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METHODS TO MEASURE THE NOISINESS OF ROADS

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1 INTRODUCTION

Measuring the acoustic quality of roads is crucial for traffic noise abatement. The European directive on environmental noise of 2002 created a short and long term need for efficient and cost-effective measures to reduce/prevent traffic noise. Silent road surfaces are expected to play a key role herein. Standard ISO 11819-1 describes the Statistical Pass-By (SPB) method, which is one of the most important methods to measure the noisiness of the road. Currently this standard is revised to include a method to measure the acoustical quality of a road in a built-up urban environment. The adapted conceived method is called "Backing board (BB) method. This contribution deals with the research conducted at BRRC regarding the BB and the accuracy of both the "free field" SPB and the BB variant.

2 THE SPB-METHOD

The "Statistical Pass-By method" is described in Standard ISO 11819-1.
Microphone and radar tachometer are installed at the road side. The speed and the maximum sound pressure level of minimum 100 cars (category 1) and 80 heavy vehicles (category 2) are measured. The measurement is performed during their passage in front of a microphone that is installed next to the road surface of which the acoustical quality has to be assessed. The horizontal distance of the microphone to the centre of the measured lane is 7,5 m +- 0,1 m. The height of the microphone with respect to the road is 1,2 m +- 0,1 m The vehicles have to be isolated. Heavy vehicles are divided into two categories: heavy vehicles with two axles (category 2a) and heavy vehicles with more than two axles (category 2b). Minimum 30 heavy vehicles of each heavy vehicle category are measured.

Figure 1 SPB-method

A graph with the maximum sound pressure level in function of the logarithm of the speed is plotted and the average value of the maximum sound pressure level is calculated at a reference speed. This method is used for three vehicle categories (cars, heavy vehicles with two axles and heavy vehicles with more than two axles). A weighted average is calculated based upon the results of the three vehicle categories: SPB-index (SPBI). SPBI appears a suitable value for the acoustical quality of the road surface.

