Noise Reducing Devices: an Austrian Experience with the new European Technical Specification for Measurements of in-Situ Sound Diffraction

M Conter[1], M. Haider[2]

[1]*arsenal research, Vienna, Email: marco.conter@arsenal.ac.at*
[2]*arsenal research, Vienna, Email: manfred.haider@arsenal.ac.at*

Introduction

Traffic noise is one of the major environmental concerns within the European Union. The most important solution to noise abatement along roads and railways is the construction of noise barriers.

In order to measure the acoustic performance in real life conditions and the long-term performance of these devices, the working group CEN/ TC226/ WG6 has developed the so called Adrienne method. This measurement method was introduced in 2003 with the technical specifications CEN/TS 1793-5 [1], dealing with in-situ sound absorption and sound insulation, and CEN/TS 1793-4 [2], dealing with in-situ sound diffraction. Added devices for sound diffraction are becoming more relevant in the last years to increase the acoustic performance of barriers.

This paper describes one of the first Austrian research activities dealing with measurements of in-situ sound diffraction based on this Technical Specification. This study, carried out in 2006 by arsenal research, compares the acoustic behaviour of aluminium cassettes, alternately mounted as flat reference barriers, partially non flat products, added devices on the top of the barrier, transparent insertions and digital prints on the surface. In detail, the authors measured and analysed the in-situ acoustic properties sound absorption, sound insulation and sound diffraction of each variant. The research was carried out for the company Forster Metallbau GmbH.

The Adrienne method for measurements of sound diffraction

The so-called Adrienne method is a very flexible in-situ method to measure the acoustic properties of a noise barrier. Using this method it is possible to characterize the device under test concerning sound absorption, sound insulation and sound diffraction.

In the European Standard CEN/TS 1793-5 and CEN/TS 1793-4 this method is described in more detail, here only a short overview of the measuring method for sound diffraction will be given. This method can also be used for testing of added barrier top devices.

For applying this method we have to use a loudspeaker emitting a spherical sound wave, which impinges on the noise barrier surface. The used signal is a Maximum Length Sequence (MLS) signal, which allows the determination of the impulse response with a very high signal-to-noise ratio. The sound source emits a signal that travels towards the device under test. The microphone placed on the other side of the device receives the diffracted sound.

The impinging sound energy is determined by measuring the impulse response at the microphone position with and without the added device. The impulse responses are corrected for geometrical attenuation, assuming spherical sound wave propagation. This measurement has to be repeated for all the measurement positions.

Fig. 1 shows the setup of the measurements for sound diffraction. The source is placed in two different positions (S1 and S4) in order to test also the oblique incidence of the impinging sound. The height of the source is half a meter below the top of the added device. The minimum length of the barrier is 10 meters and its minimum height 4 meters. The microphone positions are placed so that 4 positions (M1, M2, M3, M4) are in front of the sound source S1 and the other 4 positions (M7, M8, M9, M10) are in front of the sound source S4 but with an angle of 45° between the noise barrier and the line connecting source and microphones.

For each source position a free-field measurement without the noise barrier is required as a reference.

