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Austrian experience with the backing board method for statistical pass-by measurements

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Traffic noise is one of the major environmental concerns within the countries of the European Union. 80 to 90% of the traffic noise pollution is generated by road traffic. The major part of the noise emitted by vehicles on roads in the mid- to high-speed range is nowadays due to tyre/road noise. It is generated by the interaction between tyre and road surface, and therefore the measurement of the typical noise emission is essential for the classification of pavements with regard to noise. The SPB method (Statistical Pass-By, ISO 11819-1) is nowadays the most widely used method to characterise road surfaces, but it is difficult to apply especially in the presence of roadside noise barriers. The backing board method, further developed within the EU Project SILENCE in the past years, offers a possibility to measure and to characterise surfaces also close to reflective objects and in urban environments. This paper describes the first Austrian experimental experience with the application of this variant of the SPB method.

1 Introduction

Road traffic noise is a major source of noise annoyance due to the extent and pervasiveness of the road networks and the high traffic volumes found in industrialized countries (see [1]). Especially in urban areas major roads pass through densely populated areas, affecting a large number of people. Traffic noise abatement using noise barriers is often impossible or inefficient in these environments. Suburbanization along motorways expands these problems also into the rural areas. The combination of relatively low noise protection limits and the use of noise barriers as primary means of noise abatement have led to long sections of motorway framed with medium-to-high noise barriers in Austria. While they are effective, the need for alternative and complementary noise abatement at the source is rising. Modern low-noise road surfaces can contribute substantially to the reduction of road traffic noise (see [2]).One important requirement for their widespread application is a reliable classification of their specific noise reduction. For this reason standardized methods have been developed to assess the pavement influence on road traffic noise.

2 The Backing Board method

The most widely used method for the characterization of the influence of pavements on road traffic noise emission is the so-called Statistical Pass-By method (SPB), detailed in ISO 11819-1 [3]. It relies on measuring the maximum sound pressure levels (L_{max} or L_{Amax}) of a statistically significant number of vehicle pass-bys at a distance of 7.5 m from the centre of the lane and at a height of 1.2 m above the ground. However, this method requires free-field conditions in a large radius around the microphone position at the roadside, which includes the absence of reflecting obstacles. Both in urban areas and along motorways with installed noise barriers this condition is often very difficult to fulfil. Therefore several research institutes involved in the EU project SILENCE [6], which includes also research on measurement methods for low-noise pavements, have teamed up to develop a variant of the SPB method which permits its application also in the presence of obstacles behind the microphone position. The basic principle of this so-called "Backing Board method" is explained in a paper by Fégeant [4] and consists in utilizing a rigid board (the Backing Board) of sufficient size to emulate an infinite rigid plane. An impinging plane wave will be reflected back with a doubling of the pressure amplitude at the surface, resulting in a 6 dB increase in noise level compared to a measurement at the same position without the presence of the rigid plane. In theory this allows to neglect the effects of any objects behind the board, while incurring a constant $\Delta L = +6$ dB level increase in all frequency bands. A practical realization consists in the embedding of a free-field microphone in the board with the membrane level with its surface, or in the use of a special surface microphone. The corresponding free-field level can then be easily determined by subtracting 6 dB from the measurement results.

However, in practice some limitations have to be taken into account. As the board cannot be infinite, frequency-dependent diffraction effects from the edges and corners create a varying sound field across the surface. Therefore a microphone position has to be selected where the 6 dB increase is realized at least for the overall sound pressure level. Moreover, it is still possible that large or close reflecting objects behind the microphone position can influence the results. Additionally, the Backing Board Method can only be used if all disturbing objects are located at the roadside opposite the passing vehicles and behind the measurement position. This would include a façade behind the microphone, but not the situation in a street canyon with opposite facades. The possible influence of any opposite objects has to be assessed for each specific measurement situation. Nevertheless this method promises to increase the number of potential measurement sites considerably. Therefore the authors, who work at arsenal research in Austria, being also a partner in SILENCE, have undertaken tests to evaluate the applicability of this method for roadside measurements in Austria. They used previous experience from the UK Transport Research laboratory in [5] and the SILENCE project partners Belgian Road Research Centre (BRRC, Belgium) and Bundesanstalt für Straßenwesen (BASt, Germany) to set up a measurement configuration based on a surface microphone.

3 Measurements and results

All measurement setups were based on a real time analyzer system capable of recording the third-octave band levels from 100 Hz to 10 kHz. The reference measurement setup was a free-field microphone at the SPB position 7.5 m away from the source or the centre of the lane and 1.2 m above the ground. All results were compared to this setup.

The authors used a Backing Board with the dimensions of 90 x 75 cm x 4 cm made of layered and compressed wood and mounted on a metal stand with its lower edge 83.5 cm above the ground. A surface microphone was attached to the surface in varying positions with adhesive tape (see Fig. 1)

The sound source was either a loudspeaker (half dodecahedron) positioned on the ground and emitting pink noise or controlled vehicle pass-bys.