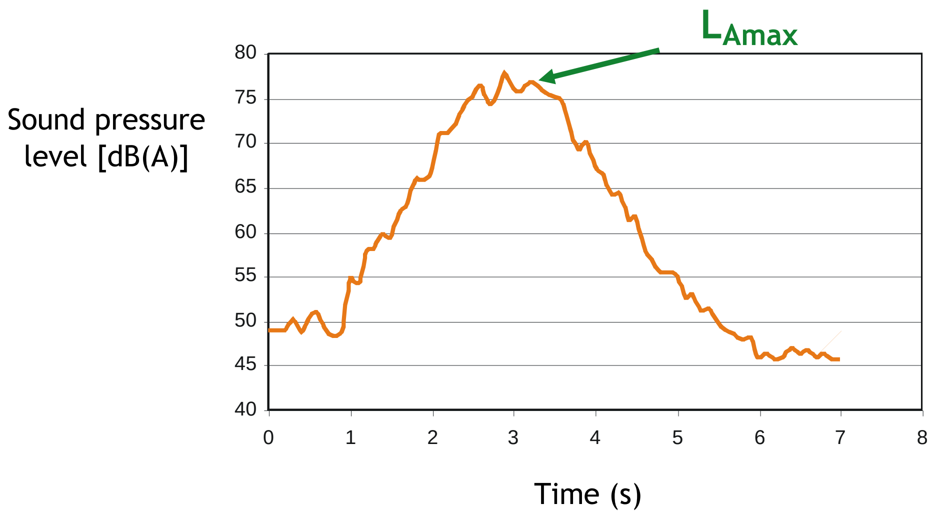

Figure 2 Evolution sound pressure level of passing vehicle

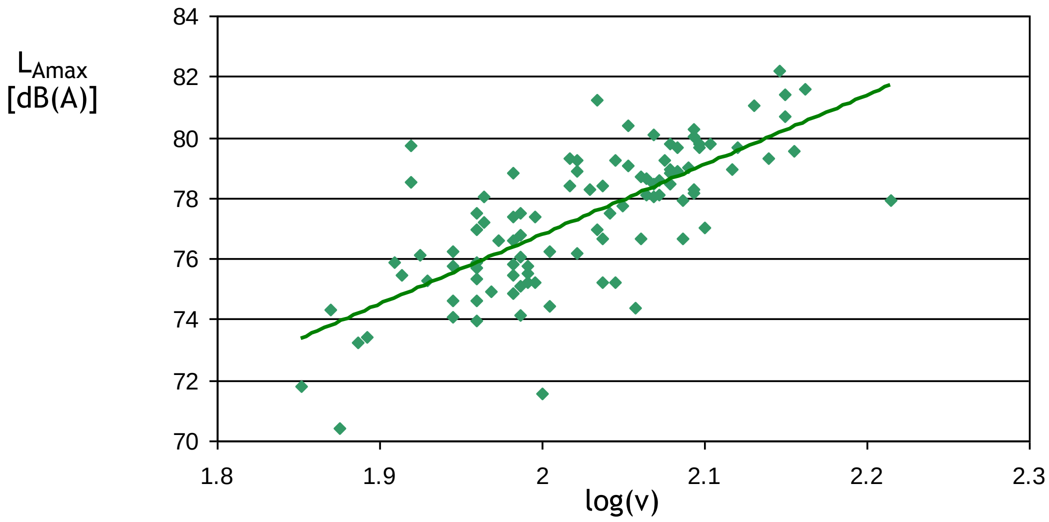

Figure 3 Graph of 100 vehicles: maximum sound pressure level (L_{Amax}) in function of logarithm of speed; linear regression line to determine L_{Amax} at reference speed (L_{veh})

The big advantage of this method is the representativity with respect to noise exposure to the environment. However this method also shows some disadvantages: it is strongly weather dependent, only the acoustic quality of the road surface in front of the microphone is evaluated (point measurement), the measurement is time consuming, often a road doesn't have enough heavy vehicles and severe conditions are imposed to the environment of the microphone. No reflecting objects (facades, vehicles, …) are allowed at a distance of less than 10 m of the microphone which makes it difficult to measure in a built-up urban environment.

3 THE BACKING BOARD-METHOD

For the revision of standard ISO 11819-1 “Statistical Pass-By method”, which is currently ongoing, ISO/TC43/SC1/WG33 would like to include a method more suitable to measure the acoustic quality of a road in a built-up urban environment.
The backing board-method is the application of the SPB-method with a board behind the microphone. This board eliminates the influence of sound coming from behind (like sound reflections caused by buildings). The sound coming from the front is reflected by the board in a controlled way. In theory the measured sound pressure level increases 6 dB(A) by doubling the sound pressure. Previous research has been performed in the European SILENCE project[1], but an extra validation was necessary. In reality the backing board doesn’t imply an exact sound pressure level increase of 6 dB(A) because of diffraction effects at the edges of the board, leading to a sound interference pattern on the surface of the board. The accurate determination of this correction factor and the uncertainty of the results are among of the goals of this round robin test.

Figure 4 Backing board

4 ROUND ROBIN TEST

4.1 Introduction

On 11 and 12 August 2009, an international round robin test was organized by the Belgian Road Research Centre near Brussels[2]. Measurements were performed in free field conditions and with backing board by eight different institutes from six countries. The purpose of the test was to assess the reproducibility of the SPB and BB method. Also the influence of the operator was tested during this round robin test. In this paper the results of this international test are presented.

