EUROPEAN COMMISSION
DG RESEARCH

SIXTH FRAMEWORK PROGRAMME
PRIORITY 6
SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS
INTEGRATED PROJECT – CONTRACT N. 516288

NOISE CLASSIFICATION METHODS FOR URBAN ROAD SURFACES

Classification Methodology

Deliverable no.	F.D14
Dissemination level	Public
Work Package	WP F4 Noise classification methods for urban road surfaces Task F4.2 Measurement of Singularities
Author(s)	Wolfram Bartolomaeus
Co-author(s)	None
Status (F: final, D: draft)	F
File Name	SILENCE_F.D14_20080115_bast_final.doc
Project Start Date and Duration	01 February 2005, 36 months

TABLE OF CONTENTS

TABLES

FIGURES

1 Introduction

1.1 Role within SILENCE

Subproject F of the SILENCE project is concerned with the role of road surfaces in the generation of road traffic noise. The project focuses especially on noise abatement in urban areas, and consequently urban road surfaces and their noise emission properties are the main interest of subproject F. The work packages within subproject F deal with the following topics:

- WP F1: New production technologies for surfaces on urban streets
- WP F2: New production technologies for surfaces on urban main roads
- WP F3: Improved systems for the maintenance of quieter surfaces
- WP F4: Noise classification methods for urban road surfaces
- WP F5: Testing of novel road surfacing materials

Within the subproject, work package F4 plays the important part of providing tools for other work packages to assess the success of new types of road surfaces or the maintenance of existing pavements. Within F4, the tasks are distributed as follows:

- Task F4.1: State of the art
- Task F4.2: Measurement methods
- Task F4.3: Classification by type, condition and location
- Task F4.4: Corrections for local discontinuities
- Task F4.5: Noise performance development model

This document is the output of the work in task F4.4 and is concerned with providing a proposal for correction factors for local discontinuities at road surfaces like manhole covers, humps and bumps and tram crossings. It relies on the deliverable F.D12 which describes the measurement methods and their fields of application in detail.

1.2 Aim

The aim of this document is to

- Propose correction factors for local discontinuities at road surfaces in urban areas according to their typical noise emissions with respect to a “normal” surface as reference.
- Give hints how to avoid noisy local discontinuities.

From the results of measurements with the backing board technique at manhole covers, humps and bumps and at tram crossings conclusions are drawn for possible correction factors. All measurements are well documented in the annex.

2 Problem of noise emission measurements in urban situation

2.1 Standard methods

Two internationally standardised procedures have been produced by the working group 33 of the Technical Committee 43 “Acoustics” / Subcommittee 1 “Noise” of the International Standardisation Organisation (ISO TC43/SC1/WG33 “Measuring method for comparing traffic noise on different road surfaces”). The standardised methods are:

- The Statistical Pass-By Method (SPB) based on ISO 11819-1 (ISO 11819-1, 1997)
- The Close-Proximity Method (CPX) based on ISO /CD 11819-2

Even if one of them is still a draft, both are widely used and recognised as standard tools for investigating the noise emission properties of road surfaces. They can be applied to high-speed roads as well as to low-speed ones, albeit the use for urban roads has not been specifically addressed with all its implications in the standards.

A third widely used method, the **Controlled Pass-By Method (CPB)**, is basically a variant of the SPB method where a small number of test vehicles are chosen to represent the general types of vehicles required in the SPB method.

In this study only SPB and CPB measurements have been conducted. The normal horizontal distance from then centre of the vehicle passing by to the microphone is 7.50 m for both methods. The height of the microphone above the road surface plane is 1.20 m.

2.2 Adoption to urban situations: the Backing Board

For the adoption of noise emission measurements with SPB and CPB in urban situations the Backing Board method (BB) was established. In this method the normal free field (FF) microphone is substituted by a microphone mounted on the BB. This is applicable for both SPB and CPB. In the following SPB-FF and CPB-FF ore even SPB and CPB will indicate the normal measurement situation as stated in the ISO document. SPB-BB and CPB-BB will indicate that a BB is used instead of a free field microphone.

