time. However, it must be noted in this case the standard road types are more silent than normal.

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