4.2 Participants

Eight institutes participated at this test:

- BASt (« Bundesanstalt für Straßenwesen », Gemany)
- Cidaut (« Fundación para la Investigación y Desarrollo en Transporte y Energía » Spain) and CEDEX (« Centro de Estudios y Experimentación de Obras Públicas », Spain)
- DRI (« Danish Road Institute – Vejdirektoratet », Denmark)
- INRETS (« Institut national de recherche sur les transports et leur sécurité », France)
- M+P (consultant, Netherlands)
- Vinçotte (consultant, Belgium)
- Flemish Government - Road Engineering Division (Belgium)
- BRRC (« Belgian Road Research Centre », Belgium)

4.3 Test locations

Two test locations near Brussels were selected: one at the Brusselsesteenweg in Eppegem with dense asphalt concrete and one at the Tervuursesteenweg in Hofstade with SMA 0/10.

Figure 5 Brusselsesteenweg Eppegem (left) - Tervuursesteenweg Hofstade (right)

Figure 6 Brusselsesteenweg Eppegem (left) - Tevuursesteenweg Hofstade (right)

The red star on the photos indicates the location of the measurement equipment. The blue arrow indicates the direction of traffic that has been measured.

4.4 Test program

To assess the influence of the operator, two different tests are performed without backing board.
The first test is carried out with a coordinator giving a signal when the passing vehicle has to be measured or when the vehicle is excluded from the test. In this test the influence of the operator is excluded. This coordinator determines also the vehicle category by raising a sign with a colour code.
In reality it is possible that a vehicle is measured by one institute, but considered as invalid by another one. Also the various interpretation of vehicle categories causes diverse measurements. Therefore the second test is performed without coordinating person. The vehicles are evaluated by each operator. The results of both tests are compared to assess a possible influence of the operator.
A SPB measurement is performed on the same road section with backing board to see the influence of the backing board on the sound pressure level.
The microphones/backing boards of the different institutes stand next to each other as close as possible in order to monitor nearly the same road section.
Performed tests:

- Eppegem Free Field (FF)
- Eppegem Free Field with coordinator

- Hofstade Free Field
- Hofstade Backing Board (BB)

4.5 Measurement conditions

Eppegem: Measurements were performed on 11 August 2009. Weather conditions:

- Cloudy and sometimes a bit rainy
- Air temperature ca. 23 °C
- Road temperature ca. 29,5 °C
- Maximum 2,5 m distance between microphones FF

Figure 7 Position microphones Eppegem

Hofstade: Measurements were performed on 12 August 2009. Weather conditions:

- Cloudy
- Air temperature ca. 24,5 °C
- Road temperature ca. 30 °C
- Maximum 7,5 m distance between microphones BB-FF

Figure 8 Position microphones Hofstade

The backing board has a rectangular shape and a mass of 13,14 kg/m². The width is 90 cm and the height 75 cm. The microphone is situated in the right lower corner of the board, 33 cm from the right edge and 23 cm from the lower edge[3]. Participants were asked to use the same mass and dimensions.

4.6 Results

4.6.1 Influence coordinator

Next graphs show the $L_{veh,cat.1}$ results of the free field measurements in Eppegem without coordinator.