A second adoption to urban environment is the measurement distance. Since beside narrow roads there is often not enough space for a horizontal distance of 7.50 m a horizontal distance of 5.00 m is chosen instead. To get the right angle to the noise source the measurement height was adjusted to 0.80 m. For comparison between BB and FF also measurements with FF at 5.00 m and with BB at 7.50 m horizontal distance were performed (indicated as FF-5.0 and BB-7.5)

2.3 Description of the equipment

The equipment for measurements with BB is the same as for measurements under free field conditions. But the microphone has to be fixed on a hard reflection board (Ljunggren, 1997).

There are different shapes of boards in use, rectangles and irregular shaped (Goubert, 2006). The material has to be at least 12 mm of wood to avoid vibrations. The small board of BASt is of size 90 cm in width and 75 cm in height.

Figure 1: Backing Board (BB) at a measurement site in Cologne

The best position for the microphone on the board can be derived from a figure from literature (Fégeant, 1997). The position must be out of geometric symmetry lines of the board to minimise the effect of diffraction with constructive interference around the edges of the board. The position for the microphone was chosen in the right lower corner of the board, 33 cm from the right edge and 23 cm from the lower edge (see Figure 1).

3 Measurements on site

3.1 Measurement set-up for comparison measurements

In three campaigns measurements with Backing Board (BB) and under free field conditions (FF) of SPB and CPB were conducted in autumn 2006 and spring 2007. On all sites two BBs and two FF microphones were used, both at a distance of 5.0 m and 7.5 m to the middle of the driving lane (see Figure 2).

Figure 2: Measurement sites for SPB and CPB with Free Field (FF) and Backing Board (BB) at "Belgische Allee" in Cologne

3.2 Results of comparison measurements

For 430 passenger cars with speed of 45 km/h to 160 km/h the pass by noise were measured at three sites, namely a motorway, a rural road and an urban street. Correction factors (theoretical and measured) from all results (BB and FF at 7.5 m and at 5.0 m distance) are given in table 1.

Table 1: Correction factors for Backing Board (BB) to Free Field (FF) in dB(A)

correction	**BB-5.0 - FF-7.5**	BB-5.0 - BB-7.5	FF-5.0 - FF-7.5	BB-5.0 - FF-5.0	BB-7.5 - FF-7.5	BB-7.5 - FF-5.0
theoretical	9.5	3.5	3.5	6.0	6.0	2.5
measured	**9.3**	2.9	3.3	6.0	**6.3**	3.1
difference	-0.3	-0.6	-0.2	0.0	0.3	0.6
standard deviation	0.5	0.5	0.6	0.5	0.5	0.6

There exists no speed dependency at all. The scatter of the values can be states as normal for weather conditions at measurement sites outside. The mean value and the median value of the correction for the BB are identical and result in 9.3 dB(A). The correction factor from BB to FF at a distance of 7.5 m is 6.3 dB(A). The standard deviation given in table 1 is derived from the root mean square of the sum the standard deviations of the both measurements. All results are preliminary and only valid for passenger cars. Although the values for heavy trucks are quite similar (9.0 dB(A) and 5.9 dB(A)).

3.3 Spectra of Backing Board measurements

In Figure 3 the spectra from SPB measurements at a measurement site on a rural road are given for the frequency range of 20 Hz to 20 kHz. For the position FF 25 m the damping with propagation is much better for the high frequency range above let say 100 Hz then below.

In additional the Traffic Noise Spectrum (TNS, DIN EN 1793-3) is drawn for FF-7.5 (75.7 dB(A)). Comparing to the other spectra the low frequency part of it is more dominant. This reflects the fact that this spectrum is derived from the noise emission of both passenger cars and trucks.

