ENVIRONMENTAL NOISE CONTROL
The 2005 Congress and Exposition on Noise Control Engineering
07-10 August 2005 - Rio de Janeiro - Brazil

Two-layer porous asphalt: an international survey in the frame of the Noise Innovation Programme (IPG)

Luc Goubert[a]; Jan Hooghwerff[b]; Peter The[c]; Rob Hofman[d]

[a]Belgian Road Research Centre, B-1200 Brussels, Belgium
[b]M+P Noise and Vibration Control, NL-5260 CB Vught, The Netherlands
[c]Road and Hydraulic Engineering Institute NL-2628 Delft, The Netherlands
[d] Road and Hydraulic Engineering Institute NL-2628 Delft, The Netherlands

[a]l.goubert@brrc.be; [b]hooghwerff@db.mp.nl; [c]b.h.p.a.m.the@dww.rws.minvenw.nl; [d]r.hofman@dww.rws.minvenw.nl

Abstract Two-layer porous asphalt is among the quietest types of road surfacing, but has two aspects that could be improved: it is less durable than most conventional road surfacings and its initially excellent acoustic properties tend to deteriorate as it becomes older. In this paper, the results are given from a study in which data available on some 40 Dutch (on secondary and local roads only) and 20 other European sections were studied in order to obtain state-of-the-art information about lifetime and acoustic performance development. Experience with sections of two-layer porous asphalt that served a full life cycle and were consequently removed exists only in The Netherlands. The average lifetime of the sections removed in the past equals 7.0 years. However, indications are found that the lifetime of the more recent laid two-layer porous asphalt might be longer. Dependence of durability on traffic volume is discussed. It will be shown that the initial noise reduction of sections with only smaller aggregates are, on average, a little better than that of sections with coarser aggregates. Sufficient data is available from periodic acoustic measurements on several sections in The Netherlands and abroad in order to draw sensible conclusions about the development of the noisiness during the first three years of the lifetime. On the other hand, few data is available on surfacings older than three years.

1. INTRODUCTION

Two-layer porous asphalt has been applied in The Netherlands since the early nineties and has until now been among the best-performing pavement types from an acoustic point of view. Road surface texture is optimized by the use of small-sized aggregates in the thin porous upper layer (typical thickness 2-3 cm), which results in little megatexture and minimizes vibrations in tyres. The thicker layer underneath (typical thickness 4-5 cm), with coarse aggregates, has a high voids content, which allows effective absorption in the relevant part of the noise spectrum. The so-called “horn” effect, which amplifies tyre noise by multiple reflections between the tyre tread and reflective road surfaces, is suppressed. Air pumping under the tyres is avoided, as the air can "escape" through the interconnected voids in the pavement before it is compressed.

The use of two-layer porous asphalt also has disadvantages. It is more expensive than single-layer porous asphalt and much more expensive than conventional dense asphalt, but less expensive than noise barriers. The surface has also to be renewed more often. Its technical lifetime is shorter than that of conventional road pavements, as it is more subject to ravelling. And, unfortunately, its acoustic properties tend to deteriorate as well as it becomes older because its voids are clogged by mud, dust, leaves, oil, etc. This may result in less effective noise absorption and hence a shorter functional lifetime.

Since the late nineties, test sections in two-layer porous asphalt have been constructed in other (mostly European) countries as well. This study deals with the experience with two-layer porous asphalt on local and secondary roads in The Netherlands and on (mainly) local and secondary roads abroad.

2. METHOD OF WORKING

Several sources were consulted to obtain information about two-layer porous asphalt sections: for The Netherlands, all the information about sections on local and secondary roads was provided by the Dutch consultant M + P. For road sections outside The Netherlands, several means were used: internet search, literature search, contact of PIARC committee C4.3 members,… etc.

Not all sections reported are fully documented. The SPB method [1] is most suitable to characterize the acoustic quality of the sections. As very few SPB results are available on heavy vehicles (owing to the "local" nature of the roads), the study only dealt with SPB results on cars.