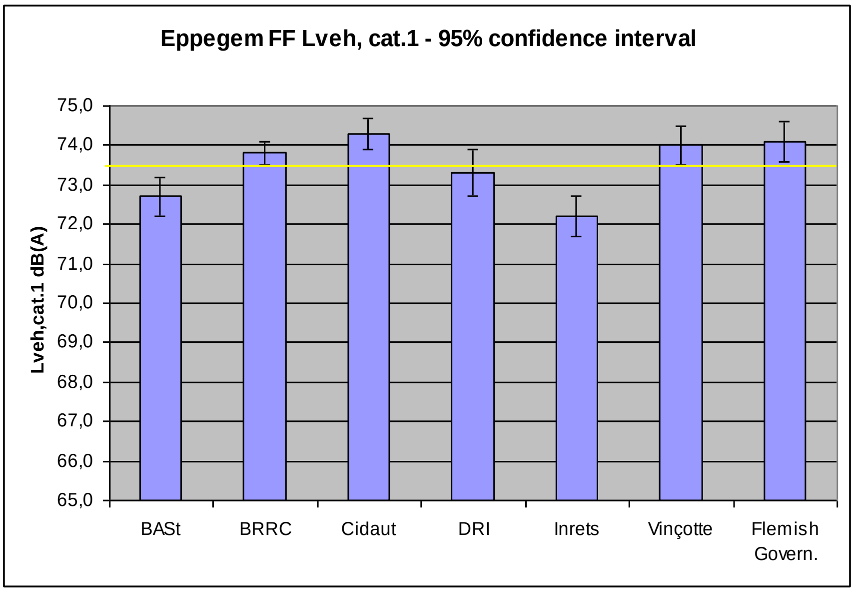

Figure 9 $L_{veh,cat.1}$ results different institutes

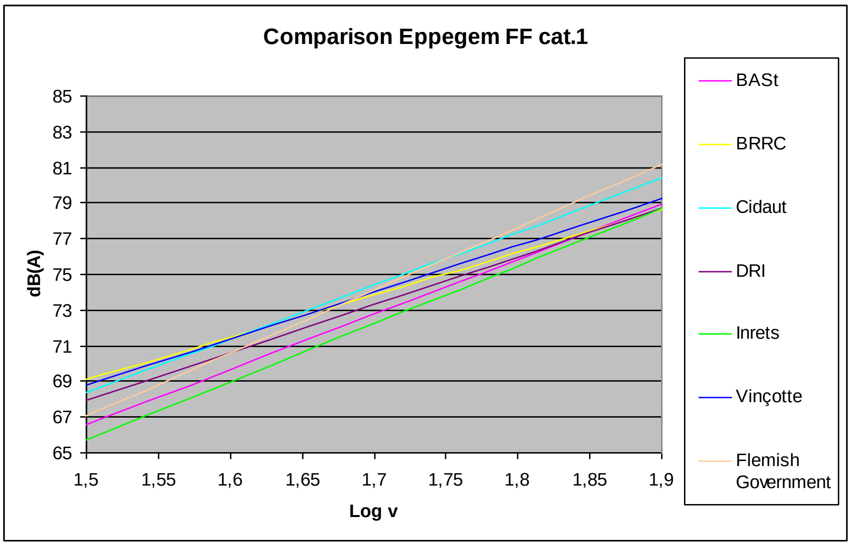

Figure 10 Comparison graphs “log v – maximum sound pressure level” different institutes

A standard deviation of 0,8 dB(A) is found for cars during the free field test in Eppegem which implies a good reliability of the SPB method.
The slopes of the regression lines are very similar for the various institutes.
Only the vehicles that were measured completely (speed and sound level) by all institutes were taken into account for the test with coordinator. No significant difference may be noted between the test with and without coordinator. The standard deviation of vehicle category 1 decreases with only

0,1 dB(A). For vehicle category 2a however, there is a larger decrease of 0,8 dB(A) but not enough vehicles of category 2a or 2b were measured to draw a reliable conclusion.
A large difference was noted for $L_{veh,cat.2a}$ between various institutes for the free field test without coordinator. It is feasible to state that this was due to the different interpretation of vehicle categories. During the test with coordinator this difference in interpretation was eliminated which resulted in a smaller standard deviation.

Figure 11 Standard deviations for different categories of test with and without coordinator

Standard deviation	Without coordinator	With coordinator
$L_{veh,cat.1}$	0,8 dB(A)	0,7 dB(A)
$L_{veh,cat.2a}$	2,0 dB(A)	1,2 dB(A)
$L_{veh,cat.2b}$	0,7 dB(A)	0,7 dB(A)

4.6.2 Speed and vehicle sound pressure level

When comparing per vehicle all speed values measured by the institutes during the coordinator test, a standard deviation per vehicle may be calculated.
If a value is an outlier or a straggler[4] it is very probably erroneous, for example if all institutes measure a value of ca. 60 km/h and one institute measures 30 km/h.
Even when leaving out the outliers and stragglers, a mean standard deviation of 3,1 km/h is obtained, which is a rather high value. Further to the standard ISO 11819-1 the vehicle speed has to be measured with a standard uncertainty of less than 3 %. Not all institutes comply with this requirement.
When comparing per vehicle all vehicle sound pressure level values, leaving out the outliers and stragglers, a mean standard deviation of 0,3 dB(A) is obtained, which is a good result.