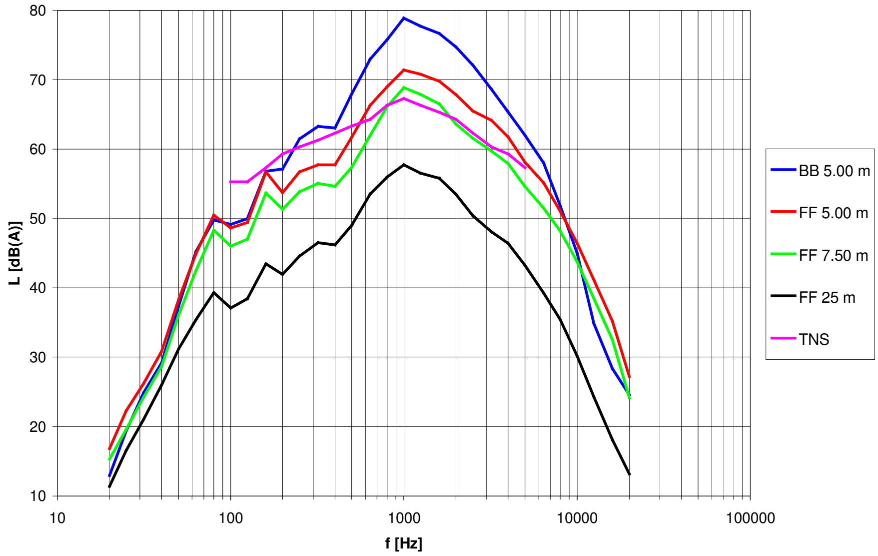

Figure 3: Spectra from SPB measurements at a site on a rural road

4 Results from measurements of singularities

For all measurements linear regressions of maximum pass-by noise level versus logarithm of pass-by speed were done. The abbreviation used for the measurements of singularities is “nor”. Then the differences of noise levels according to a reference surface (abbreviation “ref”) nearby were calculated.

In some cases it was not possible to measure with the backing board at a perpendicular position to the driving direction. In this case an extra correction was used, derived from CPB measurements performed at the test site of the BASt. All measurements of reference surfaces were corrected regarding the mean value of all levels.

4.1 Measurements of manhole covers

There where three manhole covers (MC) measured with CPB and one of them with SPB too.

4.1.1 Results for manhole covers

Normally the noise level is rising with speed (MC1 and MC2), but some times the noise level in decreasing. The manhole cover MC3 is quite deep under the surface level of the road. Therefore the vehicles are jumping over it at higher speeds. The tendency not to overrun a manhole cover is getting higher at higher speed. Therefore the SPB-differences are lower at higher speed.