Table 1 – Data available per country

Countries with sections	Total number of sections	Number of sections with SPB data	Number of sections with other acoustic data	Number of sections with technical data
The Netherlands	39	23	0	39
Belgium	1	1	0	1
Germany	3	3	?	?
Denmark	3	3	3	3
Italy	4	1	3	4
France	3	3	0	3
Japan	> 96	0	> 96	> 96
Sweden	1	1	1	1
Switzerland	3	2	1	1
Spain	1	0	1	1

SPB-data from two of the three German test sections were not accessible for the author; nor were these data available from the numerous Japanese test sections.

3. TECHNICAL LIFETIME OF TWO-LAYER POROUS ASPHALT

3.1 Lifetime of removed road sections

Lifetime histogram

Some of the two-layer porous asphalt sections that were ever built have already been removed, mostly because they were at the end of their technical lifetimes. All the removed sections which served a full lifetime, were located in The Netherlands. Figure 1 presents both the technical lifetimes of the removed sections and the ages of the existing sections in poor technical condition (which are all Dutch). The sections in poor condition have been considered as being at the end of their technical lifetimes and, consequently, not counted as "existing" but as "removed".

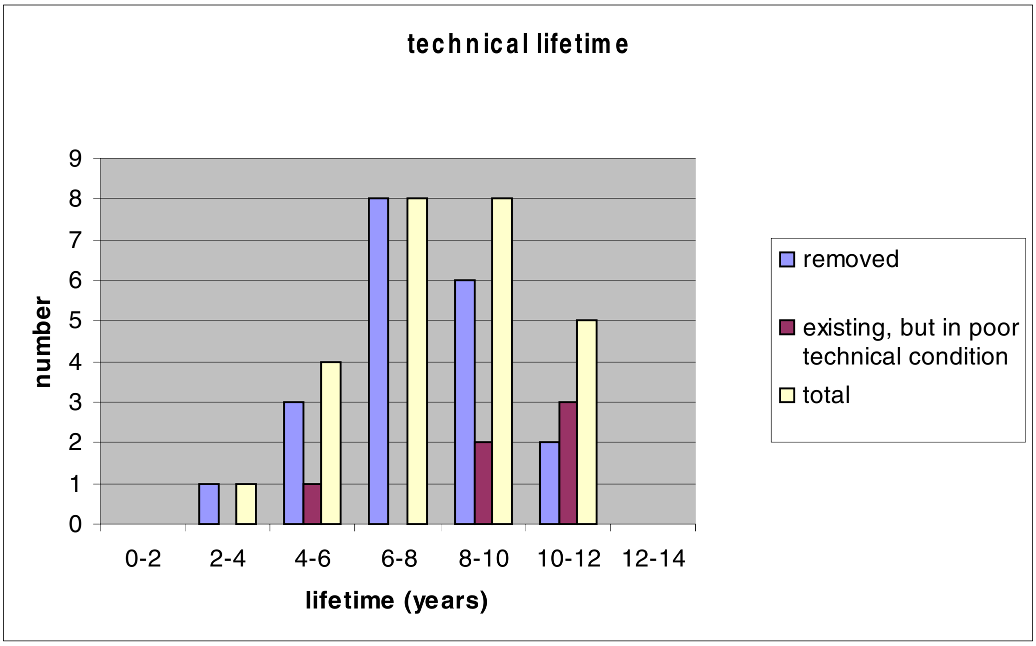

Figure 1 – Technical lifetime distributions (all sections are Dutch)

Statistical data about technical lifetime are given in Table 2.