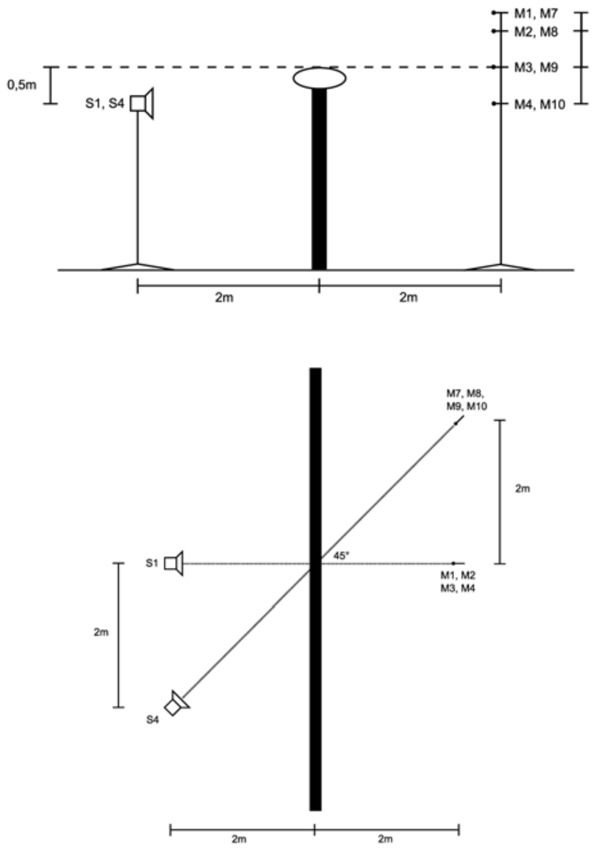

Figure 1: Setup of the measurements for sound diffraction: on the top the side view of the setup, on the bottom the ground view of the setup.

A time window, also called "Adrienne" window, is then applied to the impulse responses to filter out unwanted reflections from the ground or other nearby objects in the time domain. Fig.2 shows the Adrienne window and an example of the diffracted impulse response. The original measured signal is represented with a red line; the blue line is the signal after windowing, without unwanted reflections.

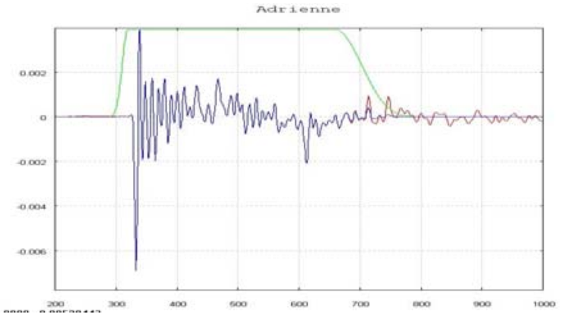

Figure 2: Impulse response of the diffracted signal (red line), Adrienne window (green line) and the diffracted windowed signal (blue line) now ready for processing.

The results undergo a Fast-Fourier-transform and are presented in third-octave bands. Equation (1) shows the definition of the diffraction index DI (also called Miller index) for each third-octave band. This index is the ratio between the diffracted and the incident sound intensity. The lowest frequency that can be measured with this method depends on the height of the barrier.

$$DI_j = -10 \cdot \log_{10} \left\{ \frac{\sum_{k=1}^{n} \int_{\Delta f_j} \left| F[h_{dk}(t) w_{dk}(t)] \right|^2 df \left(\frac{d_k}{d_i} \right)^2}{n \cdot \int_{\Delta f_j} \left| F[h_i(t) w_i(t)] \right|^2 df} \right\} \quad (1)$$

Where:

$h_i(t)$ is the reference component of the free-field impulse response (IR);

$h_{dk}(t)$ is the diffracted component of the IR;

$d_i(t)$ is the geometrical spreading correction factor for the reference free-field component;

$d_k(t)$ is the geometrical spreading correction factor for the diffracted component at the *k*-th point (k=1, ..,n)

$w_i(t)$ is the reference free-field component time window;

$w_{dk}(t)$ is the time window for the diffracted component at the *k*-th point;

t is the time from the beginning of the IR;

Δf_j *j*-th 1/3 octave frequency band (from 100 Hz to 5000 Hz);

n is the number of measuring points;

F is the symbol of the Fourier transform.