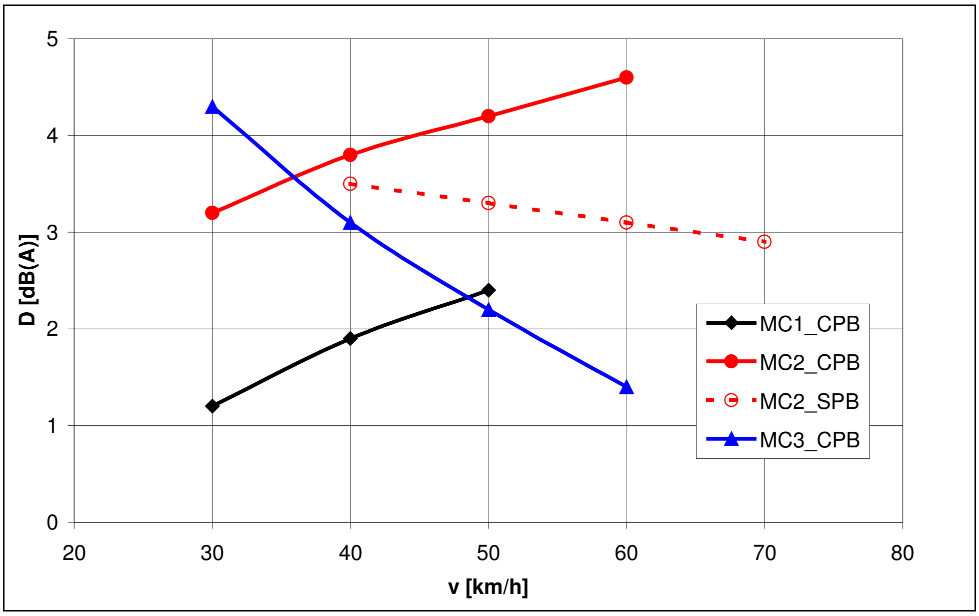

Figure 4 Differences from noise level to reference surface for manhole covers

The overall additional noise from manhole covers for urban speed up to 60 km/h is about 1 dB(A) up to 5 dB(A).

4.1.2 Results for humps and bumps

A modern smooth hump made of concrete blocks is nearly not louder than the normal road surface (HB1). Older humps made of cobble stone (HB2) are at higher speed as noisy as bumps (HB3 and HB4). As an average the difference in noise level to a normal road surface is about 6 dB(A) to 9 dB(A) for older humps and for bumps.

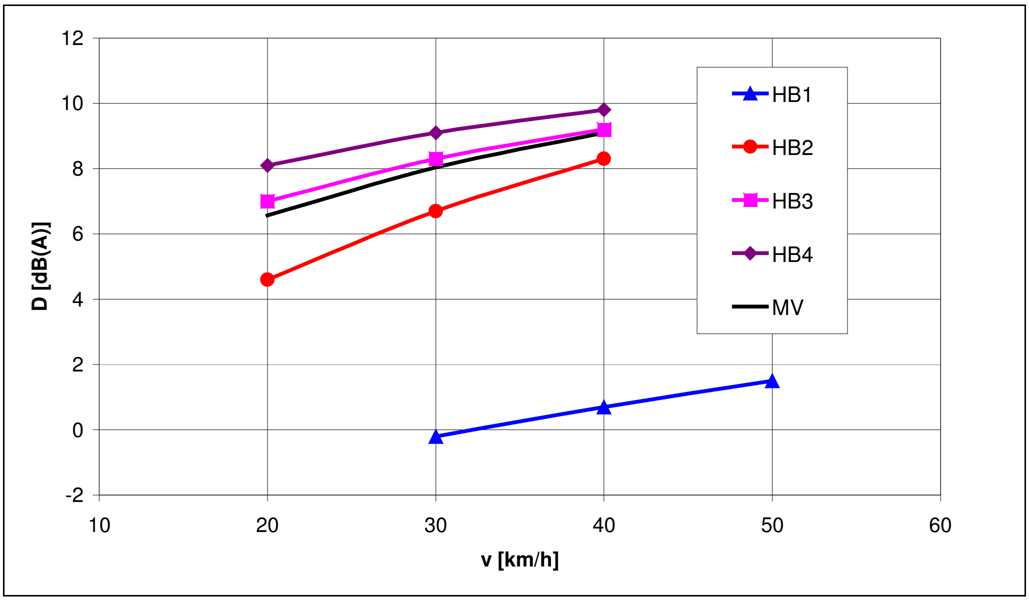

Figure 5: Differences from noise level to reference surface for humps and bumps

4.1.3 Results for tram crossings

The best method to avoid noise from tram crossing is to build them under an angle to the road direction (e.g. 45° TC5_1) but be sure the rail is fixed properly (otherwise see TC5_2). The additional noise from a normal tram crossing at 0° is up to 10 dB(A) for 70 km/h.

For normal urban speed of 30 km/h to 60 km/h there is an additional noise level of less then 2 db(A) up to more than 9 dB(A).