Table 2 – Technical lifetime statistics

	Removed	Existing, but in poor condition	Total
Number	20	6	26
Average (years)	7.0	9.2	7.5
Standard deviation (years)	2.2	1.5	2.2

Lifetime as a function of traffic parameters

Relatively few data are available on traffic on the (nearly) removed sections. The lifetimes as a function of the volumes of motor vehicles (Figure 2) seem to show a very slight correlation. In view of the small number of data points, these data need to be treated with the greatest caution. It is very likely that another factor, namely the extent of shearing traffic (especially at lorry exits, bus stops, etc.), is much more relevant for the occurrence of ravelling. Unfortunately, little data, which is not even quantitative, is available on this. Nevertheless, for lack of more data, the trend in Figure 2 could be taken as a first approach or rough estimate. More data points are needed to confirm this trend.

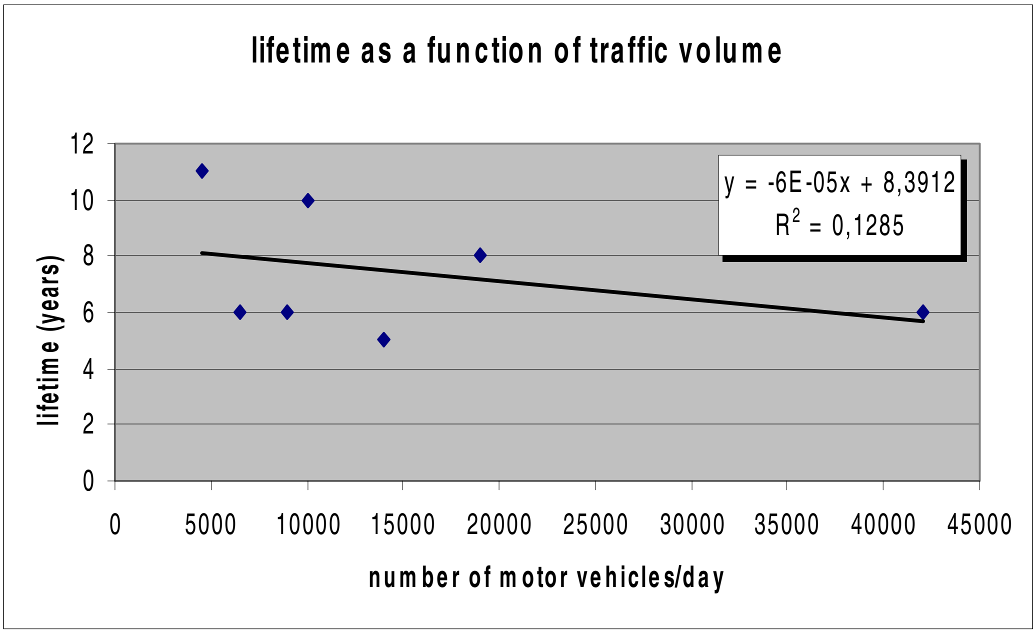

Figure 2 – Lifetime of two-layer porous asphalt sections as a function of the daily volume of motor vehicles

3.2 Age distribution of existing sections

Figure 3 shows the age distribution of the existing sections in The Netherlands and in foreign countries. All the sections in Figure 3 still exist and are in good condition. The bin width of the histogram is two years.