In order to characterise the performance of device under test using only a single number, the method calculates first the diffraction index difference for each j-th third-octave band and than applies the normalized traffic noise spectrum. Equation 2 shows the calculation of the diffraction index difference ΔDI.

$$\Delta DI_j = DI_{ad,j} - DI_{0,j} \quad (2)$$

Where $DI_{ad,j}$ represents the diffraction index for each band measured with added device and $DI_{0,j}$ the diffraction index without added device. Equation 3 shows the calculation of the single-number rating, in decibels, using the normalized spectrum.

$$DL_{\Delta DI} = -10 \cdot \log_{10} \left\{ \frac{\sum_{j=1}^{18} 10^{0,1L_j} 10^{-0,1\Delta DI_j}}{\sum_{j=1}^{18} 10^{0,1L_j}} \right\} \quad (3)$$

Where L_i is the dB (A)-value of the *i*-th third-octave band of the road traffic noise spectrum according to the European standard EN 1793-3. This normalized value represents the performance of the added device, the bigger this value the better the attenuation due to the added device.

The Adrienne method has been designed principally to overcome the disadvantages of the laboratory method using a reverberation chamber by measurements of sound insulation and sound absorption. Nevertheless this method is very useful also for testing sound diffraction and for testing the acoustical performance of added devices.

The biggest advantage of the Adrienne method is the possibility to test these characteristics with mobile equipment in-situ and without the use of special test rooms. It is also possible to test the acoustical long-term performance of the barrier in order to test its durability and to find construction errors.

Measurements and experimental results

Tested device

The scope of this study is principally to apply the measurements method for sound diffraction and to test two possible solutions for increasing the overall performance of an aluminium noise barrier due to added devices placed on the top of the barrier.

The measurements were carried out by arsenal research using the Adrienne method for sound diffraction in April 2006 for the Forster Metallbau GmbH at the company site. The investigated noise barrier was made of aluminium cassettes with acoustic absorbing material.

The added device under test was a triangular element made of aluminium cassettes with absorbing material with a height of 50 cm and a maximum depth of 20 cm.

Fig. 3 shows this element in detail (the added device is the element in red). The left picture shows the element before mounting, the picture in the middle shows it after mounting in the middle of the barrier and the right picture after mounting on the top of the barrier.

Figure 3: The added device tested during these measurements before mounting (left), after the mounting in the middle of the barrier (middle) and on the top of the barrier (right).

Measurement positions and configurations

The device under test is a part of the barrier and the height of the barrier will not change after the mounting of the device. For this reason, the reference measurements, to perform without the added device, were performed on the part of the barrier where no added devices were mounted.

During this measurement campaign two versions of the added device were tested: in the first configuration the triangular element was only on the loudspeaker side of the barrier; in the second configuration this element was on both sides of the barrier. The height of the noise barrier is 4 m and is based on a 0.5 m high concrete foundation.

Fig. 4 and Fig. 5 illustrate the setup of the measurements for sound diffraction for the source position S4 (for the non normal incidence of the diffraction) and the setup for the free-field measurement for the source position S1 (for the normal incidence of the diffraction).

Figure 4: The setup of the measurements for sound diffraction for the source position S4 using an angle of 45° between the noise barrier and the line connecting source and microphones.

Figure 5: The setup for the free-field measurement for the source position S1 (using normal incidence).

According to the CEN/TS 1793-4, the microphone positions during this measurement campaign were the 8 mandatory positions (M1 to M4 and M7 to M10) as shown in Fig.1 and 4 optional positions (M5, M6, M11 and M12).

Table 1 explains the exact position of these measuring points related to the height of the top of the added device. The position M1 to M6 are related to the source position S1, the positions M7 to M12 are related to the source position S4.

Microphone positions	Height [m]
M1 and M7	0,75
M2 and M8	0,5
M3 and M9	0,0
M4 and M10	-0,5
M5 and M11	0,25
M6 and M12	-0,25

Table 1: Height of the measuring points related to the height of the top of the added device.

Experimental results

The diffraction index difference ΔDI, which represents the spectra of the difference between the diffracted energy of the reference barrier and the diffracted energy of the barrier with added device, is illustrated in Fig. 5 (in blue the added device with one-sided element and in red the device with two-sided element). For the frequencies between 1000 and 5000 Hz the values are positive for both configurations: ΔDI is between 1 and 4 dB, which represents a good attenuation of the diffracted sound due to the added device for this frequency range. For the frequencies lower than 200 Hz the values are positive, but not as good as for the high frequencies: the values are between 0 and 1.3 dB. For the middle-low frequencies (between 250 and 800 Hz) the values are positive for the added device with one-sided element and negative for the two-sided element.