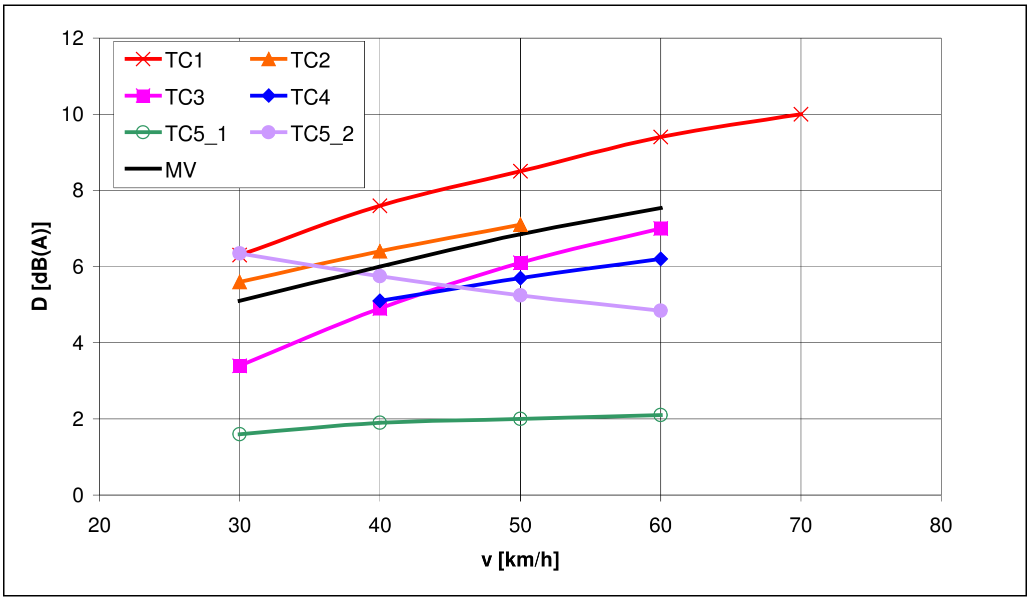

Figure 6: Differences from noise level to reference surface for tram crossings

5 Conclusions

5.1 Using Backing Board

The small Backing Board (BB) is useful for all speed ranges where SPB measurements are performed. It can be used in urban situations as well as beside motorways e.g. with reflecting sound barriers.

From SPB measurements of passenger cars on site robust correction factors for the BB were derived. Comparable BB to free field (FF) conditions at standard geometry (7.5 m distance) the correction factor for passenger cars is 6.3 dB(A) and for BB at 5.0 m distance to standard FF 9.3 dB(A) in the speed range from 45 km/h to 160 km/h. Until now these correction factors are preliminary, because of the small number events (443 passenger cars). The correction values for heavy trucks are quite similar: 9,0 dB(A) and 5.9 dB(A).The frequency range for the BB is limited from about 200 Hz to 4 kHz; But the influence on the A-weighted level is negligible.

5.2 Correction factors for singularities

The additional noise from man hole covers is up to 4 or 5 dB(A) in the normal urban speed range. From humps, bumps and tram crossing the additional noise is up to about 10 dB(A), but there are existing good measures (humps made with concrete stones, tram crossing with an angle to driving direction) to avoid these high levels.

In [8] a proposal for classification of the additional noise from singularities is given. There are three classes:

- from 1 dB(A) to 2 dB(A): "Low"
- from 2 dB(A) to 5 dB(A): "Moderate"
- more than 5 dB(A): "High"

For differences in noise level of less than 1 dB(A) the effect is negligible.

A proposal for correction factors and possible measures for avoiding high noise levels at singularities are given below.

5.2.1 Manhole covers

The additional noise from manhole covers is depending strong on the way the manhole cover is build in, the location of the manhole cover (in or out of the wheel tracks) and the surface of the manhole cover itself. A manhole cover can be noisier for low speeds, when it build in uneven. A manhole cover build in even is emitting more noise than the normal road surface because of its rough texture.

The proposal for correction is:

- $\pm 0\ dB(A)$ in a speed range of 30 km/h to 70 km/h for smooth textured and even build in manhole covers. The difference in noise level is negligible.
- $+3\ dB(A)$ in a speed range of 30 km/h to 70 km/h for roughly textured or uneven build in manhole covers. The difference in noise level is "Moderate".