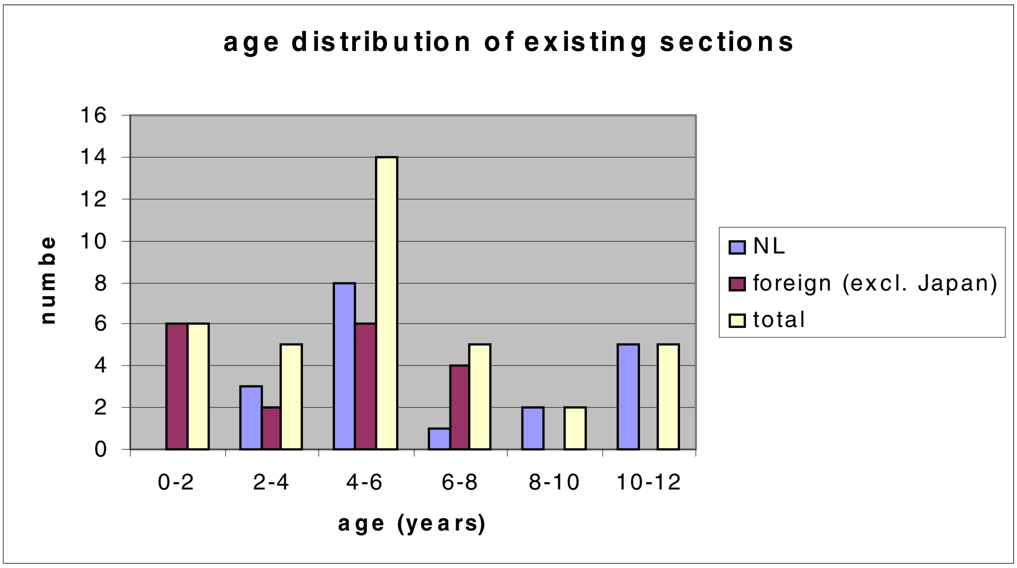

Figure 3 – Age distribution of existing sections of two-layer porous asphalt

The averages and standard deviations of the ages of the sections in The Netherlands and abroad are given in Table 3.

Table 3 – Averages and standard deviations of existing sections

	NL	Foreign	Total
Number	19	19	38
Average (years)	6.4	3.3	4.8
Standard deviation (years)	3.0	2.4	3.1

The average age of the existing sections of two-layer porous asphalt is twice as high in The Netherlands as abroad. It should be emphasized that this does not mean that the sections in The Netherlands have a better quality than abroad, but only that The Netherlands have done pioneering work in this field. The sections dealt with in Table 3 are all in good condition. Hence no conclusions about lifetime can be drawn, but the existence of very old sections which are still in good condition supports the indication that the average lifetime of recent sections may be higher than that of the sections built in the beginning.

4. DEVELOPMENT OF THE ACOUSTIC PROPERTIES OF TWO-LAYER POROUS ASPHALT

4.1 Initial noisiness of the sections

Distribution of initial noisiness

The histogram of the available initial values of L_{veh} (at reference speed 50 km/h, temperature corrected, according to -0,05 dB(A)/°C) are given in Figure 4. Bin width is 1 dB(A). An “initial” value is a value measured within one year after construction (typically 2 to 6 months after construction).