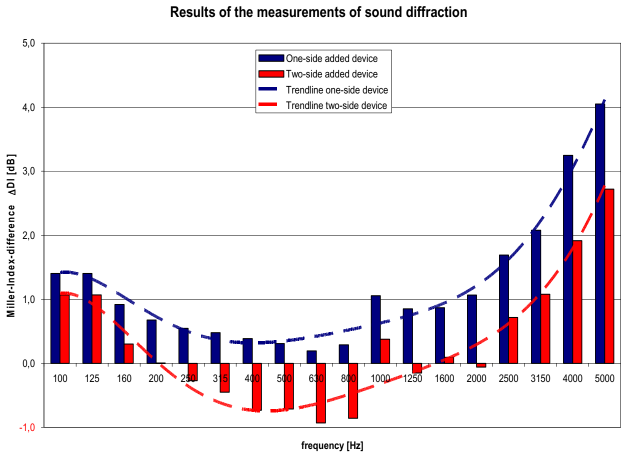

Figure 5: Results of the measurements of sound diffraction: diffraction index difference from 100 to 5000 Hz. Added device with one-side element on the top (blue bars) and added device with two-side element on the top (red bars). The blue and the red lines represent the polynomial trend lines of the data.

The diagram in Fig. 5 shows that both configurations have a similar trend line with a minimum value in the 630 Hz third-octave band. The main reason for that could be that the two devices are made of the same material, which produces absorption and reflection for the same third-octave bands.

The single-number rating of the diffraction index difference $DL_{\Delta DI}$ is the overall value for the performance of the added device. Table 2 illustrates the performance of the two tested devices (added device with one-sided element and added device with two-sided element).

Type of added device	$DL_{\Delta DI}$ [dB]
One-sided element	0,8
Two-sided element	-0,1

Table 2: Overall performance of the added devices.

For both configurations the height of the barrier has not changed after the mounting of the added device because the added device is part of the last element of the barrier. For this reason rather small values of $DL_{\Delta DI}$. were expected. Nevertheless the value of $DL_{\Delta DI}$ for the first configuration (one-sided element) is very close to 1 dB, which is a very good performance in terms of sound diffraction due to the shape of the relatively small added device only and not due to its height. On the contrary, for the second configuration (two-sided element) the value of $DL_{\Delta DI}$ is negative and very close to zero, which means that the added device provides no additional screening due to diffraction. A possible reason for the negative performance of the added device with the two-sided element is that probably the positive effect of the one-sided element has been deleted from the other side of the added device. For more detailed considerations further investigation will be needed.

Conclusions

The development of added devices is becoming more and more important in the last years. The performance of a noise barrier can be increased by these devices. For this reason the Adrienne method proposed in the European draft standard CEN/TS 1793-4 can be very useful in order to test new products and to verify the real performance in-situ of these devices. Additionally the real long-term performance of the devices can also be easily examined using this in-situ method.

In this paper an investigation of two different added devices was carried out using the Adrienne method according to the European technical specification CEN/TS 1739-4. The study shows that this method is feasible and easy to apply.

The recent interest of the Austrian Road Administration ASFiNAG and some noise barriers producers for the development of new added devices and the use of this method for testing these products confirm the need of an easy method for measurements of sound diffraction.

References

[1] CEN/TS 1793-5 Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 5: Intrinsic characteristics – In-situ values of sound reflection and airborne sound insulation, 2003, CEN

[2] CEN/TS 1793-4 Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 5: Intrinsic characteristics – In-situ values of sound diffraction, 2004, CEN

[3] EN 1793-3 Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 3: Normalized traffic noise spectrum, 1997, CEN