The measurements were performed in free-field conditions at a small side road near the site of arsenal research in Vienna. Wind speed did not exceed 2 m/s and the temperature was 15 °C. The ground surface along the propagation path between the source and the microphone position was covered with standard asphalt concrete. (see Fig. 1)

Fig.1 Left the setup of the measurements with the BB (backing board), right the surface microphone during the measurement at position B1 (in red also position F1).

3.1 Measurements on the board

The first set of measurements was designed to find the optimal microphone position on the board which would yield a 6 dB increase compared to the free-field measurements. The sound source for the backing board measurements was the pink noise loudspeaker positioned on the ground 7.5 m away from the board. As the setup was symmetrical with respect to the vertical axis of the board, measurements were restricted to the centre line and the right half of the board, while assuming identical results on the left half. The authors determined a square grid with a distance of 10 cm between adjacent measurement positions in both horizontal and vertical directions (rows 1-8 and columns 1-7). This grid was centred on the board and complemented by positions along the vertical axis (M). Measurements were finally carried out only in the columns M and 5-8. Additionally the positions B1 determined by the Belgian team from BRRC and the position F1 given by Fégeant [4] as optimal position (28.8 cm right of the vertical axis and 6 cm above the horizontal axis) were used, including the points F2-F4 and B2-B4 created by mirroring about the horizontal and vertical axis. (see Fig. 2)

The distance correction due to the deviation from the reference position 1 cm below the centre of the board (position M4) according to the SPB method was calculated to be less than 0.1 dB and therefore neglected. The reference position

Table 1 and table 2 show the results for the differences in overall sound pressure level L_{eq} between the Backing Board (BB) setup at the grid, B and F positions and the free field (FF) reference SPB setup.

The grid positions show level differences $\Delta L = L_{BB}\text{-}L_{FF}$ between 3.3 and 7.5 dB, while the B positions give ΔL between 6.5 and 6.7 dB. The F positions are closest to the expected 6 dB value, ranging from ΔL = 5.8 to 6.2 dB.

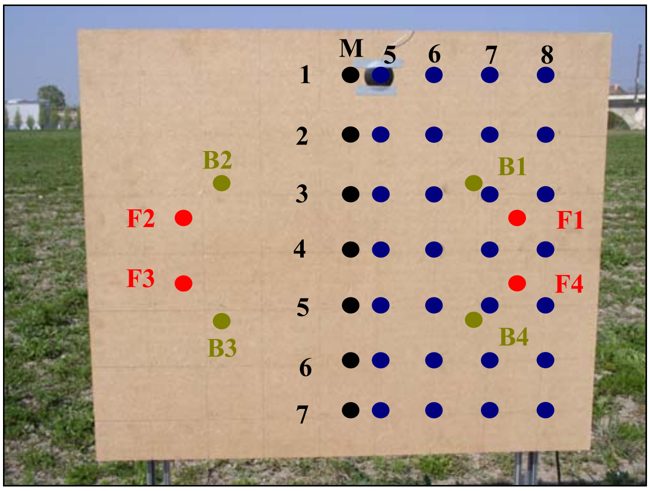


Fig.2 The backing board with the all measurement positions. In green the B positions, in red the F positions, in blue the positions on the grid (only the right part of the board has been measured), in black the positions in middle of the board (1 to 7 are the rows, M to 8 are the columns of the grid).

Row\Column of the grid on the board	M	5	6	7	8
1	5.1	5.1	5.0	4.1	3.4
2	6.7	6.7	6.4	5.7	4.3
3	7.4	7.3	6.9	6.3	4.8
4	7.5	7.4	7.1	6.3	4.9
5	7.1	6.9	6.8	6.0	4.8
6	6.1	6.1	5.9	5.5	4.2
7	4.6	4.5	4.3	4.2	3.3

Table 1 Level difference ΔL (in dB) between reference measurements (with free-field microphone at 1.2 m height) and the positions on the board

Position	Level difference ΔL [dB]	Position	Level difference [dB]
B1	6.7	F1	6.1
B2	6.6	F2	6.2
B3	6.5	F3	5.8
B4	6.5	F4	6.0
		avg.	6.3

Table 2 Level difference (in dB) between reference measurement (with free-field microphone at 1.2 m height)

and the positions on the board (for B and F points and for the average of these positions)

Extrapolating the results for ΔL into a contour plot for the whole board results in a set of concentric zones (see Fig. 3). Both the F and B positions are close to the theoretical optimum and will therefore be used for further analysis.