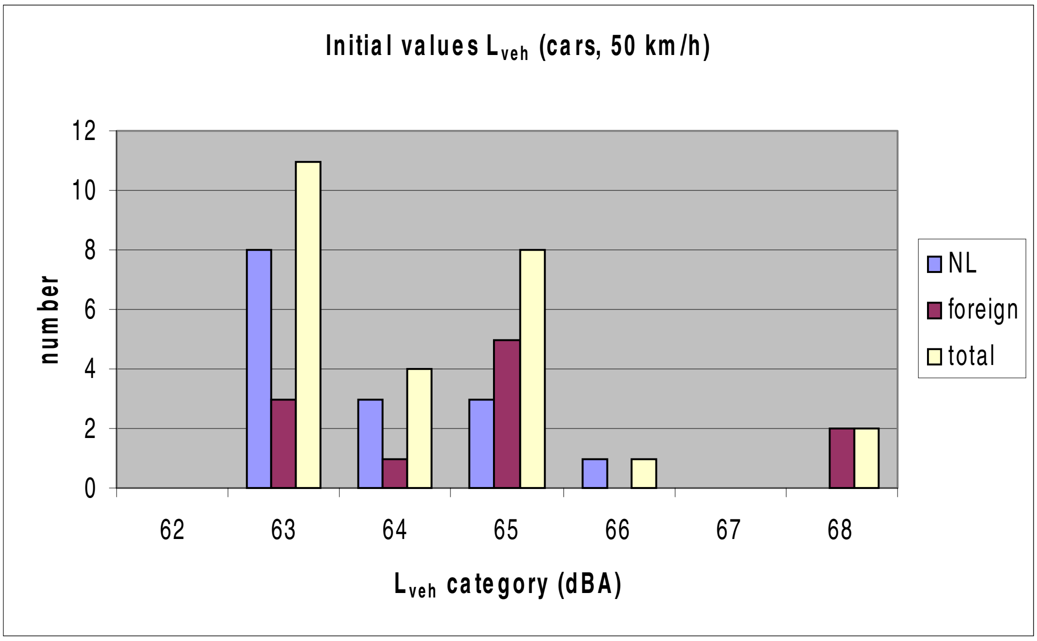

Figure 4 – Distribution of initial L_{veh} values for cars at the reference speed of 50 km/h

The statistical values are summarized in Table 4.

Table 4 – Statistical parameters for initial values of L_{veh} for cars at 50 km/h

Sections with largest aggregate size ≤ 6 mm	NL	Foreign	All
Number	9	6	15
Average L_{veh} (dBA)	63.1	64.1	63.5
Standard deviation on L_{veh} (dBA)	0.4	0.8	0.8
Sections with largest aggregate size > 6 mm	NL	Foreign	All
Number	6	5	11
Average L_{veh} (dBA)	64.4	65.7	65.0
Standard deviation on L_{veh} (dBA)	1.0	2.1	1.7
Sections with all aggregate sizes	NL	Foreign	All
Number	15	11	26
Average L_{veh} (dBA)	63.6	64.6	64.1
Standard deviation on L_{veh} (dBA)	0.9	1.7	1.4

For both the sections with small (≤ 6 mm) aggregates and the sections with coarser aggregates, the Dutch sections seem on average about 1 dB(A) quieter than the foreign sections. However, one has to be careful in drawing conclusions about this rather small difference, as the measurement results might be somewhat biased by country-dependent factors (e.g. different measurement heights, differences in car fleet composition,…). For a very small number of Dutch sections, namely four, one disposes both of L_{veh} values measured on a height of 5 m (like all the other Dutch L_{veh}-values proposed in this report) and of L_{veh} values measured on a microphon height of 1,2 m (like most of the foreign values). The average value of the latter is 0,8 dB(A) higher. This is an indication that the difference between Dutch and foreign values for the mean of L_{veh} might indeed be due to country dependent factors, but the sample size is unfortunately very small.

The Dutch sections with small aggregate sizes are on average 1.3 dB(A) quieter than the sections with coarser aggregates. This difference can be considered as significant, as the standard deviations on the averages are very small and the country-dependent factors are not involved.

The foreign sections show a similar difference in noisiness between sections with smaller and with coarser aggregates. This difference is even larger than in the Dutch case (1.6 dB(A)), owing to the fact that very coarse aggregates were used for the top layer in some cases (e.g. 11 mm in Sweden), resulting in relatively noisy surfaces. The difference in noisiness between foreign sections with smaller and coarser granulates may also – in spite of the country-dependent biasing factors – be significant.

Initial noisiness as a function of design parameters

Figure 5 shows the relation between the maximum aggregate sizes used in the top layer and the initial noisiness of the sections (all). There appears to be a clear correlation between these two factors.