5.2.2 Humps and bumps

A modern smooth hump made of concrete blocks is nearly not louder than the normal road surface. Older humps made of cobble stone are at higher speed as noisy as bumps.

The proposal for correction is:

- $\frac{v-30}{10} dB(A)$ in a speed range of 30 km/h to 50 km/h for modern even humps made of smooth concrete block stones with smooth ramps. The difference in noise level is negligible for a speed up to 40 km/h and "Moderate" for a speed between 40 km/h and 50 km/h

- $+8\ dB(A) + \frac{v-30}{10} dB(A)$, (speed ***v*** in km/h) in a speed range of 30 km/h to 50 km/h for old uneven humps made of rough cobble stones or for severe bumps. The difference in noise level is "High" in all cases.

5.2.3 Tram crossings

For normal urban speed of 30 km/h to 60 km/h there is an additional noise level of less then 2 dB(A) up to more than 9 dB(A) for tram crossings. Not properly fixed tram crossings are noisy at low speeds.

In (8) there are reported differences in noise level for tram crossing of about 10 dB(A) for a speed of 50 km/h.

In (9) the noise level from various tram crossings are reported. For an old "conventional" tram crossing with 90° of rails to road direction the noise level at 50 km/h for standard Free Field CPB is 78.5 dB(A) which correspondents to the value of 75.8 dB(A) to 77.1 dB(A) for the noise level of the 90° tram crossings measured within this project. For the 45° tram crossing at the same speed the values within report (9) is 71.1 dB(A) and within this report 70.9 which is almost the same.

The proposal for correction is:

- $+2\ dB(A)$ a speed range of 30 km/h to 70 km/h for tram crossings with an angle of less then 80° to the driving direction and with even surface. The difference in noise level is "Low" if in good condition and "Moderate" if in bad condition.

- $+5\ dB(A) + \frac{v-30}{10} dB(A)$, (speed, ***v*** in km/h) in a speed range of 30 km/h to 70 km/h for tram crossings with an orientation perpendicular to the driving direction but even surface. The difference in noise level is "High".

- $+8\ dB(A) + \frac{v-30}{10} dB(A)$, (speed ***v*** in km/h) in a speed range of 30 km/h to 70 km/h for tram crossings with uneven surface made of rough cobble. The difference in noise level is "High".

6 Sources

6.1 Reference list

1. Haider, M. Descornet, G.: ‘Noise Classification Methods for Urban Road Surfaces - Classification Methodology’, SILENCE Deliverable D13, 2006
2. ISO 11819-1:1997, ‘Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 1: Statistical Pass-by method’, International Organisation for Standardisation, Geneva
3. Ljunggren, S. (1997), ‘Measurement of noise immission from wind turbines at noise receptor locations,’ IEA recommended practices for wind turbine testing and evaluation
4. Goubert, L. et al. (2006), ‘About the development of the backing board method to evaluate the noisiness of road surfaces’, Proceedings of Inter-Noise 2006, I-INCE, Honolulu, December 03-06, 2006
5. Fégeant, O. (1997), ‘On the Use of a Vertical Microphone Board to Improve Low Signal-to-Noise Ratios During Outdoor Measurements’, Applied Acoustics, Vol. 53, No. 4, pp. 201-312.
6. DIN EN 1793-3:1997, ‘Lärmschutzeinrichtungen an Straßen - Prüfverfahren zur Bestimmung der akustischen Eigenschaften - Teil 3: Standardisiertes Verkehrslärmspektrum’ . Beuth Verlag, Berlin
7. Berengier, M.: 'Detection System for Pavement Discontinuities', SILENCE Deliverable D7, 2006
8. Thomsen, S. N.; Kragh, J.; Andersen, B.: 'Reduction of noise from vehicle crossing discontinuities on urban streets', SILENCE Delibverable D2, 2007