4.6.3 Backing board

Following graphs show the $L_{veh,cat.1}$ results of the measurements in Hofstade with and without backing board. Standard deviations of 0,8 dB(A) and 1,0 dB(A) are noted for vehicle category 1 during the free field test and the backing board test which implies a good reproducibility of the SPB method.

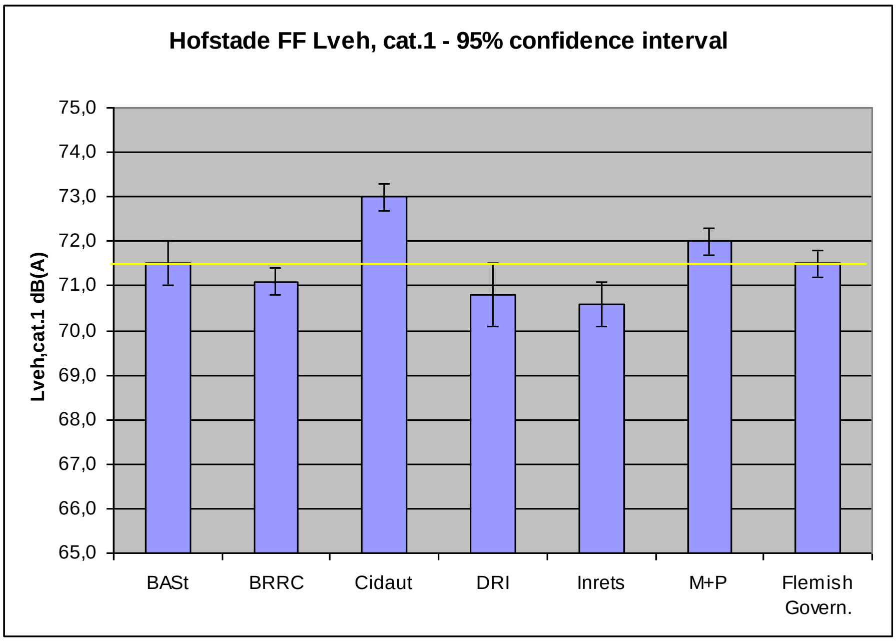

Figure 12 $L_{veh,cat.1}$ results different institutes free field

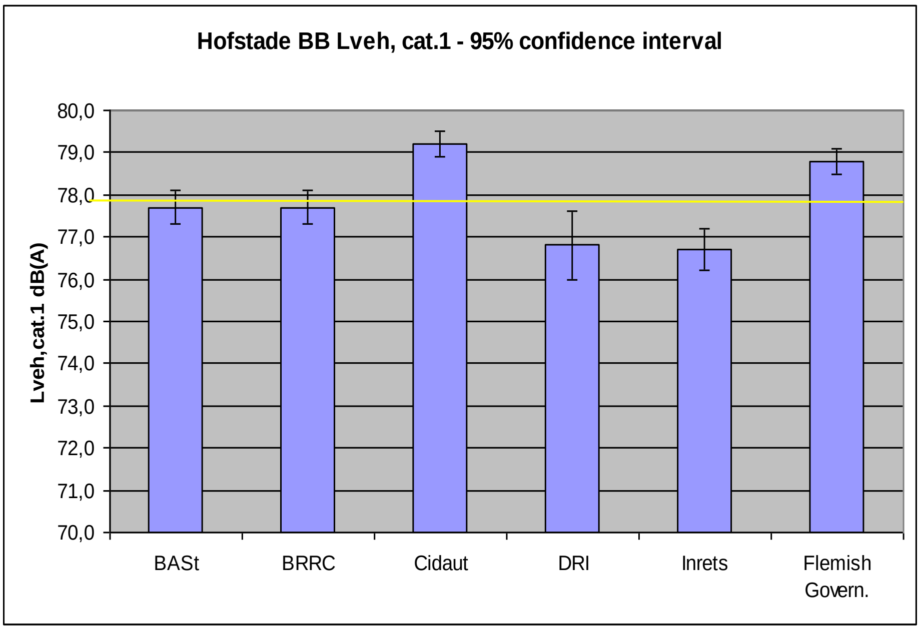

Figure 13 $L_{veh,cat.1}$ results different institutes backing board

Instead of the theoretical 6 dB(A) sound pressure level increase by the presence of the BB, one found a mean augmentation with 6,4 dB(A) for cars and an augmentation with 5,7 dB(A) for two axle heavy vehicles. However not enough vehicles of category 2a were measured and the 95% confidence interval is too large to draw a reliable conclusion.