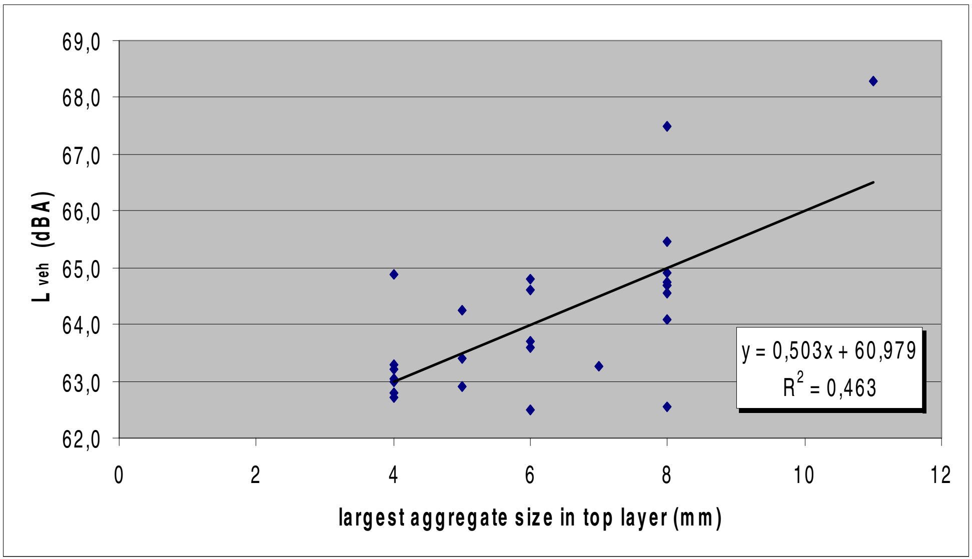

Figure 5 - Relation between the largest aggregate size in the top layer and Lveh at 50 km/h

If noisiness L_{veh} is plotted against the total thickness of the two porous layers for all the sections with known initial noisiness, no trend becomes apparent. However, if the same plot is made only for the sections with small-sized aggregates (Figure 6), the decreasing trend of noisiness with increasing total layer thickness is quite obvious.

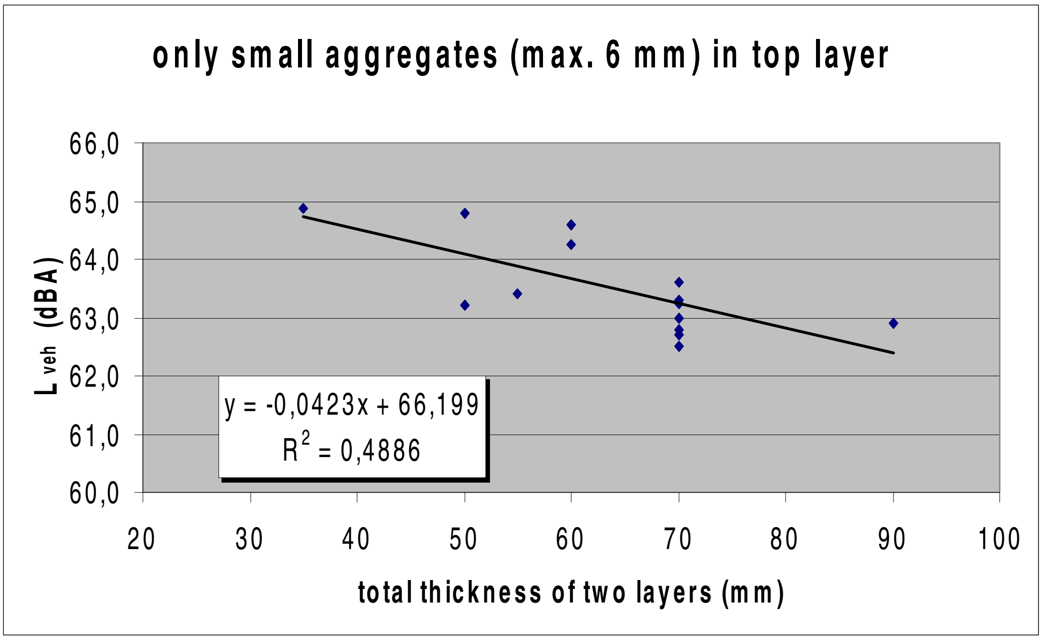

Figure 6– Relation between the total thickness of the porous layers and L_{veh} at 50 km/h for the sections with only small aggregates (≤ 6 mm) in the top layer

4.2 Noisiness of two-layer porous asphalt as a function of age

An important item is the extent to which the excellent acoustic properties of two-layer porous asphalt (initially typically 5 dB(A) more silent than conventional dense asphalt) are preserved as it grows older. On a few Dutch and foreign sections, one or more measurements subsequent to that of the initial value for L_{veh} (see 4.1) were performed after 1, 2, 3 ... years of service. For each section, the initial value was subtracted from the subsequent values to evaluate the increase in noisiness of the two-layer porous asphalt. Figure 7 shows the results for this increase in noisiness with time elapsed since the initial measurement of L_{veh}.