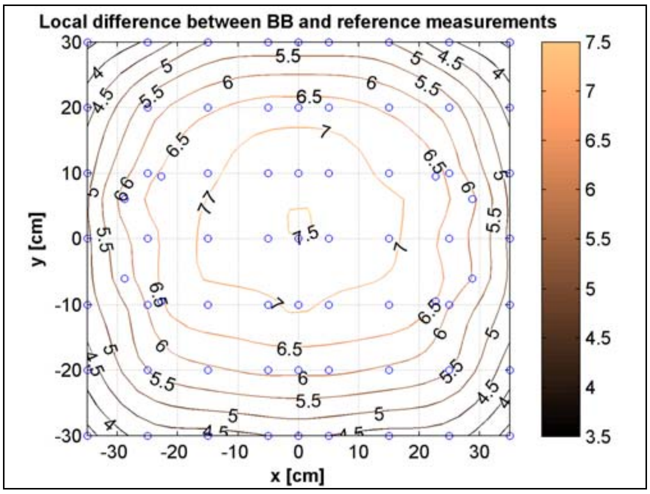


Fig.3 Contour plot of the local difference between reference and backing board measurements for the overall values (the 6 dB line is the best one from the theoretical point of view).

3.2 Results on the spectral resolution

Apart from the overall levels, which are essential for the classification of road pavements, ideally also the third-octave band results of the free-field reference measurement should be reproducible from the backing board results.

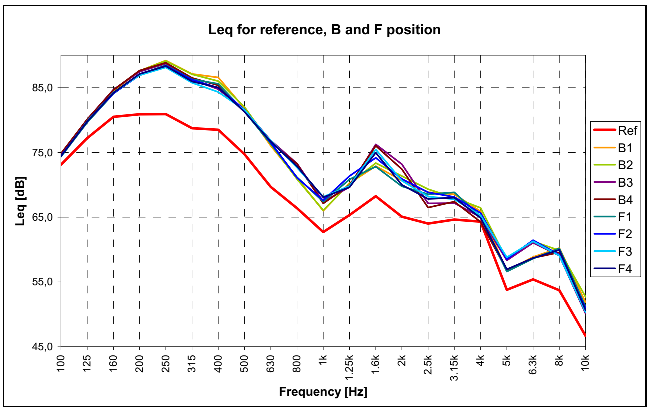


Fig.4 Spectral resolution of the reference measurement (red line) and the measurements at the B and F positions on the board.

Fig. 4 shows the absolute third-octave band levels of the reference measurement and the measurements at the B and F positions. The overall shape of all spectra shows similar features.

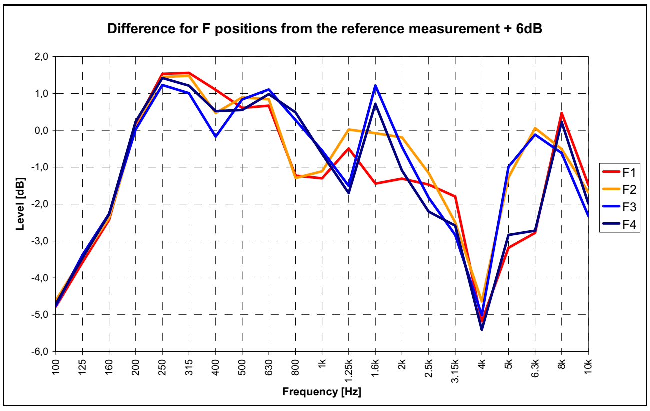


Fig.5 Spectral resolution of level difference between the reference measurements (+ 6 dB) and the measurements at the F positions on the board.

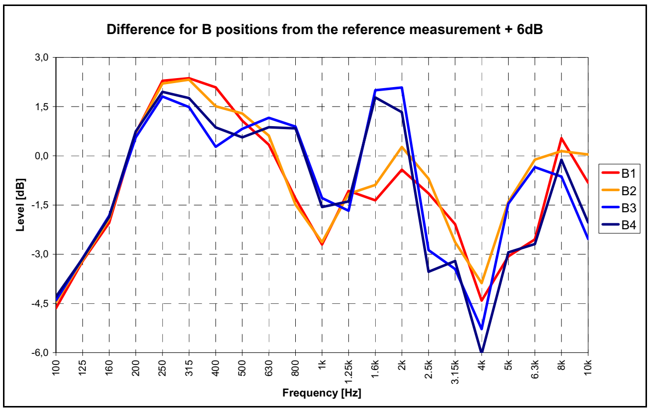


Fig.6 Spectral resolution of level difference between the reference measurements (+ 6 dB) and the measurements at the B positions on the board.

Fig. 5 and 6 show the deviation $\Delta L_d = \Delta L - 6$ dB from the expected 6 dB level difference for the B and F positions. All spectra have large deviations at low frequencies and a pronounced dip at 4 kHz. Relatively low deviations can be found at F1, F2, B1 and B2. Taking the results for the overall levels into account, the authors have selected F1, F4 B1 and B4 for the subsequent measurements.