Institutes which measured on two channels at the same time achieve a value of ca. 6,0-6,1 dB(A) for cars 1 which is very close to the theoretical value. Perhaps the higher value of the other institutes is due to the measurement of different vehicles for free field and backing board test.
The following graph summarizes the measured increase of the sound pressure level, caused by the backing board for vehicle category 1 and 2a with their 95% confidence intervals.

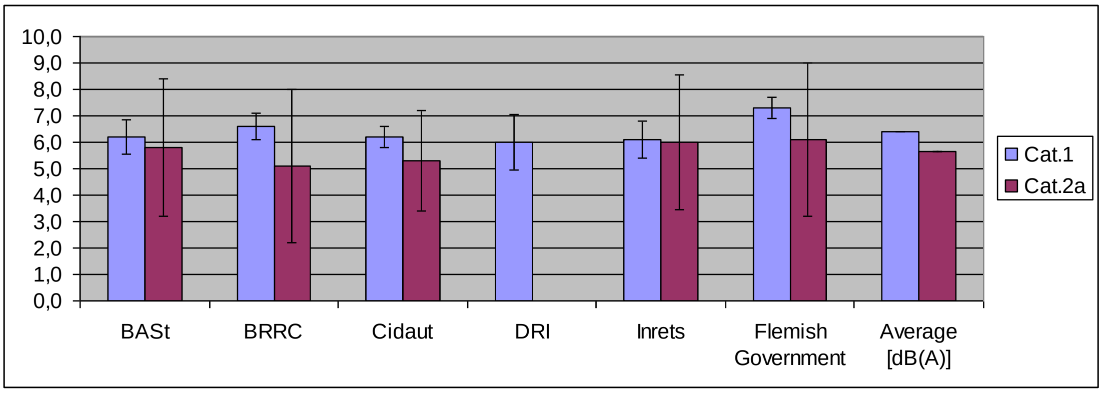

Figure 14 Measured increase sound pressure level caused by backing board

4.6.4 Comparison different tests

Following graph contains the deviation of $L_{veh,cat.1}$ with respect to the average of different tests. Cidaut measures systematically higher values and Inrets lower values.