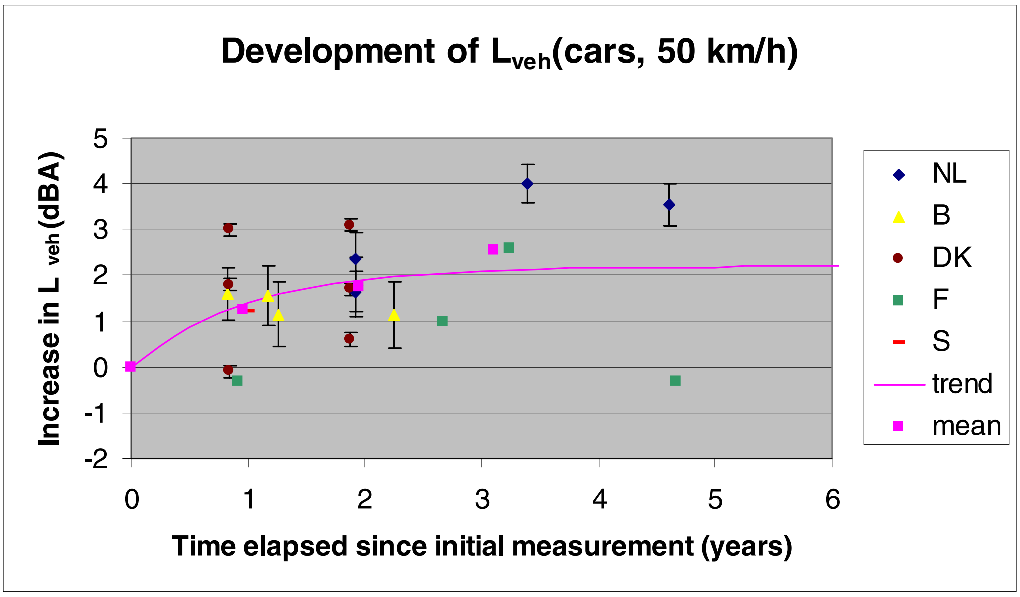

Figure 7 – Increase of parameter L_{veh} with time elapsed since the measurement of the initial value for L_{veh}

Error bars derived from the combination of the 95 %-confidence interval of the initial and subsequent measurement are shown where available. The data points appear to be quite scattered, mainly owing to differences in performance of the sections considered. There are very few data points beyond three years of service. To discern a trend in the data, the data points were grouped within classes of elapsed time: (1 ± 0.5) year, (2 ± 0.5) years, and (3 ± 0.5) years. An average increase in L_{veh} was calculated for each class (Table 5).

Table 5 – Parameters per elapsed time class

Elapsed time class	(1 ± 0.5) year	(2 ± 0.5) year	(3 ± 0.5) year
Number of points	8	7	3
Mean elapsed time	1.0	1.9	3.1
Mean increase L_{veh}	1.2	1.8	2.5
Std. deviation increase L_{veh}	1.1	0.8	1.5

It appears that, *on average*, the noisiness of two-layer porous asphalt increases by about 1dB(A) in the first year, and by another 1 dB(A) within the second year after its application. This effect can be explained by the pores in the surface becoming partially clogged during the first years of service, thereby decreasing sound absorption and increasing noisiness. It seems likely that, on average, noisiness remains stable between three years of age and the end of technical lifetime, but there are very few measurement points to support this. The three mean values of the first “elapsed time classes” are indicated in Figure 7 as pink square dots. The trend line (in pink) is an empirical fit to the mean values.