3.3 Measurements with reflecting objects

In order to determine the shielding performance of the backing board with respect to large reflecting objects, measurements with a vehicle directly behind it (see Fig. 7).

Fig.7 Experimental setup for the measurements with a reflecting object near to the backing board.

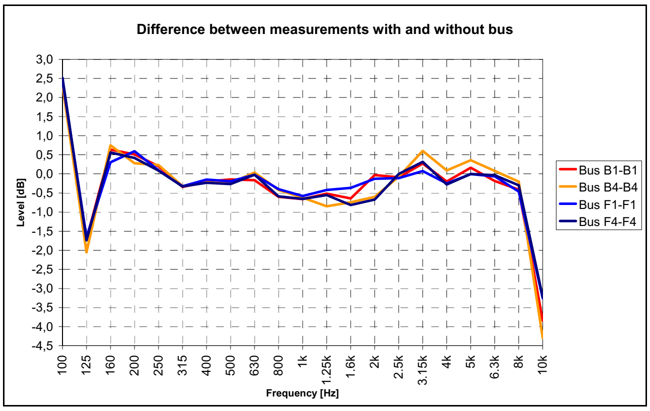


Fig.8 Spectral resolution of level difference between the measurements with and without reflecting object (in this case the bus) at the positions B1, B4, F1 and F4.

The level difference resulting from the presence of the vehicle is within the measurement uncertainty both for the overall levels and the third-octave band levels from 160 Hz to 8 kHz. (see Fig. 8 and Table 3)

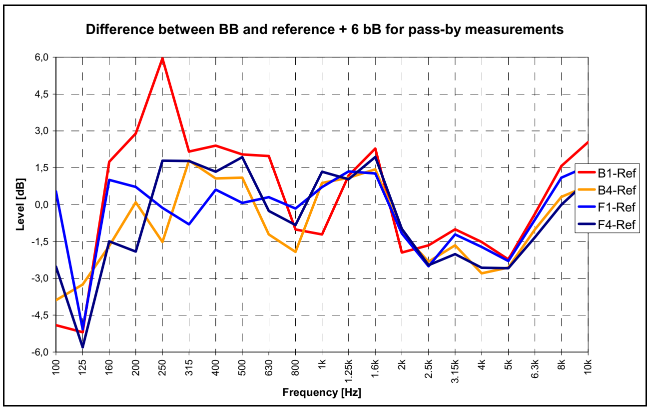
Leq	Level difference
B1	0,1 dB
B4	0,0 dB
F1	0,1 dB
F4	0,1 dB

Table 3 Overall level differences between the measurements with and without reflecting object at the positions B1, B4, F1 and F4

3.4 Pass-by measurements

Finally the setup was tested in a series of controlled pass-by measurements at 60 km/h. The measured quantity was the A-weighted maximum pass-by sound pressure level L_{Amax}. The backing board setup recorded the same pass-by as the reference setup, which was placed a few metres further on up the road. (see Fig. 9)

.Fig.9 Setup for the pass-by measurements at 60 km/h (simultaneous measurements with the surface microphone on the board and with the free-field microphone for the pass-by measurement).



. Fig.10 Spectral resolution of level difference between the reference measurements (+ 6 dB, channel 1) and the measurements at the B1, B4, F1 and F4 positions (channel 2) on the board.

The spectral deviation $\Delta L_d = \Delta L$ - 6 dB from the expected level difference is shown in Fig. 10. The results for F1 actually show less deviation from the optimum spectrum than for the pink noise measurements. Also the overall level differences ΔL shown in table 4 are very close to the expected 6 dB.

L_{Amax}	Level difference ΔL
B1	6,2 dB(A)
F1	6,1 dB(A)
B4	6,2 dB(A)
F4	6,4 dB(A)

Table 4 Level difference between the pass-by reference measurements and the BB method at the positions B1, B4, F1 and F4

4 Conclusions

The experiments have shown that the Backing Board variant can be used as a suitable method for roadside measurements of traffic noise in situations where reflecting objects are present behind the microphone position. The authors determined F1 to be the optimum position for practical use. It showed very favourable results for the determination of overall sound pressure levels from backing board results. However, the spectra show large deviations in some frequency ranges even for the best measurement positions in this investigation, which makes a simple derivation of free-field third-octave band levels from backing board results impossible. The effect was worse for artificial sound signals than for actual vehicle pass-bys. Nevertheless the situation can maybe be improved by using calibrated correction curves, which will have to be determined in further investigations. The shielding performance of the backing board was seen to be very good. The authors will continue to develop this method for the intended use and are planning further in-situ tests on Austrian motorways and in urban areas.

Acknowledgments

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References

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