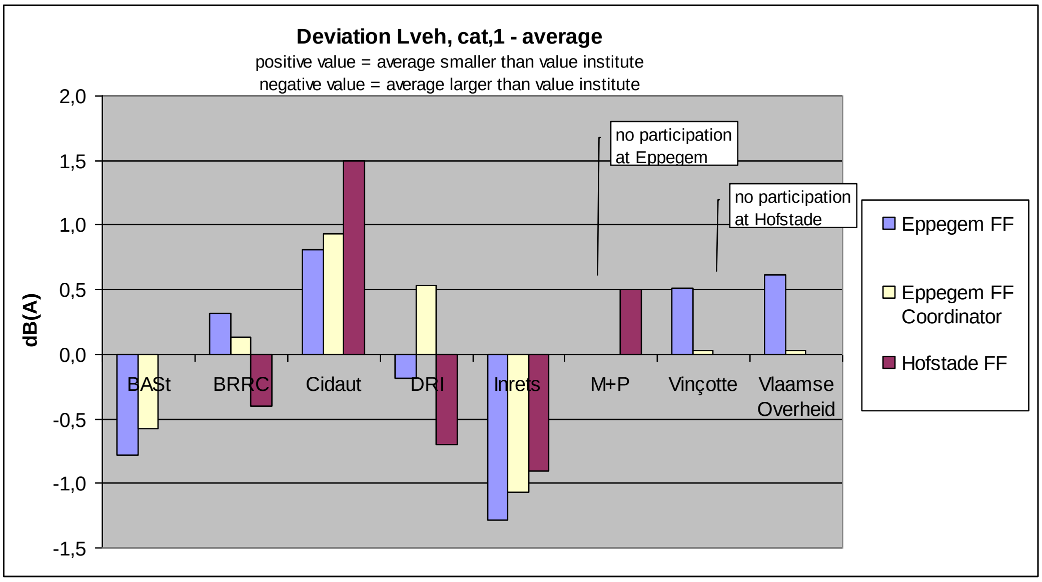

Figure 15 Deviation $L_{veh,cat.1}$ different institutes with respect to average

4.6.5 Conclusions round robin test

- A varying interpretation of vehicle categories leads to a significant difference of $L_{veh,cat.2a}$ (standard deviation Eppegem FF between institutes 2,0 dB(A)). However when considering these values in the SPBI calculation, the influence can be expected to remain limited.
- The SPB-method has a reasonable accuracy. A standard deviation of 0,8 dB(A) is noted for the vehicle sound pressure level of cars. The largest difference between the highest and lowest vehicle sound pressure level is only 2,5 dB(A).
- For the speed, a high mean standard deviation of 3,1 km/h is obtained, but for sound pressure level measurements only 0,3 dB(A)
- The influence of a coordinator appears to be small. However a smaller standard deviation is noted for the test with coordinator, especially for vehicle categories 2a and 2b, which show some influence. Extra tests are recommended.
- Test results confirm the backing board correction value of ca. 6 dB(A) for vehicles of category 1. Further study is recommended for vehicles of category 2a and 2b.
- Further research is needed to make the results that are found in this round robin test more robust. Following tests could be considered:
  - Coordinator test with backing board and a coordinator test with more measured vehicles of various vehicle categories to obtain a higher accuracy and to be able to calculate SPBI.
  - Backing board and free field tests with more measured vehicles of each vehicle categories to obtain a higher accuracy and to be able to calculate SPBI.

5 CONCLUSION

The SPB-method is a suitable method to measure the noisiness of the road. It has a reasonable accuracy and is reliable. When using this method, the acoustical quality of roads may be assessed and easily compared with others.
The backing board-method makes it possible to measure the acoustical quality of a road in a built-up urban environment. Further research is needed to validate this method, especially for heavy vehicles. However until now results are promising.

6 REFERENCES

1 Haider, M.; Sandberg, U., ”Noise classification methods for urban road surfaces - User manual: Measurement methods”, SILVIA deliverable F.D12 (2006), downloadable free of charge from: http://www.silence-ip.org/site/fileadmin/public_reports/SILENCE_F.D12_20060203.pdf

2 A. Bergiers, Final Report Round Robin Test SPB Measurements: BRRC 11-12 August 2009 Eppegem-Hofstade, 12/01/2010

3 Fégeant O., “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. 291-312 (1998)

4 ISO 5725-2, “Accuracy of measurement methods and results – Part 2”, 1994