5. CONCLUSIONS

About 40 sections of two-layer porous asphalt were found on local and secondary roads in The Netherlands, and 20 sections in other European countries. The foreign sections are on average much younger than the Dutch ones. About 100 two layer porous asphalt sections were found in Japan, but acoustic data on these sections were not accessible to the author.

On average, the sections abroad are much younger than the Dutch ones. The sections that still exist in The Netherlands are on average 6.4 years old, whereas the foreign sections have an average age of only 3.3 years.

Conclusions about the technical lifetime of two-layer porous asphalt could be drawn only from the data on the older Dutch sections, as only in The Netherlands data were found about sections that were removed after serving a lifetime. The average lifetime of the sections that were removed in the past equals 7.0 years, but the lengths of life reached by existing sections that are nearing the end of their lives average 9.2 years. It is, moreover, an interesting fact that The Netherlands also have some sections of 10 years old and more, which are still in good condition. One may, therefore, expect that the current generation of two-layer porous asphalt sections will reach a longer lifetime than the 7.0 years of the already removed “old” sections.

The initial noisiness of the sections with only small aggregates (≤ 6 mm) in the top layer is somewhat (about 1.0 to 1.5 dBA) lower than those with coarser aggregates. This trend is visible within each of the subsets of Dutch and foreign sections and is significant. Both the

Dutch sections with smaller and with coarser granulates are, *on average*, about 1 dB(A) more silent than the corresponding foreign sections, but this may be due to country-dependent biasing factors (like measurement height or car fleet composition).

Initial noisiness is significantly correlated with the size of the coarsest aggregates in the top layer, and also with the total thickness of the two porous layers if the plot is limited to sections with small largest aggregate sizes (in order to eliminate the scatter of initial noisiness due to differences largest aggregate size). Not enough data are available to test the correlation of noisiness with voids content.

The development of the acoustic properties of two-layer porous asphalt is quite different from one section to another. The increase in noisiness within the first years after construction lies between 0 and 4 dB(A). The average increase of noisiness is about 1 dB(A) during the first year and another 1 dB(A) during the second year. It is not unlikely that, after this second year, the acoustic properties remain quite constant for the remainder of technical lifetime, but there are very few data available to confirm this.

6. REFERENCES

[1] ISO 11819-1:1997(E) “Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 1: Statistical Pass-By method”.

[2] Beckenbauer, T. et al., “Einbau eines 2-lagigen offenporigen Asphaltes auf der B 17 in Augsburg – Schlussbericht”, Bericht Nr. M54 928/20, Müller-BBM, München (2004).

[3] Bendtsen, H., Larsen, L.E., Greibe, P., "Udvikling af stojreducerende vejbelaegninger til bygader - Statusrapport efter 3 ars malinger", Danmarks TransportForskning, Report 4, 2004, Lyngby, Denmark (2002).

[4] Doorschot, J., Excel file with data about two-layer porous asphalt sections in The Netherlands, M+P, Vught (2004).

[5] Goubert, L., "Statistical pass-by vehicle noise measurements on full scale – Implementation on expressway test site and urban test site", report SIRUUS/BRRC/WP3.4-2001.02.00/LG of the SIRUUS (Silent Roads for Urban and Extra-Urban Use) project, European Community Commission, BRITE/EURAM PROJECT BE97-4690, Brussels, Belgium (2002).

[6] Meunier, Y., "Synthèse des mesures de bruits sur enrobés peu bruyants APPIA", unpublished document, APPIA, Issy-les-Moulineaux, France (2004).

[7] Pestalozzi, H., Belagsmessprotokoll, Standort-Nr. 653, Grolimond & Partner AG, Bern, Switzerland (2004).

[8] Pestalozzi, H., Belagsmessprotokoll, Standort-Nr. 661, Grolimond & Partner AG, Bern, Switzerland (2004).

[9] Torii, Y., non exhaustive and unpublished list of two-layer porous asphalt sections in Japan, personal communication, Expressway Technology Center, Tokyo, Japan (2004).